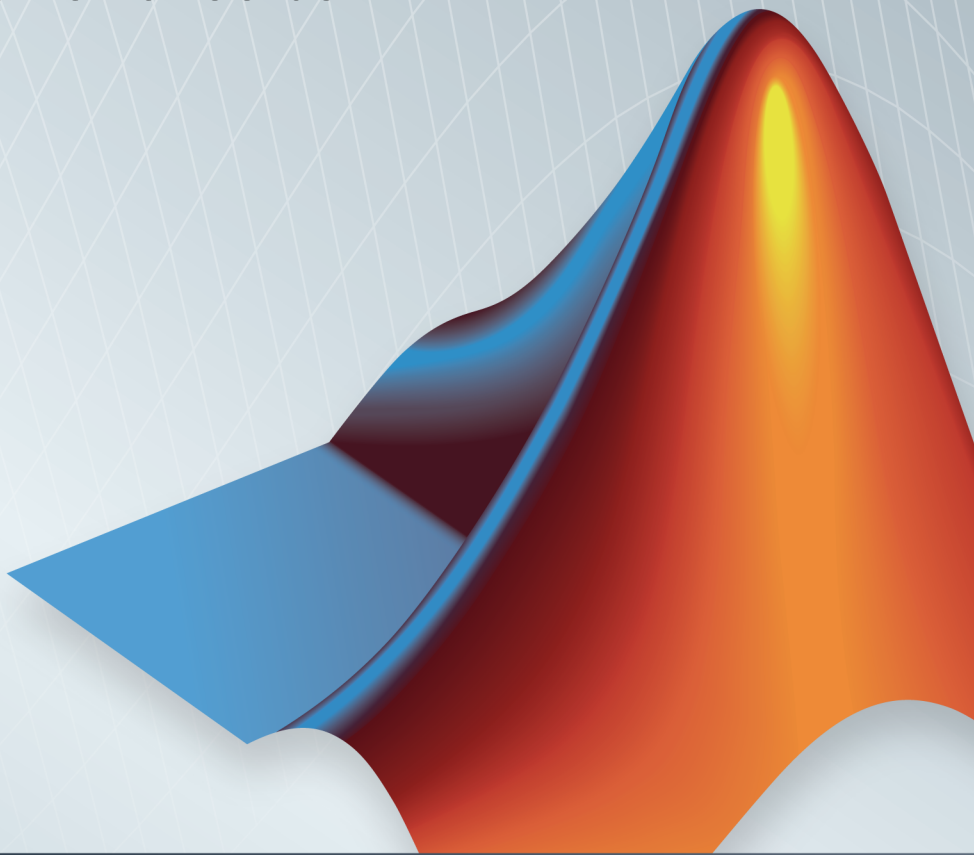


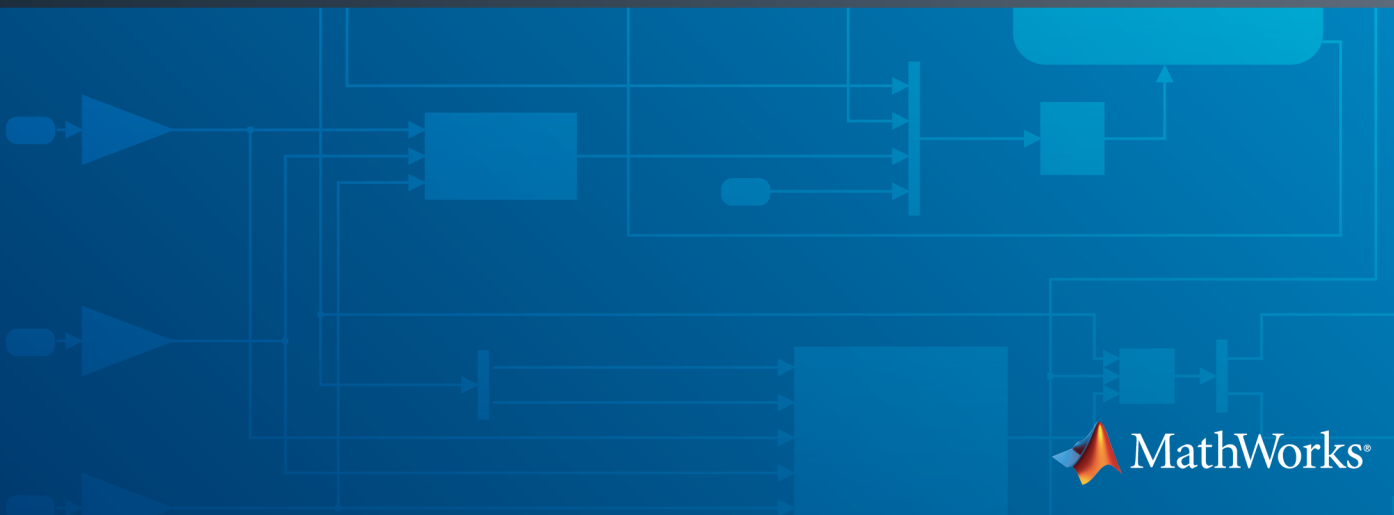
# Financial Instruments Toolbox™

## User's Guide

R2014b



# MATLAB®



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### *Financial Instruments Toolbox™ User's Guide*

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## **Glossary**

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# Getting Started

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- “Interest-Rate-Based Derivatives” on page 1-4
- “Equity-Based Derivatives” on page 1-5
- “Expected Users” on page 1-6
- “Portfolio Creation” on page 1-7
- “Pricing a Portfolio Using the Black-Derman-Toy Model” on page 1-10
- “Portfolio Management” on page 1-16

## Financial Instruments Toolbox Product Description

### Design, price, and hedge complex financial instruments

Financial Instruments Toolbox™ provides functions for pricing, modeling, and analyzing fixed-income, credit, and equity instrument portfolios. You can use the toolbox to perform cash-flow modeling and yield curve fitting analysis, compute prices and sensitivities, view price evolutions, and perform hedging analyses using common equity and fixed-income modeling methods. The toolbox lets you create new financial instrument types, fit yield curves to market data using parametric fitting models and bootstrapping, and construct dual curve-based pricing models.

You can price and analyze fixed-income and equity instruments. For fixed-income modeling, you can calculate price, yield, spread, and sensitivity values for several types of securities and derivatives, including convertible bonds, mortgage-backed securities, treasury bills, bonds, swaps, caps, floors, and floating-rate notes. For equities, you can compute price, implied volatility, and greek values of vanilla options and several exotic derivatives.

Financial Instruments Toolbox contains functions to model counterparty credit risk and CVA exposure. For credit derivatives, the toolbox includes credit default swap pricing and default probability curve modeling functions. For energy derivatives, you can model exotic and vanilla options. The toolbox also provides connectivity to Numerix® CrossAsset Integration Layer.

### Key Features

- Yield curve fitting with bootstrapping and parametric fitting models, and term-structure analysis with dual curve construction and pricing of swaps, caps, floors, and swaptions (using LIBOR-OIS and other curves)
- Black Scholes, Black, Garman-Kohlhagen, Roll-Geske-Whaley, Bjerksund-Stensland, Nengjiu Ju, Stulz, Levy jump diffusion, Longstaff-Schwartz, SABR, and tree models and Monte Carlo simulation
- Fixed-income and equity derivative calculations for price, yield, discount rate, cash-flow schedule, spread, implied volatility, option adjusted spread (OAS), and greeks
- Counterparty credit risk, CVA modeling, and credit instruments for mortgage pools, balloon mortgages, and credit default swaps
- Interest-rate instruments: bonds, stepped-coupon bonds, futures, vanilla options, Bermudan options, bonds with embedded options, vanilla swaps, forward swaps,



amortizing swaps, swaptions, caps, floors, range notes, floating-rate notes, and collared floating-rate notes

- Equity instruments: stocks, vanilla options, Bermudan options, Asian options, lookback options, barrier options, digital options, rainbow options, basket options, compound options, and chooser options
- Energy and commodity instruments: Asian options, Bermudan options, lookback options, swing options, spread options, and vanilla European/American options

## Interest-Rate-Based Derivatives

The toolbox provides functionality that supports the creation and management of these interest-rate-based instruments:

- Bonds
- Bond options (puts and calls)
- Bond with embedded options
- Caps
- Fixed-rate notes
- Floating-rate notes
- Floors
- Swaps
- Swaption

Additionally, the toolbox provides functions to create *arbitrary cash flow instruments*. The toolbox provides pricing and sensitivity routines for these instruments. For more information, see “Pricing Using Interest-Rate Term Structure” on page 2-49, “Pricing Using Interest-Rate Tree Models” on page 2-74, and “Interest-Rate Derivatives Using Closed-Form Solutions” on page 2-93.

## Equity-Based Derivatives

The toolbox also provides functions to create and manage various equity-based derivatives, including the following:

- Asian options
- Barrier options
- Basket options
- Compound options
- Digital options
- Lookback options
- Rainbow options
- Vanilla stock options (put and call options)

The toolbox also provides pricing and sensitivity routines for these instruments. (See “Pricing Equity Derivatives Using Trees” on page 3-104, “Equity Derivatives Using Closed-Form Solutions” on page 3-120, and “Basket Option” on page 3-21.)

## Expected Users

In general, this guide assumes experience working with financial derivatives and some familiarity with the underlying models.

In designing Financial Instruments Toolbox documentation, we assume your title is similar to one of these:

- Analyst, quantitative analyst
- Risk manager
- Portfolio manager
- Fund manager, asset manager
- Financial engineer
- Trader
- Student, professor, or other academic

We also assume your background, education, training, and responsibilities match some aspects of this profile:

- Finance, economics, perhaps accounting
- Engineering, mathematics, physics, other quantitative sciences
- Bachelor's degree minimum; MS or MBA likely; Ph.D. perhaps; CFA
- Comfortable with probability theory, statistics, and algebra
- Understand linear or matrix algebra, calculus, and differential equations
- Previously done traditional programming (C, Fortran, etc.)
- Responsible for instruments or analyses involving large sums of money
- Perhaps new to MATLAB®

## Portfolio Creation

### In this section...

“Introduction” on page 1-7

“Interest-Rate-Based Derivatives” on page 1-7

“Equity Derivatives” on page 1-8

“Adding Instruments to an Existing Portfolio” on page 1-8

### Introduction

The `instadd` function creates a set of instruments (portfolio) or adds instruments to an existing instrument collection. The `TypeString` argument specifies the type of the investment instrument. For interest-rate-based derivatives, the types are: `Bond`, `OptBond`, `CashFlow`, `Fixed`, `Float`, `Cap`, `Floor`, and `Swap`. For equity derivatives, the types are `Asian`, `Barrier`, `Compound`, `Lookback`, and `OptStock`.

The input arguments following `TypeString` are specific to the type of investment instrument. Thus, the `TypeString` argument determines how the remainder of the input arguments is interpreted. For example, `instadd` with the type string `Bond` creates a portfolio of bond instruments.

```
InstSet = instadd('Bond', CouponRate, Settle, Maturity, Period,
Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate,
StartDate, Face)
```

### Interest-Rate-Based Derivatives

In addition to the bond instrument already described, the toolbox can create portfolios containing the following set of interest-rate-based derivatives:

- Bond option

```
InstSet = instadd('OptBond', BondIndex, OptSpec, Strike, ExerciseDates, AmericanOpt)
```

- Arbitrary cash flow instrument

```
InstSet = instadd('CashFlow', CFlowAmounts, CFlowDates, Settle, Basis)
```

- Fixed-rate note instrument

```
InstSet = instadd('Fixed', CouponRate, Settle, Maturity, FixedReset, Basis, Principal)
```

- Floating-rate note instrument

```
InstSet = instadd('Float', Spread, Settle, Maturity, FloatReset, Basis, Principal)
```

- Cap instrument

```
InstSet = instadd('Cap', Strike, Settle, Maturity, CapReset, Basis, Principal)
```

- Floor instrument

```
InstSet = instadd('Floor', Strike, Settle, Maturity, FloorReset, Basis, Principal)
```

- Swap instrument

```
InstSet = instadd('Swap', LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType)
```

- Swaption instrument

```
InstSet = instadd('Swaption', OptSpec, Strike, ExerciseDates, Spread, ...  
Settle, Maturity, AmericanOpt, SwapReset, Basis, Principal)
```

- Bond with embedded option instrument

```
InstSet = instadd('OptEmBond', CouponRate, Settle, Maturity, OptSpec, Strike, ...  
ExerciseDates, 'AmericanOpt', AmericanOpt, 'Period', Period, 'Basis', Basis, ...  
'EndMonthRule', EndMonthRule, 'Face', Face, 'IssueDate', IssueDate, 'FirstCouponDate', ...  
FirstCouponDate, 'LastCouponDate', LastCouponDate, 'StartDate', StartDate)
```

## Equity Derivatives

The toolbox can create portfolios containing the following set of equity derivatives:

- Asian instrument

```
InstSet = instadd('Asian', OptSpec, Strike, Settle, ExerciseDates, AmericanOpt, ...  
AvgType, AvgPrice, AvgDate)
```

- Barrier instrument

```
InstSet = instadd('Barrier', OptSpec, Strike, Settle, ExerciseDates, AmericanOpt, ...  
BarrierType, Barrier, Rebate)
```

- Compound instrument

```
InstSet = instadd('Compound', UOptSpec, UStrike, USettle, UExerciseDates, UAmericanOpt, ...  
COptSpec, CStrike, CSettle, CExerciseDates, CAmericanOpt)
```

- Lookback instrument

```
InstSet = instadd('Lookback', OptSpec, Strike, Settle, ExerciseDates, AmericanOpt)
```

- Stock option instrument

```
InstSet = instadd('OptStock', OptSpec, Strike, Settle, Maturity, AmericanOpt)
```

## Adding Instruments to an Existing Portfolio

To use the `instadd` function to add additional instruments to an existing instrument portfolio, provide the name of an existing portfolio as the first argument to the `instadd` function.

Consider, for example, a portfolio containing two cap instruments only:

```
Strike = [0.06; 0.07];
Settle = '08-Feb-2000';
Maturity = '15-Jan-2003';

Port_1 = instadd('Cap', Strike, Settle, Maturity);
```

These commands create a portfolio containing two cap instruments with the same settlement and maturity dates, but with different strikes. In general, the input arguments describing an instrument can be either a scalar, or a number of instruments (NumInst)-by-1 vector in which each element corresponds to an instrument. Using a scalar assigns the same value to all instruments passed in the call to `instadd`.

Use the `instdisp` command to display the contents of the instrument set:

```
instdisp(Port_1)

Index Type Strike Settle Maturity CapReset Basis Principal
1 Cap 0.06 08-Feb-2000 15-Jan-2003 1 0 100
2 Cap 0.07 08-Feb-2000 15-Jan-2003 1 0 100
```

Now add a single bond instrument to `Port_1`. The bond has a 4.0% coupon and the same settlement and maturity dates as the cap instruments.

```
CouponRate = 0.04;
Port_1 = instadd(Port_1, 'Bond', CouponRate, Settle, Maturity);
```

Use `instdisp` again to see the resulting instrument set:

```
instdisp(Port_1)

Index Type Strike Settle Maturity CapReset Basis Principal
1 Cap 0.06 08-Feb-2000 15-Jan-2003 1 0 100
2 Cap 0.07 08-Feb-2000 15-Jan-2003 1 0 100

Index Type CouponRate Settle Maturity Period Basis EndMonthRule IssueDate ... Face
3 Bond 0.04 08-Feb-2000 15-Jan-2003 2 0 1 NaN ... 100
```

## Pricing a Portfolio Using the Black-Derman-Toy Model

This example illustrates how the Financial Instruments Toolbox™ can be used to create a Black-Derman-Toy (BDT) tree and price a portfolio of instruments using the BDT model.

### Create the Interest Rate Term Structure

The structure `RateSpec` is an interest rate term structure that defines the initial forward-rate specification from which the tree rates are derived. Use the information of annualized zero coupon rates in the table below to populate the `RateSpec` structure.

From	To	Rate
01 Jan 2005	01 Jan 2006	0.0275
01 Jan 2005	01 Jan 2007	0.0312
01 Jan 2005	01 Jan 2008	0.0363
01 Jan 2005	01 Jan 2009	0.0415
01 Jan 2005	01 Jan 2010	0.0458

```
StartDates = ['01 Jan 2005'];
```

```
EndDates = ['01 Jan 2006';  
            '01 Jan 2007';  
            '01 Jan 2008';  
            '01 Jan 2009';  
            '01 Jan 2010'];
```

```
ValuationDate = ['01 Jan 2005'];
```

```
Rates = [0.0275; 0.0312; 0.0363; 0.0415; 0.0458];
```

```
Compounding = 1;
```

```
RateSpec = intenvset('Compounding',Compounding,'StartDates', StartDates,...  
                    'EndDates', EndDates, 'Rates', Rates, 'ValuationDate', ValuationDate);
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'  
    Compounding: 1  
           Disc: [5x1 double]  
           Rates: [5x1 double]  
           EndTimes: [5x1 double]  
           StartTimes: [5x1 double]  
           EndDates: [5x1 double]
```



```

    StartDates: 732313
    ValuationDate: 732313
        Basis: 0
    EndMonthRule: 1

```

### Specify the Volatility Model

Create the structure VolSpec that specifies the volatility process with the following data.

```

Volatility = [0.005; 0.0055; 0.006; 0.0065; 0.007];
BDTVolSpec = bdtvolspec(ValuationDate, EndDates, Volatility)

```

```

BDTVolSpec =

    FinObj: 'BDTVolSpec'
    ValuationDate: 732313
    VolDates: [5x1 double]
    VolCurve: [5x1 double]
    VolInterpMethod: 'linear'

```

### Specify the Time Structure of the Tree

The structure TimeSpec specifies the time structure for an interest rate tree. This structure defines the mapping between the observation times at each level of the tree and the corresponding dates.

```

Maturity = EndDates;
BDTTimeSpec = bdttimespec(ValuationDate, Maturity, Compounding)

```

```

BDTTimeSpec =

    FinObj: 'BDTTimeSpec'
    ValuationDate: 732313
    Maturity: [5x1 double]
    Compounding: 1
    Basis: 0
    EndMonthRule: 1

```

### Create the BDT Tree

Use the previously computed values for RateSpec, VolSpec and TimeSpec to create the BDT tree.

```
BDTTree = bdttree(BDTVolSpec, RateSpec, BDTTimeSpec)
```

```
BDTTree =
```

```
    FinObj: 'BDTFwdTree'  
    VolSpec: [1x1 struct]  
    TimeSpec: [1x1 struct]  
    RateSpec: [1x1 struct]  
    tObs: [0 1 2 3 4]  
    dObs: [732313 732678 733043 733408 733774]  
    TFwd: {[5x1 double] [4x1 double] [3x1 double] [2x1 double] [4]}  
    CFlowT: {[5x1 double] [4x1 double] [3x1 double] [2x1 double] [5]}  
    FwdTree: {1x5 cell}
```

### Observe the Interest Rate Tree

Visualize the interest rate evolution along the tree by looking at the output structure BDTTree. BDTTree returns an inverse discount tree, which you can convert into an interest rate tree with the cvtree function.

```
BDTTreeR = cvtree(BDTTree);
```

Look at the upper branch and lower branch paths of the tree:

```
%Rate at root node:
```

```
RateRoot      = treepath(BDTTreeR.RateTree, [0])
```

```
%Rates along upper branch:
```

```
RatePathUp    = treepath(BDTTreeR.RateTree, [1 1 1 1])
```

```
%Rates along lower branch:
```

```
RatePathDown  = treepath(BDTTreeR.RateTree, [2 2 2 2])
```

```
RateRoot =
```

```
    0.0275
```

```
RatePathUp =
```

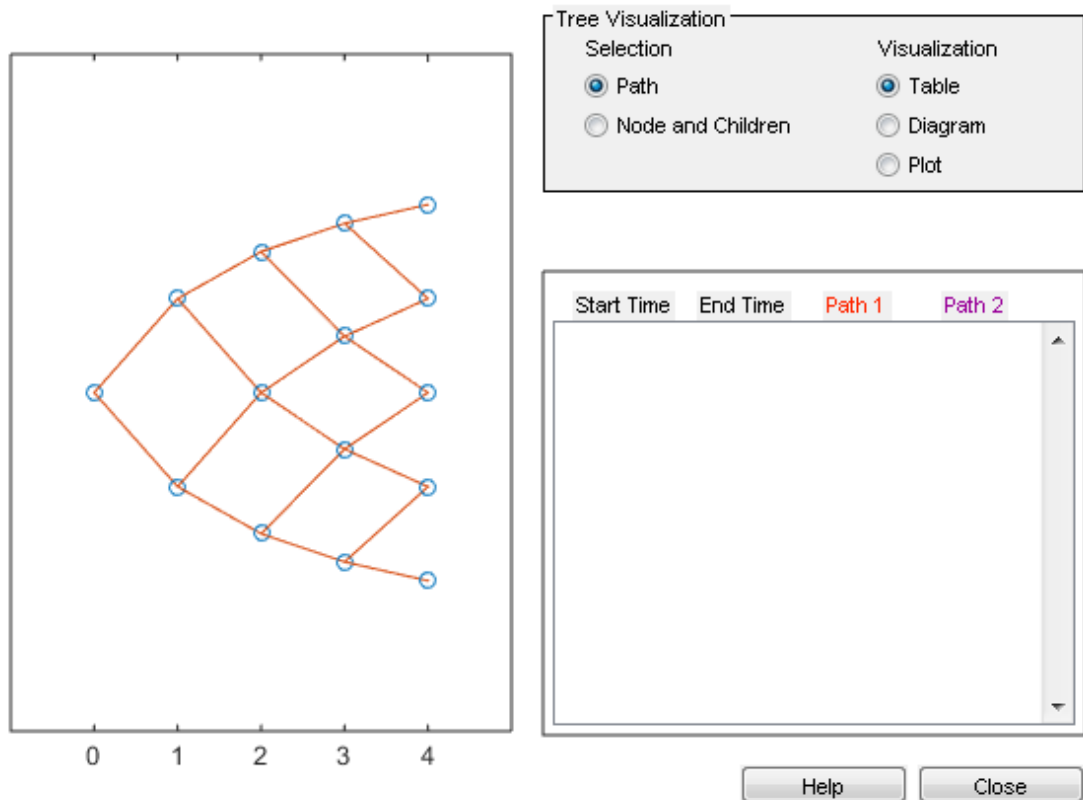
```
0.0275  
0.0347  
0.0460  
0.0560  
0.0612
```

```
RatePathDown =
```

```
0.0275  
0.0351  
0.0472  
0.0585  
0.0653
```

You can also display a graphical representation of the tree to examine interactively the rates on the nodes of the tree until maturity. The function `treeviewer` displays the structure of the rate tree in the left pane. The tree visualization in the right pane is blank, but by selecting `Diagram` and clicking on the nodes you can examine the rates along the paths.

```
treeviewer(BDTreeR)
```



### Create an Instrument Portfolio

Create a portfolio consisting of two bond instruments and a option on the 5% Bond.

```
% Bonds
CouponRate = [0.04;0.05];
Settle = '01 Jan 2005';
Maturity = ['01 Jan 2009';'01 Jan 2010'];
Period = 1;

% Option
OptSpec = {'call'};
Strike = 98;
ExerciseDates = ['01 Jan 2010'];
```

```
AmericanOpt = 1;
```

```
InstSet = instadd('Bond',CouponRate, Settle, Maturity, Period);
InstSet = instadd(InstSet,'OptBond', 2, OptSpec, Strike, ExerciseDates, AmericanOpt);
```

Examine the set of instruments contained in the variable InstSet.

```
instdisp(InstSet)
```

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate
1	Bond	0.04	01-Jan-2005	01-Jan-2009	1	0	1	NaN
2	Bond	0.05	01-Jan-2005	01-Jan-2010	1	0	1	NaN

Index	Type	UnderInd	OptSpec	Strike	ExerciseDates	AmericanOpt
3	OptBond	2	call	98	01-Jan-2010	1

### Price the Portfolio Using a BDT Tree

Calculate the price of each instrument in the instrument set.

```
Price = bdtprice(BDTTree, InstSet)
```

```
Price =
```

```
    99.6374
   102.2460
     4.2460
```

The prices in the output vector Price correspond to the prices at observation time zero ( $t_{\text{Obs}} = 0$ ), which is defined as the Valuation Date of the interest-rate tree.

In the Price vector, the first element, 99.6374, represents the price of the first instrument (4% Bond); the second element, 102.2460, represents the price of the second instrument (5% Bond), and 4.2460 represents the price of the Option.

## Portfolio Management

### In this section...

“Instrument Constructors” on page 1-16

“Creating Instruments or Properties” on page 1-17

“Searching or Subsetting a Portfolio” on page 1-19

### Instrument Constructors

The toolbox provides constructors for the most common financial instruments. A *constructor* is a function that builds a structure dedicated to a certain type of object; in this toolbox, an *object* is a type of market instrument.

The instruments and their constructors in this toolbox are listed below.

Instrument	Constructor
Asian option	instasian
Barrier option	instbarrier
Bond	instbond
Bond option	instoptbnd
Arbitrary cash flow	instcf
Compound option	instcompound
Fixed-rate note	instfixed
Floating-rate note	instfloat
Cap	instcap
Floor	instfloor
Lookback option	instlookback
Stock option	instoptstock
Swap	instswap
Swaption	instswaption

Each instrument has parameters (fields) that describe the instrument. The toolbox functions let you do the following:

- Create an instrument or portfolio of instruments.
- Enumerate stored instrument types and information fields.
- Enumerate instrument field data.
- Search and select instruments.

The instrument structure consists of various fields according to instrument type. A *field* is an element of data associated with the instrument. For example, a bond instrument contains the fields `CouponRate`, `Settle`, `Maturity`, and so on. Additionally, each instrument has a field that identifies the investment type (bond, cap, floor, and so on).

In reality, the set of parameters for each instrument is not fixed. You have the ability to add additional parameters. These additional fields are ignored by the toolbox functions. They may be used to attach additional information to each instrument, such as an internal code describing the bond.

Parameters not specified when *creating* an instrument default to NaN, which, in general, means that the functions using the instrument set (such as `intenvprice` or `hjmprice`) will use default values. At the time of *pricing*, an error occurs if any of the required fields is missing, such as `Strike` in a cap or `CouponRate` in a bond.

## Creating Instruments or Properties

Use the `instadddfield` function to create a kind of instrument or to add new properties to the instruments in an existing instrument collection.

To create a kind of instrument with `instadddfield`, you must specify three arguments:

- `Type`
- `FieldName`
- `Data`

`Type` defines the type of the new instrument, for example, `Future`. `FieldName` names the fields uniquely associated with the new type of instrument. `Data` contains the data for the fields of the new instrument.

An optional fourth argument is `ClassList`. `ClassList` specifies the data types of the contents of each unique field for the new instrument.

Use either syntax to create a kind of instrument using `instadddfield`:

```
InstSet = instadddfield('FieldName', FieldList, 'Data', DataList,...  
'Type', TypeString)  
InstSet = instadddfield('FieldName', FieldList, 'FieldClass',...  
ClassList, 'Data', DataList, 'Type', TypeString)
```

To add new instruments to an existing set, use:

```
InstSetNew = instadddfield(InstSetOld, 'FieldName', FieldList,...  
'Data', DataList, 'Type', TypeString)
```

As an example, consider a futures contract with a delivery date of July 15, 2000, and a quoted price of \$104.40. Since Financial Instruments Toolbox software does not directly support this instrument, you must create it using the function `instadddfield`. Use these parameters to create instruments:

- Type: Future
- Field names: `Delivery` and `Price`
- Data: Delivery is July 15, 2000, and price is \$104.40.

Enter the data into MATLAB software:

```
Type = 'Future';  
FieldName = {'Delivery', 'Price'};  
Data = {'Jul-15-2000', 104.4};
```

Finally, create the portfolio with a single instrument:

```
Port = instadddfield('Type', Type, 'FieldName', FieldName,...  
'Data', Data);
```

Now use the function `instdisp` to examine the resulting single-instrument portfolio:

```
instdisp(Port)  
  
Index Type    Delivery    Price  
1      Future Jul-15-2000 104.4
```

Because your portfolio `Port` has the same structure as those created using the function `instadd`, you can combine portfolios created using `instadd` with portfolios created using `instadddfield`. For example, you can now add two cap instruments to `Port` with `instadd`.

```
Strike = [0.06; 0.07];  
Settle = '08-Feb-2000';  
Maturity = '15-Jan-2003';  
  
Port = instadd(Port, 'Cap', Strike, Settle, Maturity);
```



View the resulting portfolio using `instdisp`.

```
instdisp(Port)
```

Index	Type	Delivery	Price
1	Future	15-Jul-2000	104.4

Index	Type	Strike	Settle	Maturity	CapReset	Basis	Principal
2	Cap	0.06	08-Feb-2000	15-Jan-2003	1	0	100
3	Cap	0.07	08-Feb-2000	15-Jan-2003	1	0	100

## Searching or Subsetting a Portfolio

Financial Instruments Toolbox software provides functions that enable you to:

- Find specific instruments within a portfolio.
- Create a subset portfolio consisting of instruments selected from a larger portfolio.

The `instfind` function finds instruments with a specific parameter value; it returns an instrument index (position) in a large instrument set. The `instselect` function, on the other hand, subsets a large instrument set into a portfolio of instruments with designated parameter values; it returns an instrument set (portfolio) rather than an index.

### **instfind**

The general syntax for `instfind` is

```
IndexMatch = instfind(InstSet, 'FieldName', FieldList, 'Data', ...
DataList, 'Index', IndexSet, 'Type', TypeList)
```

`InstSet` is the instrument set to search. Within `InstSet` instruments categorized by type, each type can have different data fields. The stored data field is a row vector or string for each instrument.

The `FieldList`, `DataList`, and `TypeList` arguments indicate values to search for in the `FieldName`, `Data`, and `Type` data fields of the instrument set. `FieldList` is a cell array of field name(s) specific to the instruments. `DataList` is a cell array or matrix of acceptable values for the parameter(s) specified in `FieldList`. `FieldName` and `Data` (consequently, `FieldList` and `DataList`) parameters must appear together or not at all.

`IndexSet` is a vector of integer index(es) designating positions of instruments in the instrument set to check for matches; the default is all indices available in the instrument

set. `TypeList` is a string or cell array of strings restricting instruments to match one of the `TypeList` types; the default is all types in the instrument set.

`IndexMatch` is a vector of positions of instruments matching the input criteria. Instruments are returned in `IndexMatch` if all the `FieldName`, `Data`, `Index`, and `Type` conditions are met. An instrument meets an individual field condition if the stored `FieldName` data matches any of the rows listed in the `DataList` for that `FieldName`.

### instfind Examples

The examples use the provided MAT-file `deriv.mat`.

The MAT-file contains an instrument set, `HJMInstSet`, that contains eight instruments of seven types.

```
load deriv.mat
instdisp(HJMInstSet)
```

```

Index Type CouponRate Settle      Maturity   Period Basis ... Name      Quantity
1   Bond 0.04      01-Jan-2000 01-Jan-2003   1   NaN ... 4% bond   100
2   Bond 0.04      01-Jan-2000 01-Jan-2004   2   NaN ... 4% bond    50

Index Type UnderInd OptSpec Strike ExerciseDates AmericanOpt Name      Quantity
3   OptBond 2      call    101    01-Jan-2003   NaN      Option 101   -50

Index Type CouponRate Settle      Maturity   FixedReset Basis Principal Name      Quantity
4   Fixed 0.04      01-Jan-2000 01-Jan-2003   1   NaN   NaN   4% Fixed   80

Index Type Spread Settle      Maturity   FloatReset Basis Principal Name      Quantity
5   Float 20      01-Jan-2000 01-Jan-2003   1   NaN   NaN   20BP Float   8

Index Type Strike Settle      Maturity   CapReset Basis Principal Name      Quantity
6   Cap 0.03    01-Jan-2000 01-Jan-2004   1   NaN   NaN   3% Cap     30

Index Type Strike Settle      Maturity   FloorReset Basis Principal Name      Quantity
7   Floor 0.03 01-Jan-2000 01-Jan-2004   1   NaN   NaN   3% Floor   40

Index Type LegRate Settle      Maturity   LegReset Basis Principal LegType Name      Quantity
8   Swap [0.06 20] 01-Jan-2000 01-Jan-2003 [1 1]   NaN   NaN   [NaN] 6%/20BP Swap 10
```

Find all instruments with a maturity date of January 01, 2003.

```

Mat2003 = ...
instfind(HJMInstSet, 'FieldName', 'Maturity', 'Data', '01-Jan-2003')

Mat2003 =

     1
     4
     5
```

8

Find all cap and floor instruments with a maturity date of January 01, 2004.

```
CapFloor = instfind(HJMInstSet,...
'FieldName','Maturity','Data','01-Jan-2004','Type',...
{'Cap';'Floor'})
```

```
CapFloor =
```

```
6
7
```

Find all instruments where the portfolio is long or short a quantity of 50.

```
Pos50 = instfind(HJMInstSet,'FieldName',...
'Quantity','Data',{'50';'-50'})
```

```
Pos50 =
```

```
2
3
```

### **instselect**

The syntax for `instselect` is the same syntax as for `instfind`. `instselect` returns a full portfolio instead of indexes into the original portfolio. Compare the values returned by both functions by calling them equivalently.

Previously you used `instfind` to find all instruments in `HJMInstSet` with a maturity date of January 01, 2003.

```
Mat2003 = ...
instfind(HJMInstSet,'FieldName','Maturity','Data','01-Jan-2003')
```

```
Mat2003 =
```

```
1
4
5
8
```

Now use the same instrument set as a starting point, but execute the `instselect` function instead, to produce a new instrument set matching the identical search criteria.

```
Select2003 = ...
instselect(HJMInstSet, 'FieldName', 'Maturity', 'Data', ...
'01-Jan-2003')
```

```
instdisp(Select2003)
```

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate	FirstCouponDate	LastCouponDate	Sta
1	Bond	0.04	01-Jan-2000	01-Jan-2003	1	NaN	NaN	NaN	NaN	NaN	NaN

Index	Type	CouponRate	Settle	Maturity	FixedReset	Basis	Principal	Name	Quantity
2	Fixed	0.04	01-Jan-2000	01-Jan-2003	1	NaN	NaN	4% Fixed	80

Index	Type	Spread	Settle	Maturity	FloatReset	Basis	Principal	Name	Quantity
3	Float	20	01-Jan-2000	01-Jan-2003	1	NaN	NaN	20BP Float	8

Index	Type	LegRate	Settle	Maturity	LegReset	Basis	Principal	LegType	Name	Quantity
4	Swap	[0.06 20]	01-Jan-2000	01-Jan-2003	[1 1]	NaN	NaN	[NaN]	6%/20BP Swap	10

### instselect Examples

These examples use the portfolio `ExampleInst` provided with the MAT-file `InstSetExamples.mat`.

```
load InstSetExamples.mat
instdisp(ExampleInst)
```

Index	Type	Strike	Price	Opt	Contracts
1	Option	95	12.2	Call	0
2	Option	100	9.2	Call	0
3	Option	105	6.8	Call	1000

Index	Type	Delivery	F	Contracts
4	Futures	01-Jul-1999	104.4	-1000

Index	Type	Strike	Price	Opt	Contracts
5	Option	105	7.4	Put	-1000
6	Option	95	2.9	Put	0

Index	Type	Price	Maturity	Contracts
7	TBill	99	01-Jul-1999	6

The instrument set contains 3 instrument types: `Option`, `Futures`, and `TBill`. Use `instselect` to make a new instrument set containing only options struck at 95. In other words, select all instruments containing the field `Strike` and with the data value for that field equal to 95.

```
InstSet = instselect(ExampleInst, 'FieldName', 'Strike', 'Data', 95);
instdisp(InstSet)
```

Index	Type	Strike	Price	Opt	Contracts
1	Option	95	12.2	Call	0
2	Option	95	2.9	Put	0

You can use all the various forms of `instselect` and `instfind` to locate specific instruments within this instrument set.



# Interest-Rate Derivatives

---

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- “Overview of Interest-Rate Tree Models” on page 2-32
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## Supported Interest-Rate Instruments

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### Bond

A *bond* is a long-term debt security with a preset interest-rate and maturity. At maturity you must pay the principal and interest.



The price or value of a bond is determined by discounting the expected cash flows of the bond to the present, using the appropriate discount rate. The following equation represents the relationship of the expected cash flows and discount rate:

$$B_0 = \frac{C}{2} \left[ \frac{1 - \left(1 + \frac{r}{2}\right)^{-2t}}{\frac{r}{2}} \right] + \frac{F}{\left(1 + \frac{r}{2}\right)^{2t}}$$

where:

$B_0$  is the bond value.

$C$  is the annual coupon payment.

$F$  is the face value of the bond.

$r$  is the required return on the bond.

$t$  is the number of years remaining until maturity.

Financial Instruments Toolbox supports the following for pricing and specifying a bond.

Function	Purpose
bondbybdt	Price a bond using a BDT interest-rate tree.
bondbyhw	Price a bond using an HW interest-rate tree.
bondbybk	Price a bond using a BK interest-rate tree.
bondbyhjm	Price a bond using an HJM interest-rate tree.
bondbyzero	Price a bond using a set of zero curves.
instbond	Construct a bond instrument.

## Stepped Coupon Bonds

A step-up and step-down bond is a debt security with a predetermined coupon structure over time. With these instruments, coupons increase (step up) or decrease (step down) at specific times during the life of the bond. For more information on options features (call and puts), see “Stepped Coupon Bonds with Calls and Puts” on page 2-6. The

following functions have a modified **CouponRate** argument to support a new variable coupon schedule allowing pricing of stepped coupon bonds.

<b>Function</b>	<b>Purpose</b>
bondbyzero	Price bonds using a term structure model.
bondbybdt	Price bonds using a BDT tree model.
bondbyhjm	Price bonds using an HJM tree model.
bondbyhw	Price bonds using an HW tree model.
bondbybk	Price bonds using a BK tree model.
instbond	Construct a bond instrument.
instoptbnd	Construct a bond option instrument.
instdisp	Display instruments stored in a variable.

## Sinking Fund Bonds

A sinking fund bond is a coupon bond with a sinking fund provision. This provision obligates the issuer to amortize portions of the principal before maturity, affecting bond prices since the time of the principal repayment changes. This means that investors receive the coupon and a portion of the principal paid back over time. These types of bonds reduce credit risk, since it lowers the probability of investors not receiving their principal payment at maturity. For more information on options support for sinking fund bonds, see “Sinking Fund Bonds with an Embedded Option” on page 2-7. The following functions have a modified **Face** argument to support a variable face schedule for pricing bonds with a sinking provisions.

<b>Function</b>	<b>Purpose</b>
bondbyzero	Price bonds using a term structure model.
bondbybdt	Price bonds using a BDT tree model.
bondbyhjm	Price bonds using an HJM tree model.
bondbyhw	Price bonds using an HW tree model.
bondbybk	Price bonds using a BK tree model.
instbond	Construct a bond instrument.
instoptbnd	Construct a bond option instrument.

Function	Purpose
instdisp	Display instruments stored in a variable.

## Bonds with an Amortization Schedule

A bond with an amortization schedule repays part of the principal (face value) along with the coupon payments. An amortizing bond is a special case of a sinking fund bond when there is no market purchase option and no call provision.. The following functions have a modified **Face** argument to support an amortization schedule.

Function	Purpose
bondbyzero	Price bonds using a term structure model.
bondbybdt	Price bonds using a BDT tree model.
bondbyhjm	Price bonds using an HJM tree model.
bondbyhw	Price bonds using an HW tree model.
bondbybk	Price bonds using a BK tree model.

## Bond Options

Financial Instruments Toolbox software supports three types of put and call options on bonds:

- American option: An option that you exercise any time until its expiration date.
- European option: An option that you exercise only on its expiration date.
- Bermuda option: A Bermuda option resembles a hybrid of American and European options. You can exercise it on predetermined dates only, usually monthly.

Financial Instruments Toolbox supports the following for pricing and specifying a bond option.

Function	Purpose
optbndbybdt	Price a bond option price using a BDT interest-rate tree.
optbndbyhw	Price a bond option price using an HW interest-rate tree.
optbndbybk	Price a bond option price using a BK interest-rate tree.

Function	Purpose
optbndbyhjm	Price a bond option price using an HJM interest-rate tree.
instoptbnd	Construct a bond option instrument.

## Bond with Embedded Options

A bond with embedded options allows the issuer to buy back or redeem the bond at a predetermined price at specified future dates. Financial Instruments Toolbox software supports American, European, and Bermuda callable and puttable bonds.

The pricing for a bond with embedded options is as follows:

- For a callable bond:  $PriceCallableBond = BondPrice - BondCallOption$
- For a puttable bond:  $PricePuttableBond = PriceBond + PricePutOption$

Financial Instruments Toolbox supports the following for pricing and specifying a bond with embedded options.

Function	Purpose
optembndbybdt	Price a bond with embedded options using a BDT interest-rate tree.
optembndbyhw	Price a bond with embedded options using an HW interest rate tree.
optembndbybk	Price a bond with embedded options using a BK interest-rate tree.
optembndbyhjm	Price a bond with embedded options using an HJM interest-rate tree.
instoptembnd	Construct a bond-with-embedded-options instrument.

## Stepped Coupon Bonds with Calls and Puts

A step-up and step-down bond is a debt security with a predetermined coupon structure over time. For more information on stepped coupon bonds, see “Stepped Coupon Bonds” on page 2-3. Stepped coupon bonds can have options features (call and puts). The following functions have a modified `CouponRate` argument to support a new variable

coupon schedule allowing pricing stepped coupon bonds with callable and puttable features:

Function	Purpose
optembndbybdt	Price bonds with embedded options using a BDT model tree.
optembndbyhjm	Price bonds with embedded options using an HJM model tree.
optembndbybk	Price bonds with embedded options using a BK model tree.
optembndbyhw	Price bonds with embedded options using an HW model tree.
instbond	Construct a bond instrument.
instoptbnd	Construct a bond option instrument.
instoptembnd	Construct a bond with an embedded option instrument.
instdisp	Display instruments stored in a variable.

## Sinking Fund Bonds with an Embedded Option

A sinking fund bond is a coupon bond with a sinking fund provision. For more information on sinking fund bonds, see “Sinking Fund Bonds” on page 2-4. The sinking fund bond can have a sinking fund option provision allowing the issuer to retire the sinking fund obligation either by purchasing the bonds to be redeemed from the market or by calling the bond via a sinking fund call, whichever is cheaper.

If interest rates are high, then the issuer buys back the required amount of bonds from the market since bonds will be cheap. But if interest rates are low (bond prices are high), then most likely the issuer buys the bonds at the call price. Unlike a call feature, however, if a bond has a sinking fund option provision, it is an obligation, not an option, for the issuer to buy back the increments of the issue as stated. Because of this, a sinking fund bond trades at a lower price than a nonsinking fund bond. The following functions have a modified **Face** argument to support a variable face schedule for pricing bonds with a sinking fund option provision.

Function	Purpose
optembndbybdt	Price bonds with embedded options using a BDT model tree.
optembndbyhjm	Price bonds with embedded options using an HJM model tree.
optembndbybk	Price bonds with embedded options using a BK model tree.
optembndbyhw	Price bonds with embedded options using an HW model tree.

Function	Purpose
instbond	Construct a bond instrument.
instoptbnd	Construct a bond option instrument.
instdisp	Display instruments stored in a variable.

## Fixed-Rate Note

A *fixed-rate note* is a long-term debt security with a preset interest rate and maturity, by which the interest must be paid. The principal may or may not be paid at maturity. In Financial Instruments Toolbox software, the principal is always paid at maturity.

Function	Purpose
fixedbybdt	Price a fixed-rate note using a BDT interest-rate tree.
fixedbyhw	Price a fixed-rate note using an HW interest-rate tree.
fixedbybk	Price a fixed-rate note using a BK interest-rate tree.
fixedbyhjm	Price a fixed-rate note using an HJM interest-rate tree.
fixedbyzero	Price a fixed-rate note using a set of zero curves.
instfixed	Construct a fixed-rate instrument.

## Floating-Rate Note

A *floating-rate note* is a security like a bond, but the interest rate of the note is reset periodically, relative to a reference index rate, to reflect fluctuations in market interest rates.

Function	Purpose
floatbybdt	Price a floating-rate note using a BDT interest-rate tree.
floatbyhw	Price a floating-rate note using an HW interest-rate tree.
floatbybk	Price a floating-rate note using a BK interest-rate tree.
floatbyhjm	Price a floating-rate note using an HJM interest-rate tree.

Function	Purpose
floatbyzero	Price a floating-rate note using a set of zero curves.
instfloat	Construct a floating-rate note instrument.

## Floating-Rate Note with an Amortization Schedule

A floating-rate note with an amortization schedule repays part of the principal (face value) along with the coupon payments. The following functions have a **Principal** argument to support an amortization schedule.

Function	Purpose
floatbyzero	Price floating-rate note from set of zero curves.
floatbybdt	Price floating-rate note from Black-Derman-Toy interest-rate tree.
floatbyhjm	Price floating-rate note from Heath-Jarrow-Morton interest-rate tree.
floatbyhw	Price floating-rate note from Hull-White interest-rate tree.
floatbybk	Price floating-rate note from Black-Karasinski interest-rate tree.

## Floating-Rate Note with Caps, Collars, and Floors

A floating-rate note with caps, collars, and floors This type of instrument can carry restrictions on the maximum (cap) or minimum (floor) coupon rate are paid. A cap is an unattractive feature for an investor, since they constrain the coupon rates from increasing. A floor, on the other hand, is an attractive feature, since it allows investors to get a minimum coupon rate when market rates decrease below a certain level. Also, a floating-rate note can have a collar which is a combination of a cap and a floor together. The following functions have a **CapRate** and **FloorRate** argument to support a capped, collared, or floored floating-rate note.

Function	Purpose
floatbybdt	Price a capped floating-rate note from a Black-Derman-Toy interest-rate tree.
floatbyhjm	Price a capped floating-rate note from a Heath-Jarrow-Morton interest-rate tree.

Function	Purpose
floatbyhw	Price a capped floating-rate note from a Hull-White interest-rate tree.
floatbybk	Price a capped floating-rate note from a Black-Karasinski interest-rate tree.
instfloat	Create a capped floating-rate note instrument.
instadd	Add a capped floating-rate note instrument to a portfolio.

## Floating-Rate Note with Options

Financial Instruments Toolbox supports three types of put and call options on floating rate-notes:

- American option — An option that you exercise any time until its expiration date.
- European option — An option that you exercise only on its expiration date.
- Bermuda option — A Bermuda option resembles a hybrid of American and European options; you can only exercise it on predetermined dates, usually monthly.

Financial Instruments Toolbox supports the following for pricing and specifying a floating rate-note option:

Function	Purpose
optfloatbybdt	Price an option for floating-rate note using a Black-Derman-Toy interest-rate tree.
optfloatbyhjm	Price an option for floating-rate note using a Heath-Jarrow-Morton interest-rate tree.
optfloatbyhw	Price an option for floating-rate note using a Hull-White interest-rate tree.
optfloatbybk	Price an option for floating-rate note using a Black-Karasinski interest-rate tree.
instoptfloat	Define the option instrument for floating-rate note.

## Floating-Rate Note with Embedded Options

A floating-rate note with an embedded option enables floating-rate notes to have early redemption features. A FRN with an embedded option gives investors or issuers the



option to retire the outstanding principal prior to maturity. An embedded call option gives the right to retire the note prior to the maturity date (callable floater), and an embedded put option gives the right to sell the note back at a specific price (puttable floater).

Financial Instruments Toolbox supports the following for pricing and specifying a floating rate-note with an embedded option:

Function	Purpose
optemfloatbybdt	Price an embedded option for floating-rate note using a Black-Derman-Toy interest-rate tree.
optemfloatbybk	Price an embedded option for floating-rate note using a Black-Karasinski interest-rate tree.
optemfloatbyhjm	Price an embedded option for floating-rate note using a Heath-Jarrow-Morton interest-rate tree.
optemfloatbyhw	Price an embedded option for floating-rate note using a Hull-White interest-rate tree.
instoptemfloat	Define the floating-rate note with embedded option instrument.

## Cap

A *cap* is a contract that includes a guarantee that sets the maximum interest rate to be paid by the holder, based on an otherwise floating interest rate. The payoff for a cap is:

$$\max(\text{CurrentRate} - \text{CapRate}, 0)$$

Function	Purpose
capbybdt	Price a cap instrument using a BDT interest-rate tree.
capbyhw	Price a cap instrument using an HW interest-rate tree.
capbybk	Price a cap instrument using a BK interest-rate tree.
capbyhjm	Price a cap instrument using an HJM interest-rate tree.
capbyblk	Price a cap instrument using the Black option pricing model.

Function	Purpose
instcap	Construct a cap instrument.

## Floor

A *floor* is a contract that includes a guarantee setting the minimum interest rate to be received by the holder, based on an otherwise floating interest rate. The payoff for a floor is:

$$\max(\text{FloorRate} - \text{CurrentRate}, 0)$$

Function	Purpose
floorbybdt	Price a floor instrument using a BDT interest-rate tree.
floorbyhw	Price a floor instrument using an HW interest-rate tree.
floorbybk	Price a floor instrument using a BK interest-rate tree.
floorbyhjm	Price a floor instrument using an HJM interest-rate tree.
instfloor	Construct a floor instrument.

## Range Note

A *range note* is a structured (market-linked) security whose coupon-rate is equal to the reference rate as long as the reference rate is within a certain range. If the reference rate is outside of the range, the coupon-rate is 0 for that period. This type of instrument entitles the holder to cash flows that depend on the level of some reference interest-rate that are floored to be positive and gives the holder of the note direct exposure to the reference rate. This type of instrument is useful for cases where you believe that interest rates will stay within a certain range. In return for the drawback that no interest will be paid for the time the range is left, a range note offers higher coupon rates than comparable standard products, like vanilla floating notes.

Function	Purpose
instrangefloat	Create a range note instrument.

Function	Purpose
rangefloatbybdt	Price range floating note using a BDT tree.
rangefloatbybk	Price range floating note using a BK tree.
rangefloatbyhjm	Price range floating note using an HJM tree.
rangefloatbyhw	Price range floating note using an HW tree.

## Swap

A *swap* is contract between two parties obligating the parties to exchange future cash flows. This toolbox version handles only the vanilla swap, which is composed of a floating-rate leg and a fixed-rate leg.

Function	Purpose
swapbybdt	Price a swap instrument using a BDT interest-rate tree.
swapbyhw	Price a swap instrument using an HW interest-rate tree.
swapbybk	Price a swap instrument using a BK interest-rate tree.
swapbyhjm	Price a swap instrument using an HJM interest-rate tree.
swapbyzero	Price a swap instrument using a set of zero curves.
instswap	Construct a swap instrument.

## Swap with an Amortization Schedule

A swap with an amortization schedule repays part of the principal (face value) along with the coupon payments. A swap with an amortization schedule is used to manage interest rate risk and serve as a cash flow management tool. For this particular type of swap, the notional amount decreases over time. This means that interest payments will decrease not only on the floating leg but also on the fixed leg. The following swap functions have a `Principal` argument to support an amortization schedule.

Function	Purpose
swapbyzero	Price swap instrument from set of zero curves.

Function	Purpose
swapbybdt	Price swap instrument from Black-Derman-Toy interest-rate tree.
swapbyhjm	Price swap instrument from Heath-Jarrow-Morton interest-rate tree.
swapbyhw	Price swap instrument from Hull-White interest-rate tree.
swapbybk	Price swap instrument from Black-Karasinski interest-rate tree.
instswap	Construct swap instrument.

## Forward Swap

In a forward interest-rate swap, a fixed interest rate loan is exchanged for a floating interest rate loan at a future specified date. The following functions have a **StartDate** argument to support the future date for the forward swap.

Function	Purpose
swapbyzero	Price a forward swap from a zero curve.
swapbybdt	Price a forward swap from a Black-Derman-Toy interest-rate tree.
swapbyhjm	Price a forward swap from a Heath-Jarrow-Morton interest-rate tree.
swapbyhw	Price a forward swap from a Hull-White interest-rate tree.
swapbybk	Price a forward swap from a Black-Karasinski interest-rate tree.
instswap	Create a forward swap instrument.
instadd	Add a capped floating-rate note instrument to a portfolio.

## Swaption

A swaption is an option to enter into an interest-rate swap contract. A call swaption allows the option buyer to enter into an interest-rate swap where the buyer of the option pays the fixed-rate and receives the floating-rate. A put swaption allows the option buyer to enter into an interest-rate swap where the buyer of the option receives the fixed-rate and pays the floating-rate.

Function	Purpose
swaptionbybdt	Price a swaption instrument using a BDT interest-rate tree.
swaptionbyhw	Price a swaption instrument using an HW interest-rate tree.
swaptionbybk	Price a swaption instrument using a BK interest-rate tree.
swaptionbyhjm	Price a swaption instrument using an HJM interest-rate tree.
swaptionbyblk	Price swaptions using the Black model with a forward on a swap.
instswaption	Construct a swaption instrument.

Use `swaptionbyblk` to price a swaption using the Black model. The Black model is standard model used in the swaption market when pricing European swaptions. This type of model is widely used by when speed is important to quickly obtain a price at settlement date, even if the price is less accurate than other swaption pricing models based on interest-rate tree models.

## Bond Futures

Bond futures are futures contracts where the commodity for delivery is a government bond. There are established global markets for government bond futures. Bond futures provide a liquid alternative for managing interest-rate risk.

In the U.S. market, the Chicago Mercantile Exchange (CME) offers futures on Treasury bonds and notes with maturities of 2, 5, 10, and 30 years. Typically, the following bond future contracts from the CME have maturities of 3, 6, 9, and 12 months:

- 30-year U.S. Treasury bond
- 10-year U.S. Treasury bond
- 5-year U.S. Treasury bond
- 2-year U.S. Treasury bond

The short position in a Treasury bond or note future contract must deliver to the long position in one of many possible existing Treasury bonds. For example, in a 30-year Treasury bond future, the short position must deliver a Treasury bond with at least 15

years to maturity. Because these bonds have different values, the bond future contract is standardized by computing a conversion factor. The conversion factor normalizes the price of a bond to a theoretical bond with a coupon of 6%. The price of a bond future contract is represented as:

$$\text{InvoicePrice} = \text{FutPrice} \times \text{CF} + \text{AI}$$

where:

*FutPrice* is the price of the bond future.

*CF* is the conversion factor for a bond to deliver in a futures contract.

*AI* is the accrued interest.

The short position in a futures contract has the option of which bond to deliver and, in the U.S. bond market, when in the delivery month to deliver the bond. The short position typically chooses to deliver the bond known as the Cheapest to Deliver (CTD). The CTD bond most often delivers on the last delivery day of the month.

Financial Instruments Toolbox software supports the following bond futures:

- U.S. Treasury bonds and notes
- German Bobl, Bund, Buxl, and Schatz
- UK gilts
- Japanese government bonds (JGBs)

The functions supporting all bond futures are:

Function	Purpose
convfactor	Calculates bond conversion factors for U.S. Treasury bonds, German Bobl, Bund, Buxl, and Schatz, U.K. gilts, and JGBs.
bndfutprice	Prices bond future given repo rates.
bndfutimprepo	Calculates implied repo rates for a bond future given price.

The functions supporting U.S. Treasury bond futures are:

Function	Purpose
tfutbyprice	Calculates future prices of Treasury bonds given the spot price.

<b>Function</b>	<b>Purpose</b>
tfutbyyield	Calculates future prices of Treasury bonds given current yield.
tfutimprepo	Calculates implied repo rates for the Treasury bond future given price.
tfutpricebyrepo	Calculates Treasury bond futures price given the implied repo rates.
tfutyieldbyrepo	Calculates Treasury bond futures yield given the implied repo rates.

For more information on bond futures, see “Supported Bond Futures”.

## Calibrate the SABR Model

This example shows how to use two different methods to calibrate the SABR stochastic volatility model from market implied Black volatilities. Both approaches use `blackvolbysabr`.

### In this section...

“Load Market Implied Black Volatility Data ” on page 2-18

“Method 1: Calibrate Alpha, Rho and Nu Directly” on page 2-19

“Method 2: Calibrate Rho and Nu by Implying Alpha From At-The-Money Volatility ” on page 2-19

“Use the Calibrated Models” on page 2-21

“References” on page 2-23

### Load Market Implied Black Volatility Data

This example shows how to set up hypothetical market implied Black volatilities for European swaptions over a range of strikes before calibration. The swaptions expire in 3 years from the `Settle` date and have 10 year swaps as the underlying instrument. Note that the rates are expressed in decimals. (Changing the units will affect the numerical value and interpretation of the `Alpha` input parameter to the function `blackvolbysabr`.)

Load the market implied Black volatility data for swaptions expiring in 3 years.

```
Settle = '12-Jun-2013';
ExerciseDate = '12-Jun-2016';
```

```
MarketStrikes = [2.0 2.5 3.0 3.5 4.0 4.5 5.0]'/100;
MarketVolatilities = [45.6 41.6 37.9 36.6 37.8 39.2 40.0]'/100;
```

At the time of `Settle`, define the underlying forward rate and the at-the-money volatility.

```
CurrentForwardValue = MarketStrikes(4)
ATMVolatility = MarketVolatilities(4)
```

```
CurrentForwardValue =
```

```
0.0350
```



```
ATMVolatility =
    0.3660
```

## Method 1: Calibrate Alpha, Rho and Nu Directly

This example shows how to calibrate the Alpha, Rho, and Nu input parameters directly. The value of Beta is predetermined either by fitting historical market volatility data or by choosing a value deemed appropriate for that market [1].

Define the predetermined Beta.

```
Beta1 = 0.5;
```

After fixing the value of  $\beta$  (Beta), the parameters  $\alpha$  (Alpha),  $\rho$  (Rho) and  $\nu$  (Nu) are all fitted directly. The Optimization Toolbox™ function `lsqnonlin` generates the parameter values that minimize the squared error between the market volatilities and the volatilities computed by `blackvolbysabr`.

```
% Calibrate Alpha, Rho, and Nu
objFun = @(X) MarketVolatilities - ...
    blackvolbysabr(X(1), Beta1, X(2), X(3), Settle, ...
    ExerciseDate, CurrentForwardValue, MarketStrikes);

X = lsqnonlin(objFun, [0.5 0 0.5], [0 -1 0], [Inf 1 Inf]);

Alpha1 = X(1);
Rho1 = X(2);
Nu1 = X(3);
```

Local minimum possible.

`lsqnonlin` stopped because the final change in the sum of squares relative to its initial value is less than the default value of the function tolerance.

## Method 2: Calibrate Rho and Nu by Implying Alpha From At-The-Money Volatility

This example shows how to use an alternative calibration method where the value of  $\beta$  (Beta) is again predetermined as in Method 1.

Define the predetermined Beta.

```
Beta2 = 0.5;
```

However, after fixing the value of  $\beta$  (Beta), the parameters  $\rho$  (Rho) and  $\nu$  (Nu) are fitted directly while  $\alpha$  (Alpha) is implied from the market at-the-money volatility. Models calibrated using this method produce at-the-money volatilities that are equal to market quotes. This approach is widely used in swaptions, where at-the-money volatilities are quoted most frequently and are important to match. In order to imply  $\alpha$  (Alpha) from market at-the-money volatility ( $\sigma_{ATM}$ ), the following cubic polynomial is solved for  $\alpha$  (Alpha), and the smallest positive real root is selected [2].

$$\frac{(1-\beta)^2 T}{24 F^{(2-2\beta)}} \alpha^3 + \frac{\rho \beta \nu T}{4 F^{(1-\beta)}} \alpha^2 + \left(1 + \frac{2-3\rho^2}{24} \nu^2 T\right) \alpha - \sigma_{ATM} F^{(1-\beta)} = 0$$

where:

- $F$  is the current forward value.
- $T$  is the year fraction to maturity.

To accomplish this, define an anonymous function as:

```
% Year fraction from Settle to option maturity
T = yearfrac(Settle, ExerciseDate, 1);

% This function solves the SABR at-the-money volatility equation as a
% polynomial of Alpha
alpharoots = @(Rho,Nu) roots([...
    (1 - Beta2)^2*T/24/CurrentForwardValue^(2 - 2*Beta2) ...
    Rho*Beta2*Nu*T/4/CurrentForwardValue^(1 - Beta2) ...
    (1 + (2 - 3*Rho^2)*Nu^2*T/24) ...
    -ATMVolatility*CurrentForwardValue^(1 - Beta2)]);

% This function converts at-the-money volatility into Alpha by picking the
% smallest positive real root
atmVol2SabrAlpha = @(Rho,Nu) min(real(arrayfun(@(x) ...
    x*(x>0) + realmax*(x<0 | abs(imag(x))>1e-6), alpharoots(Rho,Nu)))));
```

The function `atmVol2SabrAlpha` converts at-the-money volatility into  $\alpha$  (Alpha) for a given set of  $\rho$  (Rho) and  $\nu$  (Nu). This function is then used in the objective function to fit parameters  $\rho$  (Rho) and  $\nu$  (Nu).

```

% Calibrate Rho and Nu (while converting at-the-money volatility into Alpha
% using atmVol2SabrAlpha)
objFun = @(X) MarketVolatilities - ...
    blackvolbysabr(atmVol2SabrAlpha(X(1), X(2)), ...
        Beta2, X(1), X(2), Settle, ExerciseDate, CurrentForwardValue, ...
        MarketStrikes);

X = lsqnonlin(objFun, [0 0.5], [-1 0], [1 Inf]);

Rho2 = X(1);
Nu2 = X(2);

Local minimum found.

Optimization completed because the size of the gradient is less than
the default value of the function tolerance.

The calibrated parameter  $\alpha$  (Alpha) is computed using the calibrated parameters  $\rho$ 
(Rho) and  $\nu$  (Nu).

% Obtain final Alpha from at-the-money volatility using calibrated parameters
Alpha2 = atmVol2SabrAlpha(Rho2, Nu2);

% Display calibrated parameters
C = {Alpha1 Beta1 Rho1 Nu1;Alpha2 Beta2 Rho2 Nu2};
CalibratedParameters = cell2table(C,...
    'VariableNames',{'Alpha' 'Beta' 'Rho' 'Nu'},...
    'RowNames',{'Method 1';'Method 2'})

CalibratedParameters =

```

	Alpha	Beta	Rho	Nu
Method 1	0.060277	0.5	0.2097	0.75091
Method 2	0.058484	0.5	0.20568	0.79647

## Use the Calibrated Models

This example shows how to use the calibrated models to compute new volatilities at any strike value.

Compute volatilities for models calibrated using Method 1 and Method 2 and plot the results.

```

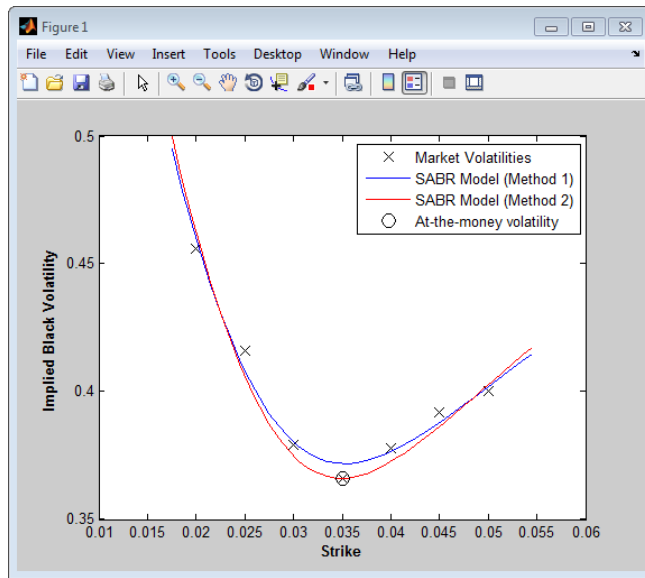
PlottingStrikes = (1.75:0.1:5.50)'/100;

% Compute volatilities for model calibrated by Method 1
ComputedVols1 = blackvolbysabr(Alpha1, Beta1, Rho1, Nu1, Settle, ...
    ExerciseDate, CurrentForwardValue, PlottingStrikes);

% Compute volatilities for model calibrated by Method 2
ComputedVols2 = blackvolbysabr(Alpha2, Beta2, Rho2, Nu2, Settle, ...
    ExerciseDate, CurrentForwardValue, PlottingStrikes);

figure;
plot(MarketStrikes,MarketVolatilities,'xk',...
    PlottingStrikes,ComputedVols1,'b', ...
    PlottingStrikes,ComputedVols2,'r', ...
    CurrentForwardValue,ATMVolatility,'ok',...
    'MarkerSize',10);
xlim([0.01 0.06]);
ylim([0.35 0.5]);
xlabel('Strike', 'FontWeight', 'bold');
ylabel('Implied Black Volatility', 'FontWeight', 'bold');
legend('Market Volatilities', 'SABR Model (Method 1)',...
    'SABR Model (Method 2)', 'At-the-money volatility');

```



Note that the model calibrated using Method 2 reproduces the market at-the-money volatility (marked with a circle) exactly.

## References

[1] Hagan, P. S., Kumar, D., Lesniewski, A. S. and Woodward, D. E., *Managing smile risk*, Wilmott Magazine, 2002.

[2] West, G., “Calibration of the SABR Model in Illiquid Markets,” *Applied Mathematical Finance*, 12(4), pp. 371-385, 2004.

## See Also

`blackvolbysabr` | `optsensbysabr` | `swaptionbyblk`

## Related Examples

- “Price a Swaption Using the SABR Model”

## Price a Swaption Using the SABR Model

This example shows how to price a swaption using the SABR model. First, a swaption volatility surface is constructed from market volatilities. This is done by calibrating the SABR model parameters separately for each swaption maturity. The swaption price is then computed by using the implied Black volatility on the surface as an input to the `swaptionbyblk` function.

### In this section...

“Load Market Swaption Volatility Data” on page 2-24

“Calibrate the SABR Model Parameters for Each Swaption Maturity” on page 2-25

“Construct a Volatility Surface” on page 2-27

“Use `swaptionbyblk` to Price a Swaption” on page 2-28

“References” on page 2-30

### Load Market Swaption Volatility Data

This example shows how to set up hypothetical market implied Black volatilities for European swaptions over a range of strikes (rows) and exercise dates (columns). All swaptions have 10 year swaps as the underlying instruments and the rates are expressed in decimals.

Load the market implied Black volatility data for swaptions.

```
Settle = '12-Jun-2013';
ExerciseDates = {'12-Sep-2013'; '12-Jun-2014'; '12-Jun-2015'; ...
                '12-Jun-2016'; '12-Jun-2017'; '12-Jun-2018'; '12-Jun-2020'; ...
                '12-Jun-2023'};
```

```
YearsToExercise = yearfrac(Settle, ExerciseDates, 1);
NumMaturities = length(YearsToExercise);
```

```
MarketVolatilities = [ ...
    57.6 53.7 49.4 45.6 44.1 41.1 35.2 32.0
    46.6 46.9 44.8 41.6 39.8 37.4 33.4 31.0
    35.9 39.3 39.6 37.9 37.2 34.7 30.5 28.9
    34.1 36.5 37.8 36.6 35.0 31.9 28.1 26.6
    41.0 41.3 39.5 37.8 36.0 32.6 29.0 26.0
```

```
45.8 43.4 41.9 39.2 36.9 33.2 29.6 26.3
50.3 46.9 44.0 40.0 37.5 33.8 30.2 27.3]/100;
```

```
MarketStrikes = [ ...
1.00 1.25 1.68 2.00 2.26 2.41 2.58 2.62;
1.50 1.75 2.18 2.50 2.76 2.91 3.08 3.12;
2.00 2.25 2.68 3.00 3.26 3.41 3.58 3.62;
2.50 2.75 3.18 3.50 3.76 3.91 4.08 4.12;
3.00 3.25 3.68 4.00 4.26 4.41 4.58 4.62;
3.50 3.75 4.18 4.50 4.76 4.91 5.08 5.12;
4.00 4.25 4.68 5.00 5.26 5.41 5.58 5.62]/100;
```

The current underlying forward rates and the corresponding at-the-money volatilities across the eight swaption maturities are represented in the fourth rows of the two matrices.

```
CurrentForwardValues = MarketStrikes(4,:);
ATMVolatilities = MarketVolatilities(4,:);
```

```
CurrentForwardValues =
```

```
0.0250    0.0275    0.0318    0.0350    0.0376    0.0391    0.0408    0.0412
```

```
ATMVolatilities =
```

```
0.3410    0.3650    0.3780    0.3660    0.3500    0.3190    0.2810    0.2660
```

## Calibrate the SABR Model Parameters for Each Swaption Maturity

This example shows how to use the model implemented in the function `blackvolbysabr`, a static SABR model, where the model parameters are assumed to be constant with respect to time. The parameters are calibrated separately for each swaption maturity (years to exercise) in a for loop. To better represent market at-the-money volatilities, the  $\alpha$  (Alpha) parameter values are implied by the market at-the-money volatilities (see "Method 2" for "Calibrate the SABR Model").

Define the predetermined Beta.

```
Beta = 0.5;
Betas = repmat(Beta, NumMaturities, 1);
Alphas = zeros(NumMaturities, 1);
```

```

Rhos = zeros(NumMaturities, 1);
Nus = zeros(NumMaturities, 1);

Calibrate SABR model parameters for each swaption maturity.

options = optimoptions('lsqnonlin','Display','none');

for k = 1:NumMaturities
    % This function solves the SABR at-the-money volatility equation as a
    % polynomial of Alpha
    alphanu = @(Rho,Nu) roots([...
        (1 - Beta)^2*YearsToExercise(k)/24/CurrentForwardValues(k)^(2 - 2*Beta) ...
        Rho*Beta*Nu*YearsToExercise(k)/4/CurrentForwardValues(k)^(1 - Beta) ...
        (1 + (2 - 3*Rho^2)*Nu^2*YearsToExercise(k)/24) ...
        -ATMVolatilities(k)*CurrentForwardValues(k)^(1 - Beta)]);

    % This function converts at-the-money volatility into Alpha by picking the
    % smallest positive real root
    atmVol2SabrAlpha = @(Rho,Nu) min(real(arrayfun(@(x) ...
        x*(x>0) + realmax*(x<0 || abs(imag(x))>1e-6), alphanu(Rho,Nu))));

    % Fit Rho and Nu (while converting at-the-money volatility into Alpha)
    objFun = @(X) MarketVolatilities(:,k) - ...
        blackvolbysabr(atmVol2SabrAlpha(X(1), X(2)), ...
            Beta, X(1), X(2), Settle, ExerciseDates(k), CurrentForwardValues(k), ...
            MarketStrikes(:,k));

    X = lsqnonlin(objFun, [0 0.5], [-1 0], [1 Inf], options);
    Rho = X(1);
    Nu = X(2);

    % Get final Alpha from the calibrated parameters
    Alpha = atmVol2SabrAlpha(Rho, Nu);

    Alphas(k) = Alpha;
    Rhos(k) = Rho;
    Nus(k) = Nu;
end

```

Display calibrated parameters in a table.

```

CalibratedParameters = array2table([Alphas Betas Rhos Nus],...
    'VariableNames',{'Alpha' 'Beta' 'Rho' 'Nu'},...
    'RowNames',{'3M into 10Y';'1Y into 10Y';...
    '2Y into 10Y';'3Y into 10Y';'4Y into 10Y';...

```



```

    '5Y into 10Y'; '7Y into 10Y'; '10Y into 10Y'})
CalibratedParameters =

```

	Alpha	Beta	Rho	Nu
3M into 10Y	0.051947	0.5	0.39572	1.4146
1Y into 10Y	0.054697	0.5	0.2955	1.1257
2Y into 10Y	0.058433	0.5	0.24175	0.93463
3Y into 10Y	0.058484	0.5	0.20568	0.79647
4Y into 10Y	0.056054	0.5	0.13685	0.76993
5Y into 10Y	0.051072	0.5	0.060285	0.73595
7Y into 10Y	0.04475	0.5	0.083385	0.66341
10Y into 10Y	0.044548	0.5	0.02261	0.49487

## Construct a Volatility Surface

This example shows how to use the calibrated model to compute new volatilities at any strike value to produce a smooth smile for a given maturity. This can be repeated for each maturity to form a volatility surface.

Compute volatilities using the calibrated models for each maturity.

```

PlottingStrikes = (0.95:0.1:5.8)'/100;
ComputedVols = zeros(length(PlottingStrikes), NumMaturities);

% Compute volatilities using the calibrated models for each maturity
for k = 1:NumMaturities
    ComputedVols(:,k) = blackvolbysabr(Alphas(k), Betas(k), Rhos(k), Nus(k), Settle, ...
        ExerciseDates(k), CurrentForwardValues(k), PlottingStrikes);
end

```

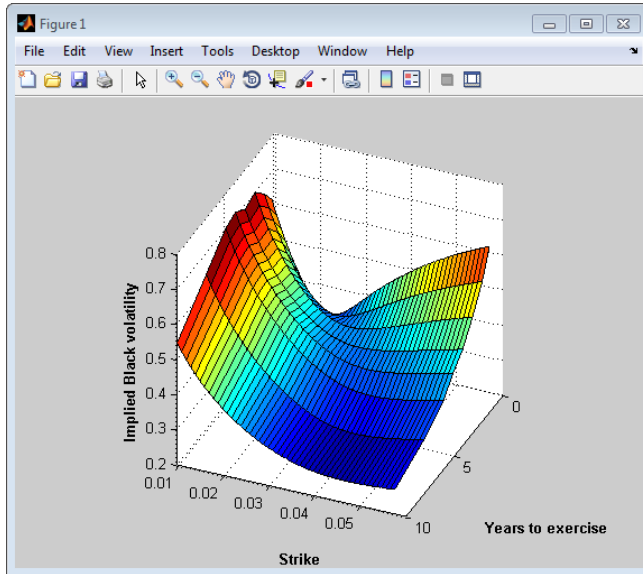
Plot the volatility surface.

```

figure;
surf(YearsToExercise, PlottingStrikes, ComputedVols);
xlim([0 10]); ylim([0.0095 0.06]); zlim([0.2 0.8]);
view(113,32);
set(gca, 'Position', [0.13 0.11 0.775 0.815], ...
    'PlotBoxAspectRatioMode', 'manual');
xlabel('Years to exercise', 'Fontweight', 'bold');
ylabel('Strike', 'Fontweight', 'bold');

```

```
zlabel('Implied Black volatility', 'Fontweight', 'bold');
```



Note, in this volatility surface, the smiles tend to get flatter for longer swaption maturities (years to exercise). This is consistent with the  $\nu$  ( $\text{Nu}$ ) parameter values tending to decrease with swaption maturity, as shown previously in the table for `CalibratedParameters`.

### Use `swaptionbyblk` to Price a Swaption

This example shows how to use the volatility surface to price a swaption that matures in 5 years.

Define a swaption (for a 10 year swap) that matures in 5 years.

```
SwaptionSettle = '12-Jun-2013';  
SwaptionExerciseDate = '12-Jun-2018';  
SwapMaturity = '12-Jun-2028';  
Reset = 1;  
OptSpec = 'call';  
Strike = 0.0263;
```

Assume that the interest-rate term structure at the time of the swaption `Settle` date is:

```

ValuationDate = '12-Jun-2013';
EndDates = {'12-Jul-2013'; '12-Sep-2013'; '12-Dec-2013'; '12-Jun-2014'; ...
            '12-Jun-2015'; '12-Jun-2016'; '12-Jun-2017'; '12-Jun-2018'; ...
            '12-Jun-2019'; '12-Jun-2020'; '12-Jun-2021'; '12-Jun-2022'; ...
            '12-Jun-2023'; '12-Jun-2025'; '12-Jun-2028'; '12-Jun-2033'};
Rates = [0.2 0.3 0.4 0.7 0.5 0.7 1.0 1.4 1.7 1.9 ...
         2.1 2.3 2.5 2.8 3.1 3.3]'/100;
Compounding = 1;

RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', ValuationDate, ...
                    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)

RateSpec =

    FinObj: 'RateSpec'
  Compounding: 1
        Disc: [16x1 double]
        Rates: [16x1 double]
    EndTimes: [16x1 double]
    StartTimes: [16x1 double]
    EndDates: [16x1 double]
    StartDates: 735397
  ValuationDate: 735397
        Basis: 0
    EndMonthRule: 1

```

Using this `RateSpec`, compute the current forward swap rate using the function `swapbyzero`.

```

LegRate = [NaN 0]; % To compute the forward swap rate, set the coupon rate to NaN.
[~, CurrentForwardSwapRate] = swapbyzero(RateSpec, LegRate, SwaptionSettle, SwapMaturity,
    'StartDate', SwaptionExerciseDate);

```

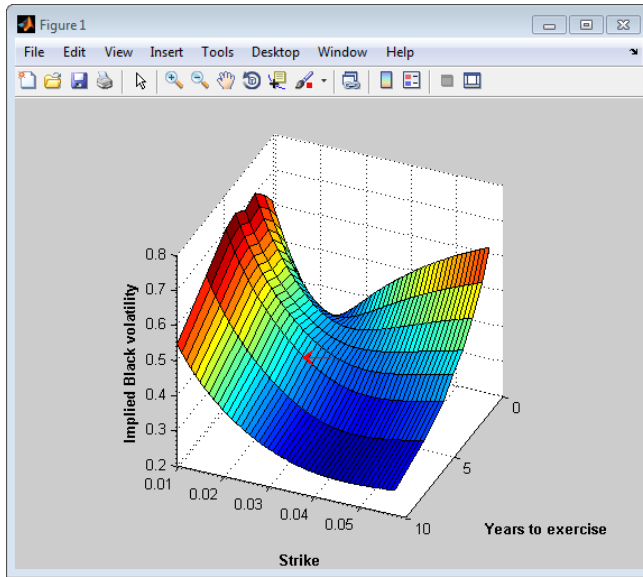
Compute the SABR implied Black volatility for this swaption using the function `blackvolbysabr` (and it is marked with a red arrow in the figure that follows).

```

SABRBlackVolatility = blackvolbysabr(Alphas(6), Betas(6), Rhos(6), Nus(6), SwaptionSettle,
    SwaptionExerciseDate, CurrentForwardSwapRate, Strike)

text (YearsToExercise(6), Strike, SABRBlackVolatility, '\leftarrow', ...
    'Color', 'r', 'FontWeight', 'bold', 'FontSize', 22);

```



Price the swaption using the SABR implied Black volatility as an input to the function `swaptionbyblk`.

```
Price = swaptionbyblk(RateSpec, OptSpec, Strike, SwaptionSettle, SwaptionExerciseDate,  
SwapMaturity, SABRBlackVolatility, 'Reset', Reset)
```

```
SABRBlackVolatility =
```

```
0.3932
```

```
Price =
```

```
14.2403
```

## References

[1] Hagan, P. S., Kumar, D., Lesniewski, A. S. and Woodward, D. E., “Managing Smile Risk,” *Wilmott Magazine*, 2002.

[2] West, G., “Calibration of the SABR Model in Illiquid Markets,” *Applied Mathematical Finance*, 12(4), pp. 371-385, 2004.

## See Also

[blackvolbysabr](#) | [swapbyzero](#) | [swaptionbyblk](#)

## Related Examples

- “Calibrate the SABR Model”

## Overview of Interest-Rate Tree Models

<b>In this section...</b>
“Interest-Rate Modeling” on page 2-32
“Rate and Price Trees” on page 2-33
“Viewing Rate or Price Movement” on page 2-34

### Interest-Rate Modeling

Financial Instruments Toolbox software computes prices and sensitivities of interest-rate contingent claims based on several methods of modeling changes in interest rates over time:

- The interest-rate term structure

This model uses sets of zero-coupon bonds to predict changes in interest rates.

- Heath-Jarrow-Morton (HJM) model

The HJM model considers a given initial term structure of interest rates and a specification of the volatility of forward rates to build a tree representing the evolution of the interest rates, based on a statistical process.

- Black-Derman-Toy (BDT) model

In the BDT model, all security prices and rates depend on the short rate (annualized 1-period interest rate). The model uses long rates and their volatilities to construct a tree of possible future short rates. The resulting tree can then be used to determine the value of interest-rate sensitive securities from this tree.

- Hull-White (HW) model

The Hull-White model incorporates the initial term structure of interest rates and the volatility term structure to build a trinomial recombining tree of short rates. The resulting tree is used to value interest-rate dependent securities. The implementation of the HW model in Financial Instruments Toolbox software is limited to one factor.

- Black-Karasinski (BK) model

The BK model is a single-factor, log-normal version of the HW model.

For detailed information about interest-rate models, see:

- “Pricing Using Interest-Rate Term Structure” on page 2-49 for a discussion of price and sensitivity based on portfolios of zero-coupon bonds
- “Pricing Using Interest-Rate Tree Models” on page 2-74 for a discussion of price and sensitivity based on the HJM and BDT interest-rate models

---

**Note** Historically, the initial version of Financial Instruments Toolbox software provided only the HJM interest-rate model. A later version added the BDT model. The current version adds both the HW and BK models. This section provides extensive examples of using the HJM and BDT models to compute prices and sensitivities of interest-rate based financial derivatives.

The HW and BK tree structures are similar to the BDT tree structure. To avoid needless repetition throughout this section, documentation is provided only where significant deviations from the BDT structure exist. Specifically, “HW and BK Tree Structures” on page 2-70 explains the few noteworthy differences among the various formats.

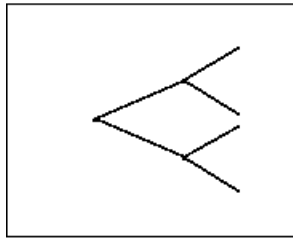
---

## Rate and Price Trees

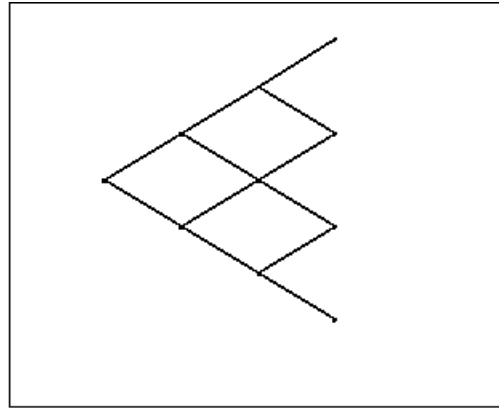
The interest-rate or price trees supported in this toolbox can be either *binomial* (two branches per node) or *trinomial* (three branches per node). Typically, binomial trees assume that underlying interest rates or prices can only either increase or decrease at each node. Trinomial trees allow for a more complex movement of rates or prices. With trinomial trees the movement of rates or prices at each node is unrestricted (for example, up-up-up or unchanged-down-down).

### Types of Trees

Financial Instruments Toolbox trees can be classified as *bushy* or *recombining*. A bushy tree is a tree in which the number of branches increases exponentially relative to observation times; branches never recombine. In this context, a recombining tree is the opposite of a bushy tree. A recombining tree has branches that recombine over time. From any given node, the node reached by taking the path up-down is the same node reached by taking the path down-up. A bushy tree and a recombining binomial tree are illustrated next.



**Bushy Tree**



**Recombining Binomial Tree**

In this toolbox the Heath-Jarrow-Morton model works with bushy trees. The Black-Derman-Toy model, on the other hand, works with recombining binomial trees.

The other two interest rate models supported in this toolbox, Hull-White and Black-Karasinski, work with recombining trinomial trees.

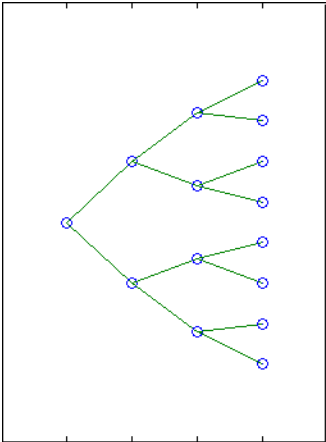
### Viewing Rate or Price Movement

This toolbox provides the data file `deriv.mat` that contains four interest-rate based trees:

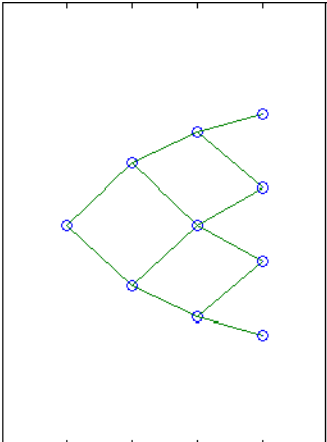
- `HJMTree` — A bushy binomial tree
- `BDTTree` — A recombining binomial tree
- `HWTTree` and `BKTree` — Recombining trinomial trees

The toolbox also provides the `treeviewer` function, which graphically displays the shape and data of price, interest rate, and cash flow trees. Viewed with `treeviewer`, the bushy shape of an HJM tree and the recombining shape of a BDT tree are apparent.



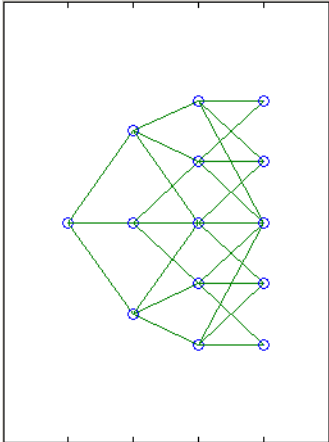


**HJMTree (bushy)**



**BDTTree (recombining)**

With treeviewer, you can also see the recombining shape of HW and BK trinomial trees.



**HWTree and BKTree (recombining)**

## Understanding the Interest-Rate Term Structure

In this section...
“Introduction” on page 2-36
“Interest Rates Versus Discount Factors” on page 2-36
“Interest-Rate Term Conversions” on page 2-41
“Modeling the Interest-Rate Term Structure” on page 2-44

### Introduction

The *interest-rate term structure* represents the evolution of interest rates through time. In MATLAB software, the interest-rate environment is encapsulated in a structure called `RateSpec` (*rate specification*). This structure holds all information required to completely identify the evolution of interest rates. Several functions included in Financial Instruments Toolbox software are dedicated to the creating and managing of the `RateSpec` structure. Many others take this structure as an input argument representing the evolution of interest rates.

Before looking further at the `RateSpec` structure, examine three functions that provide key functionality for working with interest rates: `disc2rate`, its opposite, `rate2disc`, and `ratetimes`. The first two functions map between discount factors and interest rates. The third function, `ratetimes`, calculates the effect of term changes on the interest rates.

### Interest Rates Versus Discount Factors

*Discount factors* are coefficients commonly used to find the current value of future cash flows. As such, there is a direct mapping between the rate applicable to a period of time, and the corresponding discount factor. The function `disc2rate` converts discount factors for a given term (period) into interest rates. The function `rate2disc` does the opposite; it converts interest rates applicable to a given term (period) into the corresponding discount factors.

#### Calculating Discount Factors from Rates

As an example, consider these annualized zero-coupon bond rates.

From	To	Rate
15 Feb 2000	15 Aug 2000	0.05
15 Feb 2000	15 Feb 2001	0.056
15 Feb 2000	15 Aug 2001	0.06
15 Feb 2000	15 Feb 2002	0.065
15 Feb 2000	15 Aug 2002	0.075

To calculate the discount factors corresponding to these interest rates, call `rate2disc` using the syntax

```
Disc = rate2disc(Compounding, Rates, EndDates, StartDates,
ValuationDate)
```

where:

- **Compounding** represents the frequency at which the zero rates are compounded when annualized. For this example, assume this value to be 2.
- **Rates** is a vector of annualized percentage rates representing the interest rate applicable to each time interval.
- **EndDates** is a vector of dates representing the end of each interest-rate term (period).
- **StartDates** is a vector of dates representing the beginning of each interest-rate term.
- **ValuationDate** is the date of observation for which the discount factors are calculated. In this particular example, use February 15, 2000 as the beginning date for all interest-rate terms.

Next, set the variables in MATLAB.

```
StartDates = [ '15-Feb-2000' ];
EndDates = [ '15-Aug-2000'; '15-Feb-2001'; '15-Aug-2001'; ...
'15-Feb-2002'; '15-Aug-2002' ];
Compounding = 2;
ValuationDate = [ '15-Feb-2000' ];
Rates = [0.05; 0.056; 0.06; 0.065; 0.075];
```

Finally, compute the discount factors.

```
Disc = rate2disc(Compounding, Rates, EndDates, StartDates, ...
ValuationDate)
```

Disc =

```

0.9756
0.9463
0.9151
0.8799
0.8319

```

By adding a fourth column to the rates table (see “Calculating Discount Factors from Rates” on page 2-36) to include the corresponding discounts, you can see the evolution of the discount factors.

From	To	Rate	Discount
15 Feb 2000	15 Aug 2000	0.05	0.9756
15 Feb 2000	15 Feb 2001	0.056	0.9463
15 Feb 2000	15 Aug 2001	0.06	0.9151
15 Feb 2000	15 Feb 2002	0.065	0.8799
15 Feb 2000	15 Aug 2002	0.075	0.8319

### Optional Time Factor Outputs

The function `rate2disc` optionally returns two additional output arguments: `EndTimes` and `StartTimes`. These vectors of time factors represent the start dates and end dates in discount periodic units. The scale of these units is determined by the value of the input variable `Compounding`.

To examine the time factor outputs, find the corresponding values in the previous example.

```
[Disc, EndTimes, StartTimes] = rate2disc(Compounding, Rates, ...
EndDates, StartDates, ValuationDate);
```

Arrange the two vectors into a single array for easier visualization.

```
Times = [StartTimes, EndTimes]
```

Times =

```

0    1
0    2

```

```

0     3
0     4
0     5

```

Because the valuation date is equal to the start date for all periods, the `StartTimes` vector is composed of 0s. Also, since the value of `Compounding` is 2, the rates are compounded semiannually, which sets the units of periodic discount to 6 months. The vector `EndDates` is composed of dates separated by intervals of 6 months from the valuation date. This explains why the `EndTimes` vector is a progression of integers from 1 to 5.

### Alternative Syntax (`rate2disc`)

The function `rate2disc` also accommodates an alternative syntax that uses periodic discount units instead of dates. Since the relationship between discount factors and interest rates is based on time periods and not on absolute dates, this form of `rate2disc` allows you to work directly with time periods. In this mode, the valuation date corresponds to 0, and the vectors `StartTimes` and `EndTimes` are used as input arguments instead of their date equivalents, `StartDates` and `EndDates`. This syntax for `rate2disc` is:

```
Disc = rate2disc(Compounding, Rates, EndTimes, StartTimes)
```

Using as input the `StartTimes` and `EndTimes` vectors computed previously, you should obtain the previous results for the discount factors.

```
Disc = rate2disc(Compounding, Rates, EndTimes, StartTimes)
```

```
Disc =
```

```

0.9756
0.9463
0.9151
0.8799
0.8319

```

### Calculating Rates from Discounts

The function `disc2rate` is the complement to `rate2disc`. It finds the rates applicable to a set of compounding periods, given the discount factor in those periods. The syntax for calling this function is:

```
Rates = disc2rate(Compounding, Disc, EndDates, StartDates,
```

```
ValuationDate)
```

Each argument to this function has the same meaning as in `rate2disc`. Use the results found in the previous example to return the rate values you started with.

```
Rates = disc2rate(Compounding, Disc, EndDates, StartDates, ...  
ValuationDate)
```

```
Rates =
```

```
0.0500  
0.0560  
0.0600  
0.0650  
0.0750
```

### Alternative Syntax (`disc2rate`)

As in the case of `rate2disc`, `disc2rate` optionally returns `StartTimes` and `EndTimes` vectors representing the start and end times measured in discount periodic units. Again, working with the same values as before, you should obtain the same numbers.

```
[Rates, EndTimes, StartTimes] = disc2rate(Compounding, Disc, ...  
EndDates, StartDates, ValuationDate);
```

Arrange the results in a matrix convenient to display.

```
Result = [StartTimes, EndTimes, Rates]
```

```
Result =
```

```
0    1.0000    0.0500  
0    2.0000    0.0560  
0    3.0000    0.0600  
0    4.0000    0.0650  
0    5.0000    0.0750
```

As with `rate2disc`, the relationship between rates and discount factors is determined by time periods and not by absolute dates. Consequently, the alternate syntax for `disc2rate` uses time vectors instead of dates, and it assumes that the valuation date corresponds to time = 0. The time-based calling syntax is:

```
Rates = disc2rate(Compounding, Disc, EndTimes, StartTimes);
```

Using this syntax, you again obtain the original values for the interest rates.

```
Rates = disc2rate(Compounding, Disc, EndTimes, StartTimes)
```

```
Rates =
    0.0500
    0.0560
    0.0600
    0.0650
    0.0750
```

## Interest-Rate Term Conversions

Interest rate evolution is typically represented by a set of interest rates, including the beginning and end of the periods the rates apply to. For zero rates, the start dates are typically at the valuation date, with the rates extending from that valuation date until their respective maturity dates.

### Spot Curve to Forward Curve Conversion

Frequently, given a set of rates including their start and end dates, you may be interested in finding the rates applicable to different terms (periods). This problem is addressed by the function `ratetimes`. This function interpolates the interest rates given a change in the original terms. The syntax for calling `ratetimes` is

```
[Rates, EndTimes, StartTimes] = ratetimes(Compounding, RefRates,
RefEndDates, RefStartDates, EndDates, StartDates, ValuationDate);
```

where:

- **Compounding** represents the frequency at which the zero rates are compounded when annualized.
- **RefRates** is a vector of initial interest rates representing the interest rates applicable to the initial time intervals.
- **RefEndDates** is a vector of dates representing the end of the interest rate terms (period) applicable to **RefRates**.
- **RefStartDates** is a vector of dates representing the beginning of the interest rate terms applicable to **RefRates**.
- **EndDates** represent the maturity dates for which the interest rates are interpolated.
- **StartDates** represent the starting dates for which the interest rates are interpolated.

- **ValuationDate** is the date of observation, from which the **StartTimes** and **EndTimes** are calculated. This date represents time = 0.

The input arguments to this function can be separated into two groups:

- The initial or reference interest rates, including the terms for which they are valid
- Terms for which the new interest rates are calculated

As an example, consider the rate table specified in “Calculating Discount Factors from Rates” on page 2-36.

From	To	Rate
15 Feb 2000	15 Aug 2000	0.05
15 Feb 2000	15 Feb 2001	0.056
15 Feb 2000	15 Aug 2001	0.06
15 Feb 2000	15 Feb 2002	0.065
15 Feb 2000	15 Aug 2002	0.075

Assuming that the valuation date is February 15, 2000, these rates represent zero-coupon bond rates with maturities specified in the second column. Use the function `ratetimes` to calculate the forward rates at the beginning of all periods implied in the table. Assume a compounding value of 2.

```
% Reference Rates.
RefStartDates = ['15-Feb-2000'];
RefEndDates   = ['15-Aug-2000'; '15-Feb-2001'; '15-Aug-2001';...
                 '15-Feb-2002'; '15-Aug-2002'];
Compounding   = 2;
ValuationDate = ['15-Feb-2000'];
RefRates      = [0.05; 0.056; 0.06; 0.065; 0.075];

% New Terms.
StartDates = ['15-Feb-2000'; '15-Aug-2000'; '15-Feb-2001';...
              '15-Aug-2001'; '15-Feb-2002'];
EndDates   = ['15-Aug-2000'; '15-Feb-2001'; '15-Aug-2001';...
              '15-Feb-2002'; '15-Aug-2002'];
% Find the new rates.
Rates = ratetimes(Compounding, RefRates, RefEndDates,...
                 RefStartDates, EndDates, StartDates, ValuationDate)

Rates =
```



```

0.0500
0.0620
0.0680
0.0801
0.1155

```

Place these values in a table like the previous one. Observe the evolution of the forward rates based on the initial zero-coupon rates.

From	To	Rate
15 Feb 2000	15 Aug 2000	0.0500
15 Aug 2000	15 Feb 2001	0.0620
15 Feb 2001	15 Aug 2001	0.0680
15 Aug 2001	15 Feb 2002	0.0801
15 Feb 2002	15 Aug 2002	0.1155

### Alternative Syntax (`ratetimes`)

The `ratetimes` function can provide the additional output arguments `StartTimes` and `EndTimes`, which represent the time factor equivalents to the `StartDates` and `EndDates` vectors. The `ratetimes` function uses time factors for interpolating the rates. These time factors are calculated from the start and end dates, and the valuation date, which are passed as input arguments. `ratetimes` can also use time factors directly, assuming `time = 0` as the valuation date. This alternate syntax is:

```
[Rates, EndTimes, StartTimes] = ratetimes(Compounding, RefRates,
RefEndTimes, RefStartTimes, EndTimes, StartTimes);
```

Use this alternate version of `ratetimes` to find the forward rates again. In this case, you must first find the time factors of the reference curve. Use `date2time` for this.

```
RefEndTimes = date2time(ValuationDate, RefEndDates, Compounding)
```

```
RefEndTimes =
```

```

1
2
3
4

```

5

```
RefStartTimes = date2time(ValuationDate, RefStartDates,...  
Compounding)
```

```
RefStartTimes =
```

0

These are the expected values, given semiannual discounts (as denoted by a value of 2 in the variable `Compounding`), end dates separated by 6-month periods, and the valuation date equal to the date marking beginning of the first period (time factor = 0).

Now call `ratetimes` with the alternate syntax.

```
[Rates, EndTimes, StartTimes] = ratetimes(Compounding,...  
RefRates, RefEndTimes, RefStartTimes, EndTimes, StartTimes);
```

```
Rates =
```

```
0.0500  
0.0620  
0.0680  
0.0801  
0.1155
```

`EndTimes` and `StartTimes` have, as expected, the same values they had as input arguments.

```
Times = [StartTimes, EndTimes]
```

```
Times =
```

```
0    1  
1    2  
2    3  
3    4  
4    5
```

### Modeling the Interest-Rate Term Structure

Financial Instruments Toolbox software includes a set of functions to encapsulate interest-rate term information into a single structure. These functions present a

convenient way to package all information related to interest-rate terms into a common format, and to resolve interdependencies when one or more of the parameters is modified. For information, see:

- “Creating or Modifying (`intenvset`)” on page 2-45 for a discussion of how to create or modify an interest-rate term structure (`RateSpec`) using the `intenvset` function
- “Obtaining Specific Properties (`intenvget`)” on page 2-47 for a discussion of how to extract specific properties from a `RateSpec`

### Creating or Modifying (`intenvset`)

The main function to create or modify an interest-rate term structure `RateSpec` (rates specification) is `intenvset`. If the first argument to this function is a previously created `RateSpec`, the function modifies the existing rate specification and returns a new one. Otherwise, it creates a `RateSpec`.

When using `RateSpec` to specify the rate term structure to price instruments based on yields (zero coupon rates) or forward rates, specify zero rates or forward rates as the input argument. However, the `RateSpec` structure is not limited or specific to this problem domain. `RateSpec` is an encapsulation of rates-times relationships; `intenvset` acts as either a constructor or a modifier, and `intenvget` as an accessor. The interest rate models supported by the Financial Instruments Toolbox software work either with zero coupon rates or forward rates.

The other `intenvset` arguments are property-value pairs, indicating the new value for these properties. The properties that can be specified or modified are:

- `Basis`
- `Compounding`
- `Disc`
- `EndDates`
- `EndMonthRule`
- `Rates`
- `StartDates`
- `ValuationDate`

To learn about the properties `EndMonthRule` and `Basis`, type `help ftbEndMonthRule` and `help ftbBasis` or see the Financial Toolbox™ documentation.

Consider again the original table of interest rates (see “Calculating Discount Factors from Rates” on page 2-36).

From	To	Rate
15 Feb 2000	15 Aug 2000	0.05
15 Feb 2000	15 Feb 2001	0.056
15 Feb 2000	15 Aug 2001	0.06
15 Feb 2000	15 Feb 2002	0.065
15 Feb 2000	15 Aug 2002	0.075

Use the information in this table to populate the `RateSpec` structure.

```

StartDates = [ '15-Feb-2000' ];
EndDates =   [ '15-Aug-2000' ;
               '15-Feb-2001' ;
               '15-Aug-2001' ;
               '15-Feb-2002' ;
               '15-Aug-2002' ];
Compounding = 2;
ValuationDate = [ '15-Feb-2000' ];
Rates = [0.05; 0.056; 0.06; 0.065; 0.075];

rs = intenvset('Compounding',Compounding,'StartDates',...
StartDates, 'EndDates', EndDates, 'Rates', Rates,...
'ValuationDate', ValuationDate)

rs =

    FinObj: 'RateSpec'
  Compounding: 2
        Disc: [5x1 double]
        Rates: [5x1 double]
    EndTimes: [5x1 double]
  StartTimes: [5x1 double]
    EndDates: [5x1 double]
  StartDates: 730531
ValuationDate: 730531
        Basis: 0
  EndMonthRule: 1

```

Some of the properties filled in the structure were not passed explicitly in the call to `RateSpec`. The values of the automatically completed properties depend on the

properties that are explicitly passed. Consider for example the `StartTimes` and `EndTimes` vectors. Since the `StartDates` and `EndDates` vectors are passed in, and the `ValuationDate`, `intenvset` has all the information required to calculate `StartTimes` and `EndTimes`. Hence, these two properties are read-only.

### Obtaining Specific Properties (`intenvget`)

The complementary function to `intenvset` is `intenvget`, which gets function specific properties from the interest-rate term structure. Its syntax is:

```
ParameterValue = intenvget(RateSpec, 'ParameterName')
```

To obtain the vector `EndTimes` from the `RateSpec` structure, enter:

```
EndTimes = intenvget(rs, 'EndTimes')
```

```
EndTimes =
```

```
1
2
3
4
5
```

To obtain `Disc`, the values for the discount factors that were calculated automatically by `intenvset`, type:

```
Disc = intenvget(rs, 'Disc')
```

```
Disc =
```

```
0.9756
0.9463
0.9151
0.8799
0.8319
```

These discount factors correspond to the periods starting from `StartDates` and ending in `EndDates`.

---

**Caution** Although you can directly access these fields within the structure instead of using `intenvget`, it is advised not to do so. The format of the interest-rate term

structure could change in future versions of the toolbox. Should that happen, any code accessing the `RateSpec` fields directly would stop working.

---

Now use the `RateSpec` structure with its functions to examine how changes in specific properties of the interest-rate term structure affect those depending on it. As an exercise, change the value of `Compounding` from 2 (semiannual) to 1 (annual).

```
rs = intenvset(rs, 'Compounding', 1);
```

Since `StartTimes` and `EndTimes` are measured in units of periodic discount, a change in `Compounding` from 2 to 1 redefines the basic unit from semiannual to annual. This means that a period of 6 months is represented with a value of 0.5, and a period of 1 year is represented by 1. To obtain the vectors `StartTimes` and `EndTimes`, enter:

```
StartTimes = intenvget(rs, 'StartTimes');  
EndTimes = intenvget(rs, 'EndTimes');  
Times = [StartTimes, EndTimes]
```

```
Times =
```

```
    0    0.5000  
    0    1.0000  
    0    1.5000  
    0    2.0000  
    0    2.5000
```

Since all the values in `StartDates` are the same as the valuation date, all `StartTimes` values are 0. On the other hand, the values in the `EndDates` vector are dates separated by 6-month periods. Since the redefined value of compounding is 1, `EndTimes` becomes a sequence of numbers separated by increments of 0.5.

## Pricing Using Interest-Rate Term Structure

### In this section...

“Introduction” on page 2-49

“Computing Instrument Prices” on page 2-50

“Computing Instrument Sensitivities” on page 2-51

“OAS for Callable and Puttable Bonds” on page 2-53

“Agency OAS” on page 2-53

### Introduction

The instruments can be presented to the functions as a portfolio of different types of instruments or as groups of instruments of the same type. The current version of the toolbox can compute price and sensitivities for four instrument types using interest-rate curves:

- Bonds
- Fixed-rate notes
- Floating-rate notes
- Swaps
- OAS for callable and puttable bonds
- Agency OAS

In addition to these instruments, the toolbox also supports the calculation of price and sensitivities of arbitrary sets of cash flows.

Note that options and interest-rate floors and caps are absent from the above list of supported instruments. These instruments are not supported because their pricing and sensitivity function require a stochastic model for the evolution of interest rates. The interest-rate term structure used for pricing is treated as deterministic, and as such is not adequate for pricing these instruments.

Financial Instruments Toolbox software also contains functions that use the Heath-Jarrow-Morton (HJM) and Black-Derman-Toy (BDT) models to compute prices and sensitivities for financial instruments. These models support computations involving options and interest-rate floors and caps. See “Pricing Using Interest-Rate Tree Models”

on page 2-74 for information on computing price and sensitivities of financial instruments using the HJM and BDT models.

## Computing Instrument Prices

The main function used for pricing portfolios of instruments is `intenvprice`. This function works with the family of functions that calculate the prices of individual types of instruments. When called, `intenvprice` classifies the portfolio contained in `InstSet` by instrument type, and calls the appropriate pricing functions. The map between instrument types and the pricing function `intenvprice` calls is

<code>bondbyzero:</code>	Price a bond by a set of zero curves
<code>fixedbyzero:</code>	Price a fixed-rate note by a set of zero curves
<code>floatbyzero:</code>	Price a floating-rate note by a set of zero curves
<code>swapbyzero:</code>	Price a swap by a set of zero curves

You can use each of these functions individually to price an instrument. Consult the reference pages for specific information on using these functions.

`intenvprice` takes as input an interest-rate term structure created with `intenvset`, and a portfolio of interest-rate contingent derivatives instruments created with `instadd`.

The syntax for using `intenvprice` to price an entire portfolio is

```
Price = intenvprice(RateSpec, InstSet)
```

where:

- `RateSpec` is the interest-rate term structure.
- `InstSet` is the name of the portfolio.

### Example: Pricing a Portfolio of Instruments

Consider this example of using the `intenvprice` function to price a portfolio of instruments supplied with Financial Instruments Toolbox software.

The provided MAT-file `deriv.mat` stores a portfolio as an instrument set variable `ZeroInstSet`. The MAT-file also contains the interest-rate term structure `ZeroRateSpec`. You can display the instruments with the function `instdisp`.



```
load deriv.mat;
instdisp(ZeroInstSet)

Index Type CouponRate Settle      Maturity      Period Basis...
1   Bond 0.04      01-Jan-2000   01-Jan-2003   1   NaN...
2   Bond 0.04      01-Jan-2000   01-Jan-2004   2   NaN...

Index Type CouponRate Settle      Maturity      FixedReset Basis...
3   Fixed 0.04      01-Jan-2000   01-Jan-2003   1   NaN...

Index Type Spread Settle      Maturity      FloatReset Basis...
4   Float 20      01-Jan-2000   01-Jan-2003   1   NaN...

Index Type LegRate      Settle      Maturity      LegReset Basis...
5   Swap [0.06 20] 01-Jan-2000   01-Jan-2003   [1 1] NaN...
```

Use `intenvprice` to calculate the prices for the instruments contained in the portfolio `ZeroInstSet`.

```
format bank
Prices = intenvprice(ZeroRateSpec, ZeroInstSet)
```

```
Prices =

    98.72
    97.53
    98.72
   100.55
     3.69
```

The output `Prices` is a vector containing the prices of all the instruments in the portfolio in the order indicated by the `Index` column displayed by `instdisp`. Consequently, the first two elements in `Prices` correspond to the first two bonds; the third element corresponds to the fixed-rate note; the fourth to the floating-rate note; and the fifth element corresponds to the price of the swap.

## Computing Instrument Sensitivities

In general, you can compute sensitivities either as dollar price changes or as percentage price changes. The toolbox reports all sensitivities as dollar sensitivities.

Using the interest-rate term structure, you can calculate two types of derivative price sensitivities, delta and gamma. *Delta* represents the dollar sensitivity of prices to shifts in the observed forward yield curve. *Gamma* represents the dollar sensitivity of delta to shifts in the observed forward yield curve.

The `intenvsens` function computes instrument sensitivities and instrument prices. If you need both the prices and sensitivity measures, use `intenvsens`. A separate call to `intenvprice` is not required.

Here is the syntax

```
[Delta, Gamma, Price] = intenvsens(RateSpec, InstSet)
```

where, as before:

- `RateSpec` is the interest-rate term structure.
- `InstSet` is the name of the portfolio.

### Example: Sensitivities and Prices

Here is an example that uses `intenvsens` to calculate both sensitivities and prices.

```
format bank
load deriv.mat;
[Delta, Gamma, Price] = intenvsens(ZeroRateSpec, ZeroInstSet);
```

Display the results in a single matrix in bank format.

```
All = [Delta Gamma Price]
```

```
All =
```

-272.64	1029.84	98.72
-347.44	1622.65	97.53
-272.64	1029.84	98.72
-1.04	3.31	100.55
-282.04	1059.62	3.69

To view the per-dollar sensitivity, divide the first two columns by the last one.

```
[Delta./Price, Gamma./Price, Price]
```

```
ans =
```

-2.76	10.43	98.72
-3.56	16.64	97.53
-2.76	10.43	98.72
-0.01	0.03	100.55
-76.39	286.98	3.69

## OAS for Callable and Puttable Bonds

Option Adjusted Spread (OAS) is a useful way to value and compare securities with embedded options, like callable or puttable bonds. Basically, when the constant or flat spread is added to the interest-rate curve/rates in the tree, the pricing model value equals the market price. Financial Instruments Toolbox supports pricing American, European and Bermuda callable and puttable bonds using different interest rate models. The pricing for a bond with embedded options is:

- For a callable bond, where the holder has bought a bond and sold a call option to the issuer:

$$\text{Price callable bond} = \text{Price Option free bond} - \text{Price call option}$$

- For a puttable bond, where the holder has bought a bond and a put option:

$$\text{Price puttable bond} = \text{Price Option free bond} + \text{Price put option}$$

There are two additional sensitivities related to OAS for bonds with embedded options: Option Adjusted Duration and Option Adjusted Convexity. These are similar to the concepts of modified duration and convexity for option-free bonds. The measure Duration is a general term that describes how sensitive a bond's price is to a parallel shift in the yield curve. Modified Duration and Modified Convexity assume that the bond's cash flows do not change when the yield curve shifts. This is not true for OA Duration or OA Convexity because the cash flows may change due to the option risk component of the bond.

Function	Purpose
oasbybdt	Compute OAS using a BDT model.
oasbybk	Compute OAS using a BK model.
oasbyhjm	Compute OAS using an HJM model.
oasbyhw	Compute OAS using an HW model.

## Agency OAS

Often bonds are issued with embedded options, which then makes standard price/yield or spread measures irrelevant. For example, a municipality concerned about the chance that interest rates may fall in the future might issue bonds with a provision that allows the bond to be repaid before the bond's maturity. This is a call option on the bond and

must be incorporated into the valuation of the bond. Option-adjusted spread (OAS), which adjusts a bond spread for the value of the option, is the standard measure for valuing bonds with embedded options. Financial Instruments Toolbox software supports computing option-adjusted spreads for bonds with single embedded options using the agency model.

The Securities Industry and Financial Markets Association (SIFMA) has a simplified approach to compute OAS for agency issues (Government Sponsored Entities like Fannie Mae and Freddie Mac) termed “Agency OAS”. In this approach, the bond has only one call date (European call) and uses Black’s model (see *The BMA European Callable Securities Formula* at <http://www.sifma.org>) to value the bond option. The price of the bond is computed as follows:

$$\text{Price}_{\text{Callable}} = \text{Price}_{\text{NonCallable}} - \text{Price}_{\text{Option}}$$

where

$\text{Price}_{\text{Callable}}$  is the price of the callable bond.

$\text{Price}_{\text{NonCallable}}$  is the price of the noncallable bond, i.e., price of the bond using `bndspread`.

$\text{Price}_{\text{Option}}$  is the price of the option, i.e., price of the option using Black’s model.

The Agency OAS is the spread, when used in the previous formula, yields the market price. Financial Instruments Toolbox software supports these functions:

Agency OAS Functions	Purpose
<code>agencyoas</code>	Compute the OAS of the callable bond using the Agency OAS model.
<code>agencyprice</code>	Price the callable bond OAS using Agency using the OAS model.

For more information on agency OAS, see “Agency Option-Adjusted Spreads”.

# Understanding Interest-Rate Tree Models

## In this section...

“Introduction” on page 2-55

“Building a Tree of Forward Rates” on page 2-56

“Specifying the Volatility Model (VolSpec)” on page 2-57

“Specifying the Interest-Rate Term Structure (RateSpec)” on page 2-60

“Specifying the Time Structure (TimeSpec)” on page 2-61

“Creating Trees” on page 2-63

“Examining Trees” on page 2-64

## Introduction

Financial Instruments Toolbox software supports the Black-Derman-Toy (BDT), Black-Karasinski (BK), Heath-Jarrow-Morton (HJM), and Hull-White (HW) interest-rate models. The Heath-Jarrow-Morton model is one of the most widely used models for pricing interest-rate derivatives. The model considers a given initial term structure of interest rates and a specification of the volatility of forward rates to build a tree representing the evolution of the interest rates, based on a statistical process. For further explanation, see the book *Modelling Fixed Income Securities and Interest Rate Options* by Robert A. Jarrow.

The Black-Derman-Toy model is another analytical model commonly used for pricing interest-rate derivatives. The model considers a given initial zero rate term structure of interest rates and a specification of the yield volatilities of long rates to build a tree representing the evolution of the interest rates. For further explanation, see the paper “A One Factor Model of Interest Rates and its Application to Treasury Bond Options” by Fischer Black, Emanuel Derman, and William Toy.

The Hull-White model incorporates the initial term structure of interest rates and the volatility term structure to build a trinomial recombining tree of short rates. The resulting tree is used to value interest rate dependent securities. The implementation of the Hull-White model in Financial Instruments Toolbox software is limited to one factor.

The Black-Karasinski model is a single factor, log-normal version of the Hull-White model.

For further information on the Hull-White and Black-Karasinski models, see the book *Options, Futures, and Other Derivatives* by John C. Hull.

### Building a Tree of Forward Rates

The tree of forward rates is the fundamental unit representing the evolution of interest rates in a given period of time. This section explains how to create a forward-rate tree using Financial Instruments Toolbox software.

---

**Note** To avoid needless repetition, this document uses the HJM and BDT models to illustrate the creation and use of interest-rate trees. The HW and BK models are similar to the BDT model. Where specific differences exist, they are documented in “HW and BK Tree Structures” on page 2-70.

---

The MATLAB functions that create rate trees are `hjmtree` and `bdttree`. The `hjmtree` function creates the structure, `HJMTree`, containing time and forward-rate information for a bushy tree. The `bdttree` function creates a similar structure, `BDTTree`, for a recombining tree.

This structure is a self-contained unit that includes the tree of rates (found in the `FwdTree` field of the structure) and the volatility, rate, and time specifications used in building this tree.

These functions take three structures as input arguments:

- The volatility model `VolSpec`. (See “Specifying the Volatility Model (VolSpec)” on page 2-57.)
- The interest-rate term structure `RateSpec`. (See “Specifying the Interest-Rate Term Structure (RateSpec)” on page 2-60.)
- The tree time layout `TimeSpec`. (See “Specifying the Time Structure (TimeSpec)” on page 2-61.)

An easy way to visualize any trees you create is with the `treeviewer` function, which displays trees in a graphical manner. See “Graphical Representation of Trees” on page 2-128 for information about `treeviewer`.

#### Calling Sequence

The calling syntax for `hjmtree` is

```
HJMTree = hjmtree(VolSpec, RateSpec, TimeSpec)
```

Similarly, the calling syntax for `bdttree` is

```
BDTTree = bdttree(VolSpec, RateSpec, TimeSpec)
```

Each of these functions requires `VolSpec`, `RateSpec`, and `TimeSpec` input arguments:

- `VolSpec` is a structure that specifies the forward-rate volatility process. You create `VolSpec` using either of the functions `hjmvolspec` or `bdtvolspec`.

The `hjmvolspec` function supports the specification of up to three factors. It handles these models for the volatility of the interest-rate term structure:

- Constant
- Stationary
- Exponential
- Vasicek
- Proportional

A one-factor model assumes that the interest term structure is affected by a single source of uncertainty. Incorporating multiple factors allows you to specify different types of shifts in the shape and location of the interest-rate structure. See `hjmvolspec` for details.

The `bdtvolspec` function supports only a single volatility factor. The volatility remains constant between pairs of nodes on the tree. You supply the input volatility values in a vector of decimal values. See `bdtvolspec` for details.

- `RateSpec` is the interest-rate specification of the initial rate curve. You create this structure with the function `intenvset`. (See “Modeling the Interest-Rate Term Structure” on page 2-44.)
- `TimeSpec` is the tree time layout specification. You create this variable with the functions `hjmtimespec` or `bdttimespec`. It represents the mapping between level times and level dates for rate quoting. This structure indirectly determines the number of levels in the tree.

## Specifying the Volatility Model (VolSpec)

Because HJM supports multifactor (up to 3) volatility models while BDT (also, BK and HW) supports only a single volatility factor, the `hjmvolspec` and `bdtvolspec` functions

require different inputs and generate slightly different outputs. For examples, see “Creating an HJM Volatility Model” on page 2-58. For BDT examples see “Creating a BDT Volatility Model” on page 2-59.

### Creating an HJM Volatility Model

The function `hjmvolspec` generates the structure `VolSpec`, which specifies the volatility process  $\sigma(t, T)$  used in the creation of the forward-rate trees. In this context capital  $T$  represents the starting time of the forward rate, and  $t$  represents the observation time. The volatility process can be constructed from a combination of factors specified sequentially in the call to function that creates it. Each factor specification starts with a string specifying the name of the factor, followed by the pertinent parameters.

### HJM Volatility Specification Example

Consider an example that uses a single factor, specifically, a constant-sigma factor. The constant factor specification requires only one parameter, the value of  $\sigma$ . In this case, the value corresponds to 0.10.

```
HJMVolSpec = hjmvolspec('Constant', 0.10)
```

```
HJMVolSpec =
```

```
    FinObj: 'HJMVolSpec'  
  FactorModels: {'Constant'}  
    FactorArgs: {{1x1 cell}}  
    SigmaShift: 0  
    NumFactors: 1  
    NumBranch: 2  
      PBranch: [0.5000 0.5000]  
    Fact2Branch: [-1 1]
```

The `NumFactors` field of the `VolSpec` structure, `VolSpec.NumFactors = 1`, reveals that the number of factors used to generate `VolSpec` was one. The `FactorModels` field indicates that it is a `Constant` factor, and the `NumBranches` field indicates the number of branches. As a consequence, each node of the resulting tree has two branches, one going up, and the other going down.

Consider now a two-factor volatility process made from a proportional factor and an exponential factor.

```
% Exponential factor
```



```

Sigma_0 = 0.1;
Lambda = 1;
% Proportional factor
CurveProp = [0.11765; 0.08825; 0.06865];
CurveTerm = [ 1 ; 2 ; 3 ];
% Build VolSpec
HJMVolSpec = hjmvolspec('Proportional', CurveProp, CurveTerm,...
1e6, 'Exponential', Sigma_0, Lambda)

HJMVolSpec =

    FinObj: 'HJMVolSpec'
  FactorModels: {'Proportional' 'Exponential'}
    FactorArgs: {{1x3 cell} {1x2 cell}}
    SigmaShift: 0
    NumFactors: 2
    NumBranch: 3
      PBranch: [0.2500 0.2500 0.5000]
    Fact2Branch: [2x3 double]

```

The output shows that the volatility specification was generated using two factors. The tree has 3 branches per node. Each branch has probabilities of 0.25, 0.25, and 0.5, going from top to bottom.

### Creating a BDT Volatility Model

The function `bdtvolspec` generates the structure `VolSpec`, which specifies the volatility process. The function requires three input arguments:

- The valuation date `ValuationDate`
- The yield volatility end dates `VolDates`
- The yield volatility values `VolCurve`

An optional fourth argument `InterpMethod`, specifying the interpolation method, can be included.

The syntax used for calling `bdtvolspec` is:

```
BDTVolSpec = bdtvolspec(ValuationDate, VolDates, VolCurve,...
InterpMethod)
```

where:

- `ValuationDate` is the first observation date in the tree.

- `VolDates` is a vector of dates representing yield volatility end dates.
- `VolCurve` is a vector of yield volatility values.
- `InterpMethod` is the method of interpolation to use. The default is `linear`.

### BDT Volatility Specification Example

Consider the following example:

```
ValuationDate = datenum('01-01-2000');
EndDates = datenum(['01-01-2001'; '01-01-2002'; '01-01-2003';
'01-01-2004'; '01-01-2005']);
Volatility = [.2; .19; .18; .17; .16];
```

Use `bdtvolspec` to create a volatility specification. Because no interpolation method is explicitly specified, the function uses the `linear` default.

```
BDTVolSpec = bdtvolspec(ValuationDate, EndDates, Volatility)
```

```
BDTVolSpec =
    FinObj: 'BDTVolSpec'
  ValuationDate: 730486
    VolDates: [5x1 double]
    VolCurve: [5x1 double]
  VolInterpMethod: 'linear'
```

### Specifying the Interest-Rate Term Structure (RateSpec)

The structure `RateSpec` is an interest term structure that defines the initial forward-rate specification from which the tree rates are derived. “Modeling the Interest-Rate Term Structure” on page 2-44 explains how to create these structures using the function `intenvset`, given the interest rates, the starting and ending dates for each rate, and the compounding value.

### Rate Specification Creation Example

Consider the following example:

```
Compounding = 1;
Rates = [0.02; 0.02; 0.02; 0.02];
StartDates = ['01-Jan-2000';
              '01-Jan-2001';
              '01-Jan-2002';
```

```

EndDates =    '01-Jan-2003'];
              ['01-Jan-2001';
              '01-Jan-2002';
              '01-Jan-2003';
              '01-Jan-2004'];
ValuationDate = '01-Jan-2000';

RateSpec = intenvset('Compounding',1,'Rates', Rates,...
                    'StartDates', StartDates, 'EndDates', EndDates,...
                    'ValuationDate', ValuationDate)

RateSpec =

    FinObj: 'RateSpec'
    Compounding: 1
           Disc: [4x1 double]
           Rates: [4x1 double]
           EndTimes: [4x1 double]
           StartTimes: [4x1 double]
           EndDates: [4x1 double]
           StartDates: [4x1 double]
    ValuationDate: 730486
           Basis: 0
    EndMonthRule: 1

```

Use the function `datedisp` to examine the dates defined in the variable `RateSpec`. For example:

```

datedisp(RateSpec.ValuationDate)
01-Jan-2000

```

## Specifying the Time Structure (TimeSpec)

The structure `TimeSpec` specifies the time structure for an interest-rate tree. This structure defines the mapping between the observation times at each level of the tree and the corresponding dates.

`TimeSpec` is built using either the `hjmtimespec` or `bdttimespec` function. These functions require three input arguments:

- The valuation date `ValuationDate`
- The maturity date `Maturity`
- The compounding rate `Compounding`

For example, the syntax used for calling `hjmtimespec` is

```
TimeSpec = hjmtimespec(ValuationDate, Maturity, Compounding)
```

where:

- `ValuationDate` is the first observation date in the tree.
- `Maturity` is a vector of dates representing the cash flow dates of the tree. Any instrument cash flows with these maturities fall on tree nodes.
- `Compounding` is the frequency at which the rates are compounded when annualized.

### Creating a Time Specification

Calling the time specification creation functions with the same data used to create the interest-rate term structure, `RateSpec` builds the structure that specifies the time layout for the tree.

#### HJM Time Specification Example

Consider the following example:

```
Maturity = EndDates;  
HJMTimeSpec = hjmtimespec(ValuationDate, Maturity, Compounding)
```

```
HJMTimeSpec =
```

```
    FinObj: 'HJMTimeSpec'  
ValuationDate: 730486  
    Maturity: [4x1 double]  
    Compounding: 1  
           Basis: 0  
    EndMonthRule: 1
```

Note that maturities specified when building `TimeSpec` need not coincide with the `EndDates` of the rate intervals in `RateSpec`. Since `TimeSpec` defines the time-date mapping of the tree, the rates in `RateSpec` are interpolated to obtain the initial rates with maturities equal to those in `TimeSpec`.

#### Creating a BDT Time Specification

Consider the following example:

```
Maturity = EndDates;  
BDTTimeSpec = bdttimespec(ValuationDate, Maturity, Compounding)
```

```
BDTTimeSpec =

    FinObj: 'BDTTimeSpec'
  ValuationDate: 730486
    Maturity: [4x1 double]
  Compounding: 1
    Basis: 0
  EndMonthRule: 1
```

## Creating Trees

Use the `VolSpec`, `RateSpec`, and `TimeSpec` you have previously created as inputs to the functions used to create HJM and BDT trees.

### Creating an HJM Tree

```
% Reset the volatility factor to the Constant case
HJMVolSpec = hjmvolspec('Constant', 0.10);

HJMTree = hjmtree(HJMVolSpec, RateSpec, HJMTimeSpec)

HJMTree =

    FinObj: 'HJMFwdTree'
  VolSpec: [1x1 struct]
 TimeSpec: [1x1 struct]
 RateSpec: [1x1 struct]
   tObs: [0 1 2 3]
   TFwd: {[4x1 double] [3x1 double] [2x1 double] [3]}
  CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4]}
  FwdTree: {[4x1 double][3x1x2 double][2x2x2 double][1x4x2 double]}
```

### Creating a BDT Tree

Now use the previously computed values for `VolSpec`, `RateSpec`, and `TimeSpec` as input to the function `bdttree` to create a BDT tree.

```
BDTTree = bdttree(BDTVVolSpec, RateSpec, BDTTimeSpec)

BDTTree =

    FinObj: 'BDTFwdTree'
  VolSpec: [1x1 struct]
 TimeSpec: [1x1 struct]
 RateSpec: [1x1 struct]
   tObs: [0 1.00 2.00 3.00]
   TFwd: {[4x1 double] [3x1 double] [2x1 double] [3.00]}
```

```
CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4.00]}
FwdTree: {[1.02] [1.02 1.02] [1.01 1.02 1.03] [1.01 1.02 1.02 1.03]}
```

### Examining Trees

When working with the models, Financial Instruments Toolbox software uses trees to represent forward rates, prices, and so on. At the highest level, these trees have structures wrapped around them. The structures encapsulate information required to interpret completely the information contained in a tree.

Consider this example, which uses the interest rate and portfolio data in the MAT-file `deriv.mat` included in the toolbox.

Load the data into the MATLAB workspace.

```
load deriv.mat
```

Display the list of the variables loaded from the MAT-file.

```
whos
```

Name	Size	Bytes	Class	Attributes
BDTInstSet	1x1	15956	struct	
BDTTree	1x1	5138	struct	
BKInstSet	1x1	15946	struct	
BKTree	1x1	5904	struct	
CRRInstSet	1x1	12434	struct	
CRRTree	1x1	5058	struct	
EQPInstSet	1x1	12434	struct	
EQPTree	1x1	5058	struct	
HJMInstSet	1x1	15948	struct	
HJMTree	1x1	5838	struct	
HWInstSet	1x1	15946	struct	
HWTree	1x1	5904	struct	
ITTInstSet	1x1	12438	struct	
ITTree	1x1	8862	struct	
ZeroInstSet	1x1	10282	struct	
ZeroRateSpec	1x1	1580	struct	

### HJM Tree Structure

You can now examine in some detail the contents of the `HJMTree` structure contained in this file.

```
HJMTree
```

```
HJMTree =
```

```
  FinObj: 'HJMTree'
  VolSpec: [1x1 struct]
```

```

TimeSpec: [1x1 struct]
RateSpec: [1x1 struct]
  tObs: [0 1 2 3]
  TFwd: {[4x1 double] [3x1 double] [2x1 double] [3]}
  CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4]}
  FwdTree: {[4x1 double][3x1x2 double][2x2x2 double][1x4x2 double]}

```

`FwdTree` contains the actual forward-rate tree. MATLAB software represents it as a cell array with each cell array element containing a tree level.

The other fields contain other information relevant to interpreting the values in `FwdTree`. The most important are `VolSpec`, `TimeSpec`, and `RateSpec`, which contain the volatility, time structure, and rate structure information respectively.

### First Node

Observe the forward rates in `FwdTree`. The first node represents the valuation date, `tObs = 0`.

```
HJMTree.FwdTree{1}
```

```

ans =

    1.0356
    1.0468
    1.0523
    1.0563

```

---

**Note** Financial Instruments Toolbox software uses *inverse discount* notation for forward rates in the tree. An inverse discount represents a factor by which the current value of an asset is multiplied to find its future value. In general, these forward factors are reciprocals of the discount factors.

---

Look closely at the `RateSpec` structure used in generating this tree to see where these values originate. Arrange the values in a single array.

```
[HJMTree.RateSpec.StartTimes HJMTree.RateSpec.EndTimes...
HJMTree.RateSpec.Rates]
```

```

ans =

    0    1.0000    0.0356
  1.0000    2.0000    0.0468
  2.0000    3.0000    0.0523

```

```
3.0000    4.0000    0.0563
```

If you find the corresponding inverse discounts of the interest rates in the third column, you have the values at the first node of the tree. You can turn interest rates into inverse discounts using the function `rate2disc`.

```
Disc = rate2disc(HJMTree.TimeSpec.Compounding,...  
HJMTree.RateSpec.Rates, HJMTree.RateSpec.EndTimes,...  
HJMTree.RateSpec.StartTimes);  
FRates = 1./Disc
```

```
FRates =  
    1.0356  
    1.0468  
    1.0523  
    1.0563
```

### Second Node

The second node represents the first-rate observation time,  $t_{\text{obs}} = 1$ . This node displays two states: one representing the branch going up and the other representing the branch going down.

Note that `HJMTree.VolSpec.NumBranch = 2`.

```
HJMTree.VolSpec
```

```
ans =  
  
    FinObj: 'HJMVolSpec'  
    FactorModels: {'Constant'}  
    FactorArgs: {{1x1 cell}}  
    SigmaShift: 0  
    NumFactors: 1  
    NumBranch: 2  
    PBranch: [0.5000 0.5000]  
    Fact2Branch: [-1 1]
```

Examine the rates of the node corresponding to the up branch.

```
HJMTree.FwdTree{2}(:, :, 1)
```

```
ans =  
  
    1.0364  
    1.0420
```



```
1.0461
```

Now examine the corresponding down branch.

```
HJMTree.FwdTree{2}(:, :, 2)
```

```
ans =
```

```
1.0574
1.0631
1.0672
```

### Third Node

The third node represents the second observation time, `tObs = 2`. This node contains a total of four states, two representing the branches going up and the other two representing the branches going down. Examine the rates of the node corresponding to the up states.

```
HJMTree.FwdTree{3}(:, :, 1)
```

```
ans =
```

```
1.0317    1.0526
1.0358    1.0568
```

Next examine the corresponding down states.

```
HJMTree.FwdTree{3}(:, :, 2)
```

```
ans =
```

```
1.0526    1.0738
1.0568    1.0781
```

### Isolating a Specific Node

Starting at the third level, indexing within the tree cell array becomes complex, and isolating a specific node can be difficult. The function `bushpath` isolates a specific node by specifying the path to the node as a vector of branches taken to reach that node. As an example, consider the node reached by starting from the root node, taking the branch up, then the branch down, and then another branch down. Given that the tree has only two branches per node, branches going up correspond to a 1, and branches going down correspond to a 2. The path up-down-down becomes the vector `[1 2 2]`.

```
FRates = bushpath(HJMTree.FwdTree, [1 2 2])
```

```
FRates =  
  
    1.0356  
    1.0364  
    1.0526  
    1.0674
```

`bushpath` returns the spot rates for all the nodes touched by the path specified in the input argument, the first one corresponding to the root node, and the last one corresponding to the target node.

Isolating the same node using direct indexing obtains

```
HJMTree.FwdTree{4}(:, 3, 2)  
  
ans =  
  
    1.0674
```

As expected, this single value corresponds to the last element of the rates returned by `bushpath`.

You can use these techniques with any type of tree generated with Financial Instruments Toolbox software, such as forward-rate trees or price trees.

### BDT Tree Structure

You can now examine in some detail the contents of the `BDTTree` structure.

`BDTTree`

```
BDTTree =  
  
    FinObj: 'BDTFwdTree'  
    VolSpec: [1x1 struct]  
    TimeSpec: [1x1 struct]  
    RateSpec: [1x1 struct]  
    tObs: [0 1.00 2.00 3.00]  
    TFwd: {[4x1 double] [3x1 double] [2x1 double] [3.00]}  
    CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4.00]}  
    FwdTree: {[1.10] [1.10 1.14] [1.10 1.14 1.19] [1.09 1.12 1.16 1.22]}
```

`FwdTree` contains the actual rate tree. MATLAB software represents it as a cell array with each cell array element containing a tree level.

The other fields contain other information relevant to interpreting the values in `FwdTree`. The most important are `VolSpec`, `TimeSpec`, and `RateSpec`, which contain the volatility, time structure, and rate structure information respectively.

Look at the `RateSpec` structure used in generating this tree to see where these values originate. Arrange the values in a single array.

```
[BDTTree.RateSpec.StartTimes BDTTree.RateSpec.EndTimes...
BDTTree.RateSpec.Rates]
```

```
ans =
```

```
      0    1.0000    0.1000
      0    2.0000    0.1100
      0    3.0000    0.1200
      0    4.0000    0.1250
```

Look at the rates in `FwdTree`. The first node represents the valuation date, `tObs = 0`. The second node represents `tObs = 1`. Examine the rates at the second, third, and fourth nodes.

```
BDTTree.FwdTree{2}
```

```
ans =
```

```
      1.0979    1.1432
```

The second node represents the first observation time, `tObs = 1`. This node contains a total of two states, one representing the branch going up (1.0979) and the other representing the branch going down (1.1432).

---

**Note** The convention in this document is to display *prices* going up on the upper branch. Consequently, when displaying *rates*, rates are falling on the upper branch and increasing on the lower branch.

---

```
BDTTree.FwdTree{3}
```

```
ans =
```

```
      1.0976    1.1377    1.1942
```

The third node represents the second observation time, `tObs = 2`. This node contains a total of three states, one representing the branch going up (1.0976), one representing the branch in the middle (1.1377) and the other representing the branch going down (1.1942).

```
BDTTree.FwdTree{4}
```

```
ans =  
  
    1.0872    1.1183    1.1606    1.2179
```

The fourth node represents the third observation time, `tObs = 3`. This node contains a total of four states, one representing the branch going up (`1.0872`), two representing the branches in the middle (`1.1183` and `1.1606`), and the other representing the branch going down (`1.2179`).

### Isolating a Specific Node

The function `treepath` isolates a specific node by specifying the path to the node as a vector of branches taken to reach that node. As an example, consider the node reached by starting from the root node, taking the branch up, then the branch down, and finally another branch down. Given that the tree has only two branches per node, branches going up correspond to a 1, and branches going down correspond to a 2. The path up-down-down becomes the vector `[1 2 2]`.

```
FRates = treepath(BDTree.FwdTree, [1 2 2])
```

```
FRates =  
  
    1.1000  
    1.0979  
    1.1377  
    1.1606
```

`treepath` returns the short rates for all the nodes touched by the path specified in the input argument, the first one corresponding to the root node, and the last one corresponding to the target node.

### HW and BK Tree Structures

The HW and BK tree structures are similar to the BDT tree structure. You can see this if you examine the sample HW tree contained in the file `deriv.mat`.

```
load deriv.mat;  
HWTree  
  
HWTree =  
  
    FinObj: 'HWFwdTree'  
    VolSpec: [1x1 struct]  
    TimeSpec: [1x1 struct]  
    RateSpec: [1x1 struct]  
    tObs: [0 1.00 2.00 3.00]
```

```

dObs: [731947.00 732313.00 732678.00 733043.00]
CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4.00]}
Probs: {[3x1 double] [3x3 double] [3x5 double]}
Connect: {[2.00] [2.00 3.00 4.00] [2.00 2.00 3.00 4.00 4.00]}
FwdTree: {[1.03] [1.05 1.04 1.02] [1.08 1.07 1.05 1.03 1.01] [1.09 1.08 1.06 1.04 1.02]}

```

All fields of this structure are similar to their BDT counterparts. There are two additional fields not present in BDT: **Probs** and **Connect**. The **Probs** field represents the occurrence probabilities at each branch of each node in the tree. The **Connect** field describes the connectivity of the nodes of a given tree level to nodes to the next tree level.

### Probs Field

While BDT and one-factor HJM models have equal probabilities for each branch at a node, HW and BK do not. For HW and BK trees, the **Probs** field indicates the likelihood that a particular branch will be taken in moving from one node to another node on the next level.

The **Probs** field consists of a cell array with 1 cell per tree level. Each cell is a 3-by-**NUMNODES** array with the top row representing the probability of an up movement, the middle row representing the probability of a middle movement, and the last row the probability of a down movement.

As an illustration, consider the first two elements of the **Probs** field of the structure, corresponding to the first (root) and second levels of the tree.

```
HWTree.Probs{1}
```

```

0.166666666666667
0.666666666666667
0.166666666666667

```

```
HWTree.Probs{2}
```

```

0.12361333418768    0.166666666666667    0.21877591615172
0.65761074966060    0.666666666666667    0.65761074966060
0.21877591615172    0.166666666666667    0.12361333418768

```

Reading from top to bottom, the values in **HWTree.Probs{1}** correspond to the up, middle, and down probabilities at the root node.

**HWTree.Probs{2}** is a 3-by-3 matrix of values. The first column represents the top node, the second column represents the middle node, and the last column represents the bottom node. As with the root node, the first, second, and third rows hold the values for up, middle, and down branching off each node.

As expected, the sum of all the probabilities at any node equals 1.

```
sum(HWTree.Probs{2})  
1.0000    1.0000    1.0000
```

### Connect Field

The other field that distinguishes HW and BK tree structures from the BDT tree structure is **Connect**. This field describes how each node in a given level connects to the nodes of the next level. The need for this field arises from the possibility of nonstandard branching in a tree.

The **Connect** field of the HW tree structure consists of a cell array with 1 cell per tree level.

```
HWTree.Connect  
  
ans =  
  
    [2]    [1x3 double]    [1x5 double]
```

Each cell contains a 1-by-**NUMNODES** vector. Each value in the vector relates to a node in the corresponding tree level and represents the index of the node in the next tree level that the middle branch of the node connects to.

If you subtract 1 from the values contained in **Connect**, you reveal the index of the nodes in the next level that the up branch connects to. If you add 1 to the values, you reveal the index of the corresponding down branch.

As an illustration, consider `HWTree.Connect{1}`:

```
HWTree.Connect{1}  
  
ans =  
  
    2
```

This indicates that the middle branch of the root node connects to the second (from the top) node of the next level, as expected. If you subtract 1 from this value, you obtain 1, which tells you that the up branch goes to the top node. If you add 1, you obtain 3, which points to the last node of the second level of the tree.

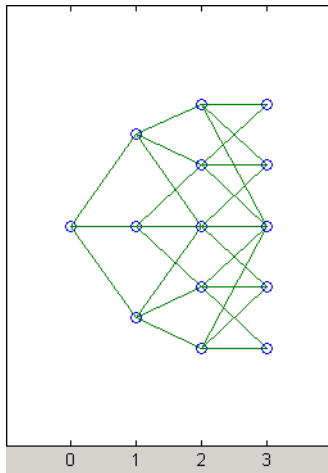
Now consider level 3 in this example:

```
HWTree.Connect{3}
```

```
2      2      3      4      4
```

On this level, there is nonstandard branching. This can be easily recognized because the middle branch of two nodes is connected to the same node on the next level.

To visualize this, consider the following illustration of the tree.



Here it becomes apparent that there is nonstandard branching at the third level of the tree, on the top and bottom nodes. The first and second nodes connect to the same trio of nodes on the next level. Similar branching occurs at the bottom and next-to-bottom nodes of the tree.

## Pricing Using Interest-Rate Tree Models

In this section...
“Introduction” on page 2-74
“Computing Instrument Prices” on page 2-74
“Computing Instrument Sensitivities” on page 2-82
“Calibrating Hull-White Model Using Market Data” on page 2-84

### Introduction

For purposes of illustration, this section relies on the HJM and BDT models. The HW and BK functions that perform price and sensitivity computations are not explicitly shown here. Functions that use the HW and BK models operate similarly to the BDT model.

### Computing Instrument Prices

The portfolio pricing functions `hjmprice` and `bdtprice` calculate the price of any set of supported instruments, based on an interest-rate tree. The functions are capable of pricing these instrument types:

- Bonds
- Bond options
- Bond with embedded options
- Arbitrary cash flows
- Fixed-rate notes
- Floating-rate notes
- Floating-rate notes with options or embedded options
- Caps
- Floors
- Range Notes
- Swaps
- Swaptions



For example, the syntax for calling `hjmprice` is:

```
[Price, PriceTree] = hjmprice(HJMTree, InstSet, Options)
```

Similarly, the calling syntax for `bdtpprice` is:

```
[Price, PriceTree] = bdtpprice(BDTTree, InstSet, Options)
```

Each function requires two input arguments: the interest-rate tree and the set of instruments, `InstSet`. An optional argument `Options` further controls the pricing and the output displayed. (See Appendix B for information about the `Options` argument.)

`HJMTree` is the Heath-Jarrow-Morton tree sampling of a forward-rate process, created using `hjmtree`. `BDTTree` is the Black-Derman-Toy tree sampling of an interest-rate process, created using `bdttree`. See “Building a Tree of Forward Rates” on page 2-56 to learn how to create these structures.

`InstSet` is the set of instruments to be priced. This structure represents the set of instruments to be priced independently using the model.

`Options` is an options structure created with the function `derivset`. This structure defines how the tree is used to find the price of instruments in the portfolio, and how much additional information is displayed in the command window when calling the pricing function. If this input argument is not specified in the call to the pricing function, a default `Options` structure is used. The pricing options structure is described in “Pricing Options Structure” on page B-2.

The portfolio pricing functions classify the instruments and call the appropriate instrument-specific pricing function for each of the instrument types. The HJM instrument-specific pricing functions are `bondbyhjm`, `cfbyhjm`, `fixedbyhjm`, `floatbyhjm`, `optbndbyhjm`, `rangefloatbyhjm`, `swapbyhjm`, and `swaptionbyhjm`. A similarly named set of functions exists for BDT models. You can also use these functions directly to calculate the price of sets of instruments of the same type.

### HJM Pricing Example

Consider the following example, which uses the portfolio and interest-rate data in the MAT-file `deriv.mat` included in the toolbox. Load the data into the MATLAB workspace.

```
load deriv.mat
```

Use the MATLAB `whos` command to display a list of the variables loaded from the MAT-file.

`whos`

Name	Size	Bytes	Class	Attributes
BDTInstSet	1x1	15956	struct	
BDTTree	1x1	5138	struct	
BKInstSet	1x1	15946	struct	
BKTree	1x1	5904	struct	
CRRInstSet	1x1	12434	struct	
CRRTree	1x1	5058	struct	
EQPInstSet	1x1	12434	struct	
EQPTree	1x1	5058	struct	
HJMInstSet	1x1	15948	struct	
HJMTree	1x1	5838	struct	
HWInstSet	1x1	15946	struct	
HWTTree	1x1	5904	struct	
ITTInstSet	1x1	12438	struct	
ITTree	1x1	8862	struct	
ZeroInstSet	1x1	10282	struct	
ZeroRateSpec	1x1	1580	struct	

`HJMTree` and `HJMInstSet` are the input arguments required to call the function `hjmprice`.

Use the function `instdisp` to examine the set of instruments contained in the variable `HJMInstSet`.

`instdisp(HJMInstSet)`

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate	FirstCouponDate	LastCouponDate	StartDate	Face
1	Bond	0.04	01-Jan-2000	01-Jan-2003	1	NaN	NaN	NaN	NaN	NaN	NaN	NaN
2	Bond	0.04	01-Jan-2000	01-Jan-2004	2	NaN	NaN	NaN	NaN	NaN	NaN	NaN

Index	Type	UnderInd	OptSpec	Strike	ExerciseDates	AmericanOpt	Name	Quantity
3	OptBond	2	call	101	01-Jan-2003	NaN	Option 101	-50

Index	Type	CouponRate	Settle	Maturity	FixedReset	Basis	Principal	Name	Quantity
4	Fixed	0.04	01-Jan-2000	01-Jan-2003	1	NaN	NaN	4% Fixed	80

Index	Type	Spread	Settle	Maturity	FloatReset	Basis	Principal	Name	Quantity
5	Float	20	01-Jan-2000	01-Jan-2003	1	NaN	NaN	20BP Float	8

Index	Type	Strike	Settle	Maturity	CapReset	Basis	Principal	Name	Quantity
6	Cap	0.03	01-Jan-2000	01-Jan-2004	1	NaN	NaN	3% Cap	30

Index	Type	Strike	Settle	Maturity	FloorReset	Basis	Principal	Name	Quantity
7	Floor	0.03	01-Jan-2000	01-Jan-2004	1	NaN	NaN	3% Floor	40

Index	Type	LegRate	Settle	Maturity	LegReset	Basis	Principal	LegType	Name	Quantity
8	Swap	[0.06 20]	01-Jan-2000	01-Jan-2003	[1 1]	NaN	NaN	[NaN]	6%/20BP Swap	10

Index	Type	CouponRate	Settle	Maturity	Period	Basis	...	Name	Quantity
1	Bond	0.04	01-Jan-2000	01-Jan-2003	1	NaN	...	4% bond	100
2	Bond	0.04	01-Jan-2000	01-Jan-2004	2	NaN	...	4% bond	50

Note that there are eight instruments in this portfolio set: two bonds, one bond option, one fixed-rate note, one floating-rate note, one cap, one floor, and one swap. Each instrument has a corresponding index that identifies the instrument prices in the price vector returned by `hjmprice`.

Now use `hjmprice` to calculate the price of each instrument in the instrument set.

```
Price = hjmprice(HJMTree, HJMInstSet)
```

```
Warning: Not all cash flows are aligned with the tree. Result will
be approximated.
```

```
Price =
    98.7159
    97.5280
     0.0486
    98.7159
   100.5529
     6.2831
     0.0486
     3.6923
```

---

**Note** The warning shown above appears because some of the cash flows for the second bond do not fall exactly on a tree node.

---

## BDT Pricing Example

Load the MAT-file `deriv.mat` into the MATLAB workspace.

```
load deriv.mat
```

Use the MATLAB `whos` command to display a list of the variables loaded from the MAT-file.

```
whos
```

Name	Size	Bytes	Class	Attributes
BDTInstSet	1x1	15956	struct	
BDTTree	1x1	5138	struct	
BKInstSet	1x1	15946	struct	
BKTree	1x1	5904	struct	

```

CRRInstSet      1x1      12434  struct
CRRTree         1x1      5058   struct
EQPInstSet     1x1      12434  struct
EQPTree        1x1      5058   struct
HJMInstSet     1x1      15948  struct
HJMTree        1x1      5838   struct
HWInstSet      1x1      15946  struct
HWTTree        1x1      5904   struct
ITTIInstSet    1x1      12438  struct
ITTTTree       1x1      8862   struct
ZeroInstSet    1x1      10282  struct
ZeroRateSpec   1x1      1580   struct

```

BDTTree and BDTInstSet are the input arguments required to call the function `bdtprice`.

Use the function `instdisp` to examine the set of instruments contained in the variable `BDTInstSet`.

### `instdisp(BDTInstSet)`

```

Index Type CouponRate Settle      Maturity      Period Basis EndMonthRule IssueDate FirstCouponDate LastCouponDate StartDate Face
1   Bond 0.1      01-Jan-2000   01-Jan-2003   1   NaN  NaN      NaN      NaN      NaN      NaN      NaN
2   Bond 0.1      01-Jan-2000   01-Jan-2004   2   NaN  NaN      NaN      NaN      NaN      NaN      NaN

Index Type  UnderInd OptSpec Strike ExerciseDates AmericanOpt Name      Quantity
3   OptBond 1      call    95      01-Jan-2002  NaN      Option 95 -50

Index Type CouponRate Settle      Maturity      FixedReset Basis Principal Name      Quantity
4   Fixed 0.1      01-Jan-2000   01-Jan-2003   1   NaN  NaN      10% Fixed 80

Index Type Spread Settle      Maturity      FloatReset Basis Principal Name      Quantity
5   Float 20      01-Jan-2000   01-Jan-2003   1   NaN  NaN      20BP Float 8

Index Type Strike Settle      Maturity      CapReset Basis Principal Name      Quantity
6   Cap 0.15  01-Jan-2000   01-Jan-2004   1   NaN  NaN      15% Cap 30

Index Type Strike Settle      Maturity      FloorReset Basis Principal Name      Quantity
7   Floor 0.09  01-Jan-2000   01-Jan-2004   1   NaN  NaN      9% Floor 40

Index Type LegRate Settle      Maturity      LegReset Basis Principal LegType Name      Quantity
8   Swap [0.15 10] 01-Jan-2000   01-Jan-2003   [1 1]  NaN  NaN      [NaN]  15%/10BP Swap 10

```

Note that there are eight instruments in this portfolio set: two bonds, one bond option, one fixed-rate note, one floating-rate note, one cap, one floor, and one swap. Each instrument has a corresponding index that identifies the instrument prices in the price vector returned by `bdtprice`.

Now use `bdtprice` to calculate the price of each instrument in the instrument set.

```
Price = bdtprice(BDTTree, BDTInstSet)
```

```
Warning: Not all cash flows are aligned with the tree. Result will
```

be approximated.

```
Price =
    95.5030
    93.9079
     1.7657
    95.5030
   100.4865
     1.4863
     0.0245
     7.4222
```

### Price Vector Output

The prices in the output vector `Price` correspond to the prices at observation time zero (`tObs = 0`), which is defined as the valuation date of the interest-rate tree. The instrument indexing within `Price` is the same as the indexing within `InstSet`.

In the HJM example, the prices in the `Price` vector correspond to the instruments in this order.

```
InstNames = instget(HJMInstSet, 'FieldName', 'Name')
```

```
InstNames =
    4% bond
    4% bond
    Option 101
    4% Fixed
    20BP Float
    3% Cap
    3% Floor
    6%/20BP Swap
```

Consequently, in the `Price` vector, the fourth element, 98.7159, represents the price of the fourth instrument (4% fixed-rate note); the sixth element, 6.2831, represents the price of the sixth instrument (3% cap).

In the BDT example, the prices in the `Price` vector correspond to the instruments in this order.

```
InstNames = instget(BDTInstSet, 'FieldName', 'Name')
```

```
InstNames =
```

```
10% Bond
10% Bond
Option 95
10% Fixed
20BP Float
15% Cap
9% Floor
15%/10BP Swap
```

Consequently, in the `Price` vector, the fourth element, 95.5030, represents the price of the fourth instrument (10% fixed-rate note); the sixth element, 1.4863, represents the price of the sixth instrument (15% cap).

### Price Tree Structure Output

If you call a pricing function with two output arguments, for example,

```
[Price, PriceTree] = hjmprice(HJMTree, HJMInstSet)
```

you generate a price tree along with the price information.

The optional output price tree structure `PriceTree` holds all the pricing information.

### HJM Price Tree

In the HJM example, the first field of this structure, `FinObj`, indicates that this structure represents a price tree. The second field, `PBush`, is the tree holding the price of the instruments in each node of the tree. The third field, `AIBush`, is the tree holding the accrued interest of the instruments in each node of the tree. Finally, the fourth field, `tObs`, represents the observation time of each level of `PBush` and `AIBush`, with units in terms of compounding periods.

In this example, the price tree looks like

```
PriceTree =
```

```
FinObj: 'HJMPriceTree'
PBush: {[8x1 double] [8x1x2 double] ... [8x8 double]}
AIBush: {[8x1 double] [8x1x2 double] ... [8x8 double]}
tObs: [0 1 2 3 4]
```

Both `PBush` and `AIBush` are 1-by-5 cell arrays, consistent with the five observation times of `tObs`. The data display has been shortened here to fit on a single line.

Using the command line interface, you can directly examine `PriceTree.PBush`, the field within the `PriceTree` structure that contains the price tree with the price vectors at every state. The first node represents `tObs = 0`, corresponding to the valuation date.

```
PriceTree.PBush{1}
```

```
ans =
```

```

98.7159
97.5280
 0.0486
98.7159
100.5529
 6.2831
 0.0486
 3.6923
```

With this interface, you can observe the prices for *all* instruments in the portfolio at *a specific time*.

### BDT Price Tree

The BDT output price tree structure `PriceTree` holds all the pricing information. The first field of this structure, `FinObj`, indicates that this structure represents a price tree. The second field, `Ptree`, is the tree holding the price of the instruments in each node of the tree. The third field, `AITree`, is the tree holding the accrued interest of the instruments in each node of the tree. The fourth field, `tObs`, represents the observation time of each level of `Ptree` and `AITree`, with units in terms of compounding periods.

You can directly examine the field within the `PriceTree` structure, which contains the price tree with the price vectors at every state. The first node represents `tObs = 0`, corresponding to the valuation date.

```
[Price, PriceTree] = bdtprice(BDTree, BDTInstSet)
```

```
PriceTree.PTree{1}
```

```
ans =
```

```

95.5030
93.9079
 1.7657
95.5030
100.4865
```

```
1.4863
0.0245
7.4222
```

### Computing Instrument Sensitivities

Sensitivities can be reported either as dollar price changes or percentage price changes. The delta, gamma, and vega sensitivities that the toolbox computes are dollar sensitivities.

The functions `hjmsens` and `bdtSENS` compute the delta, gamma, and vega sensitivities of instruments using an interest-rate tree. They also optionally return the calculated price for each instrument. The sensitivity functions require the same two input arguments used by the pricing functions (`HJMTree` and `HJMInstSet` for HJM; `BDTTree` and `BDTInstSet` for BDT).

Sensitivity functions calculate the dollar value of delta and gamma by shifting the observed forward yield curve by 100 basis points in each direction, and the dollar value of vega by shifting the volatility process by 1%. To obtain the per-dollar value of the sensitivities, divide the dollar sensitivity by the price of the corresponding instrument.

#### HJM Sensitivities Example

The calling syntax for the function is:

```
[Delta, Gamma, Vega, Price] = hjmsens(HJMTree, HJMInstSet)
```

Use the previous example data to calculate the price of instruments.

```
load deriv.mat
[Delta, Gamma, Vega, Price] = hjmsens(HJMTree, HJMInstSet);

Warning: Not all cash flows are aligned with the tree. Result will
be approximated.
```

---

**Note** The warning appears because some of the cash flows for the second bond do not fall exactly on a tree node.

---

You can conveniently examine the sensitivities and the prices by arranging them into a single matrix.

```
All = [Delta, Gamma, Vega, Price]
```



All =

-272.65	1029.90	0.00	98.72
-347.43	1622.69	-0.04	97.53
-8.08	643.40	34.07	0.05
-272.65	1029.90	0.00	98.72
-1.04	3.31	0	100.55
294.97	6852.56	93.69	6.28
-47.16	8459.99	93.69	0.05
-282.05	1059.68	0.00	3.69

As with the prices, each row of the sensitivity vectors corresponds to the similarly indexed instrument in `HJMIInstSet`. To view the *per-dollar sensitivities*, divide each dollar sensitivity by the corresponding instrument price.

### BDT Sensitivities Example

The calling syntax for the function is:

```
[Delta, Gamma, Vega, Price] = bdsens(BDTree, BDTInstSet);
```

Arrange the sensitivities and prices into a single matrix.

```
All = [Delta, Gamma, Vega, Price]
```

All =

-232.67	803.71	-0.00	95.50
-281.05	1181.93	-0.01	93.91
-50.54	246.02	5.31	1.77
-232.67	803.71	0	95.50
0.84	2.45	0	100.49
78.38	748.98	13.54	1.49
-4.36	382.06	2.50	0.02
-253.23	863.81	0	7.42

To view the *per-dollar sensitivities*, divide each dollar sensitivity by the corresponding instrument price.

```
All = [Delta ./ Price, Gamma ./ Price, Vega ./ Price, Price]
```

All =

-2.44	8.42	-0.00	95.50
-2.99	12.59	-0.00	93.91
-28.63	139.34	3.01	1.77
-2.44	8.42	0	95.50
0.01	0.02	0	100.49
52.73	503.92	9.11	1.49
-177.89	15577.42	101.87	0.02
-34.12	116.38	0	7.42

## Calibrating Hull-White Model Using Market Data

The pricing of interest rate derivative securities relies on models that describe the underlying process. These interest rate models depend on one or more parameters that you must determine by matching the model predictions to the existing data available in the market. In the Hull-White model, there are two parameters related to the short rate process: mean reversion and volatility. Calibration is used to determine these parameters, such that the model can reproduce, as close as possible, the prices of caps or floors observed in the market. The calibration routines find the parameters that minimize the difference between the model price predictions and the market prices for caps and floors.

For a Hull-White model, the minimization is two dimensional, with respect to mean reversion ( $\alpha$ ) and volatility ( $\sigma$ ). That is, calibrating the Hull-White model minimizes the difference between the model's predicted prices and the observed market prices of the corresponding caplets or floorlets.

### Hull-White Model Calibration Example

Use market data to identify the implied volatility ( $\sigma$ ) and mean reversion ( $\alpha$ ) coefficients needed to build a Hull-White tree to price an instrument. The ideal case is to use the volatilities of the caps or floors used to calculate **Alpha** ( $\alpha$ ) and **Sigma** ( $\sigma$ ). This will most likely not be the case, so market data must be interpolated to obtain the required values.

Consider a cap with these parameters:

```
Settle = ' Jan-21-2008';  
Maturity = 'Mar-21-2011';  
Strike = 0.0690;  
Reset = 4;  
Principal = 1000;  
Basis = 0;
```

The caplets for this example would fall in:

```
capletDates = cfdates(Settle, Maturity, Reset, Basis);  
datestr(capletDates')
```

```
ans =
```

```
21-Mar-2008  
21-Jun-2008  
21-Sep-2008  
21-Dec-2008
```

21-Mar-2009  
 21-Jun-2009  
 21-Sep-2009  
 21-Dec-2009  
 21-Mar-2010  
 21-Jun-2010  
 21-Sep-2010  
 21-Dec-2010  
 21-Mar-2011

In the best case, look up the market volatilities for caplets with a **Strike** = 0.0690, and maturities in each reset date listed, but the likelihood of finding these exact instruments is low. As a consequence, use data that is available in the market and interpolate to find appropriate values for the caplets.

Based on the market data, you have the cap information for different dates and strikes. Assume that instead of having the data for **Strike** = 0.0690, you have the data for **Strike1** = 0.0590 and **Strike2** = 0.0790

<b>Maturity</b>	<b>Strike1 = 0.0590</b>	<b>Strike2 = 0.0790</b>
21-Mar-2008	0.1533	0.1526
21-Jun-2008	0.1731	0.1730
21-Sep-2008	0.1727	0.1726
21-Dec-2008	0.1752	0.1747
21-Mar-2009	0.1809	0.1808
21-Jun-2009	0.1809	0.1792
21-Sep-2009	0.1805	0.1797
21-Dec-2009	0.1802	0.1794
21-Mar-2010	0.1802	0.1733
21-Jun-2010	0.1757	0.1751
21-Sep-2010	0.1755	0.1750
21-Dec-2010	0.1755	0.1745
21-Mar-2011	0.1726	0.1719

The nature of this data lends itself to matrix nomenclature, which is perfect for MATLAB. `hwcalbycap` requires that the dates, the strikes, and the actual volatility be separated into three variables: `MarketStrike`, `MarketMat`, and `MarketVol`.

```

MarketStrike = [0.0590; 0.0790];
MarketMat = {'21-Mar-2008';
'21-Jun-2008';
'21-Sep-2008';
'21-Dec-2008';
'21-Mar-2009';
'21-Jun-2009';
'21-Sep-2009';
'21-Dec-2009';
'21-Mar-2010';
'21-Jun-2010';
'21-Sep-2010';
'21-Dec-2010';
'21-Mar-2011'};

MarketVol = [0.1533 0.1731 0.1727 0.1752 0.1809 0.1800 0.1805 0.1802 0.1735 0.1757 ...
0.1755 0.1755 0.1726; % First row in table corresponding to Strike1
0.1526 0.1730 0.1726 0.1747 0.1808 0.1792 0.1797 0.1794 0.1733 0.1751 ...
0.1750 0.1745 0.1719]; % Second row in table corresponding to Strike2

```

Complete the input arguments using this data for RateSpec:

```

Rates= [0.0627;
0.0657;
0.0691;
0.0717;
0.0739;
0.0755;
0.0765;
0.0772;
0.0779;
0.0783;
0.0786;
0.0789;
0.0792;
0.0793];

ValuationDate = '21-Jan-2008';
EndDates = {'21-Mar-2008';'21-Jun-2008';'21-Sep-2008';'21-Dec-2008';...
'21-Mar-2009';'21-Jun-2009';'21-Sep-2009';'21-Dec-2009';...
'21-Mar-2010';'21-Jun-2010';'21-Sep-2010';'21-Dec-2010';...
'21-Mar-2011';'21-Jun-2011'};

Compounding = 4;
Basis = 0;

RateSpec = intenvset('ValuationDate', ValuationDate, ...
'StartDates', ValuationDate, 'EndDates', EndDates, ...
'Rates', Rates, 'Compounding', Compounding, 'Basis', Basis)

RateSpec =

    FinObj: 'RateSpec'
  Compounding: 4
        Disc: [14x1 double]
        Rates: [14x1 double]

```

```

    EndTimes: [14x1 double]
    StartTimes: [14x1 double]
    EndDates: [14x1 double]
    StartDates: 733428
    ValuationDate: 733428
    Basis: 0
    EndMonthRule: 1

```

### Call the calibration routine to find values for volatility parameters Alpha and Sigma

Use `hwcalbycap` to calculate the values of Alpha and Sigma based on market data. Internally, `hwcalbycap` calls the Optimization Toolbox function `lsqnonlin`. You can customize `lsqnonlin` by passing an optimization options structure created by `optimoptions` and then this can be passed to `hwcalbycap` using the name-value pair argument for `OptimOptions`. For example, `optimoptions` defines the target objective function tolerance as `100*eps` and then calls `hwcalbycap`:

```

o=optimoptions('lsqnonlin','TolFun',100*eps);

[Alpha, Sigma] = hwcalbycap(RateSpec, MarketStrike, MarketMat, MarketVol,...
Strike, Settle, Maturity, 'Reset', Reset, 'Principal', Principal, 'Basis',...
Basis, 'OptimOptions', o)

Local minimum possible.

lsqnonlin stopped because the size of the current step is less than
the default value of the step size tolerance.

Warning: LSQNONLIN did not converge to an optimal solution. It exited with exitflag = 2.

> In hwcalbycapfloor at 93
   In hwcalbycap at 75

Alpha =

    1.0000e-06

Sigma =

    0.0127

```

The previous warning indicates that the conversion was not optimal. The search algorithm used by the Optimization Toolbox™ function `lsqnonlin` did not find a solution that conforms to all the constraints. To discern whether the solution is acceptable, look at the results of the optimization by specifying a third output (`OptimOut`) for `hwcalbycap`:

```

[Alpha, Sigma, OptimOut] = hwcalbycap(RateSpec, MarketStrike, MarketMat,...
MarketVol, Strike, Settle, Maturity, 'Reset', Reset, 'Principal', Principal,...
'Basis', Basis, 'OptimOptions', o);

```

The `OptimOut.residual` field of the `OptimOut` structure is the optimization residual. This value contains the difference between the Black caplets and those calculated during the optimization. You can use the `OptimOut.residual` value to calculate the percentual difference (error) compared to Black caplet prices and then decide whether the residual is acceptable. There is almost always some residual, so decide if parametrizing the market with a single value of `Alpha` and `Sigma` is acceptable.

### Price caplets using market data and Black's formula to obtain reference caplet values

To determine the effectiveness of the optimization, calculate reference caplet values using Black's formula and the market data. Note, you must first interpolate the market data to obtain the caplets for calculation:

```
MarketMatNum = datenum(MarketMat);  
[Mats, Strikes] = meshgrid(MarketMatNum, MarketStrike);  
FlatVol = interp2(Mats, Strikes, MarketVol, datenum(Maturity), Strike, 'spline');
```

Compute the price of the cap using the Black model:

```
[CapPrice, Caplets] = capbyblk(RateSpec, Strike, Settle, Maturity, FlatVol,...  
'Reset', Reset, 'Basis', Basis, 'Principal', Principal);  
Caplets = Caplets(2:end)';
```

```
Caplets =
```

```
0.3210  
1.6355  
2.4863  
3.1903  
3.4110  
3.2685  
3.2385  
3.4803  
3.2419  
3.1949  
3.2991  
3.3750
```

### Compare optimized values and Black values and display graphically

After calculating the reference values for the caplets, compare the values, analytically and graphically, to determine whether the calculated single values of `Alpha` and `Sigma` provide an adequate approximation:

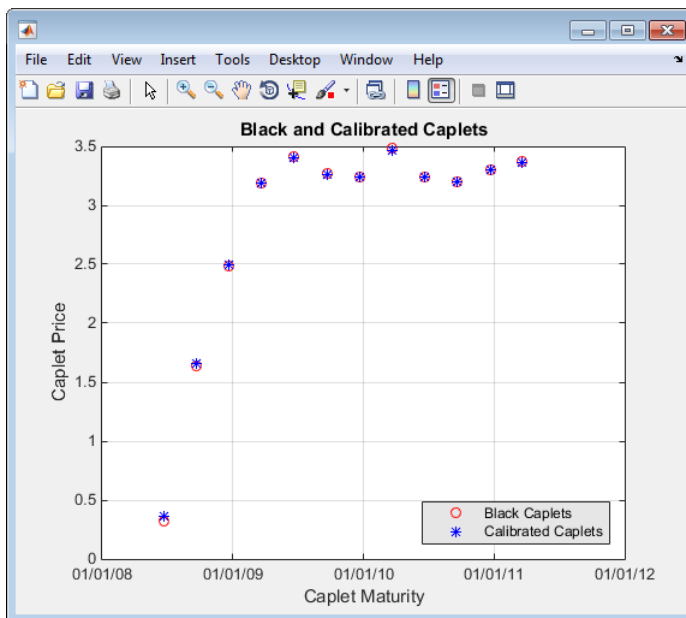
```
OptimCaplets = Caplets+OptimOut.residual;  
  
disp(' ');  
disp(' Black76 Calibrated Caplets');  
disp([Caplets OptimCaplets])
```

```

plot(MarketMatNum(2:end), Caplets, 'or', MarketMatNum(2:end), OptimCaplets, '*b');
datetick('x', 2)
xlabel('Caplet Maturity');
ylabel('Caplet Price');
title('Black and Calibrated Caplets');
h = legend('Black Caplets', 'Calibrated Caplets');
set(h, 'color', [0.9 0.9 0.9]);
set(h, 'Location', 'SouthEast');
set(gcf, 'NumberTitle', 'off')
grid on

```

Black76	Calibrated Caplets
0.3210	0.3636
1.6355	1.6603
2.4863	2.4974
3.1903	3.1874
3.4110	3.4040
3.2685	3.2639
3.2385	3.2364
3.4803	3.4683
3.2419	3.2408
3.1949	3.1957
3.2991	3.2960
3.3750	3.3663



**Compare cap prices using the Black, HW analytical, and HW tree models**

Using the calculated caplet values, compare the prices of the corresponding cap using the Black model, Hull-White analytical, and Hull-White tree models. To calculate a Hull-White tree based on Alpha and Sigma, use these calibration routines:

- Black model:

```
CapPriceBLK = CapPrice;
```

- HW analytical model:

```
CapPriceHWAAnalytical = sum(OptimCaplets);
```

- HW tree model to price the cap derived from the calibration process:

**1 Create VolSpec from the calibration parameters Alpha and Sigma:**

```
VolDates = EndDates;
VolCurve = Sigma*ones(14,1);
AlphaDates = EndDates;
AlphaCurve = Alpha*ones(14,1);
HWPVolSpec = hwpvolspec(ValuationDate, VolDates, VolCurve,AlphaDates, AlphaCurve);
```

**2 Create the TimeSpec:**

```
HWPTimeSpec = hwp timespec(ValuationDate, EndDates, Compounding);
```

**3 Build the HW tree using the HW2000 method:**

```
HWPtree = hwp tree(HWPVolSpec, RateSpec, HWPTimeSpec, 'Method', 'HW2000');
```

**4 Price the cap:**

```
Price = capbyhw(HWPtree, Strike, Settle, Maturity, Reset, Basis, Principal);

disp(' ');
disp([' CapPrice Black76 .....: ', num2str(CapPriceBLK,'%15.5f')]);
disp([' CapPrice HW analytical.....: ', num2str(CapPriceHWAAnalytical,'%15.5f')]);
disp([' CapPrice HW from capbyhw ..: ', num2str(Price,'%15.5f')]);
disp(' ');

CapPrice Black76 .....: 34.14220
CapPrice HW analytical.....: 34.18008
CapPrice HW from capbyhw ..: 34.14192
```

**Price a portfolio of instruments using the calibrated HW tree**

After building a Hull-White tree, based on parameters calibrated from market data, use HWPtree to price a portfolio of these instruments:

- Two bonds



```
CouponRate = [0.07; 0.09];
Settle= ' Jan-21-2008';
Maturity = {'Mar-21-2010'; 'Mar-21-2011'};
Period = 1;
Face = 1000;
Basis = 0;
```

- Bond with an embedded American call option

```
CouponRateOEB = 0.08;
SettleOEB = ' Jan-21-2008';
MaturityOEB = 'Mar-21-2011';
OptSpec = 'call';
StrikeOEB = 950;
ExerciseDatesOEB = 'Mar-21-2011';
AmericanOpt= 1;
Period =1;
Face = 1000;
Basis =0;
```

To price this portfolio of instruments using the calibrated HWTtree:

- 1 Use `instadd` to create the portfolio `InstSet`:

```
InstSet = instadd('Bond', CouponRate, Settle, Maturity, Period, Basis, [], [], [], [], [], Face);
InstSet = instadd(InstSet, 'OptEmBond', CouponRateOEB, SettleOEB, MaturityOEB, OptSpec, ...
StrikeOEB, ExerciseDatesOEB, 'AmericanOpt', AmericanOpt, 'Period', Period, ...
'Face', Face, 'Basis', Basis);
```

- 2 Add the cap instrument used in the calibration:

```
SettleCap = ' Jan-21-2008';
MaturityCap = 'Mar-21-2011';
StrikeCap = 0.0690;
Reset = 4;
Principal = 1000;

InstSet = instadd(InstSet, 'Cap', StrikeCap, SettleCap, MaturityCap, Reset, Basis, Principal);
```

- 3 Assign names to the portfolio instruments:

```
Names = {'7% Bond'; '8% Bond'; 'BondEmbCall'; '6.9% Cap'};
InstSet = instsetfield(InstSet, 'Index', 1:4, 'FieldName', {'Name'}, 'Data', Names);
```

- 4 Examine the set of instruments contained in `InstSet`:

```
instdisp(InstSet)
```

```
IdxType  CoupRate  Settle  Mature  Period  Basis  EOMRule  IssueDate  1stCoupDate  LastCoupDate  StartDate  Face  Name
1 Bond 0.07      21-Jan-2008  21-Mar-2010  1 0 NaN NaN      NaN NaN NaN 1000 7% Bond
2 Bond 0.09      21-Jan-2008  21-Mar-2011  1 0 NaN NaN      NaN NaN NaN 1000 8% Bond
```

```
IdxType  CoupRate  Settle  Mature  OptSpec  Stke  ExDate  Per  Basis  EOMRule  IssDate  1stCoupDate  LstCoupDate  StrtDate  Face  An
3  OptEmBond  0.08  21-Jan-2008  21-Mar-2011  call  950  21-Jan-2008  21-Mar-2011  1  0  1  NaN  NaN  NaN  NaN  1000  1  Bond
```

```
Index  Type  Strike  Settle      Maturity    CapReset  Basis  Principal  Name
4  Cap  0.069  21-Jan-2008  21-Mar-2011  4  0  1000  6.9% Cap
```

### 5 Use `hwprice` to price the portfolio using the calibrated `HWTree`:

```
format bank
PricePortfolio = hwprice(HWTree, InstSet)
```

```
PricePortfolio =
    980.45
   1023.05
    945.73
    34.14
```

## Interest-Rate Derivatives Using Closed-Form Solutions

### Pricing Caps and Floors Using the Black Option Model

Caps and floors are contracts that allow the holder to be protected if interest rates rise or decrease. The Black model uses a forward price as an underlier in place of a spot price. The assumption is that the forward price at maturity of the option is log-normally distributed.

Closed-form solutions for pricing caps and floors using the Black model support the following tasks:

Task	Function
Price the interest rate caps using the Black option pricing model.	capbyblk
Price the interest rate floors using the Black option pricing model.	floorbyblk

## Price Swaptions With Interest-Rate Models Using Simulation

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“Compare Interest-Rate Modeling Results ” on page 2-111

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### Introduction

This example shows how to price European swaptions using interest-rate models in Financial Instruments Toolbox. Specifically, a Hull-White one factor model, a Linear Gaussian two-factor model, and a LIBOR Market Model are calibrated to market data and then used to generate interest-rate paths using Monte Carlo simulation.

The following sections set up the data that is then used with examples for “Simulate Interest-Rate Paths Using the Hull-White One-Factor Model” on page 2-99, “Simulate Interest-Rate Paths Using the Linear Gaussian Two-Factor Model” on page 2-102, and “Simulate Interest-Rate Paths Using the LIBOR Market Model” on page 2-105:

- “Construct Zero Curve” on page 2-95
- “Define Swaption Parameters” on page 2-97
- “Compute the Black Model and the Swaption Volatility Matrix” on page 2-97
- “Select Calibration Instruments” on page 2-97

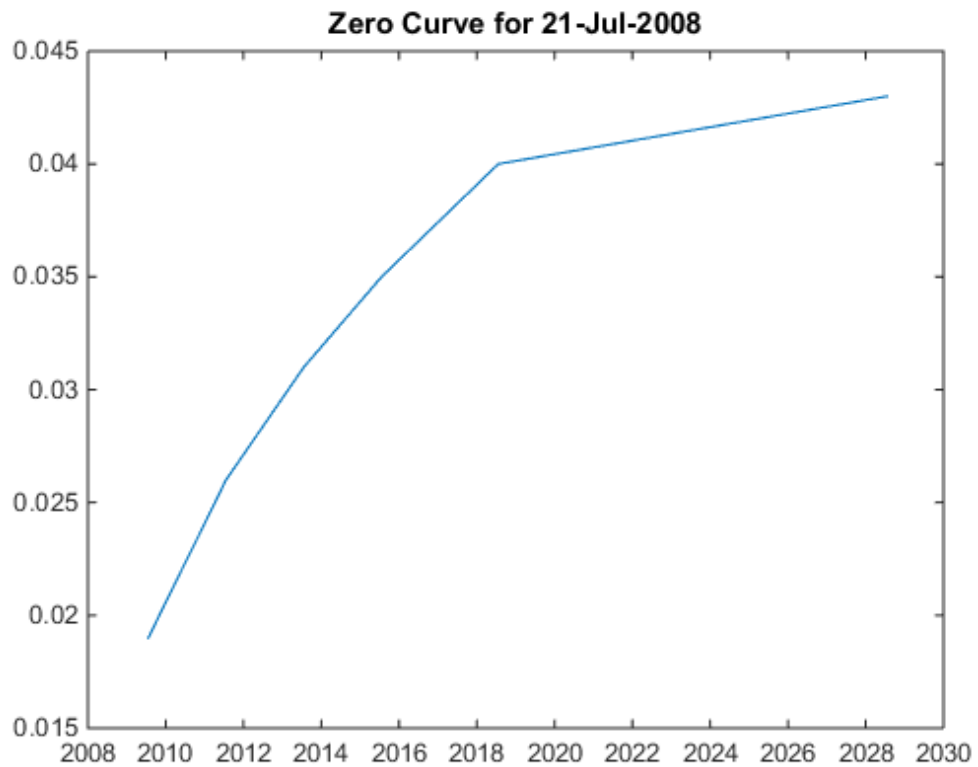
- “Compute Swaption Prices Using Black's Model” on page 2-98
- “Define Simulation Parameters” on page 2-98

## Construct Zero Curve

This example shows how to use `ZeroRates` for a zero curve that is hard-coded. You can also create a zero curve by bootstrapping the zero curve from market data (for example, deposits, futures/forwards, and swaps)

The hard-coded data for the zero curve is defined as:

```
Settle = datenum('21-Jul-2008');  
  
% Zero Curve  
CurveDates = daysadd(Settle,360*([1 3 5 7 10 20]),1);  
ZeroRates = [1.9 2.6 3.1 3.5 4 4.3]'/100;  
  
plot(CurveDates,ZeroRates)  
datetick  
title(['Zero Curve for ' datestr(Settle)]);
```



Construct an `IRCurve` object.

```
irdc = IRDataCurve('Zero',Settle,CurveDates,ZeroRates);
```

Construct the `RateSpec`.

```
RateSpec = intenvset('Rates',ZeroRates,'EndDates',CurveDates,'StartDate',Settle)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'  
  Compounding: 2  
    Disc: [6x1 double]  
    Rates: [6x1 double]
```

```

    EndTimes: [6x1 double]
    StartTimes: [6x1 double]
    EndDates: [6x1 double]
    StartDates: 733610
    ValuationDate: 733610
    Basis: 0
    EndMonthRule: 1

```

## Define Swaption Parameters

While Monte Carlo simulation is typically used to value more sophisticated derivatives (for example, Bermudan swaptions), in this example, the price of a European swaption is computed with an exercise date of 5 years and an underlying swap of 5 years.

```

InstrumentExerciseDate = datenum('21-Jul-2013');
InstrumentMaturity = datenum('21-Jul-2018');
InstrumentStrike = .045;

```

## Compute the Black Model and the Swaption Volatility Matrix

Black's model is often used to price and quote European exercise interest-rate options, that is, caps, floors and swaptions. In the case of swaptions, Black's model is used to imply a volatility given the current observed market price. The following matrix shows the Black implied volatility for a range of swaption exercise dates (columns) and underlying swap maturities (rows).

```

SwaptionBlackVol = [22 21 19 17 15 13 12
    21 19 17 16 15 13 11
    20 18 16 15 14 12 11
    19 17 15 14 13 12 10
    18 16 14 13 12 11 10
    15 14 13 12 12 11 10
    13 13 12 11 11 10 9]/100;
ExerciseDates = [1:5 7 10];
Tenors = [1:5 7 10];

EurExDatesFull = repmat(daysadd(Settle,ExerciseDates*360,1)',...
    length(Tenors),1);
EurMatFull = reshape(daysadd(EurExDatesFull,...
    repmat(360*Tenors,1,length(ExerciseDates)),1),size(EurExDatesFull));

```

## Select Calibration Instruments

Selecting the instruments to calibrate the model to is one of the tasks in calibration. For Bermudan swaptions, it is typical to calibrate to European swaptions that are co-

terminal with the Bermudan swaption to be priced. In this case, all swaptions having an underlying tenor that matures before the maturity of the swaption to be priced (21-Jul-2018) are used in the calibration.

```
% Find the swaptions that expire on or before the maturity date of the
% sample swaption
reidx = find(EurMatFull <= InstrumentMaturity);
```

### Compute Swaption Prices Using Black's Model

This example shows how to compute swaption prices using Black's Model. The swaption prices are then used to compare the model's predicted values that are obtained from the calibration process.

To compute the swaption prices using Black's model:

```
SwaptionBlackPrices = zeros(size(SwaptionBlackVol));
SwaptionStrike = zeros(size(SwaptionBlackVol));

for iSwaption=1:length(ExerciseDates)
    for iTenor=1:length(Tenors)
        [-,SwaptionStrike(iTenor,iSwaption)] = swapbyzero(RateSpec,[NaN 0], Settle, EurMatFull(iTenor,iSwaption),...
            'StartDate',EurExDatesFull(iTenor,iSwaption),'LegReset',[1 1]);
        SwaptionBlackPrices(iTenor,iSwaption) = swaptionbyblk(RateSpec, 'call', SwaptionStrike(iTenor,iSwaption),Settle,
            EurExDatesFull(iTenor,iSwaption), EurMatFull(iTenor,iSwaption), SwaptionBlackVol(iTenor,iSwaption));
    end
end
```

### Define Simulation Parameters

This example shows how to use the `simTermStructs` method with `HullWhite1F`, `LinearGaussian2F`, and `LiborMarketModel` objects.

To demonstrate using the `simTermStructs` method with `HullWhite1F`, `LinearGaussian2F`, and `LiborMarketModel` objects, use the following simulation parameters:

```
nPeriods = 5;
DeltaTime = 1;
nTrials = 1000;

Tenor = (1:10)';

SimDates = daysadd(Settle,360*DeltaTime*(0:nPeriods),1)
SimTimes = diff(yearfrac(SimDates(1),SimDates))

% For 1 year periods and an evenly spaced tenor, the exercise row will be
% the sixth row and the swaption maturity will be the 5th column
```



```

exRow = 6;
endCol = 5;

SimDates =
    733610
    733975
    734340
    734705
    735071
    735436

SimTimes =
    1.0000
    1.0000
    1.0000
    1.0027
    1.0000

```

## Simulate Interest-Rate Paths Using the Hull-White One-Factor Model

This example shows how to simulate interest-rate paths using the Hull-White one-factor model. Before beginning this example that uses a `HullWhite1F` model, make sure you have set up the data as described in:

- “Construct Zero Curve” on page 2-95
- “Define Swaption Parameters” on page 2-97
- “Compute the Black Model and the Swaption Volatility Matrix” on page 2-97
- “Select Calibration Instruments” on page 2-97
- “Compute Swaption Prices Using Black's Model” on page 2-98
- “Define Simulation Parameters” on page 2-98

The Hull-White one-factor model describes the evolution of the short rate and is specified using the zero curve,  $\alpha$ , and  $\sigma$  parameters for the equation

$$dr = [\theta(t) - \alpha(t)r]dt + \sigma(t)dW$$

where:

$dr$  is the change in the short-term interest rate over a small interval,  $dt$ .

$r$  is the short-term interest rate.

$\Theta(t)$  is a function of time determining the average direction in which  $r$  moves, chosen such that movements in  $r$  are consistent with today's zero coupon yield curve.

$\alpha$  is the mean reversion rate.

$dt$  is a small change in time.

$\sigma$  is the annual standard deviation of the short rate.

$W$  is the Brownian motion.

The Hull-White model is calibrated using the function `swaptionbyhw`, which constructs a trinomial tree to price the swaptions. Calibration consists of minimizing the difference between the observed market prices (computed above using the Black's implied swaption volatility matrix, see “Compute the Black Model and the Swaption Volatility Matrix” on page 2-97) and the model's predicted prices.

In this example, the Optimization Toolbox function `lsqnonlin` is used to find the parameter set that minimizes the difference between the observed and predicted values. However, other approaches (for example, simulated annealing) may be appropriate. Starting parameters and constraints for  $\alpha$  and  $\sigma$  are set in the variables `x0`, `lb` and `ub`; these could also be varied depending upon the particular calibration approach.

Calibrate the set of parameters that minimize the difference between the observed and predicted values using `swaptionbyhw` and `lsqnonlin`.

```
TimeSpec = hwtimespec(Settle,daysadd(Settle,360*(1:11),1), 2);
HW1Fobjfun = @(x) SwaptionBlackPrices(releidx) - ...
    swaptionbyhw(hwtree(hwvolspec(Settle,'11-Aug-2015',x(2),'11-Aug-2015',x(1)), RateSpec, TimeSpec), 'call', SwaptionStr
    EurExDatesFull(releidx), 0, Settle, EurMatFull(releidx));
options = optimset('disp','iter','MaxFunEvals',1000,'TolFun',1e-5);

% Find the parameters that minimize the difference between the observed and
% predicted prices
x0 = [.1 .01];
lb = [0 0];
ub = [1 1];
HW1Fparams = lsqnonlin(HW1Fobjfun,x0,lb,ub,options);

HW_alpha = HW1Fparams(1)
HW_sigma = HW1Fparams(2)
```

Iteration	Func-count	f(x)	Norm of step	First-order optimality	CG-iterations
0	3	0.481427		8.91	
1	6	0.321311	0.00637941	0.188	0
2	9	0.307638	0.0102855	17.1	0
3	12	0.306546	0.0128066	0.0889	0
4	15	0.306518	0.00342934	0.0245	0

```

5          18          0.306518          5.66218e-05          9.99e-05          0
Local minimum possible.
lsqnonlin stopped because the final change in the sum of squares relative to
its initial value is less than the selected value of the function tolerance.

HW_alpha =
    0.0909

HW_sigma =
    0.0092

```

Construct the HullWhite1F model using the HullWhite1F constructor.

```
HW1F = HullWhite1F(RateSpec,HW_alpha,HW_sigma)
```

```
HW1F =
```

```
HullWhite1F with properties:
```

```

ZeroCurve: [1x1 IRDataCurve]
Alpha: @(t,V)inAlpha
Sigma: @(t,V)inSigma

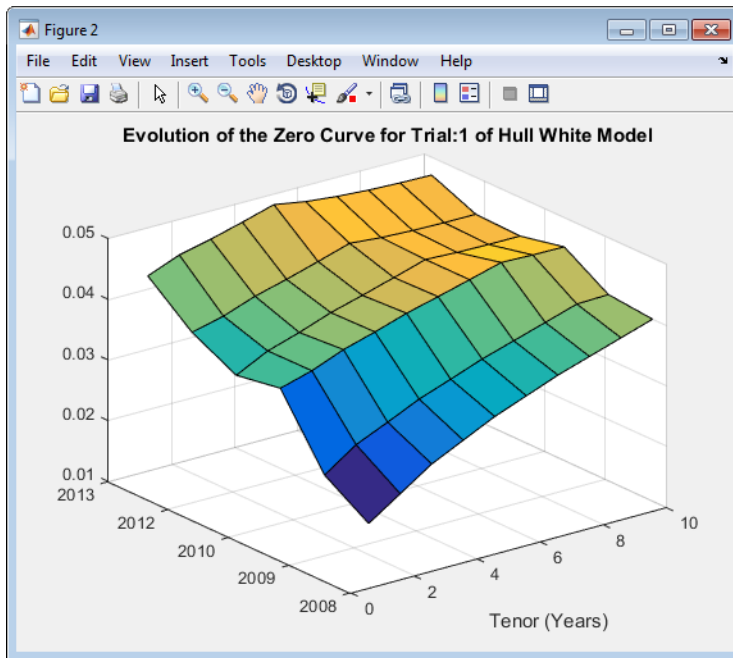
```

Use Monte Carlo simulation to generate the interest-rate paths with HullWhite1F.simTermStructs.

```

HW1FSimPaths = HW1F.simTermStructs(nPeriods,'NTRIALS',nTrials,...
    'DeltaTime',DeltaTime,'Tenor',Tenor,'antithetic',true);
trialIdx = 1;
figure
surf(Tenor,SimDates,HW1FSimPaths(:,:,trialIdx))
datetick y kepticks keeplimits
title(['Evolution of the Zero Curve for Trial:' num2str(trialIdx) ' of Hull White Model'])
xlabel('Tenor (Years)')

```



Price the European swaption.

```
DF = exp(bsxfun(@times,-HW1FSimPaths, repmat(Tenor',[nPeriods+1 1])));
SwapRate = (1 - DF(exRow,endCol,:))./sum(bsxfun(@times,1,DF(exRow,1:endCol,:)));
PayoffValue = 100*max(SwapRate-InstrumentStrike,0).*sum(bsxfun(@times,1,DF(exRow,1:endCol,:)));
RealizedDF = prod(exp(bsxfun(@times,-HW1FSimPaths(2:exRow,1,:), SimTimes(1:exRow-1))),1);
HW1F_SwaptionPrice = mean(RealizedDF.*PayoffValue);
```

```
HW1F_SwaptionPrice =
    2.7649
```

## Simulate Interest-Rate Paths Using the Linear Gaussian Two-Factor Model

This example shows how to simulate interest-rate paths using the Linear Gaussian two-factor model. Before beginning this example that uses a `LinearGaussian2F` model, make sure you have set up the data as described in:

- “Construct Zero Curve” on page 2-95
- “Define Swaption Parameters” on page 2-97
- “Compute the Black Model and the Swaption Volatility Matrix” on page 2-97

- “Select Calibration Instruments” on page 2-97
- “Compute Swaption Prices Using Black's Model” on page 2-98
- “Define Simulation Parameters” on page 2-98

The Linear Gaussian two-factor model (called the G2++ by Brigo and Mercurio, see “Interest-Rate Modeling Using Monte Carlo Simulation” on page C-12) is also a short rate model, but involves two factors. Specifically:

$$r(t) = x(t) + y(t) + \phi(t)$$

$$dx(t) = -a(t)x(t)dt + \sigma(t)dW_1(t), x(0) = 0$$

$$dy(t) = -b(t)y(t)dt + \eta(t)dW_2(t), y(0) = 0$$

where  $dW_1(t)dW_2(t) = \rho dt$  is a two-dimensional Brownian motion with correlation  $\rho$ , and  $\phi$  is a function chosen to match the initial zero curve.

The function `swaptionbylg2f` is used to compute analytic values of the swaption price for model parameters and consequently can be used to calibrate the model. Calibration consists of minimizing the difference between the observed market prices (computed above using the Black's implied swaption volatility matrix, see “Compute the Black Model and the Swaption Volatility Matrix” on page 2-97) and the model's predicted prices.

In this example, the approach is similar to “Simulate Interest-Rate Paths Using the Hull-White One-Factor Model” on page 2-99 and the Optimization Toolbox function `lsqnonlin` is used to minimize the difference between the observed swaption prices and the predicted swaption prices. However, other approaches (for example, simulated annealing) may also be appropriate. Starting parameters and constraints for  $a$ ,  $b$ ,  $\eta$ ,  $\rho$ , and  $\sigma$  are set in the variables `x0`, `lb`, and `ub`; these could also be varied depending upon the particular calibration approach.

Calibrate the set of parameters that minimize the difference between the observed and predicted values using `swaptionbylg2f` and `lsqnonlin`.

```
G2PPobjfun = @(x) SwaptionBlackPrices(releidx) - swaptionbylg2f(irdc,x(1),x(2),x(3),x(4),x(5),SwaptionStrike(releidx),...
    EurExDatesFull(releidx),EurMatFull(releidx),'Reset',1);
```

```
options = optimset('disp','iter','MaxFunEvals',1000,'ToIFun',1e-5);
x0 = [.2 .1 .02 .01 -.5];
lb = [0 0 0 0 -1];
ub = [1 1 1 1 1];
LG2Fparams = lsqnonlin(G2PPobjfun,x0,lb,ub,options);
```

Iteration	Func-count	f(x)	Norm of step	First-order optimality	CG-iterations
0	6	4.63874		27.7	
1	12	3.12695	0.116051	58.3	0
2	18	0.466886	0.110096	12.5	0
3	24	0.17667	0.0440836	3.2	0
4	30	0.17667	0.0688327	3.2	0
5	36	0.154169	0.0172082	0.246	0
6	42	0.150196	0.0344163	0.0356	0
7	48	0.143753	0.0688327	5.35	0
8	54	0.143753	0.0669431	5.35	0
9	60	0.140589	0.0167358	0.522	0
10	66	0.13942	0.0334716	0.42	0
11	72	0.13768	0.0669431	0.147	0
12	78	0.136894	0.133886	28.6	0
13	84	0.135024	0.0250289	3.56	0
14	90	0.13492	0.0139061	4.24	0
15	96	0.134879	0.00348578	0.232	0
16	102	0.134879	0.038352	0.232	0
17	108	0.134869	0.00836789	0.294	0

Local minimum possible.

lsqnonlin stopped because the final change in the sum of squares relative to its initial value is less than the selected value of the function tolerance.

```
LG2Fparams =
```

```
    0.1694    0.0355    0.0073    0.0106   -0.7291
```

Create the G2PP object and use Monte Carlo simulation to generate the interest-rate paths with `LinearGaussian2F.simTermStructs`.

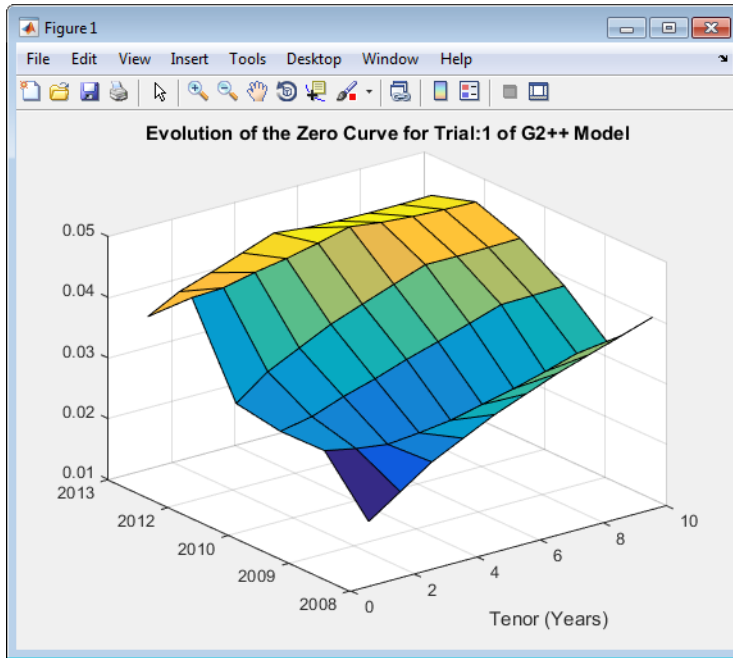
```
LG2f_a = LG2Fparams(1);
LG2f_b = LG2Fparams(2);
LG2f_sigma = LG2Fparams(3);
LG2f_eta = LG2Fparams(4);
LG2f_rho = LG2Fparams(5);

G2PP = LinearGaussian2F(RateSpec, LG2f_a, LG2f_b, LG2f_sigma, LG2f_eta, LG2f_rho);

G2PPSimPaths = G2PP.simTermStructs(nPeriods, 'NTRIALS', nTrials, ...
    'DeltaTime', DeltaTime, 'Tenor', Tenor, 'antithetic', true);

trialIdx = 1;
figure
surf(Tenor, SimDates, G2PPSimPaths(:, :, trialIdx))
datetick y keepticks keeplimits
title(['Evolution of the Zero Curve for Trial:' num2str(trialIdx) ' of G2++ Model'])
```

```
xlabel('Tenor (Years)')
```



Price the European swaption.

```
DF = exp(bsxfun(@times,-G2PPSimPaths, repmat(Tenor', [nPeriods+1 1])));
SwapRate = (1 - DF(exRow,endCol,:))./sum(bsxfun(@times,1,DF(exRow,1:endCol,:)));
PayoffValue = 100*max(SwapRate-InstrumentStrike,0).*sum(bsxfun(@times,1,DF(exRow,1:endCol,:)));
RealizedDF = prod(exp(bsxfun(@times,-G2PPSimPaths(2:exRow,1,:), SimTimes(1:exRow-1))),1);
G2PP_SwaptionPrice = mean(RealizedDF.*PayoffValue)
```

```
G2PP_SwaptionPrice =
```

```
2.6186
```

## Simulate Interest-Rate Paths Using the LIBOR Market Model

This example shows how to simulate interest-rate paths using the LIBOR market model. Before beginning this example that uses a `LiborMarketModel`, make sure you have set up the data as described in:

- “Construct Zero Curve” on page 2-95

- “Define Swaption Parameters” on page 2-97
- “Compute the Black Model and the Swaption Volatility Matrix” on page 2-97
- “Select Calibration Instruments” on page 2-97
- “Compute Swaption Prices Using Black's Model” on page 2-98
- “Define Simulation Parameters” on page 2-98

The LIBOR Market Model (LMM) differs from short rate models in that it evolves a set of discrete forward rates. Specifically, the lognormal LMM specifies the following diffusion equation for each forward rate

$$\frac{dF_i(t)}{F_i} = -\mu_i dt + \sigma_i(t) dW_i$$

where:

$W$  is an  $N$ -dimensional geometric Brownian motion with

$$dW_i(t)dW_j(t) = \rho_{ij}$$

The LMM relates the drifts of the forward rates based on no-arbitrage arguments. Specifically, under the Spot LIBOR measure, the drifts are expressed as

$$\mu_i(t) = -\sigma_i(t) \sum_{j=q(t)}^i \frac{\tau_j \rho_{i,j} \sigma_j(t) F_j(t)}{1 + \tau_j F_j(t)}$$

where:

$\tau_i$  is the time fraction associated with the  $i$  th forward rate

$q(t)$  is an index defined by the relation

$$T_{q(t)-1} < t < T_{q(t)}$$

and the Spot LIBOR numeraire is defined as

$$B(t) = P(t, T_{q(t)}) \prod_{n=0}^{q(t)-1} (1 + \tau_n F_n(T_n))$$



The choice with the LMM is how to model volatility and correlation and how to estimate the parameters of these models for volatility and correlation. In practice, you may use a combination of historical data (for example, observed correlation between forward rates) and current market data. For this example, only swaption data is used. Further, many different parameterizations of the volatility and correlation exist. For this example, two relatively straightforward parameterizations are used.

One of the most popular functional forms in the literature for volatility is:

$$\sigma_i(t) = \varphi_i(\alpha(T_i - t) + b)e^{c(T_i - t)} + d$$

where # adjusts the curve to match the volatility for the  $i$  th forward rate. For this example, all of the #s will be taken to be 1. For the correlation, the following functional form is used:

$$\rho_{i,j} = e^{-\beta|i-j|}$$

Once the functional forms have been specified, these parameters need to be estimated using market data. One useful approximation, initially developed by Rebonato, is the following, which relates the Black volatility for a European swaption, given a set of volatility functions and a correlation matrix

$$(v_{\alpha,\beta}^{LFM})^2 = \sum_{i,j=\alpha+1}^{\beta} \frac{w_i(0)w_j(0)F_i(0)F_j(0)\rho_{i,j}}{S_{\alpha,\beta}(0)^2} \int_0^{T_\alpha} \sigma_i(t)\sigma_j(t)dt$$

where:

$$w_i(t) = \frac{\tau_i P(t, T_i)}{\sum_{k=\alpha+1}^{\beta} \tau_k P(t, t_k)}$$

This calculation is done using the function `blackvolbyrebonato` to compute analytic values of the swaption price for model parameters, and consequently, is then used to calibrate the model. Calibration consists of minimizing the difference between the observed implied swaption Black volatilities and the predicted Black volatilities.

In this example, the approach is similar to “Simulate Interest-Rate Paths Using the Hull-White One-Factor Model” on page 2-99 and “Simulate Interest-Rate Paths Using the Linear Gaussian Two-Factor Model” on page 2-102 where the Optimization Toolbox function `lsqnonlin` is used to minimize the difference between the observed swaption prices and the predicted swaption prices. However, other approaches (for example, simulated annealing) may also be appropriate. Starting parameters and constraints for  $\alpha$ ,  $b$ ,  $d$ , and  $\beta$  are set in the variables `x0`, `lb`, and `ub`; these could also be varied depending upon the particular calibration approach.

Calibrate the set of parameters that minimize the difference between the observed and predicted values using `blackvolbyrebonato` and `lsqnonlin`.

```
nRates = 10;

CorrFunc = @(i,j,Beta) exp(-Beta*abs(i-j));

objfun = @(x) SwaptionBlackVol(reidx) - blackvolbyrebonato(RateSpec,...
    repmat({@t) ones(size(t)).*(x(1)*t + x(2)).*exp(-x(3)*t) + x(4)},nRates-1,1),...
    CorrFunc(meshgrid(1:nRates-1)',meshgrid(1:nRates-1),x(5)),...
    EurExDatesFull(reidx),EurMatFull(reidx),'Period',1);

options = optimset('disp','iter','MaxFunEvals',1000,'TolFun',1e-5);

x0 = [.2 .05 1 .05 .2];
lb = [0 0 .5 0 .01];
ub = [1 1 2 .3 1];
LMMparams = lsqnonlin(objfun,x0,lb,ub,options)
```

Iteration	Func-count	f(x)	step	optimality	CG-iterations
0	6	0.212571		0.493	
1	12	0.0151459	0.229951	0.0352	0
2	18	0.0112531	0.193839	0.00108	0
3	24	0.00937762	0.310582	0.00688	0
4	30	0.00911658	0.0790873	7.03e-05	0
5	36	0.00911658	0.517804	7.03e-05	0
6	42	0.00907618	0.129451	0.0028	0
7	48	0.00904774	0.0428543	6.33e-05	0
8	54	0.00904497	0.258902	0.00771	0
9	60	0.00902206	0.0115259	4.5e-05	0
10	66	0.00901664	0.0647254	0.000899	0

Local minimum possible.

`lsqnonlin` stopped because the final change in the sum of squares relative to its initial value is less than the selected value of the function tolerance.

```
LMMparams =
    0.0797    0.2419    0.6073    0.0739    0.0100
```

Calculate `VolFunc` for the LMM object.

```

a = LMMparams(1);
b = LMMparams(2);
c = LMMparams(3);
d = LMMparams(4);

Beta = LMMparams(5);

VolFunc = repmat(@(t) ones(size(t)).*(a*t + b).*exp(-c*t) + d),nRates-1,1);

```

Plot the volatility function.

```

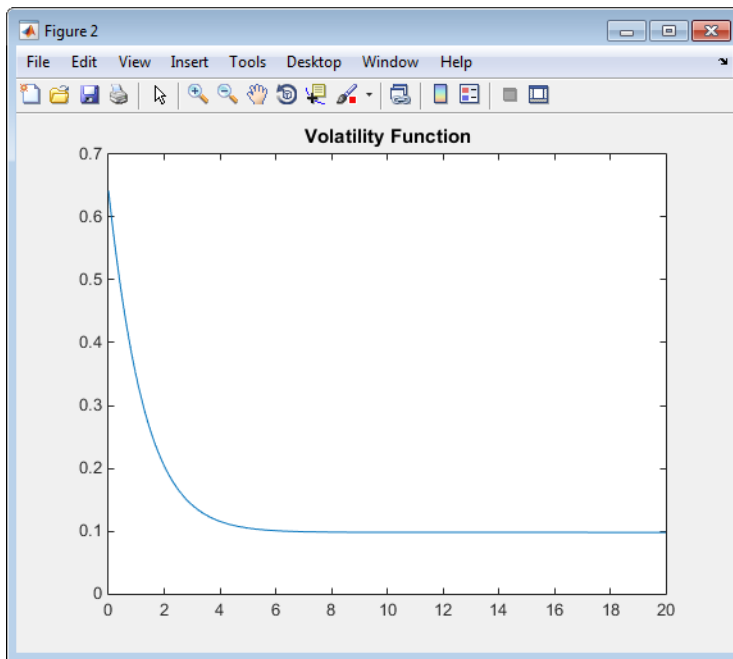
figure
fplot(VolFunc{1},[0 20])
title('Volatility Function')

```

```

CorrelationMatrix = CorrFunc(meshgrid(1:nRates-1)',meshgrid(1:nRates-1),Beta);

```



Inspect the correlation matrix.

```

disp('Correlation Matrix')
fprintf([repmat('%1.3f ',1,length(CorrelationMatrix)) '\n'],CorrelationMatrix)

```

Correlation Matrix

```

1.000 0.990 0.980 0.970 0.961 0.951 0.942 0.932 0.923
0.990 1.000 0.990 0.980 0.970 0.961 0.951 0.942 0.932
0.980 0.990 1.000 0.990 0.980 0.970 0.961 0.951 0.942
0.970 0.980 0.990 1.000 0.990 0.980 0.970 0.961 0.951
0.961 0.970 0.980 0.990 1.000 0.990 0.980 0.970 0.961
0.951 0.961 0.970 0.980 0.990 1.000 0.990 0.980 0.970
0.942 0.951 0.961 0.970 0.980 0.990 1.000 0.990 0.980
0.932 0.942 0.951 0.961 0.970 0.980 0.990 1.000 0.990
0.923 0.932 0.942 0.951 0.961 0.970 0.980 0.990 1.000

```

Create the LMM object and use Monte Carlo simulation to generate the interest-rate paths with `LiborMarketModel.simTermStructs`.

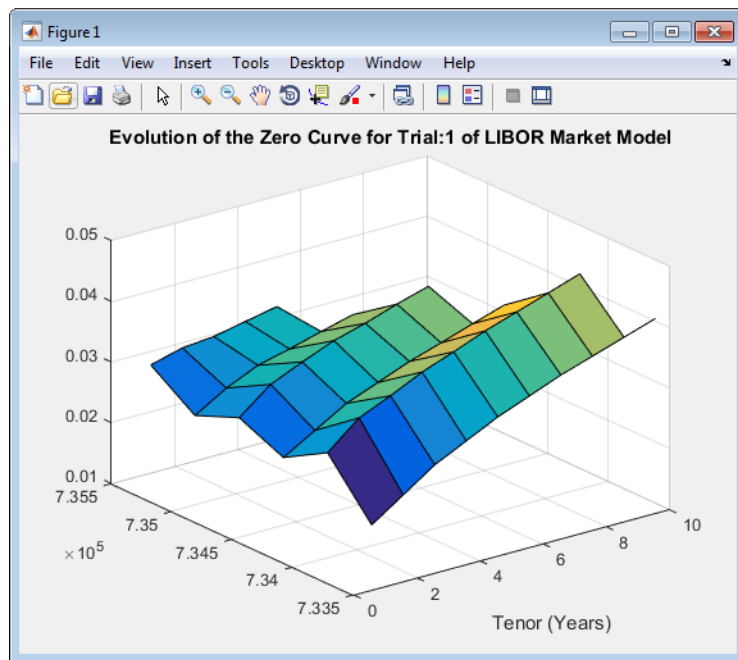
```

LMM = LiborMarketModel(irdc,VolFunc,CorrelationMatrix,'Period',1);

[LMMZeroRates, ForwardRates] = LMM.simTermStructs(nPeriods,'nTrials',nTrials);

trialIdx = 1;
figure
tmpPlotData = LMMZeroRates(:, :, trialIdx);
tmpPlotData(tmpPlotData == 0) = NaN;
surf(Tenor, SimDates, tmpPlotData)
title(['Evolution of the Zero Curve for Trial:' num2str(trialIdx) ' of LIBOR Market Model'])
xlabel('Tenor (Years)')

```



Price the European swaption.

```
DF = exp(bsxfun(@times,-LMMZeroRates, repmat(Tenor', [nPeriods+1 1])));
SwapRate = (1 - DF(exRow,endCol,:))./sum(bsxfun(@times,1,DF(exRow,1:endCol,:)));
PayoffValue = 100*max(SwapRate-InstrumentStrike,0).*sum(bsxfun(@times,1,DF(exRow,1:endCol,:)));
RealizedDF = prod(exp(bsxfun(@times,-LMMZeroRates(2:exRow,1,:), SimTimes(1:exRow-1))),1);
LMM_SwaptionPrice = mean(RealizedDF.*PayoffValue)
```

```
LMM_SwaptionPrice =
```

```
2.8739
```

## Compare Interest-Rate Modeling Results

This example shows how to compare the results for pricing a European swaptions with different interest-rate models.

Compare the results for pricing a European swaptions with interest-rate models using Monte Carlo simulation.

```
disp(' ')
fprintf('      # of Monte Carlo Trials: %8d\n'      , nTrials)
fprintf('      # of Time Periods/Trial: %8d\n\n'  , nPeriods)
fprintf('HW1F European Swaption Price: %8.4f\n', HW1F_SwaptionPrice)
fprintf('LG2F Europesn Swaption Price: %8.4f\n', G2PP_SwaptionPrice)
fprintf('LMM European Swaption Price: %8.4f\n', LMM_SwaptionPrice)
```

```
# of Monte Carlo Trials:      1000
# of Time Periods/Trial:      5
```

```
HW1F European Swaption Price: 2.7649
LG2F Europesn Swaption Price: 2.6186
LMM European Swaption Price: 2.8739
```

## References

Brigo, D. and F. Mercurio, *Interest Rate Models - Theory and Practice with Smile, Inflation and Credit*, Springer Finance, 2006.

Andersen, L. and V. Piterbarg, *Interest Rate Modeling*, Atlantic Financial Press. 2010.

Hull, J, *Options, Futures, and Other Derivatives*, Springer Finance, 2003.

Glasserman, P, *Monte Carlo Methods in Financial Engineering*, Prentice Hall, 2008.

Rebonato, R., K. McKay, and R. White, *The Sabr/Libor Market Model: Pricing, Calibration and Hedging for Complex Interest-Rate Derivatives*, John Wiley & Sons, 2010.

### See Also

HullWhite1F | LinearGaussian2F | LiborMarketModel |  
HullWhite1F.simTermStructs | LinearGaussian2F.simTermStructs |  
LiborMarketModel.simTermStructs | blackvolbyrebonato | capbylg2f |  
floorbylg2f | lsqnonlin | swaptionbyhw | swaptionbylg2f

### Related Examples

- “Pricing Bermudan Swaptions with Monte Carlo Simulation”

## Pricing Bermudan Swaptions with Monte Carlo Simulation

This example shows how to price Bermudan swaptions using interest-rate models in Financial Instruments Toolbox™. Specifically, a Hull-White one factor model, a Linear Gaussian two-factor model, and a LIBOR Market Model are calibrated to market data and then used to generate interest-rate paths using Monte Carlo simulation.

### Zero Curve

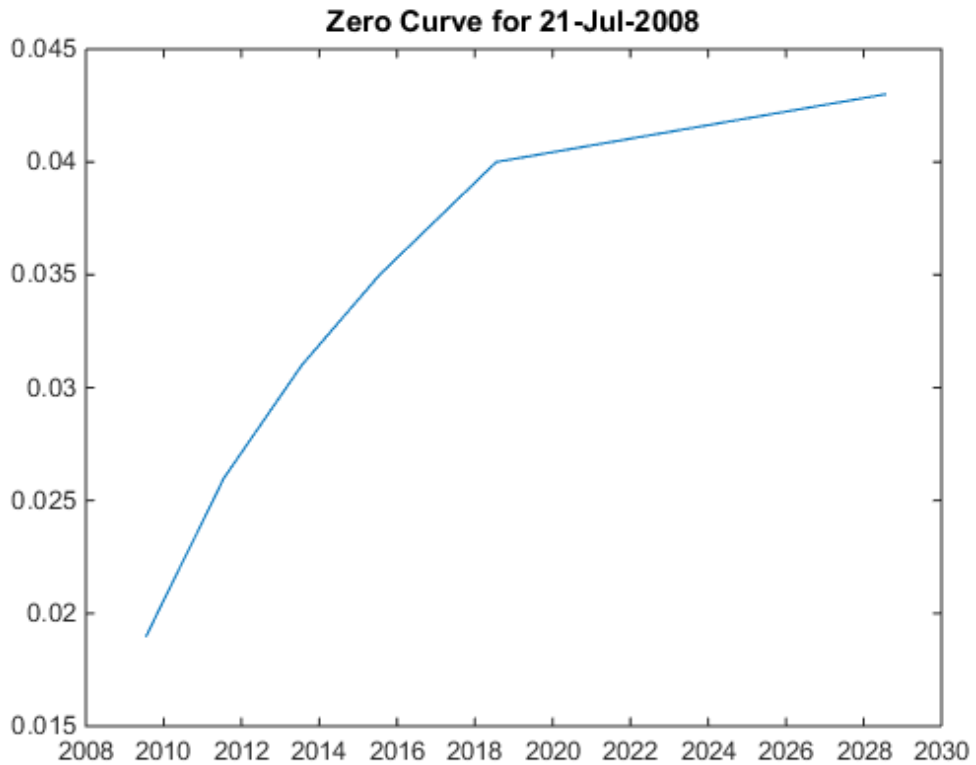
In this example, the `ZeroRates` for a zero curve is hard-coded. You can also create a zero curve by bootstrapping the zero curve from market data (for example, deposits, futures/forwards, and swaps). The hard-coded data for the zero curve is defined as:

```
Settle = datenum('21-Jul-2008');

% Zero Curve
CurveDates = daysadd(Settle,360*([1 3 5 7 10 20]),1);
ZeroRates = [1.9 2.6 3.1 3.5 4 4.3]'/100;

plot(CurveDates,ZeroRates)
datetick
title(['Zero Curve for ' datestr(Settle)]);

RateSpec = intenvset('Rates',ZeroRates,'EndDates',CurveDates,'StartDate',Settle);
```



### Define Swaption Parameters

For this example we will compute the price of a 10-no-call-1 Bermudan swaption.

```
BermudanExerciseDates = daysadd(Settle,360*(1:9),1);  
BermudanMaturity = datenum('21-Jul-2018');  
BermudanStrike = .045;
```

### Black's Model and the Swaption Volatility Matrix

Black's model is often used to price and quote European exercise interest-rate options, that is, caps, floors and swaptions. In the case of swaptions, Black's model is used to imply a volatility given the current observed market price. The following matrix



shows the Black implied volatility for a range of swaption exercise dates (columns) and underlying swap maturities (rows).

```
SwaptionBlackVol = [22 21 19 17 15 13 12
    21 19 17 16 15 13 11
    20 18 16 15 14 12 11
    19 17 15 14 13 12 10
    18 16 14 13 12 11 10
    15 14 13 12 12 11 10
    13 13 12 11 11 10 9]/100;
ExerciseDates = [1:5 7 10];
Tenors = [1:5 7 10];

EurExDatesFull = repmat(daysadd(Settle,ExerciseDates*360,1)',...
    length(Tenors),1);
EurMatFull = reshape(daysadd(EurExDatesFull,...
    repmat(360*Tenors,1,length(ExerciseDates)),1),size(EurExDatesFull));
```

### Selecting the Calibration Instruments

Selecting the instruments to calibrate the model to is one of the tasks in calibration. For Bermudan swaptions, it is typical to calibrate to European swaptions that are co-terminal with the Bermudan swaption to be priced. In this case, all swaptions having an underlying tenor that matures before the maturity of the swaption to be priced are used in the calibration.

```
% Find the swaptions that expire on or before the maturity date of the
% sample swaption
reidx = find(EurMatFull <= BermudanMaturity);
```

### Compute Swaption Prices Using Black's Model

Swaption prices are computed using Black's Model. The swaption prices are then used to compare the model's predicted values. To compute the swaption prices using Black's model:

```
% Compute Swaption Prices using Black's model
SwaptionBlackPrices = zeros(size(SwaptionBlackVol));
SwaptionStrike = zeros(size(SwaptionBlackVol));

for iSwaption=1:length(ExerciseDates)
    for iTenor=1:length(Tenors)
        [~,SwaptionStrike(iTenor,iSwaption)] = swapbyzero(RateSpec,[NaN 0], Settle, Eur
            'StartDate',EurExDatesFull(iTenor,iSwaption),'LegReset',[1 1]);
```

```

        SwaptionBlackPrices(iTenor,iSwaption) = swaptionbyblk(RateSpec, 'call', SwaptionBlk,
        EurExDatesFull(iTenor,iSwaption), EurMatFull(iTenor,iSwaption), SwaptionBlk);
    end
end

```

### Simulation Parameters

The following parameters will be used; each exercise date is a simulation date.

```

nPeriods = 9;
DeltaTime = 1;
nTrials = 1000;

Tenor = (1:10)';

SimDates = daysadd(Settle,360*DeltaTime*(0:nPeriods),1);
SimTimes = diff(yearfrac(SimDates(1),SimDates));

```

### Hull White 1 Factor Model

The Hull-White one-factor model describes the evolution of the short rate and is specified by the following:

$$dr = [\theta(t) - \alpha r]dt + \sigma dW$$

The Hull-White model is calibrated using the function `SWAPTIONNYHW`, which constructs a trinomial tree to price the swaptions. Calibration consists of minimizing the difference between the observed market prices (computed above using the Black's implied swaption volatility matrix) and the model's predicted prices.

In this example, the Optimization Toolbox™ function `LSQNONLIN` is used to find the parameter set that minimizes the difference between the observed and predicted values. However, other approaches (for example, simulated annealing) may be appropriate. Starting parameters and constraints for  $\alpha$  and  $\sigma$  are set in the variables `x0`, `lb` and `ub`; these could also be varied depending upon the particular calibration approach.

```

TimeSpec = hwtimespec(Settle,daysadd(Settle,360*(1:11),1), 2);
HW1Fobjfun = @(x) SwaptionBlackPrices(releidx) - ...
    swaptionbyhw(hwtree(hwvolspec(Settle,'11-Aug-2015',x(2),'11-Aug-2015',x(1)), RateSpec,
    EurExDatesFull(releidx), 0, EurExDatesFull(releidx), EurMatFull(releidx)));
options = optimset('disp','iter','MaxFunEvals',1000,'TolFun',1e-5);

```

```

% Find the parameters that minimize the difference between the observed and
% predicted prices
x0 = [.1 .01];
lb = [0 0];
ub = [1 1];
HW1Fparams = lsqnonlin(HW1Fobjfun,x0,lb,ub,options);

HW_alpha = HW1Fparams(1);
HW_sigma = HW1Fparams(2);

% Construct the HullWhite1F model using the HullWhite1F constructor.
HW1F = HullWhite1F(RateSpec,HW_alpha,HW_sigma);

% Use Monte Carlo simulation to generate the interest-rate paths with
% HullWhite1F.simTermStructs.
HW1FSimPaths = HW1F.simTermStructs(nPeriods,'NTRIALS',nTrials,...
    'DeltaTime',DeltaTime,'Tenor',Tenor,'antithetic',true);

% Examine one simulation
trialIdx = 1;
figure
surf(Tenor,SimDates,HW1FSimPaths(:,:,trialIdx))
datetick y kepticks keeplimits
title(['Evolution of the Zero Curve for Trial:' num2str(trialIdx) ' of Hull White Model'])
xlabel('Tenor (Years)')

% Price the swaption using the helper function hBermudanSwaption
HW1FBermPrice = hBermudanSwaption(HW1FSimPaths,SimDates,Tenor,BermudanStrike,...
    BermudanExerciseDates,BermudanMaturity);

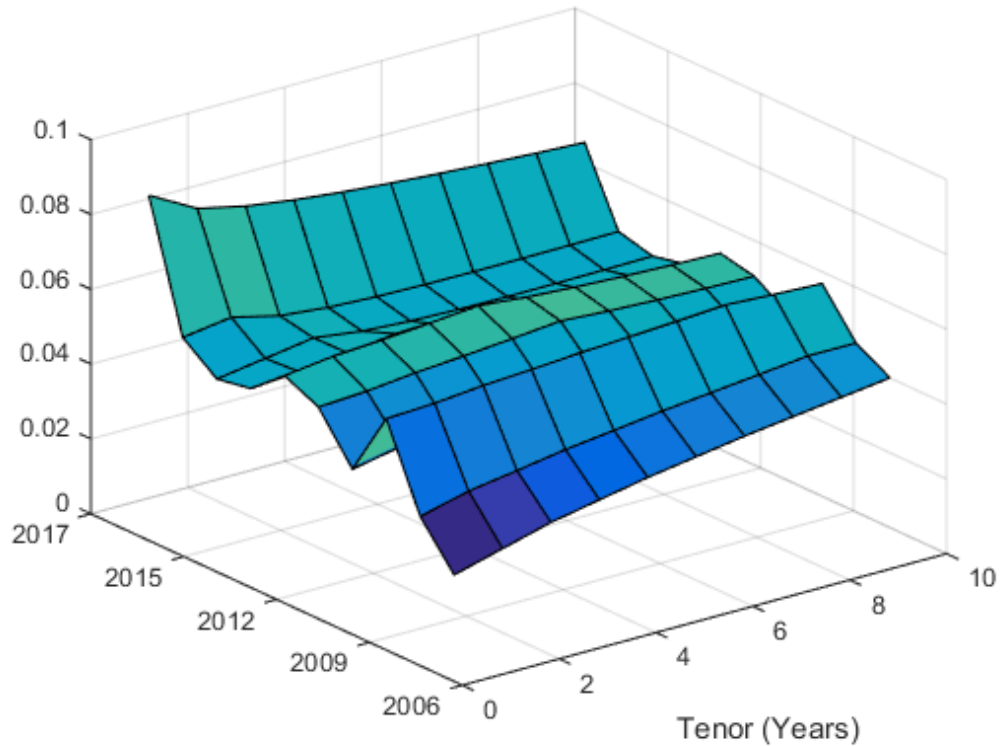
```

Iteration	Func-count	f(x)	Norm of step	First-order optimality
0	3	0.555648		14.8
1	6	0.130818	0.0156718	0.745
2	9	0.126276	0.00920988	0.785
3	12	0.126201	0.00528749	0.0448
4	15	0.126201	0.000123543	0.000111

Local minimum possible.

lsqnonlin stopped because the final change in the sum of squares relative to its initial value is less than the selected value of the function tolerance.

**Evolution of the Zero Curve for Trial:1 of Hull White Model**



**Linear Gaussian 2 Factor Model**

The Linear Gaussian two-factor model (called the G2++ by Brigo and Mercurio) is also a short rate model, but involves two factors. Specifically:

$$r(t) = x(t) + y(t) + \varphi(t)$$

$$dx(t) = -ax(t)dt + \sigma dW_1(t)$$

$$dy(t) = -by(t)dt + \eta dW_2(t)$$

where  $dW_1(t)dW_2(t)$  is a two-dimensional Brownian motion with correlation  $\rho$

$$dW_1(t)dW_2(t) = \rho$$

and  $\varphi$  is a function chosen to match the initial zero curve.

The function SWAPTIONBYLG2F is used to compute analytic values of the swaption price for model parameters and consequently can be used to calibrate the model. Calibration consists of minimizing the difference between the observed market prices and the model's predicted prices.

```
% Calibrate the set of parameters that minimize the difference between the
% observed and predicted values using SWAPTIONBYLG2F and LSQNONLIN.
G2PPobjfun = @(x) SwaptionBlackPrices(reidx) - ...
    swaptionbylg2f(RateSpec,x(1),x(2),x(3),x(4),x(5),SwaptionStrike(reidx),...
    EurExDatesFull(reidx),EurMatFull(reidx),'Reset',1);
x0 = [.2 .1 .02 .01 -.5];
lb = [0 0 0 0 -1];
ub = [1 1 1 1 1];
LG2Fparams = lsqnonlin(G2PPobjfun,x0,lb,ub,options);

LG2f_a = LG2Fparams(1);
LG2f_b = LG2Fparams(2);
LG2f_sigma = LG2Fparams(3);
LG2f_eta = LG2Fparams(4);
LG2f_rho = LG2Fparams(5);

% Create the G2PP object and use Monte Carlo simulation to generate the
% interest-rate paths with LinearGaussian2F.simTermStructs.
G2PP = LinearGaussian2F(RateSpec,LG2f_a,LG2f_b,LG2f_sigma,LG2f_eta,LG2f_rho);

G2PPSimPaths = G2PP.simTermStructs(nPeriods,'NTRIALS',nTrials,...
    'DeltaTime',DeltaTime,'Tenor',Tenor,'antithetic',true);

% Examine one simulation
trialIdx = 1;
figure
surf(Tenor,SimDates,G2PPSimPaths(:,:,trialIdx))
datetick y keepticks keeplimits
title(['Evolution of the Zero Curve for Trial:' num2str(trialIdx) ' of G2++ Model'])
```

```
xlabel('Tenor (Years)')
```

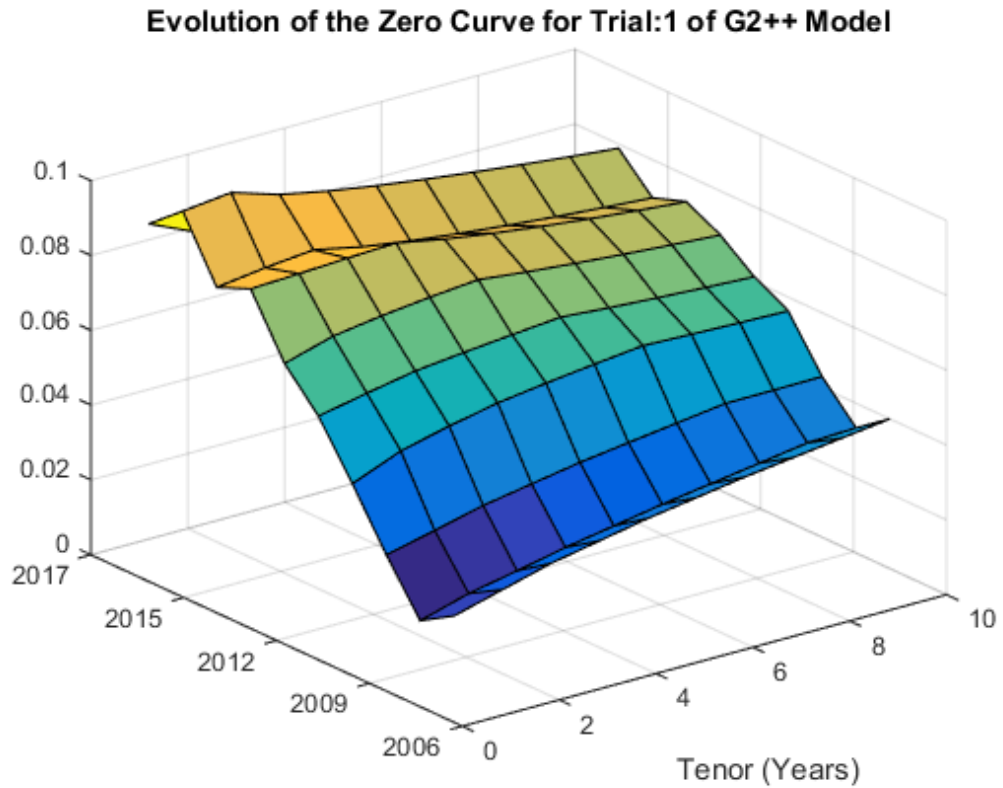
```
% Price the swaption using the helper function hBermudanSwaption
```

```
LG2FBermPrice = hBermudanSwaption(G2PPSimPaths,SimDates,Tenor,BermudanStrike,BermudanEx
```

Iteration	Func-count	f(x)	Norm of step	First-order optimality
0	6	12.1928		67.1
1	12	1.36663	0.0974259	8.54
2	18	1.36663	0.112377	8.54
3	24	0.442322	0.0280943	1.3
4	30	0.236944	0.0561887	3.23
5	36	0.13078	0.0840412	7.66
6	42	0.0394584	0.0145002	6.79
7	48	0.0275889	0.0372418	0.755
8	54	0.0261953	0.112377	0.693
9	60	0.0234048	0.206006	0.142
10	66	0.0225717	0.140341	0.116
11	72	0.02254	0.0245665	1.45
12	78	0.0225305	0.0187906	1.36

Local minimum possible.

lsqnonlin stopped because the final change in the sum of squares relative to its initial value is less than the selected value of the function tolerance.



### LIBOR Market Model

The LIBOR Market Model (LMM) differs from short rate models in that it evolves a set of discrete forward rates. Specifically, the lognormal LMM specifies the following diffusion equation for each forward rate

$$\frac{dF_i(t)}{F_i} = -\mu_i dt + \sigma_i(t) dW_i$$

where

$\sigma_i$  is the volatility function for each rate and  $dW$  is an N dimensional geometric Brownian motion with:

$$dW_i(t)dW_j(t) = \rho_{ij}$$

The LMM relates the drifts of the forward rates based on no-arbitrage arguments.

The choice with the LMM is how to model volatility and correlation and how to estimate the parameters of these models for volatility and correlation. In practice, you may use a combination of historical data (for example, observed correlation between forward rates) and current market data. For this example, only swaption data is used. Further, many different parameterizations of the volatility and correlation exist. For this example, two relatively straightforward parameterizations are used.

One of the most popular functional forms in the literature for volatility is:

$$\sigma_i(t) = \phi_i(a(T_i - t) + b)e^{c(T_i-t)} + d$$

where  $\phi$  adjusts the curve to match the volatility for the  $i^{th}$  forward rate. For this example, all of the Phi's will be taken to be 1.

For the correlation, the following functional form will be used:

$$\rho_{i,j} = e^{-\beta|i-j|}$$

Once the functional forms have been specified, these parameters need to be estimated using market data. One useful approximation, initially developed by Rebonato, is the following, which computes the Black volatility for a European swaption, given an LMM with a set of volatility functions and a correlation matrix.

$$(v_{\alpha,\beta}^{LFM})^2 = \sum_{i,j=\alpha+1}^{\beta} \frac{w_i(0)w_j(0)F_i(0)F_j(0)\rho_{i,j}}{S_{\alpha,\beta}(0)^2} \int_0^{T_\alpha} \sigma_i(t)\sigma_j(t)dt$$

where

$$w_i(t) = \frac{\tau_i P(t, T_i)}{\sum_{k=\alpha+1}^{\beta} \tau_k P(t, t_k)}$$



This calculation is done using BLACKVOLBYREBONATO to compute analytic values of the swaption price for model parameters, and consequently, is then used to calibrate the model. Calibration consists of minimizing the difference between the observed implied swaption Black volatilities and the predicted Black volatilities.

```

nRates = 10;

CorrFunc = @(i,j,Beta) exp(-Beta*abs(i-j));

objfun = @(x) SwaptionBlackVol(reidx) - blackvolbyrebonato(RateSpec,...
    repmat({@(t) ones(size(t)).*(x(1)*t + x(2)).*exp(-x(3)*t) + x(4)},nRates-1,1),...
    CorrFunc(meshgrid(1:nRates-1)',meshgrid(1:nRates-1),x(5)),...
    EurExDatesFull(reidx),EurMatFull(reidx),'Period',1);

x0 = [.2 .05 1 .05 .2];
lb = [0 0 .5 0 .01];
ub = [1 1 2 .3 1];
LMMparams = lsqnonlin(objfun,x0,lb,ub,options);

% Calculate VolFunc for the LMM object.
a = LMMparams(1);
b = LMMparams(2);
c = LMMparams(3);
d = LMMparams(4);

Beta = LMMparams(5);

VolFunc = repmat({@(t) ones(size(t)).*(a*t + b).*exp(-c*t) + d},nRates-1,1);

% Plot the volatility function
figure
fplot(VolFunc{1},[0 20])
title('Volatility Function')

% Inspect the correlation matrix
CorrelationMatrix = CorrFunc(meshgrid(1:nRates-1)',meshgrid(1:nRates-1),Beta);
disp('Correlation Matrix')
fprintf([repmat('%1.3f ',1,length(CorrelationMatrix)) '\n'],CorrelationMatrix)

% Create the LMM object and use Monte Carlo simulation to generate the
% interest-rate paths with LiborMarketModel.simTermStructs.
LMM = LiborMarketModel(RateSpec,VolFunc,CorrelationMatrix,'Period',1);

[LMMZeroRates, ForwardRates] = LMM.simTermStructs(nPeriods,'nTrials',nTrials);

```

```

% Examine one simulation
trialIdx = 1;
figure
tmpPlotData = LMMZeroRates(:, :, trialIdx);
tmpPlotData(tmpPlotData == 0) = NaN;
surf(Tenor, SimDates, tmpPlotData)
title(['Evolution of the Zero Curve for Trial:' num2str(trialIdx) ' of LIBOR Market Mo
xlabel('Tenor (Years)')

% Price the swaption using the helper function hBermudanSwaption
LMMTenor = 1:10;
LMMBermPrice = hBermudanSwaption(LMMZeroRates, SimDates, LMMTenor, .045, BermudanExercised

```

Iteration	Func-count	f(x)	Norm of step	First-order optimality
0	6	0.251221		0.496
1	12	0.0206191	0.276585	0.0333
2	18	0.0165669	0.220027	0.00194
3	24	0.0146667	0.380455	0.00835
4	30	0.0143206	0.0563957	0.00428
5	36	0.0142098	0.0315698	0.00123
6	42	0.014196	0.0399949	9.95e-05
7	48	0.0141888	0.232112	0.00302
8	54	0.014175	0.0226519	5.02e-05
9	60	0.0141697	0.0580279	0.000427

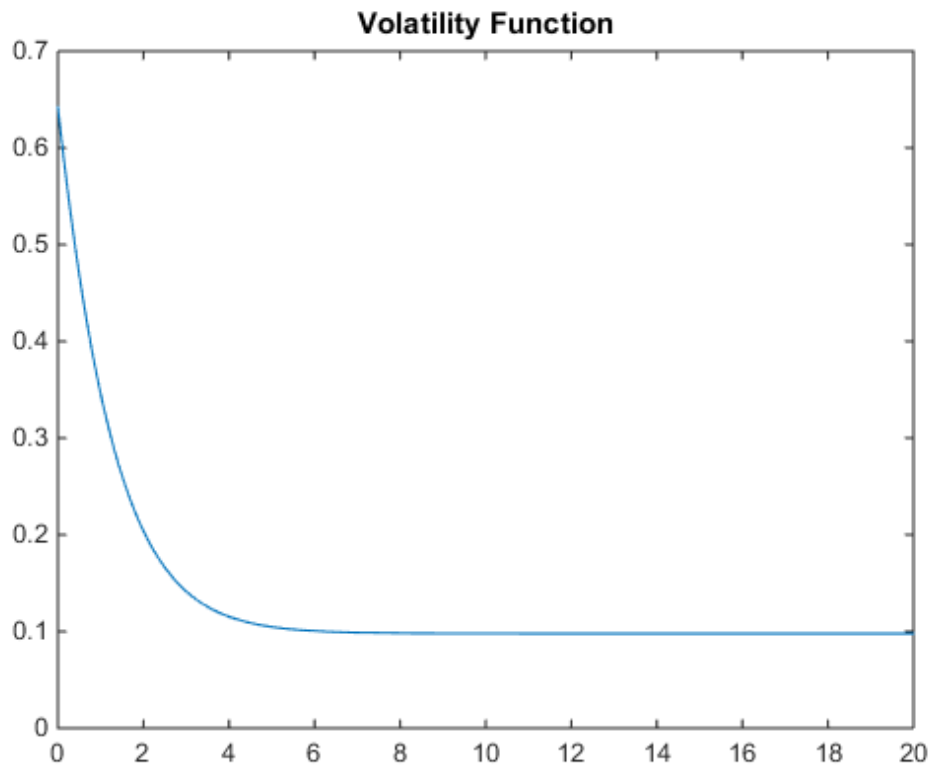
Local minimum possible.

lsqnonlin stopped because the final change in the sum of squares relative to its initial value is less than the selected value of the function tolerance.

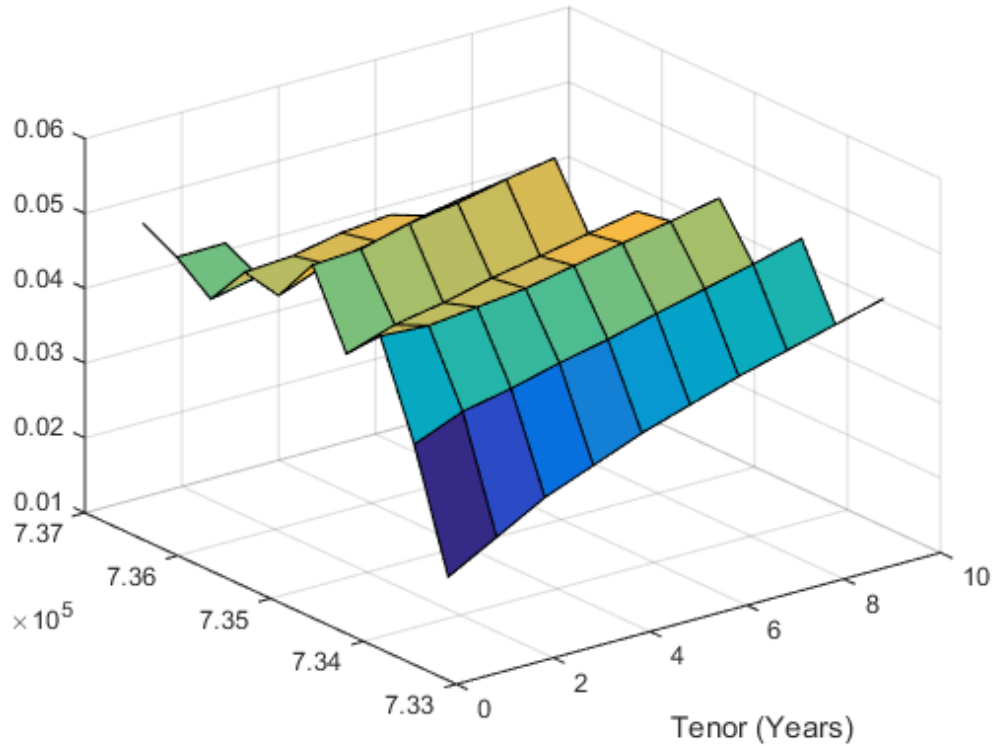
```

Correlation Matrix
1.000 0.990 0.980 0.970 0.961 0.951 0.942 0.932 0.923
0.990 1.000 0.990 0.980 0.970 0.961 0.951 0.942 0.932
0.980 0.990 1.000 0.990 0.980 0.970 0.961 0.951 0.942
0.970 0.980 0.990 1.000 0.990 0.980 0.970 0.961 0.951
0.961 0.970 0.980 0.990 1.000 0.990 0.980 0.970 0.961
0.951 0.961 0.970 0.980 0.990 1.000 0.990 0.980 0.970
0.942 0.951 0.961 0.970 0.980 0.990 1.000 0.990 0.980
0.932 0.942 0.951 0.961 0.970 0.980 0.990 1.000 0.990
0.923 0.932 0.942 0.951 0.961 0.970 0.980 0.990 1.000

```



Evolution of the Zero Curve for Trial:1 of LIBOR Market Model



**Results**

```

disp(' ')
fprintf('      # of Monte Carlo Trials: %8d\n'      , nTrials)
fprintf('      # of Time Periods/Trial: %8d\n\n'    , nPeriods)
fprintf('HW1F Bermudan Swaption Price: %8.4f\n', HW1FBermPrice)
fprintf('LG2F Bermudan Swaption Price: %8.4f\n', LG2FBermPrice)
fprintf('LMM Bermudan Swaption Price: %8.4f\n', LMMBermPrice)

```

```

# of Monte Carlo Trials:      1000
# of Time Periods/Trial:      9

```

```

HW1F Bermudan Swaption Price:  3.8606
LG2F Bermudan Swaption Price:  3.5496

```

LMM Bermudan Swaption Price: 3.6988

## **Bibliography**

This example is based on the following books, papers and journal articles:

- 1** Andersen, L. and V. Piterbarg (2010). Interest Rate Modeling, Atlantic Financial Press.
- 2** Brigo, D. and F. Mercurio (2001). Interest Rate Models - Theory and Practice with Smile, Inflation and Credit (2nd ed. 2006 ed.). Springer Verlag.
- 3** Glasserman, P. (2003). Monte Carlo Methods in Financial Engineering. Springer.
- 4** Hull, J. (2008). Options, Futures, and Other Derivatives. Prentice Hall.
- 5** Rebonato, R., K. McKay, and R. White (2010). The Sabr/Libor Market Model: Pricing, Calibration and Hedging for Complex Interest-Rate Derivatives. John Wiley & Sons.

## Graphical Representation of Trees

In this section...
“Introduction” on page 2-128
“Observing Interest Rates” on page 2-128
“Observing Instrument Prices” on page 2-132

### Introduction

You can use the function `treeviewer` to display a graphical representation of a tree, allowing you to examine interactively the prices and rates on the nodes of the tree until maturity. To get started with this process, first load the data file `deriv.mat` included in this toolbox.

```
load deriv.mat
```

---

**Note** `treeviewer` price tree diagrams follow the convention that increasing prices appear on the upper branch of a tree and, consequently, decreasing prices appear on the lower branch. Conversely, for interest rate displays, *decreasing* interest rates appear on the upper branch (prices are rising) and *increasing* interest rates on the lower branch (prices are falling).

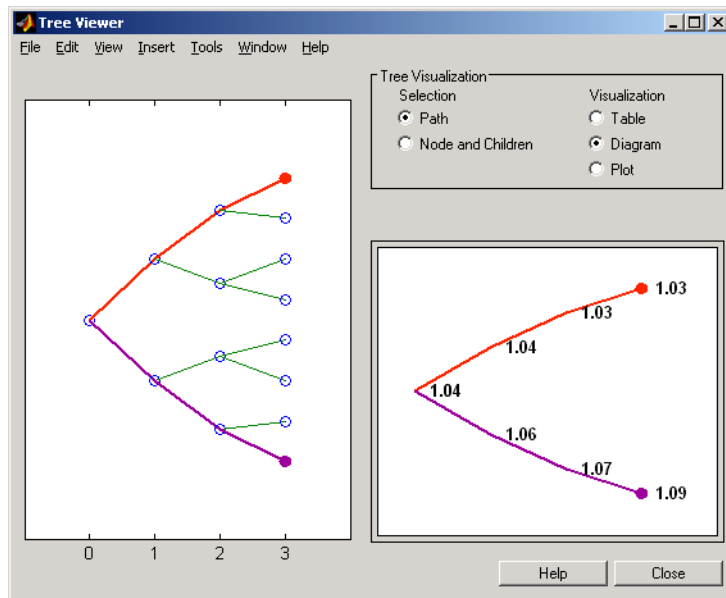
---

For information on the use of `treeviewer` to observe interest rate movement, see “Observing Interest Rates” on page 2-128. For information on using `treeviewer` to observe the movement of prices, see “Observing Instrument Prices” on page 2-132.

### Observing Interest Rates

If you provide the name of an interest rate tree to the `treeviewer` function, it displays a graphical view of the path of interest rates. For example, here is the `treeviewer` representation of all the rates along both the up and down branches of `HJMTree`.

```
treeviewer(HJMTree)
```



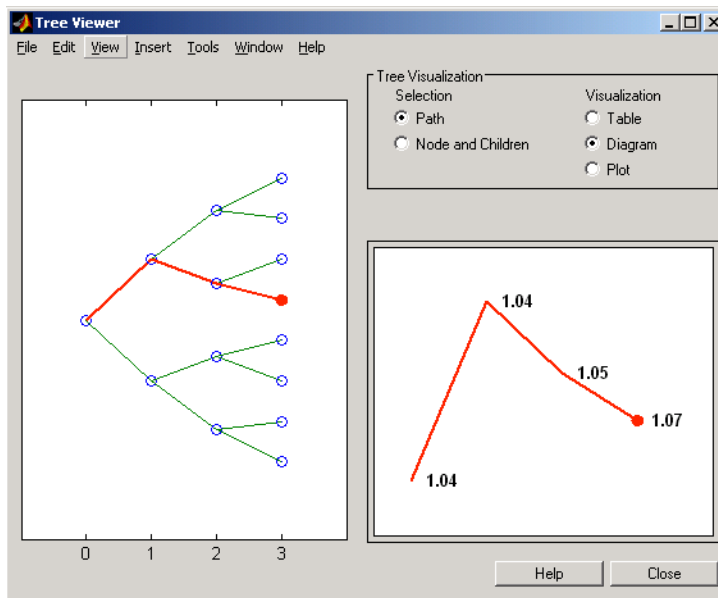
The example in “Isolating a Specific Node” on page 2-67 used `bushpath` to find the path of forward rates along an HJM tree by taking the first branch up and then two branches down the rate tree.

```
FRates = bushpath(HJMTree.FwdTree, [1 2 2])
```

```
FRates =
```

```
1.0356
1.0364
1.0526
1.0674
```

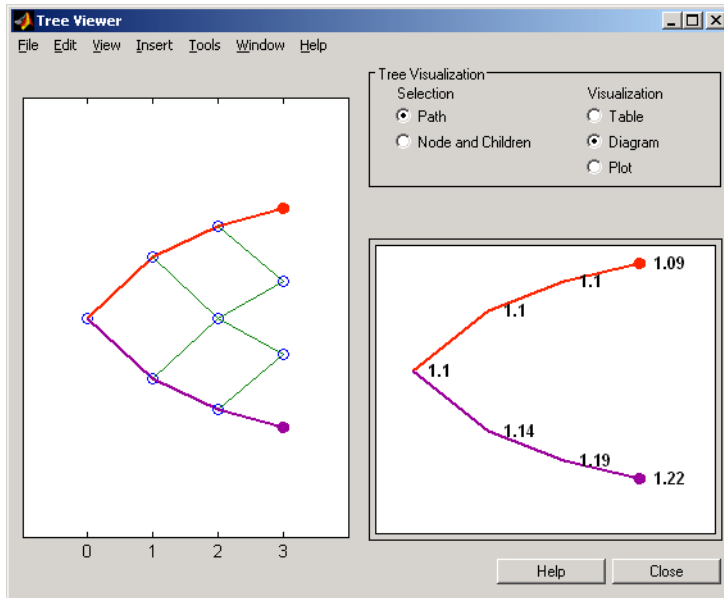
With the `treeview` function you can display the identical information by clicking along the same sequence of nodes, as shown next.



Next is a `treeviewer` representation of interest rates along several branches of `BDTTree`.

```
treeviewer(BDTTree)
```






---

**Note** When using `treeviewer` with recombining trees, such as BDT, BK, and HW, you must click each node in succession from the beginning to the end. Because these trees can recombine, `treeviewer` is unable to complete the path automatically.

---

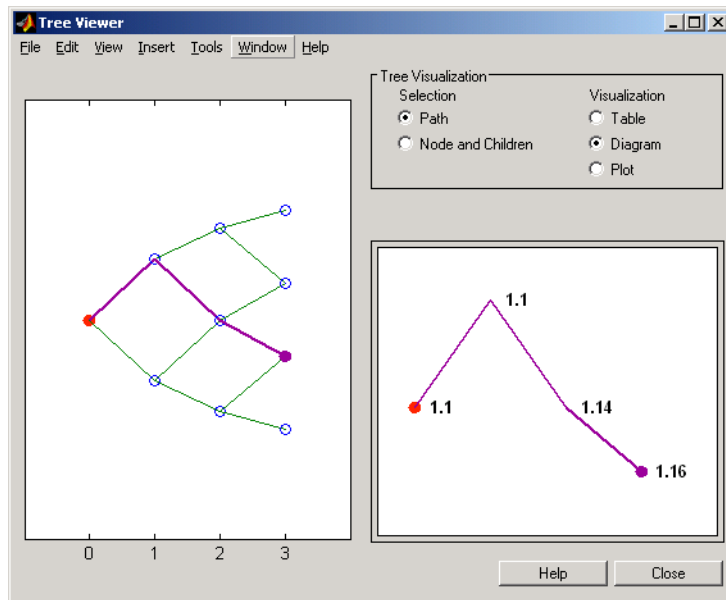
The example in “Isolating a Specific Node” on page 2-67 used `treepath` to find the path of interest rates taking the first branch up and then two branches down the rate tree.

```
FRates = treepath(BDTTree.FwdTree, [1 2 2])
```

```
FRates =
```

```
1.1000
1.0979
1.1377
1.1606
```

You can display the identical information by clicking along the same sequence of nodes, as shown next.

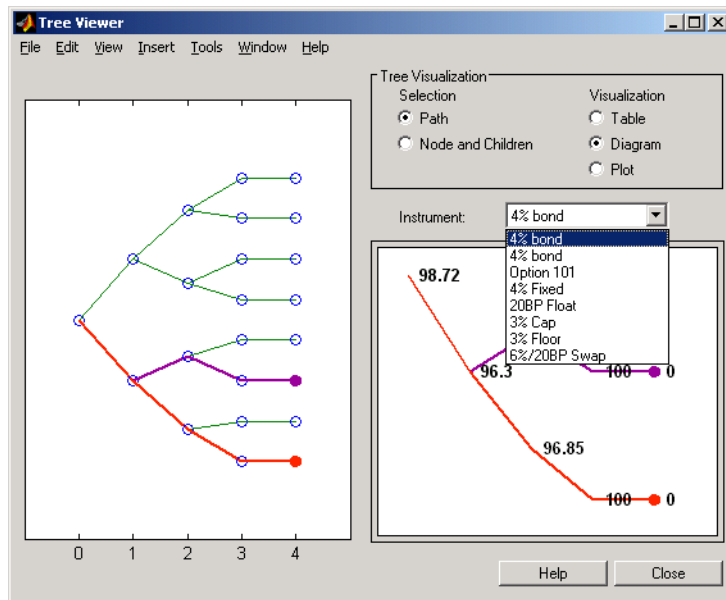


## Observing Instrument Prices

To use `treeviewer` to display a tree of instrument prices, provide the name of an instrument set along with the name of a price tree in your call to `treeviewer`, for example:

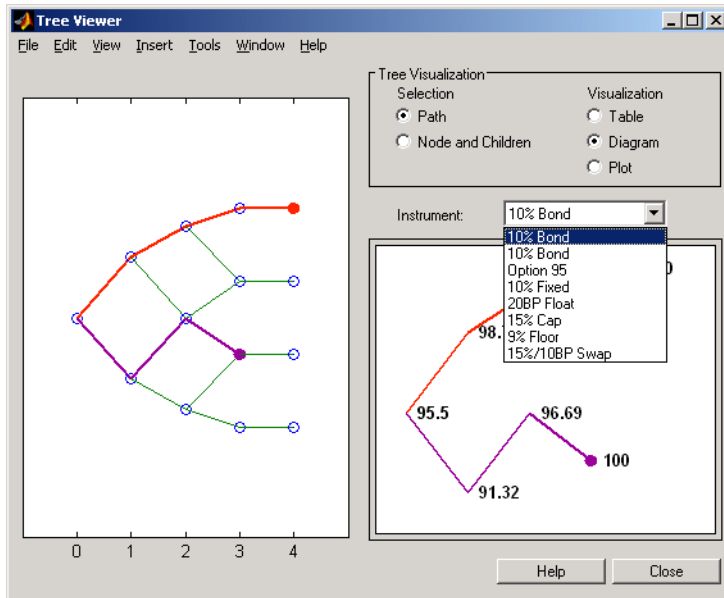
```
load deriv.mat
[Price, PriceTree] = hjmprice(HJMTree, HJMInstSet);
treeviewer(PriceTree, HJMInstSet)
```

With `treeviewer` you select *each instrument individually* in the instrument portfolio for display.



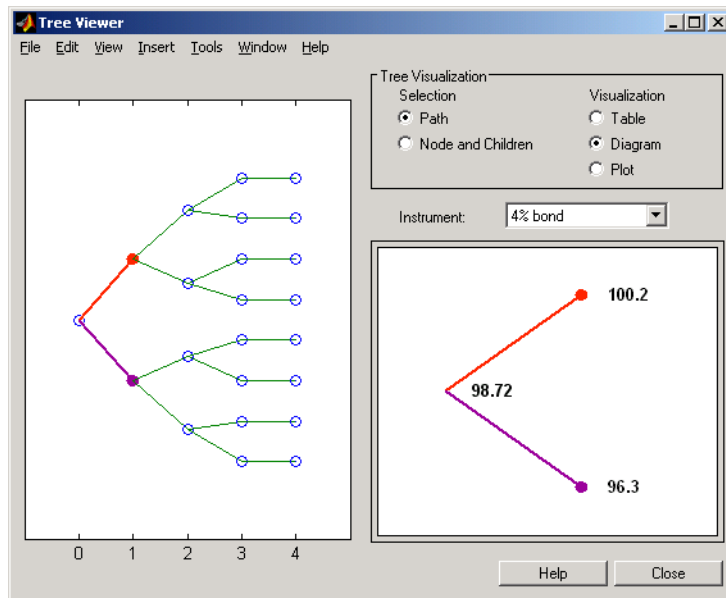
You can use an analogous process to view instrument prices based on the BDT interest rate tree included in `deriv.mat`.

```
load deriv.mat
[BDTPrice, BDTPriceTree] = bdtprice(BDTree, BDTInstSet);
treeviewer(BDTPriceTree, BDTInstSet)
```

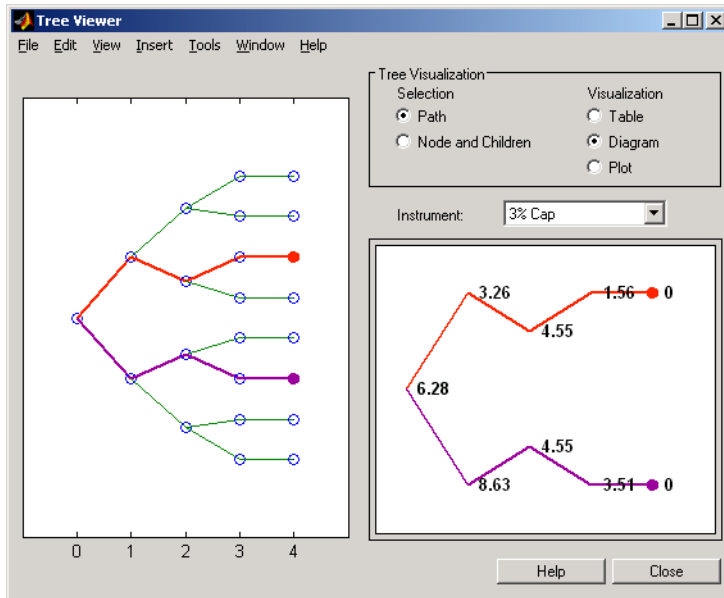


### Valuation Date Prices

You can use `treeviewer` instrument-by-instrument to observe instrument prices through time. For the first 4% bond in the HJM instrument portfolio, `treeviewer` indicates a valuation date price of 98.72, the same value obtained by accessing the `PriceTree` structure directly.



As a further example, look at the sixth instrument in the price vector, the 3% cap. At the valuation date, its value obtained directly from the structure is 6.2831. Use `treeviewer` on this instrument to confirm this price.



**Additional Observation Times**

The second node represents the first-rate observation time,  $t_{obs} = 1$ . This node displays two states, one representing the branch going up and the other one representing the branch going down.

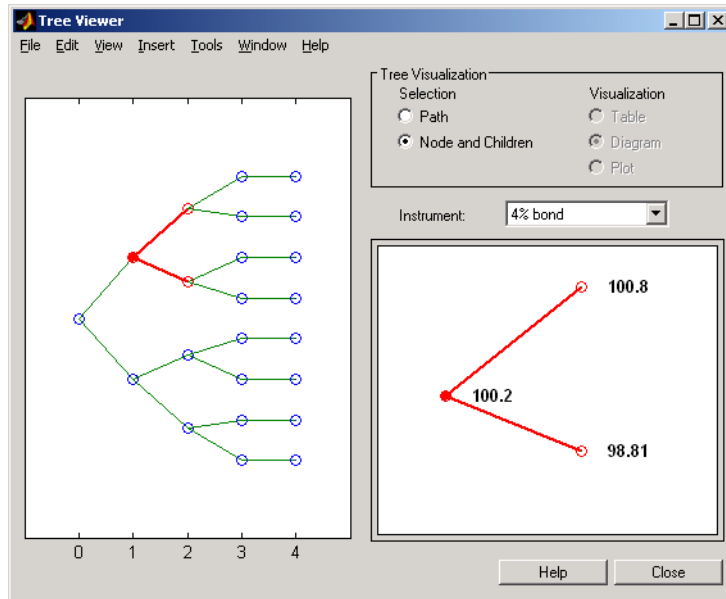
Examine the prices of the node corresponding to the up branch.

```
PriceTree.PBush{2}(:, :, 1)
```

ans =

- 100.1563
- 99.7309
- 0.1007
- 100.1563
- 100.3782
- 3.2594
- 0.1007
- 3.5597

As before, you can use `treeviewer`, this time to examine the price for the 4% bond on the up branch. `treeviewer` displays a price of 100.2 for the first node of the up branch, as expected.



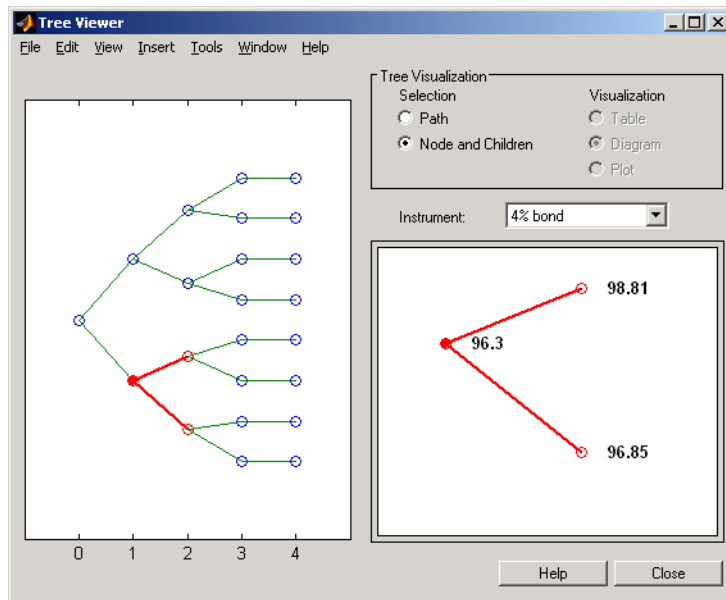
Now examine the corresponding down branch.

```
PriceTree.PBush{2}(:, :, 2)
```

```
ans =
```

```
96.3041
94.1986
    0
96.3041
100.3671
 8.6342
    0
-0.3923
```

Use `treeviewer` once again, now to observe the price of the 4% bond on the down branch. The displayed price of 96.3 conforms to the price obtained from direct access of the `PriceTree` structure. You may continue this process as far along the price tree as you want.





# Equity Derivatives

---

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- “Supported Energy Derivatives” on page 3-32
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- “Hedging Strategies Using Spread Options” on page 3-56
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## Understanding Equity Trees

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“Introduction” on page 3-2
“Building Equity Binary Trees” on page 3-3
“Building Implied Trinomial Trees” on page 3-8
“Examining Equity Trees ” on page 3-14
“Differences Between CRR and EQP Tree Structures” on page 3-18

### Introduction

Financial Instruments Toolbox software supports three types of recombining tree models to represent the evolution of stock prices:

- Cox-Ross-Rubinstein (CRR) model
- Equal probabilities (EQP) model
- Leisen-Reimer (LR) model
- Implied trinomial tree (ITT) model

For a discussion of recombining trees, see “Rate and Price Trees” on page 2-33.

The CRR, EQP, LR, and ITT models are examples of discrete time models. A discrete time model divides time into discrete bits; prices can only be computed at these specific times.

The CRR model is one of the most common methods used to model the evolution of stock processes. The strength of the CRR model lies in its simplicity. It is a good model when dealing with many tree levels. The CRR model yields the correct expected value for each node of the tree and provides a good approximation for the corresponding local volatility. The approximation becomes better as the number of time steps represented in the tree is increased.

The EQP model is another discrete time model. It has the advantage of building a tree with the exact volatility in each tree node, even with small numbers of time steps. It also provides better results than CRR in some given trading environments, for example, when stock volatility is low and interest rates are high. However, this additional precision causes increased complexity, which is reflected in the number of calculations required to build a tree.

The LR model is another discrete time model. It has the advantage of producing estimates close to the Black-Scholes model using only a small number of steps, while also minimizing the oscillation.

The ITT model is a CRR-style implied trinomial tree which takes advantage of prices quoted from liquid options in the market with varying strikes and maturities to build a tree that more accurately represents the market. An ITT model is commonly used to price exotic options in such a way that they are consistent with the market prices of standard options.

## Building Equity Binary Trees

The tree of stock prices is the fundamental unit representing the evolution of the price of a stock over a given period of time. The MATLAB functions `crmtree`, `eqptree`, and `lmtree` create CRR trees, EQP trees, and LR trees, respectively. These functions create an output tree structure along with information about the parameters used for creating the tree.

The functions `crmtree`, `eqptree`, and `lmtree` take three structures as input arguments:

- The stock parameter structure `StockSpec`
- The interest-rate term structure `RateSpec`
- The tree time layout structure `TimeSpec`

### Calling Sequence for Equity Binary Trees

The calling syntax for `crmtree` is:

```
CRRTree = crmtree (StockSpec, RateSpec, TimeSpec)
```

Similarly, the calling syntax for `eqptree` is:

```
EQPTree = eqptree (StockSpec, RateSpec, TimeSpec)
```

And, the calling syntax for `lmtree` is:

```
LRTree = lmtree(StockSpec, RateSpec, TimeSpec, Strike)
```

All three functions require the structures `StockSpec`, `RateSpec`, and `TimeSpec` as input arguments:

- **StockSpec** is a structure that specifies parameters of the stock whose price evolution is represented by the tree. This structure, created using the function `stockspec`, contains information such as the stock's original price, its volatility, and its dividend payment information.
- **RateSpec** is the interest-rate specification of the initial rate curve. Create this structure with the function `intenvset`.
- **TimeSpec** is the tree time layout specification. Create these structures with the functions `crtimespec`, `eqptimespec`, and `lrtimespec`. The structures contain information regarding the mapping of relevant dates into the tree structure, plus the number of time steps used for building the tree.

#### Specifying the Stock Structure for Equity Binary Trees

The structure **StockSpec** encapsulates the stock-specific information required for building the binary tree of an individual stock's price movement.

You generate **StockSpec** with the function `stockspec`. This function requires two input arguments and accepts up to three additional input arguments that depend on the existence and type of dividend payments.

The syntax for calling `stockspec` is:

```
StockSpec = stockspec(Sigma, AssetPrice, DividendType, ...  
DividendAmounts, ExDividendDates)
```

where:

- **Sigma** is the decimal annual volatility of the underlying security.
- **AssetPrice** is the price of the stock at the valuation date.
- **DividendType** is a string specifying the type of dividend paid by the stock. Allowed values are `cash`, `constant`, or `continuous`.
- **DividendAmounts** has a value that depends on the specification of **DividendType**. For **DividendType** `cash`, **DividendAmounts** is a vector of cash dividends. For **DividendType** `constant`, it is a vector of constant annualized dividend yields. For **DividendType** `continuous`, it is a scalar representing a continuously annualized dividend yield.
- **ExDividendDates** also has a value that depends on the nature of **DividendType**. For **DividendType** `cash` or `constant`, **ExDividendDates** is vector of dividend dates. For **DividendType** `continuous`, **ExDividendDates** is ignored.

### Stock Structure Example Using a Binary Tree

Consider a stock with a price of \$100 and an annual volatility of 15%. Assume that the stock pays three cash \$5.00 dividends on dates January 01, 2003; July 01, 2003; and January 01, 2004. You specify these parameters in MATLAB as:

```
Sigma = 0.15;
AssetPrice = 100;
DividendType = 'cash';
DividendAmounts = [5; 5; 5];
ExDividendDates = {'jan-01-2004', 'july-01-2005', 'jan-01-2006'};

StockSpec = stockspec(Sigma, AssetPrice, DividendType, ...
    DividendAmounts, ExDividendDates)

StockSpec =

        FinObj: 'StockSpec'
         Sigma: 0.1500
    AssetPrice: 100
  DividendType: 'cash'
DividendAmounts: [3x1 double]
ExDividendDates: [3x1 double]
```

### Specifying the Interest-Rate Term Structure for Equity Binary Trees

The `RateSpec` structure defines the interest rate environment used when building the stock price binary tree. “Modeling the Interest-Rate Term Structure” on page 2-44 explains how to create these structures using the function `intenvset`, given the interest rates, the starting and ending dates for each rate, and the compounding value.

### Specifying the Tree-Time Term Structure for Equity Binary Trees

The `TimeSpec` structure defines the tree layout of the binary tree:

- It maps the valuation and maturity dates to their corresponding times.
- It defines the time of the levels of the tree by dividing the time span between valuation and maturity into equally spaced intervals. By specifying the number of intervals, you define the granularity of the tree time structure.

The syntax for building a `TimeSpec` structure is:

```
TimeSpec = crrtimespec(ValuationDate, Maturity, NumPeriods)
TimeSpec = eqptimespec(ValuationDate, Maturity, NumPeriods)

TimeSpec = lrtimespec(ValuationDate, Maturity, NumPeriods)
```

where:

- **ValuationDate** is a scalar date marking the pricing date and first observation in the tree (location of the root node). You enter **ValuationDate** either as a serial date number (generated with **datenum**) or a date string.
- **Maturity** is a scalar date marking the maturity of the tree, entered as a serial date number or a date string.
- **NumPeriods** is a scalar defining the number of time steps in the tree; for example, **NumPeriods = 10** implies 10 time steps and 11 tree levels (0, 1, 2, ..., 9, 10).

#### TimeSpec Example Using a Binary Tree

Consider building a CRR tree, with a valuation date of January 1, 2003, a maturity date of January 1, 2008, and 20 time steps. You specify these parameters in MATLAB as:

```
ValuationDate = 'Jan-1-2003';  
Maturity = 'Jan-1-2008';  
NumPeriods = 20;  
TimeSpec = crrtimespec(ValuationDate, Maturity, NumPeriods)
```

```
TimeSpec =  
  
    FinObj: 'BinTimeSpec'  
ValuationDate: 731582  
    Maturity: 733408  
    NumPeriods: 20  
    Basis: 0  
EndMonthRule: 1  
    tObs: [1x21 double]  
    dObs: [1x21 double]
```

Two vector fields in the **TimeSpec** structure are of particular interest: **dObs** and **tObs**. These two fields represent the observation times and corresponding dates of all tree levels, with **dObs(1)** and **tObs(1)**, respectively, representing the root node (**ValuationDate**), and **dObs(end)** and **tObs(end)** representing the last tree level (**Maturity**).

---

**Note** There is no relationship between the dates specified for the tree and the implied tree level times, and the maturities specified in the interest rate term structure. The rates in **RateSpec** are interpolated or extrapolated as required to meet the time distribution of the tree.

---

## Examples of Binary Tree Creation

You can now use the `StockSpec` and `TimeSpec` structures described previously to build an equal probability tree (`EQPTree`), a CRR tree (`CRRTree`), or a LR tree (`LRTree`). First, you must define the interest rate term structure. For this example, assume that the interest rate is fixed at 10% annually between the valuation date of the tree (January 1, 2003) until its maturity.

```
ValuationDate = 'Jan-1-2003';
Maturity = 'Jan-1-2008';
Rate = 0.1;
RateSpec = intenvset('Rates', Rate, 'StartDates', ...
ValuationDate, 'EndDates', Maturity, 'Compounding', -1);
```

To build a `CRRTree`, enter:

```
CRRTree = crrtree(StockSpec, RateSpec, TimeSpec)
```

```
CRRTree =
```

```
    FinObj: 'BinStockTree'
    Method: 'CRR'
    StockSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
        tObs: [1x21 double]
        dObs: [1x21 double]
    STree: {1x21 cell}
    UpProbs: [1x20 double]
```

To build an `EQPTree`, enter:

```
EQPTree = eqptree(StockSpec, RateSpec, TimeSpec)
```

```
EQPTree =
```

```
    FinObj: 'BinStockTree'
    Method: 'EQP'
    StockSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
        tObs: [1x21 double]
        dObs: [1x21 double]
    STree: {1x21 cell}
    UpProbs: [1x20 double]
```

### Building Implied Trinomial Trees

The tree of stock prices is the fundamental unit representing the evolution of the price of a stock over a given period of time. The MATLAB function `itttree` creates an output tree structure along with the information about the parameters used to create the tree.

The function `itttree` takes four structures as input arguments:

- The stock parameter structure `StockSpec`
- The interest-rate term structure `RateSpec`
- The tree time layout structure `TimeSpec`
- The stock option specification structure `StockOptSpec`

#### Calling Sequence for Implied Trinomial Trees

The calling syntax for `itttree` is:

```
ITTree = itttree (StockSpec,RateSpec,TimeSpec,StockOptSpec)
```

- `StockSpec` is a structure that specifies parameters of the stock whose price evolution is represented by the tree. This structure, created using the function `stockspec`, contains information such as the stock's original price, its volatility, and its dividend payment information.
- `RateSpec` is the interest-rate specification of the initial rate curve. Create this structure with the function `intenvset`.
- `TimeSpec` is the tree time layout specification. Create these structures with the function `itttimespec`. This structure contains information regarding the mapping of relevant dates into the tree structure, plus the number of time steps used for building the tree.
- `StockOptSpec` is a structure containing parameters of European stock options instruments. Create this structure with the function `stockoptspec`.

#### Specifying the Stock Structure for Implied Trinomial Trees

The structure `StockSpec` encapsulates the stock-specific information required for building the trinomial tree of an individual stock's price movement.

You generate `StockSpec` with the function `stockspec`. This function requires two input arguments and accepts up to three additional input arguments that depend on the existence and type of dividend payments.

The syntax for calling `stockspec` is:



```
StockSpec = stockspec(Sigma, AssetPrice, DividendType, ...
DividendAmounts, ExDividendDates)
```

where:

- **Sigma** is the decimal annual volatility of the underlying security.
- **AssetPrice** is the price of the stock at the valuation date.
- **DividendType** is a string specifying the type of dividend paid by the stock. Allowed values are **cash**, **constant**, or **continuous**.
- **DividendAmounts** has a value that depends on the specification of **DividendType**. For **DividendType cash**, **DividendAmounts** is a vector of cash dividends. For **DividendType constant**, it is a vector of constant annualized dividend yields. For **DividendType continuous**, it is a scalar representing a continuously annualized dividend yield.
- **ExDividendDates** also has a value that depends on the nature of **DividendType**. For **DividendType cash** or **constant**, **ExDividendDates** is vector of dividend dates. For **DividendType continuous**, **ExDividendDates** is ignored.

### Stock Structure Example Using an Implied Trinomial Tree

Consider a stock with a price of \$100 and an annual volatility of 12%. Assume that the stock is expected to pay a dividend yield of 6%. You specify these parameters in MATLAB as:

```
So=100;
DividendYield = 0.06;
Sigma=.12;

StockSpec = stockspec(Sigma, So, 'continuous', DividendYield)
```

```
StockSpec =

    FinObj: 'StockSpec'
    Sigma: 0.1200
    AssetPrice: 100
    DividendType: 'continuous'
    DividendAmounts: 0.0600
    ExDividendDates: []
```

### Specifying the Interest-Rate Term Structure for Implied Trinomial Trees

The structure **RateSpec** defines the interest rate environment used when building the stock price binary tree. “Modeling the Interest-Rate Term Structure” on page 2-44

explains how to create these structures using the function `intenvset`, given the interest rates, the starting and ending dates for each rate, and the compounding value.

#### Specifying the Tree-Time Term Structure for Implied Trinomial Trees

The `TimeSpec` structure defines the tree layout of the trinomial tree:

- It maps the valuation and maturity dates to their corresponding times.
- It defines the time of the levels of the tree by dividing the time span between valuation and maturity into equally spaced intervals. By specifying the number of intervals, you define the granularity of the tree time structure.

The syntax for building a `TimeSpec` structure is:

```
TimeSpec = itttimespec(ValuationDate, Maturity, NumPeriods)
```

where:

- `ValuationDate` is a scalar date marking the pricing date and first observation in the tree (location of the root node). You enter `ValuationDate` either as a serial date number (generated with `datenum`) or a date string.
- `Maturity` is a scalar date marking the maturity of the tree, entered as a serial date number or a date string.
- `NumPeriods` is a scalar defining the number of time steps in the tree; for example, `NumPeriods = 10` implies 10 time steps and 11 tree levels (0, 1, 2, ..., 9, 10).

#### TimeSpec Example Using an Implied Trinomial Tree

Consider building an ITT tree, with a valuation date of January 1, 2006, a maturity date of January 1, 2008, and four time steps. You specify these parameters in MATLAB as:

```
ValuationDate = '01-01-2006';  
EndDate = '01-01-2008';  
NumPeriods = 4;
```

```
TimeSpec = itttimespec(ValuationDate, EndDate, NumPeriods)
```

```
TimeSpec =
```

```
    FinObj: 'ITTTTimeSpec'  
ValuationDate: 732678  
    Maturity: 733408  
NumPeriods: 4  
    Basis: 0
```

```

EndMonthRule: 1
    tObs: [0 0.5000 1 1.5000 2]
    dObs: [732678 732860 733043 733225 733408]

```

Two vector fields in the `TimeSpec` structure are of particular interest: `dObs` and `tObs`. These two fields represent the observation times and corresponding dates of all tree levels, with `dObs(1)` and `tObs(1)`, respectively, representing the root node (`ValuationDate`), and `dObs(end)` and `tObs(end)` representing the last tree level (`Maturity`).

### Specifying the Option Stock Structure for Implied Trinomial Trees

The `StockOptSpec` structure encapsulates the option-stock-specific information required for building the implied trinomial tree. You generate `StockOptSpec` with the function `stockoptspec`. This function requires five input arguments. An optional sixth argument `InterpMethod`, specifying the interpolation method, can be included. The syntax for calling `stockoptspec` is:

```
[StockOptSpec] = stockoptspec(OptPrice, Strike, Settle, Maturity, OptSpec)
```

where:

- `Optprice` is a NINST-by-1 vector of European option prices.
- `Strike` is a NINST-by-1 vector of strike prices.
- `Settle` is a scalar date marking the settlement date.
- `Maturity` is a NINST-by-1 vector of maturity dates.
- `OptSpec` is a NINST-by-1 cell array of strings 'call' or 'put'.

### Option Stock Structure Example Using an Implied Trinomial Tree

Consider the following data quoted from liquid options in the market with varying strikes and maturity. You specify these parameters in MATLAB as:

```

Settle = '01/01/06';
Maturity = ['07/01/06';
            '07/01/06';
            '07/01/06';
            '01/01/07';
            '01/01/07';
            '01/01/07';
            '01/01/07';
            '07/01/07';
            '07/01/07';
            '07/01/07'];

```

```
'07/01/07';
'01/01/08';
'01/01/08';
'01/01/08';
'01/01/08';
'01/01/08'];

Strike = [113;
101;
100;
88;
128;
112;
100;
78;
144;
112;
100;
69;
162;
112;
100;
61];

OptPrice = [
4.807905472659144;
1.306321897011867;
0.048039195057173;
0;
2.310953054191461;
1.421950392866235;
0.020414826276740;
0;
5.091986935627730;
1.346534812295291;
0.005101325584140;
0;
8.047628153217246;
1.219653432150932;
0.001041436654748];

OptSpec = { 'call';
'call';
'put';
'put';
'call';
'call';
'put';
'put';
'call';
'call';
'put';
'put';
'call';
'call';
'put';
'put';
'call';
'call';
```

```

    'put';
    'put'}};

StockOptSpec = stockoptspec(OptPrice, Strike, Settle, Maturity, OptSpec)

StockOptSpec =

    FinObj: 'StockOptSpec'
    OptPrice: [16x1 double]
    Strike: [16x1 double]
    Settle: 732678
    Maturity: [16x1 double]
    OptSpec: {16x1 cell}
    InterpMethod: 'price'

```

---

**Note:** The algorithm for building the ITT tree requires specifying option prices for all tree nodes. The maturities of those options correspond to those of the tree levels, and the strike to the prices on the tree nodes. The types of option are **Calls** for the nodes above the central nodes, and **Puts** for those below and including the central nodes.

Clearly, all these options will not be available in the market, hence making interpolation and extrapolation necessary to obtain the node option prices. The degree to which the tree reflects the market will unavoidably be tied to the results of these interpolations and extrapolations. Keeping in mind that extrapolation is less accurate than interpolation, and more so the further away the extrapolated points are from the data points, the function `itttree` issues a warning with a list of the options for which extrapolation was necessary.

In some cases, it may be desirable to view a list of ideal option prices to form an idea of the ranges needed. This can be achieved by calling the function `itttree` specifying only the first three input arguments. The second output argument is a structure array containing the list of ideal options needed.

---

### Creating an Implied Trinomial Tree

You can now use the `StockSpec`, `TimeSpec`, and `StockOptSpec` structures described in “Stock Structure Example Using an Implied Trinomial Tree” on page 3-9, “TimeSpec Example Using an Implied Trinomial Tree” on page 3-10, and “Option Stock Structure Example Using an Implied Trinomial Tree” on page 3-11 to build an implied trinomial tree (ITT). First, you must define the interest rate term structure.

For this example, assume that the interest rate is fixed at 8% annually between the valuation date of the tree (January 1, 2006) until its maturity.

```
Rate = 0.08;
ValuationDate = '01-01-2006';
EndDate = '01-01-2008';

RateSpec = intenvset('StartDates', ValuationDate, 'EndDates', EndDate, ...
    'ValuationDate', ValuationDate, 'Rates', Rate, 'Compounding', -1);
```

To build an ITTtree, enter:

```
ITTtree = itttree(StockSpec, RateSpec, TimeSpec, StockOptSpec)

ITTtree =

    FinObj: 'ITStockTree'
    StockSpec: [1x1 struct]
    StockOptSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
    tObs: [0 0.500000000000000 1 1.500000000000000 2]
    dObs: [732678 732860 733043 733225 733408]
    STree: {1x5 cell}
    Probs: {[3x1 double] [3x3 double] [3x5 double] [3x7 double]}
```

## Examining Equity Trees

Financial Instruments Toolbox software uses equity binary and implied trinomial trees to represent prices of equity options and of underlying stocks. At the highest level, these trees have structures wrapped around them. The structures encapsulate information required to interpret information in the tree.

To examine an equity binary or trinomial tree, load the data in the MAT-file `deriv.mat` into the MATLAB workspace.

```
load deriv.mat
```

Display the list of variables loaded from the MAT-file with the `whos` command.

Name	Size	Bytes	Class	Attributes
BDTInstSet	1x1	15956	struct	
BDTTree	1x1	5138	struct	
BKInstSet	1x1	15946	struct	
BKTree	1x1	5904	struct	
CRRInstSet	1x1	12434	struct	
CRRTree	1x1	5058	struct	
EQPInstSet	1x1	12434	struct	
EQPTree	1x1	5058	struct	

HJMInstSet	1x1	15948	struct
HJMTree	1x1	5838	struct
HWInstSet	1x1	15946	struct
HWTTree	1x1	5904	struct
ITTIInstSet	1x1	12438	struct
ITTTTree	1x1	8862	struct
ZeroInstSet	1x1	10282	struct
ZeroRateSpec	1x1	1580	struct

## Examining a CRRTree

You can examine in some detail the contents of the `CRRTree` structure contained in this file.

### CRRTree

```
CRRTree =
    FinObj: 'BinStockTree'
    Method: 'CRR'
    StockSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
    tObs: [0 1 2 3 4]
    dObs: [731582 731947 732313 732678 733043]
    STree: {[100] [110.5171 90.4837] [122.1403 100 81.8731] [1x4 double] [1x5 double]}
    UpProbs: [0.7309 0.7309 0.7309 0.7309]
```

The `Method` field of the structure indicates that this is a CRR tree, not an EQP tree.

The fields `StockSpec`, `TimeSpec` and `RateSpec` hold the original structures passed into the function `crrtree`. They contain all the context information required to interpret the tree data.

The fields `tObs` and `dObs` are vectors containing the observation times and dates, the times and dates of the levels of the tree. In this particular case, `tObs` reveals that the tree has a maturity of 4 years (`tObs(end) = 4`) and that it has four time steps (the length of `tObs` is five).

The field `dObs` shows the specific dates for the tree levels, with a granularity of 1 day. This means that all values in `tObs` that correspond to a given day from 00:00 hours to 24:00 hours are mapped to the corresponding value in `dObs`. You can use the function `datestr` to convert these MATLAB serial dates into their string representations.

The field `UpProbs` is a vector representing the probabilities for up movements from any node in each level. This vector has 1 element per tree level. All nodes for a given level have the same probability of an up movement. In the specific case being examined, the probability of an up movement is 0.7309 for all levels, and the probability for a down movement is 0.2691 (1 - 0.7309).

Finally, the field `STree` contains the actual stock tree. It is represented in MATLAB as a cell array with each cell array element containing a vector of prices corresponding to a tree level. The prices are in descending order, that is, `CRRTree.STree{3}(1)` represents the topmost element of the third level of the tree, and `CRRTree.STree{3}(end)` represents the bottom element of the same level of the tree.

#### Examining an ITTTree

You can examine in some detail the contents of the `ITTTree` structure contained in this file.

#### ITTTree

```
ITTTree =  
  
    FinObj: 'ITStockTree'  
    StockSpec: [1x1 struct]  
    StockOptSpec: [1x1 struct]  
    TimeSpec: [1x1 struct]  
    RateSpec: [1x1 struct]  
    tObs: [0 1 2 3 4]  
    dObs: [732678 733043 733408 733773 734139]  
    STree: {1x5 cell}  
    Probs: {[3x1 double] [3x3 double] [3x5 double] [3x7 double]}
```

The fields `StockSpec`, `StockOptSpec`, `TimeSpec`, and `RateSpec` hold the original structures passed into the function `itttree`. They contain all the context information required to interpret the tree data.

The fields `tObs` and `dObs` are vectors containing the observation times and dates, the times and dates of the levels of the tree. In this particular case, `tObs` reveals that the tree has a maturity of 4 years (`tObs(end) = 4`) and that it has four time steps (the length of `tObs` is five).

The field `dObs` shows the specific dates for the tree levels, with a granularity of 1 day. This means that all values in `tObs` that correspond to a given day from 00:00 hours to 24:00 hours are mapped to the corresponding value in `dObs`. You can use the function `datestr` to convert these MATLAB serial dates into their string representations.

The field `Probs` is a vector representing the probabilities for movements from any node in each level. This vector has three elements per tree node. In the specific case being examined, at `tObs = 1`, the probability for an up movement is 0.4675, and the probability for a down movement is 0.1934.

Finally, the field `STree` contains the actual stock tree. It is represented in MATLAB as a cell array with each cell array element containing a vector of prices corresponding



to a tree level. The prices are in descending order, that is, `ITTree.STree{4}(1)` represents the top element of the fourth level of the tree, and `ITTree.STree{4}(end)` represents the bottom element of the same level of the tree.

### Isolating a Specific Node for a CRRTree

The function `treepath` can isolate a specific set of nodes of a binary tree by specifying the path used to reach the final node. As an example, consider the nodes touched by starting from the root node, then following a down movement, then an up movement, and finally a down movement. You use a vector to specify the path, with 1 corresponding to an up movement and 2 corresponding to a down movement. An up-down-up path is then represented as `[2 1 2]`. To obtain the values of all nodes touched by this path, enter:

```
SVals = treepath(CRRTree.STree, [2 1 2])
```

```
SVals =
```

```
100.0000
 90.4837
100.0000
 90.4837
```

The first value in the vector `SVals` corresponds to the root node, and the last value corresponds to the final node reached by following the path indicated.

### Isolating a Specific Node for an ITTree

The function `trintreepath` can isolate a specific set of nodes of a trinomial tree by specifying the path used to reach the final node. As an example, consider the nodes touched by starting from the root node, then following an up movement, then a middle movement, and finally a down movement. You use a vector to specify the path, with 1 corresponding to an up movement, 2 corresponding to a middle movement, and 3 corresponding to a down movement. An up-down-middle-down path is then represented as `[1 3 2 3]`. To obtain the values of all nodes touched by this path, enter:

```
pathSVals = trintreepath(ITTree, [1 3 2 3])
```

```
pathSVals =
```

```
50.0000
66.3448
50.0000
50.0000
```

37.6819

The first value in the vector `pathsVals` corresponds to the root node, and the last value corresponds to the final node reached by following the path indicated.

### Differences Between CRR and EQP Tree Structures

In essence, the structures representing CRR trees and EQP trees are similar. If you create a CRR or an EQP tree using identical input arguments, only a few of the tree structure fields differ:

- The `Method` field has a value of 'CRR' or 'EQP' indicating the method used to build the structure.
- The prices in the `STree` cell array have the same structure, but the prices within the cell array are different.
- For EQP, the structure field `UpProb` always holds a vector with all elements set to 0.5, while for CRR, these probabilities are calculated based on the input arguments passed when building the tree.

## Supported Equity Derivatives

### In this section...

“Asian Option” on page 3-19  
 “Barrier Option” on page 3-20  
 “Basket Option” on page 3-21  
 “Compound Option” on page 3-23  
 “Lookback Option” on page 3-23  
 “Digital Option” on page 3-25  
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 “Vanilla Option” on page 3-27  
 “Spread Option” on page 3-29  
 “Forwards Option” on page 3-29  
 “Futures Option” on page 3-30

### Asian Option

An *Asian* option is a path-dependent option with a payoff linked to the average value of the underlying asset during the life (or some part of the life) of the option. They are similar to lookback options in that there are two types of Asian options: fixed (average price option) and floating (average strike option). Fixed Asian options have a specified strike, while floating Asian options have a strike equal to the average value of the underlying asset over the life of the option.

There are four Asian option types, each with its own characteristic payoff formula:

- Fixed call (average price option):  $\max(0, S_{av} - X)$
- Fixed put (average price option):  $\max(0, X - S_{av})$
- Floating call (average strike option):  $\max(0, S - S_{av})$
- Floating put (average strike option):  $\max(0, S_{av} - S)$

where:

$S_{av}$  is the average price of underlying asset.

$S$  is the price of the underlying asset.

$X$  is the strike price (applicable only to fixed Asian options).

$S_{av}$  is defined using either a geometric or an arithmetic average.

The following functions support Asian options.

Function	Purpose
asianbycrr	Price Asian options from a CRR binomial tree.
asianbyeqp	Price Asian options from an EQP binomial tree.
asianbyitt	Price Asian options using an implied trinomial tree (ITT).
instasian	Construct an Asian option.
asianbyls	Price European or American Asian options using the Longstaff-Schwartz model.
asiansensbyls	Calculate prices and sensitivities of European or American Asian options using the Longstaff-Schwartz model.
asianbykv	Price European geometric Asian options using the Kemna Vorst model.
asiansensbykv	Calculate prices and sensitivities of European geometric Asian options using the Kemna Vorst model.
asianbylevy	Price European arithmetic Asian options using the Levy model.
asiansensbylevy	Calculate prices and sensitivities of European arithmetic Asian options using the Levy model.

## Barrier Option

A *barrier* option is similar to a vanilla put or call option, but its life either begins or ends when the price of the underlying stock passes a predetermined barrier value. There are four types of barrier options.

### Up Knock-In

This option becomes effective when the price of the underlying stock passes above a barrier that is above the initial stock price. Once the barrier has knocked in, it will not knock out even if the price of the underlying instrument moves below the barrier again.

### Up Knock-Out

This option terminates when the price of the underlying stock passes above a barrier that is above the initial stock price. Once the barrier has knocked out, it will not knock in even if the price of the underlying instrument moves below the barrier again.

### Down Knock-In

This option becomes effective when the price of the underlying stock passes below a barrier that is below the initial stock price. Once the barrier has knocked in, it will not knock out even if the price of the underlying instrument moves above the barrier again.

### Down Knock-Out

This option terminates when the price of the underlying stock passes below a barrier that is below the initial stock price. Once the barrier has knocked out, it will not knock in even if the price of the underlying instrument moves above the barrier again.

### Rebates

If a barrier option fails to exercise, the seller may pay a rebate to the buyer of the option. Knock-outs may pay a rebate when they are knocked out, and knock-ins may pay a rebate if they expire without ever knocking in.

The following functions support barrier options.

Function	Purpose
barrierbycrr	Price barrier options from a CRR binomial tree.
barrierbyeqp	Price barrier options from an EQP binomial tree.
barrierbyitt	Price barrier options using an implied trinomial tree (ITT).
instbarrier	Construct a barrier option.

### Basket Option

A *basket* option is an option on a portfolio of several underlying equity assets. Payout for a basket option depends on the cumulative performance of the collection of the individual assets. A basket option tends to be cheaper than the corresponding portfolio of plain vanilla options for these reasons:

- If the basket components correlate negatively, movements in the value of one component neutralize opposite movements of another component. Unless all the components correlate perfectly, the basket option is cheaper than a series of individual options on each of the assets in the basket.
- A basket option minimizes transaction costs because an investor has to purchase only one option instead of several individual options.

The payoff for a basket option is as follows:

- For a call:  $\max(\sum W_i * S_i - K; 0)$
- For a put:  $\max(\sum K - W_i * S_i; 0)$

where:

$S_i$  is the price of asset  $i$  in the basket.

$W_i$  is the quantity of asset  $i$  in the basket.

$K$  is the strike price.

Financial Instruments Toolbox software supports Longstaff-Schwartz and Nengiu Ju models for pricing basket options. The Longstaff-Schwartz model supports both European, Bermuda, and American basket options. The Nengiu Ju model only supports European basket options. If you want to price either an American or Bermuda basket option, use the functions for the Longstaff-Schwartz model. To price a European basket option, use either the functions for the Longstaff-Schwartz model or the Nengiu Ju model.

Function	Purpose
<code>basketbyls</code>	Price basket options using the Longstaff-Schwartz model.
<code>basketsensbyls</code>	Calculate price and sensitivities for basket options using the Longstaff-Schwartz model.
<code>basketbyju</code>	Price European basket options using the Nengiu Ju approximation model.
<code>basketsensbyju</code>	Calculate European basket options price and sensitivity using the Nengiu Ju approximation model.
<code>basketstockspec</code>	Specify a basket stock structure.

## Compound Option

A *compound* option is basically an option on an option; it gives the holder the right to buy or sell another option. With a compound option, a vanilla stock option serves as the underlying instrument. Compound options thus have two strike prices and two exercise dates.

There are four types of compound options:

- Call on a call
- Put on a put
- Call on a put
- Put on a call

---

**Note** The payoff formulas for compound options are too complex for this discussion. If you are interested in the details, consult the paper by Mark Rubinstein entitled “Double Trouble,” published in *Risk* 5 (1991).

---

Consider the third type, a call on a put. It gives the holder the right to buy a put option. In this case, on the first exercise date, the holder of the compound option pay the first strike price and receives a put option. The put option gives the holder the right to sell the underlying asset for the second strike price on the second exercise date.

The following functions support compound options.

Function	Purpose
compoundbycrr	Price compound options from a CRR binomial tree.
compoundbyeqp	Price compound options from an EQP binomial tree.
compoundbyitt	Price compound options using an implied trinomial tree (ITT).
instcompound	Construct a compound option.

## Lookback Option

A *lookback* option is a path-dependent option based on the maximum or minimum value the underlying asset achieves during the entire life of the option.

Financial Instruments Toolbox software supports two types of lookback options: fixed and floating. Fixed lookback options have a specified strike price, while floating lookback

options have a strike price determined by the asset path. Consequently, there are a total of four lookback option types, each with its own characteristic payoff formula:

- Fixed call:  $\max(0, S_{\max} - X)$
- Fixed put:  $\max(0, X - S_{\min})$
- Floating call:  $\max(0, S - S_{\min})$
- Floating put:  $\max(0, S_{\max} - S)$

where:

$S_{\max}$  is the maximum price of underlying stock found along the particular path followed to the node.

$S_{\min}$  is the minimum price of underlying stock found along the particular path followed to the node.

$S$  is the price of the underlying stock on the node.

$X$  is the strike price (applicable only to fixed lookback options).

The following functions support lookback options.

Function	Purpose
lookbackbycrr	Price lookback options from a CRR binomial tree.
lookbackbyeqp	Price lookback options from an EQP binomial tree.
lookbackbyitt	Price lookback options using an implied trinomial tree (ITT).
instlookback	Construct a lookback option based on an equity tree model.
lookbackbycvsg	Calculate prices of European lookback fixed and floating strike options using the Conze-Viswanathan and Goldman-Sosin-Gatto models. For more information, see “Lookback Option”.
lookbacksensbycvsg	Calculate prices and sensitivities of European fixed and floating strike lookback options using the Conze-Viswanathan and Goldman-Sosin-Gatto models. For more information, see “Lookback Option”.



Function	Purpose
lookbackbyls	Calculate prices of lookback fixed and floating strike options using the Longstaff-Schwartz model. For more information, see “Lookback Option”.
lookbacksensbyls	Calculate prices and sensitivities of lookback fixed and floating strike options using the Longstaff-Schwartz model. For more information, see “Lookback Option”.

## Digital Option

A *digital* option is an option whose payoff is characterized as having only two potential values: a fixed payout, when the option is in the money or a zero payout otherwise. This is the case irrespective of how far the asset price at maturity is above (call) or below (put) the strike.

Digital options are attractive to sellers because they guarantee a known maximum loss in the event that the option is exercised. This overcomes a fundamental problem with the vanilla options, where the potential loss is unlimited. Digital options are attractive to buyers because the option payoff is a known constant amount, and this amount can be adjusted to provide the exact quantity of protection required.

Financial Instruments Toolbox supports four types of digital options:

- Cash-or-nothing option — Pays some fixed amount of cash if the option expires in the money.
- Asset-or-nothing option — Pays the value of the underlying security if the option expires in the money.
- Gap option — One strike decides if the option is in or out of money; another strike decides the size of the payoff.
- Supershare — Pays out a proportion of the assets underlying a portfolio if the asset lies between a lower and an upper bound at the expiry of the option.

The following functions calculate pricing and sensitivity for digital options.

Function	Purpose
cashbybls	Calculate the price of cash-or-nothing digital options using the Black-Scholes model.

<b>Function</b>	<b>Purpose</b>
assetbybls	Calculate the price of asset-or-nothing digital options using the Black-Scholes model.
gapbybls	Calculate the price of gap digital options using the Black-Scholes model.
supersharebybls	Calculate the price of supershare digital options using the Black-Scholes model.
cashsensbybls	Calculate the price and sensitivities of cash-or-nothing digital options using the Black-Scholes model.
assetsensbybls	Calculate the price and sensitivities of asset-or-nothing digital options using the Black-Scholes model.
gapsensbybls	Calculate the price and sensitivities of gap digital options using the Black-Scholes model.
supersharesensbybls	Calculate the price and sensitivities of supershare digital options using the Black-Scholes model.

## Rainbow Option

A rainbow option payoff depends on the relative price performance of two or more assets. A *rainbow* option gives the holder the right to buy or sell the best or worst of two securities, or options that pay the best or worst of two assets.

Rainbow options are popular because of the lower premium cost of the structure relative to the purchase of two separate options. The lower cost reflects the fact that the payoff is generally lower than the payoff of the two separate options.

Financial Instruments Toolbox supports two types of rainbow options:

- Minimum of two assets — The option holder has the right to buy(sell) one of two risky assets, whichever one is worth less.
- Maximum of two assets — The option holder has the right to buy(sell) one of two risky assets, whichever one is worth more.

The following rainbow options speculate/hedge on two equity assets.

Function	Purpose
<code>minassetbystulz</code>	Calculate the European rainbow option price on minimum of two risky assets using the Stulz option pricing model.
<code>minassetsensbystulz</code>	Calculate the European rainbow option prices and sensitivities on minimum of two risky assets using the Stulz pricing model.
<code>maxassetbystulz</code>	Calculate the European rainbow option price on maximum of two risky assets using the Stulz option pricing model.
<code>maxassetsensbystulz</code>	Calculate the European rainbow option prices and sensitivities on maximum of two risky assets using the Stulz pricing model.

## Vanilla Option

A *vanilla option* is a category of options that includes only the most standard components. A vanilla option has an expiration date and straightforward strike price. American-style options and European-style options are both categorized as vanilla options.

The payoff for a vanilla option is as follows:

- For a call:  $\max(St - K, 0)$
- For a put:  $\max(K - St, 0)$

where:

$St$  is the price of the underlying asset at time  $t$ .

$K$  is the strike price.

The following functions support specifying or pricing a vanilla option.

Function	Purpose
<code>optstockbycrr</code>	Calculate the price of a European, Bermuda, or American stock option using a CRR tree.

Function	Purpose
optstockbyeqp	Calculate the price of a European, Bermuda, or American stock option using an EQP tree.
optstockbyitt	Calculate the price of a European, Bermuda, or American stock option using an ITT tree.
optstockbylr	Calculate the price of a European, Bermuda, or American stock option using the Leisen-Reimer (LR) binomial tree model.
optstockbybls	Price options using the Black-Scholes option pricing model.
optstocksensbybls	Calculate option prices and sensitivities using the Black-Scholes option pricing model.
optstockbyrgw	Calculate American call option prices using the Roll-Geske-Whaley option pricing model.
optstocksensbyrgw	Calculate American call option prices and sensitivities using the Roll-Geske-Whaley option pricing model.
optstockbybjs	Price American options using the Bjerksund-Stensland 2002 option pricing model.
optstocksensbybjs	Calculate American option prices and sensitivities using the Bjerksund-Stensland 2002 option pricing model.
optstockbyls	Price vanilla options using the Longstaff-Schwartz model.
optstocksensbyls	Calculate vanilla option prices and sensitivities using the Longstaff-Schwartz model.
instoptstock	Specify a European or Bermuda option.

### Bermuda Put and Call Schedule

A Bermuda option resembles a hybrid of American and European options. You exercise it on predetermined dates only, usually monthly. In Financial Instruments Toolbox software, you indicate the relevant information for a Bermuda option in two input matrices:

- **Strike** — Contains the strike price values for the option.
- **ExerciseDates** — Contains the schedule when you can exercise the option.

## Spread Option

A *spread option* is an option written on the difference of two underlying assets. For example, a European call on the difference of two assets  $X1$  and  $X2$  would have the following pay off at maturity:

$$\max(X1 - X2 - K, 0)$$

where:

$K$  is the strike price.

The following functions support spread options.

Function	Purpose
spreadbykirk	Price European spread options using the Kirk pricing model.
spreadsensbykirk	Calculate European spread option prices and sensitivities using the Kirk pricing model.
spreadbybjs	Price European spread options using the Bjerksund-Stensland pricing model.
spreadsensbybjs	Calculate European spread option prices and sensitivities using the Bjerksund-Stensland pricing model.
spreadbyfd	Price European or American spread options using the Alternate Direction Implicit (ADI) finite difference method.
spreadsensbyfd	Calculate price and sensitivities of European or American spread spread options using the Alternate Direction Implicit (ADI) finite difference method.
spreadbyls	Price European or American spread options using Monte Carlo simulations.
spreadsensbyls	Calculate price and sensitivities for European or American spread options using Monte Carlo simulations.

## Forwards Option

A *forward option* is a non-standardized contract between two parties to buy or to sell an asset at a specified future time at a price agreed upon today. The buyer of a forward

option contract has the right to hold a particular forward position at a specific price any time before the option expires. The forward option seller holds the opposite forward position when the buyer exercises the option. A call option is the right to enter into a long forward position and a put option is the right to enter into a short forward position. A closely related contract is a futures contract. A forward is like a futures in that it specifies the exchange of goods for a specified price at a specified future date. The table below displays some of the characteristics of forward and futures contracts.

Forwards	Futures
Customized contracts	Standardized contracts
Over the counter traded	Exchange traded
Exposed to default risk	Clearing house reduces default risk
Mostly used for hedging	Mostly used by hedgers and speculators
Settlement at the end of contract (no Margin required)	Daily changes are settled day by day (Margin required)
Delivery usually takes place	Delivery usually never happens

The payoff for a forward option, where the value of a forward position at maturity depends on the relationship between the delivery price ( $K$ ) and the underlying price ( $S_T$ ) at that time, is:

- For a long position:  $f_T = S_T - K$
- For a short position:  $f_T = K - S_T$

The following functions support pricing a forwards option.

Function	Purpose
optstockbyblk	Price options on forwards using the Black option pricing model.
optstocksensbyblk	Determine option prices and sensitivities on forwards using the Black pricing model.

## Futures Option

A *future option* is a standardized contract between two parties to buy or sell a specified asset of standardized quantity and quality for a price agreed upon today (the futures

price) with delivery and payment occurring at a specified future date, the delivery date. The contracts are negotiated at a futures exchange, which acts as an intermediary between the two parties. The party agreeing to buy the underlying asset in the future, the "buyer" of the contract, is said to be "long", and the party agreeing to sell the asset in the future, the "seller" of the contract, is said to be "short".

Forwards	Futures
Customized contracts	Standardized contracts
Over the counter traded	Exchange traded
Exposed to default risk	Clearing house reduces default risk
Mostly used for hedging	Mostly used by hedgers and speculators
Settlement at the end of contract (no Margin required)	Daily changes are settled day by day (Margin required)
Delivery usually takes place	Delivery usually never happens

A futures contract is the delivery of item  $J$  at time  $T$  and:

- There exists in the market a quoted price  $F(t, T)$ , which is known as the futures price at time  $t$  for delivery of  $J$  at time  $T$ .
- The price of entering a futures contract is equal to zero.
- During any time interval  $[t, s]$ , the holder receives the amount  $F(s, T) - F(t, T)$  (this reflects instantaneous marking to market).
- At time  $T$ , the holder pays  $F(T, T)$  and is entitled to receive  $J$ . Note that  $F(T, T)$  should be the spot price of  $J$  at time  $T$ .

The following functions support pricing a futures option.

Function	Purpose
optstockbyblk	Price options on futures using the Black option pricing model.
optstocksensbyblk	Determine option prices and sensitivities on futures using the Black pricing model.

## Supported Energy Derivatives

### In this section...

- “Asian Option” on page 3-32
- “Vanilla Option” on page 3-33
- “Spread Option” on page 3-34
- “Lookback Option” on page 3-35
- “Forwards Option” on page 3-36
- “Futures Option” on page 3-37

### Asian Option

An *Asian* option is a path-dependent option with a payoff linked to the average value of the underlying asset during the life (or some part of the life) of the option. They are similar to lookback options in that there are two types of Asian options: fixed (average price option) and floating (average strike option). Fixed Asian options have a specified strike, while floating Asian options have a strike equal to the average value of the underlying asset over the life of the option.

There are four Asian option types, each with its own characteristic payoff formula:

- Fixed call (average price option):  $\max(0, S_{av} - X)$
- Fixed put (average price option):  $\max(0, X - S_{av})$
- Floating call (average strike option):  $\max(0, S - S_{av})$
- Floating put (average strike option):  $\max(0, S_{av} - S)$

where:

$S_{av}$  is the average price of underlying asset.

$S$  is the price of the underlying asset.

$X$  is the strike price (applicable only to fixed Asian options).



$S_{av}$  is defined using either a geometric or an arithmetic average.

The following functions support Asian options.

Function	Purpose
asianbyls	Price European or American Asian options using the Longstaff-Schwartz model.
asiansensbyls	Calculate prices and sensitivities of European or American Asian options using the Longstaff-Schwartz model.
asianbykv	Price European geometric Asian options using the Kemna Vorst model.
asiansensbykv	Calculate prices and sensitivities of European geometric Asian options using the Kemna Vorst model.
asianbylevy	Price European arithmetic Asian options using the Levy model.
asiansensbylevy	Calculate prices and sensitivities of European arithmetic Asian options using the Levy model.

## Vanilla Option

A *vanilla option* is a category of options that includes only the most standard components. A vanilla option has an expiration date and straightforward strike price. American-style options and European-style options are both categorized as vanilla options.

The payoff for a vanilla option is as follows:

- For a call:  $\max(S_t - K, 0)$
- For a put:  $\max(K - S_t, 0)$

where:

$S_t$  is the price of the underlying asset at time  $t$ .

$K$  is the strike price.

The following functions support specifying or pricing a vanilla option.

Function	Purpose
optstockbyls	Price European, Bermudan, or American vanilla options using the Longstaff-Schwartz model.
optstocksensbyls	Calculate European, Bermudan, or American vanilla option prices and sensitivities using the Longstaff-Schwartz model.

### Spread Option

A *spread option* is an option written on the difference of two underlying assets. For example, a European call on the difference of two assets  $X1$  and  $X2$  would have the following pay off at maturity:

$$\max(X1 - X2 - K, 0)$$

where:

$K$  is the strike price.

The following functions support spread options.

Function	Purpose
spreadbykirk	Price European spread options using the Kirk pricing model.
spreadsensbykirk	Calculate European spread option prices and sensitivities using the Kirk pricing model.
spreadbybjs	Price European spread options using the Bjerksund-Stensland pricing model.
spreadsensbybjs	Calculate European spread option prices and sensitivities using the Bjerksund-Stensland pricing model.
spreadbyfd	Price European or American spread options using the Alternate Direction Implicit (ADI) finite difference method.
spreadsensbyfd	Calculate price and sensitivities of European or American spread options using the Alternate Direction Implicit (ADI) finite difference method.
spreadbyls	Price European or American spread options using Monte Carlo simulations.

Function	Purpose
spreadsensby1s	Calculate price and sensitivities for European or American spread options using Monte Carlo simulations.

For more information on using spread options, see “Pricing European and American Spread Options”.

## Lookback Option

A *lookback* option is a path-dependent option based on the maximum or minimum value the underlying asset (e.g. electricity, stock) achieves during the entire life of the option. Basically the holder of the option can ‘look back’ over time to determine the payoff. This type of option provides price protection over a selected period, reduces uncertainties with the timing of market entry, moderates the need for the ongoing management, and therefore, is usually more expensive than vanilla options.

Lookback call options give the holder the right to buy the underlying asset at the lowest price. Lookback put options give the right to sell the underlying asset at the highest price.

Financial Instruments Toolbox software supports two types of lookback options: fixed and floating. The difference is related to how the strike price is set in the contract. Fixed lookback options have a specified strike price and the option pays out the maximum of the difference between the highest (lowest) observed price of the underlying during the life of the option and the strike. Floating lookback options have a strike price determined at maturity, and it is set at the lowest (highest) price of the underlying reached during the life of the option. This means that for a floating strike lookback call (put), the holder has the right to buy (sell) the underlying asset at its lowest (highest) price observed during the life of the option. Consequently, there are a total of four lookback option types, each with its own characteristic payoff formula:

- Fixed call:  $\max(0, S_{\max} - X)$
- Fixed put:  $\max(0, X - S_{\min})$
- Floating call:  $\max(0, S - S_{\min})$
- Floating put:  $\max(0, S_{\max} - S)$

where:

$S_{\max}$  is the maximum price of underlying asset.

$S_{\min}$  is the minimum price of underlying asset.

$S$  is the price of the underlying asset at maturity.

$X$  is the strike price.

The following functions support lookback options.

Function	Purpose
lookbackbycvgs	Calculate prices of European lookback fixed and floating strike options using the Conze-Viswanathan and Goldman-Sosin-Gatto models.
lookbacksensbycvgs	Calculate prices and sensitivities of European fixed and floating strike lookback options using the Conze-Viswanathan and Goldman-Sosin-Gatto models.
lookbackbyls	Calculate prices of lookback fixed and floating strike options using the Longstaff-Schwartz model.
lookbacksensbyls	Calculate prices and sensitivities of lookback fixed and floating strike options using the Longstaff-Schwartz model.

Lookback options as well as Asian options are instruments used in the electricity market to manage purchase timing risk. Electricity purchasers cover part of their expected electricity consumption on the forward market to avoid the volatility and limited liquidity of the spot market. Using Asian options as a hedging tool is a passive approach to solving the purchase timing problem. An Asian option instrument diminishes the wrong timing risk but it also reduces any potential benefit to the buyer from falling prices. On the other hand, lookback options allow the purchasers to buy electricity at the lowest price, but as mentioned before, this instrument is more expensive than Asian and vanilla options.

## Forwards Option

A *forward option* is a non-standardized contract between two parties to buy or to sell an asset at a specified future time at a price agreed upon today. The buyer of a forward option contract has the right to hold a particular forward position at a specific price

any time before the option expires. The forward option seller holds the opposite forward position when the buyer exercises the option. A call option is the right to enter into a long forward position and a put option is the right to enter into a short forward position. A closely related contract is a futures contract. A forward is like a futures in that it specifies the exchange of goods for a specified price at a specified future date. The table below displays some of the characteristics of forward and futures contracts.

Forwards	Futures
Customized contracts	Standardized contracts
Over the counter traded	Exchange traded
Exposed to default risk	Clearing house reduces default risk
Mostly used for hedging	Mostly used by hedgers and speculators
Settlement at the end of contract (no Margin required)	Daily changes are settled day by day (Margin required)
Delivery usually takes place	Delivery usually never happens

The payoff for a forward option, where the value of a forward position at maturity depends on the relationship between the delivery price ( $K$ ) and the underlying price ( $S_T$ ) at that time, is:

- For a long position:  $f_T = S_T - K$
- For a short position:  $f_T = K - S_T$

The following functions support pricing a forwards option.

Function	Purpose
optstockbyblk	Price options on forwards using the Black option pricing model.
optstocksensbyblk	Determine option prices and sensitivities on forwards using the Black pricing model.

## Futures Option

A *future option* is a standardized contract between two parties to buy or sell a specified asset of standardized quantity and quality for a price agreed upon today (the futures price) with delivery and payment occurring at a specified future date, the

delivery date. The contracts are negotiated at a futures exchange, which acts as an intermediary between the two parties. The party agreeing to buy the underlying asset in the future, the "buyer" of the contract, is said to be "long", and the party agreeing to sell the asset in the future, the "seller" of the contract, is said to be "short."

Forwards	Futures
Customized contracts	Standardized contracts
Over the counter traded	Exchange traded
Exposed to default risk	Clearing house reduces default risk
Mostly used for hedging	Mostly used by hedgers and speculators
Settlement at the end of contract (no Margin required)	Daily changes are settled day by day (Margin required)
Delivery usually takes place	Delivery usually never happens

A futures contract is the delivery of item  $J$  at time  $T$  and:

- There exists in the market a quoted price  $F(t, T)$ , which is known as the futures price at time  $t$  for delivery of  $J$  at time  $T$ .
- The price of entering a futures contract is equal to zero.
- During any time interval  $[t, s]$ , the holder receives the amount  $F(s, T) - F(t, T)$  (this reflects instantaneous marking to market).
- At time  $T$ , the holder pays  $F(T, T)$  and is entitled to receive  $J$ . Note that  $F(T, T)$  should be the spot price of  $J$  at time  $T$ .

The following functions support pricing a futures option.

Function	Purpose
optstockbyblk	Price options on futures using the Black option pricing model.
optstocksensbyblk	Determine option prices and sensitivities on futures using the Black pricing model.

## Pricing European and American Spread Options

This example shows how to price and calculate sensitivities for European and American spread options using various techniques. First, the price and sensitivities for an European spread option is calculated using closed form solutions. Then, price and sensitivities for an American spread option is calculated using finite difference and Monte Carlo simulations. Finally, further analysis is conducted on spread options with different range of inputs.

Spread options are options on the difference of two underlying asset prices. For example, a call option on the spread between two assets will have the following payoff at maturity:

$$\max(X_1 - X_2 - K, 0)$$

where  $X_1$  is the price of the first underlying asset,  $X_2$  is the price of the second underlying asset, and  $K$  is the strike price. At maturity, if the spread  $X_1 - X_2$  is greater than the strike price  $K$ , the option holder will exercise the option and gain the difference between the spread and the strike price. If the spread is less than 0, the option holder will not exercise the option, and the payoff is 0. Spread options are frequently traded in the energy market. Two examples are:

- *Crack spreads*: Options on the spread between refined petroleum products and crude oil. The spread represents the refinement margin made by the oil refinery by "cracking" the crude oil into a refined petroleum product.
- *Spark spreads*: Options on the spread between electricity and some type of fuel. The spread represents the margin of the power plant, which takes fuel to run its generator to produce electricity.

### Overview of the Pricing Methods

There are several methods to price spread options, as discussed in [1]. This example uses the closed form, finite difference, and Monte Carlo simulations to price spread options. The advantages and disadvantages of each method is discussed below:

- Closed form solutions/approximations of partial differential equations (PDE) are advantageous because they are very fast, and extend well to computing sensitivities (Greeks). However, closed form solutions are not always available, for example for American spread options.
- The finite difference method is a numerical procedure to solve PDEs by discretizing the price and time variables into a grid. A detailed analysis of this method can be

found in [2]. It can handle cases where closed form solutions are not available. Also, finite difference extends well to calculating sensitivities because it outputs a grid of option prices for a range of underlying prices and times. However, it is slower than the closed form solutions.

- Monte Carlo simulation uses random sampling to simulate movements of the underlying asset prices. It handles cases where closed solutions do not exist. However, it usually takes a long time to run, especially if sensitivities need to be calculated.

#### Pricing an European Spread Option

The following example demonstrates the pricing of a crack spread option.

A refiner is concerned about its upcoming maintenance schedule and needs to protect against decreasing crude oil prices and increasing heating oil prices. During the maintenance the refiner needs to continue providing customers with heating oil to meet their demands. The refiner's strategy is to use spread options to manage its hedge.

On January 2013, the refiner buys a 1:1 crack spread option by purchasing heating oil futures and selling crude oil futures. CLF14 WTI crude oil futures is at \$100 per barrel and HOF14 heating oil futures contract is at \$2.6190 per gallon.

```
clear;
```

```
% Price, volatility, and dividend of heating oil
```

```
Price1gallon = 2.6190;      % $/gallon
```

```
Price1 = Price1gallon*42;   % $/barrel
```

```
Vol1 = 0.10;
```

```
Div1 = 0.03;
```

```
% Price, volatility, and dividend of WTI crude oil
```

```
Price2 = 100;              % $/barrel
```

```
Vol2 = 0.15;
```

```
Div2 = 0.02;
```

```
% Correlation of underlying prices
```

```
Corr = 0.3;
```

```
% Option type
```

```
OptSpec = 'call';
```

```
% Strike
```

```
Strike = 5;
```



```

% Settlement date
Settle = '01-Jan-2013';

% Maturity
Maturity = '01-Jan-2014';

% Risk free rate
RiskFreeRate = 0.05;

```

The pricing functions take an interest rate term structure and stock structure as inputs. Also, we need to specify which outputs we are interested in.

```

% Define RateSpec
Compounding = -1;
Basis = 1;
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
    'EndDates', Maturity, 'Rates', RiskFreeRate, 'Compounding', ...
    Compounding, 'Basis', Basis);

% Define StockSpec for the two assets
StockSpec1 = stockspec(Vol1, Price1, 'Continuous', Div1);
StockSpec2 = stockspec(Vol2, Price2, 'Continuous', Div2);

% Specify price and sensitivity outputs
OutSpec = {'Price', 'Delta', 'Gamma'};

```

The Financial Instruments Toolbox™ contains two types of closed form approximations for calculating price and sensitivities of European spread options: the Kirk's approximation (`spreadbykirk`, `spreadsensbykirk`) and the Bjerksund and Stensland model (`spreadbybjs`, `spreadsensbybjs`) [3].

The function `spreadsensbykirk` calculates prices and sensitivities for an European spread option using the Kirk's approximation.

```

% Kirk's approximation
[PriceKirk, DeltaKirk, GammaKirk] = ...
    spreadsensbykirk(RateSpec, StockSpec1, StockSpec2, Settle, ...
    Maturity, OptSpec, Strike, Corr, 'OutSpec', OutSpec)

```

```

PriceKirk =

    8.3636

```

```
DeltaKirk =  
    0.6108   -0.5590  
  
GammaKirk =  
    0.0225   0.0249
```

The function `spreadsensbybjs` calculates the prices and sensitivities for an European spread option using the Bjerksund and Stensland model. In [3], Bjerksund and Stensland explains that the Kirk's approximation tends to underprice the spread option when the strike is close to zero, and overprice when the strike is further away from zero. In comparison, the model by Bjerksund and Stensland has higher precision.

```
% Bjerksund and Stensland model  
[PriceBJS, DeltaBJS, GammaBJS] = ...  
    spreadsensbybjs(RateSpec, StockSpec1, StockSpec2, Settle, ...  
    Maturity, OptSpec, Strike, Corr, 'OutSpec', OutSpec)  
  
PriceBJS =  
    8.3662  
  
DeltaBJS =  
    0.6115   -0.5597  
  
GammaBJS =  
    0.0225   0.0248
```

A comparison of the calculated prices show that the two closed form models produce similar results for price and sensitivities. In addition to delta and gamma, the functions can also calculate theta, vega, lambda, and rho.

```
% Comparison of calculated prices  
fprintf('Comparison of prices:\n\n');
```

```

fprintf('Kirk:                %f\n', PriceKirk);
fprintf('BJS:                 %f\n\n', PriceBJS);

% Comparison of Delta
fprintf('Comparison of delta:\n\n');
fprintf('Kirk:                %f      %f\n', DeltaKirk(1), DeltaKirk(2));
fprintf('BJS:                 %f      %f\n\n', DeltaBJS(1), DeltaBJS(2));

% Comparison of Gamma
fprintf('Comparison of gamma:\n\n');
fprintf('Kirk:                %f      %f\n', GammaKirk(1), GammaKirk(2));
fprintf('BJS:                 %f      %f\n\n', GammaBJS(1), GammaBJS(2));

```

Comparison of prices:

```

Kirk:                8.363641
BJS:                 8.366158

```

Comparison of delta:

```

Kirk:                0.610790      -0.558959
BJS:                 0.611469      -0.559670

```

Comparison of gamma:

```

Kirk:                0.022533      0.024850
BJS:                 0.022495      0.024819

```

### Pricing an American Spread Option

Although the closed form approximations are fast and well suited for pricing European spread options, they cannot price American spread options. Using the finite difference method and the Monte Carlo method, an American spread option can be priced. In this example, an American spread option is priced with the same attributes as the above crack spread option.

The finite difference method numerically solves a PDE by discretizing the underlying price and time variables into a grid. The Financial Instrument Toolbox™ contains the functions `spreadbyfd` and `spreadsensbyfd`, which calculate prices and sensitivities for European and American spread options using the finite difference method. For the finite difference method, the composition of the grid has a large impact on the quality of the output and the execution time. Generally, a finely discretized grid will result in outputs that are closer to the theoretical value, but it comes at the cost of longer

execution times. The composition of the grid is controlled using optional parameters `PriceGridSize`, `TimeGridSize`, `AssetPriceMin` and `AssetPriceMax`.

% To indicate that we are pricing an American option, add an optional input % of `|AmericanOpt|` with a value of 1 to the argument of the function.

% Finite difference method for American spread option

```
[PriceFD, DeltaFD, GammaFD, PriceGrid, AssetPrice1, ...
    AssetPrice2] = ...
    spreadsensbyfd(RateSpec, StockSpec1, StockSpec2, Settle, ...
    Maturity, OptSpec, Strike, Corr, 'OutSpec', OutSpec, ...
    'PriceGridSize', [500 500], 'TimeGridSize', 100, ...
    'AssetPriceMin', [0 0], 'AssetPriceMax', [2000 2000], ...
    'AmericanOpt', 1);
```

% Display price and sensitivities

```
PriceFD
DeltaFD
GammaFD
```

```
PriceFD =
```

```
8.5463
```

```
DeltaFD =
```

```
0.6306 -0.5777
```

```
GammaFD =
```

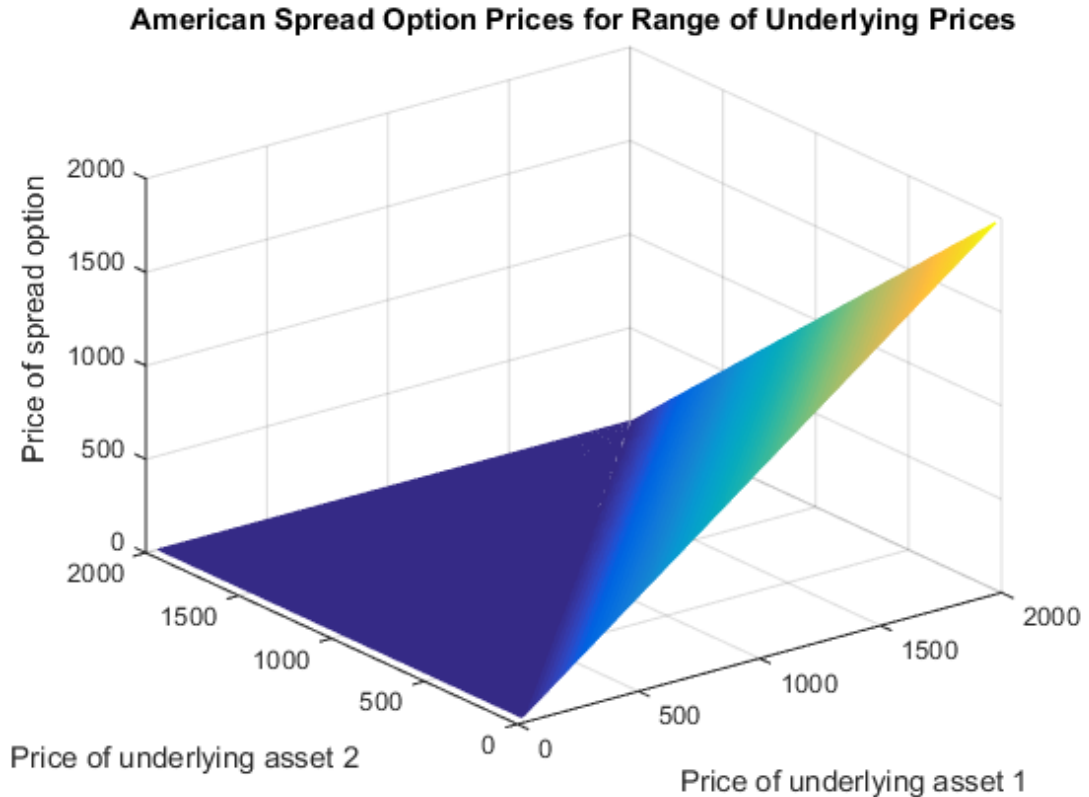
```
0.0233 0.0259
```

The function `spreadsensbyfd` also returns a grid that contains the option prices for a range of underlying prices and times. The grid of option prices at time zero, which is the option prices at the settle date, can be plotted for a range of underlying prices.

% Plot option prices

```
figure;
mesh(AssetPrice1, AssetPrice2, PriceGrid(:, :, 1)');
title('American Spread Option Prices for Range of Underlying Prices');
xlabel('Price of underlying asset 1');
```

```
ylabel('Price of underlying asset 2');
zlabel('Price of spread option');
```



An American style option can be priced by Monte Carlo methods using the least square method of Longstaff and Schwartz [4]. The Financial Instruments Toolbox™ contains the functions `spreadbyls` and `spreadsensbyls`, which calculate prices and sensitivities of European and American options using simulations. The Monte Carlo simulation method in `spreadsensbyls` generates multiple paths of simulations according to a geometric Brownian motion (GBM) for the two underlying asset prices. Similar to the finite difference method where the granularity of the grid determined the quality of the output and the execution time, the quality of output and execution time of the Monte Carlo simulation depends on the number of paths (`NumTrials`) and the number of time periods per path (`NumPeriods`). Also, note that the results obtained by Monte Carlo

simulations are not deterministic. Each run will have different results depending on the simulation outcomes.

```
% To indicate that we are pricing an American option using the Longstaff  
% and Schwartz method, add an optional input of |AmericanOpt| with a value  
% of 1 to the argument of the function.
```

```
% Monte Carlo method for American spread option  
[PriceMC, DeltaMC, GammaMC] = ...  
    spreadsensbyls(RateSpec, StockSpec1, StockSpec2, Settle, ...  
    Maturity, OptSpec, Strike, Corr, 'OutSpec', OutSpec, ...  
    'NumTrials', 1000, 'Antithetic', true, 'AmericanOpt', 1)
```

```
PriceMC =
```

```
    8.4999
```

```
DeltaMC =
```

```
    0.6325   -0.5931
```

```
GammaMC =
```

```
   -0.0873    0.0391
```

The results of the two models are compared. The prices and sensitivities calculated by the Longstaff and Schwartz method will vary at each run, depending on the outcome of the simulations. It is important to note again that the quality of the results from the finite difference method and the Monte Carlo simulation depend on the optional input parameters. For example, increasing the number of paths (`NumTrials`) for the `SPREADSENSBYLS` function will result in more precise results at the cost of longer execution times.

```
% Comparison of calculated prices  
fprintf('Comparison of prices:\n\n');  
fprintf('Finite Difference: %f\n', PriceFD);  
fprintf('Monte Carlo:           %f\n', PriceMC);
```

```
% Comparison of Delta  
fprintf('Comparison of delta:\n\n');
```

```
fprintf('Finite Difference: %f      %f\n', DeltaFD(1), DeltaFD(2));
fprintf('Monte Carlo      : %f      %f\n\n', DeltaMC(1), DeltaMC(2));
```

```
% Comparison of Gamma
```

```
fprintf('Comparison of gamma:\n\n');
fprintf('Finite Difference: %f      %f\n', GammaFD(1), GammaFD(2));
fprintf('Monte Carlo      : %f      %f\n\n', GammaMC(1), GammaMC(2));
```

```
Comparison of prices:
```

```
Finite Difference: 8.546285
Monte Carlo:      8.499894
```

```
Comparison of delta:
```

```
Finite Difference: 0.630606      -0.577686
Monte Carlo      : 0.632549      -0.593106
```

```
Comparison of gamma:
```

```
Finite Difference: 0.023273      0.025852
Monte Carlo      : -0.087340      0.039120
```

### Comparing Results for a Range of Strike Prices

As discussed earlier, the Kirk's approximation tends to overprice spread options when the strike is further away from zero. To confirm this, a spread option will be priced with the same attributes as before, but for a range of strike prices.

```
% Specify outputs
```

```
OutSpec = {'Price', 'Delta'};
```

```
% Range of strike prices
```

```
Strike = [-25; -15; -5; 0; 5; 15; 25];
```

The results from the Kirk's approximation and the Bjerkland and Stensland model will be compared against the numerical approximation from the finite difference method. Since `spreadsensbyfd` can only price one option at a time, it is called in a loop for each strike value. The Monte Carlo simulation (`spreadsensbyls`) with a large number of trial paths could also be used as a benchmark, but the finite difference will be used for this example.

```
% Kirk's approximation
```

```

[PriceKirk, DeltaKirk] = ...
    spreadsensbykirk(RateSpec, StockSpec1, StockSpec2, Settle, ...
        Maturity, OptSpec, Strike, Corr, 'OutSpec', OutSpec);

% Bjerkland and Stensland model
[PriceBJS, DeltaBJS] = ...
    spreadsensbybjs(RateSpec, StockSpec1, StockSpec2, Settle, ...
        Maturity, OptSpec, Strike, Corr, 'OutSpec', OutSpec);

% Finite difference
PriceFD = zeros(numel(Strike), 1);
DeltaFD = zeros(numel(Strike), 2);
for i = 1:numel(Strike)
    [PriceFD(i), DeltaFD(i,:)] = ...
        spreadsensbyfd(RateSpec, StockSpec1, StockSpec2, Settle, ...
            Maturity, OptSpec, Strike(i), Corr, 'OutSpec', OutSpec, ...
            'PriceGridSize', [500 500], 'TimeGridSize', 100, ...
            'AssetPriceMin', [0 0], 'AssetPriceMax', [2000 2000]);
end

% Comparison of calculated prices
fprintf('Prices for range of strikes:\n\n');
fprintf('Kirk      \tBJS      \tFD      \n');
for i = 1:numel(Strike)
    fprintf('%f\t%f\t%f\n', PriceKirk(i), PriceBJS(i), PriceFD(i));
end

Prices for range of strikes:

Kirk      BJS      FD
32.707787 32.672353 32.676040
23.605307 23.577099 23.580307
15.236908 15.228510 15.230919
11.560332 11.560332 11.562023
8.363641 8.366158 8.367212
3.689909 3.678862 3.680493
1.243753 1.219079 1.221866

```

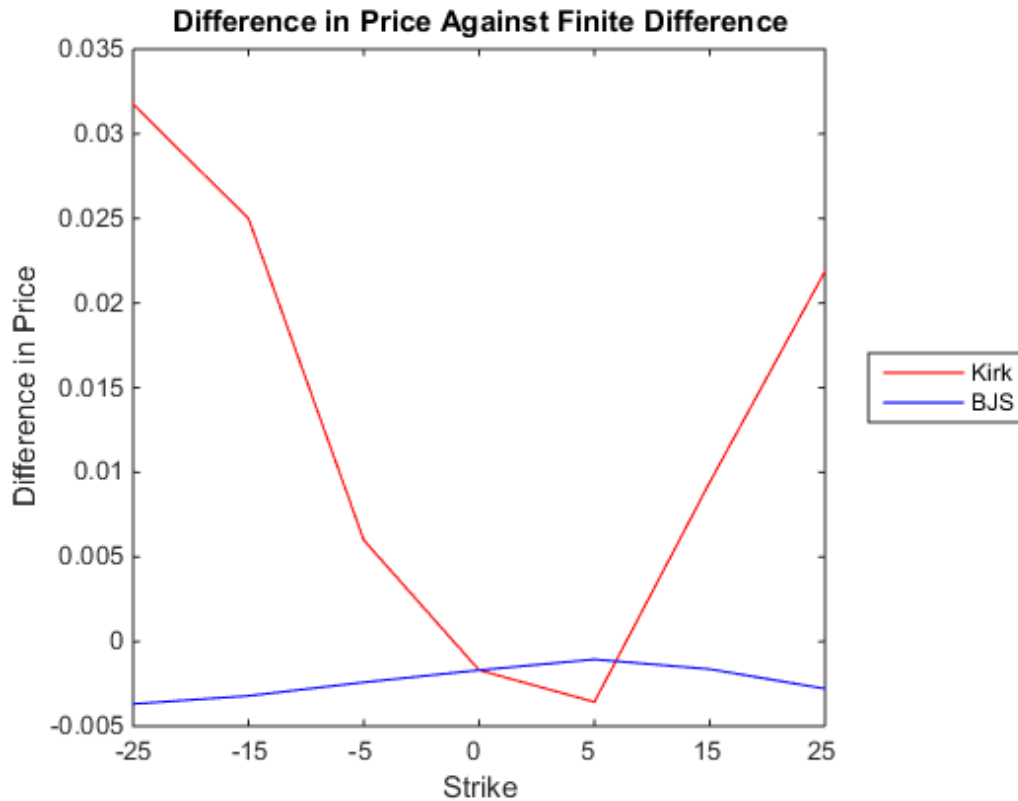
The difference in prices between the closed form and finite difference method is plotted below. It is clear that as the strike moves further away from 0, the difference between the Kirk's approximation and finite difference (red line) increases, while the difference between the Bjerkland and Stensland model and finite difference (blue line) stays at the same level. As stated in [3], the Kirk's approximation is overpricing the spread option when the strike is far away from 0.



```

% Plot of difference in price against the benchmark
figure;
plot(PriceKirk-PriceFD, 'Color', 'red');
hold on;
plot(PriceBJS-PriceFD, 'Color', 'blue');
hold off;
title('Difference in Price Against Finite Difference');
legend('Kirk', 'BJS', 'Location', 'EastOutside');
xlabel('Strike');
ax = gca;
ax.XTickLabel = Strike;
ylabel('Difference in Price');

```

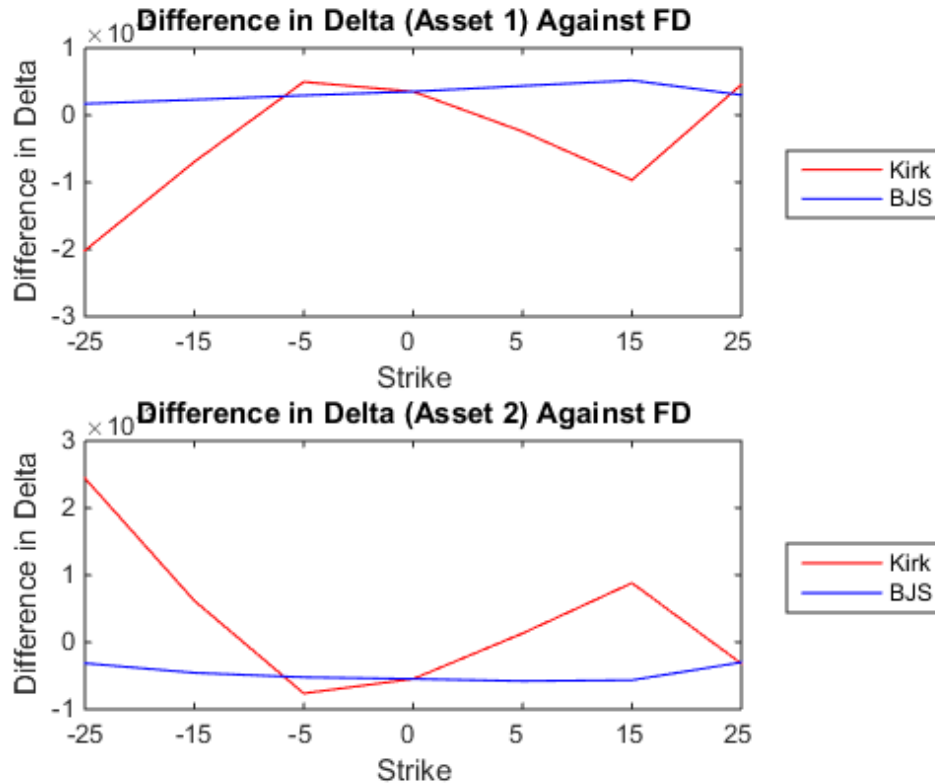


Next, the difference in delta between the closed form models and finite difference is plotted. The top plot shows the difference in delta for the first asset, and the bottom plot

shows the difference in delta for the second asset. As seen from the small increments in the y-axis of order  $10e-3$ , it can be seen that all three models (Kirk, BJS, finite difference) produce similar values for delta.

```
% Plot of difference in delta of first asset against the benchmark
figure;
subplot(2, 1, 1);
plot(DeltaKirk(:,1)-DeltaFD(:,1), 'Color', 'red');
hold on;
plot(DeltaBJS(:,1)-DeltaFD(:,1), 'Color', 'blue');
hold off;
title('Difference in Delta (Asset 1) Against FD');
legend('Kirk', 'BJS', 'Location', 'EastOutside');
xlabel('Strike');
ax = gca;
ax.XTickLabel = Strike;
ylabel('Difference in Delta');

% Plot of difference in delta of second asset against the benchmark
subplot(2, 1, 2);
plot(DeltaKirk(:,2)-DeltaFD(:,2), 'Color', 'red');
hold on;
plot(DeltaBJS(:,2)-DeltaFD(:,2), 'Color', 'blue');
hold off;
title('Difference in Delta (Asset 2) Against FD');
legend('Kirk', 'BJS', 'Location', 'EastOutside');
xlabel('Strike');
ax = gca;
ax.XTickLabel = Strike;
ylabel('Difference in Delta');
```



### Analyzing Prices and Vega at Different Levels of Volatility

To further show the type of analysis that can be conducted using these models, the above spread option will now be priced at different levels of volatility for the first asset. The price and vega will be compared at three levels of volatility for the first asset: 0.1, 0.3, and 0.5. The Bjerklund and Stensland model will be used for this analysis.

```
% Strike
Strike = 5;

% Specify output
OutSpec = {'Price', 'Vega'};
```

```
% Different levels of volatility for asset 1
Vol1 = [0.1, 0.3, 0.5];

StockSpec1 = stockspec(Vol1, Price1, 'Continuous', Div1);

% Bjerkland and Stensland model
[PriceBJS, VegaBJS] = ...
    spreadsensbybjs(RateSpec, StockSpec1, StockSpec2, Settle, ...
        Maturity, OptSpec, Strike, Corr, 'OutSpec', OutSpec);

% Display price
fprintf('\nPrices for different vol levels in asset 1:\n\n');
for i = 1:numel(Vol1)
    fprintf('%f\n', PriceBJS(i));
end

% Display vega for first asset
fprintf('\nAsset 1 vega for different vol levels in asset 1:\n\n');
for i = 1:numel(Vol1)
    fprintf('%f\n', VegaBJS(i,1));
end
fprintf('\n');

% Display vega for second asset
fprintf('\nAsset 2 vega for different vol levels in asset 1:\n\n');
for i = 1:numel(Vol1)
    fprintf('%f\n', VegaBJS(i,2));
end
fprintf('\n');
```

Prices for different vol levels in asset 1:

```
8.366158
14.209112
21.795746
```

Asset 1 vega for different vol levels in asset 1:

```
15.534849
36.212192
38.794348
```

Asset 2 vega for different vol levels in asset 1:

```

29.437036
7.133657
-0.557852

```

The change in the price and vega with respect to the volatility of the first asset is plotted below. It can be observed that as the volatility of the first asset increases, the price of the spread option also increases. Also, the changes in vega indicate that the price of the spread option becomes more sensitive to the volatility of the first asset and less sensitive to the volatility of the second asset.

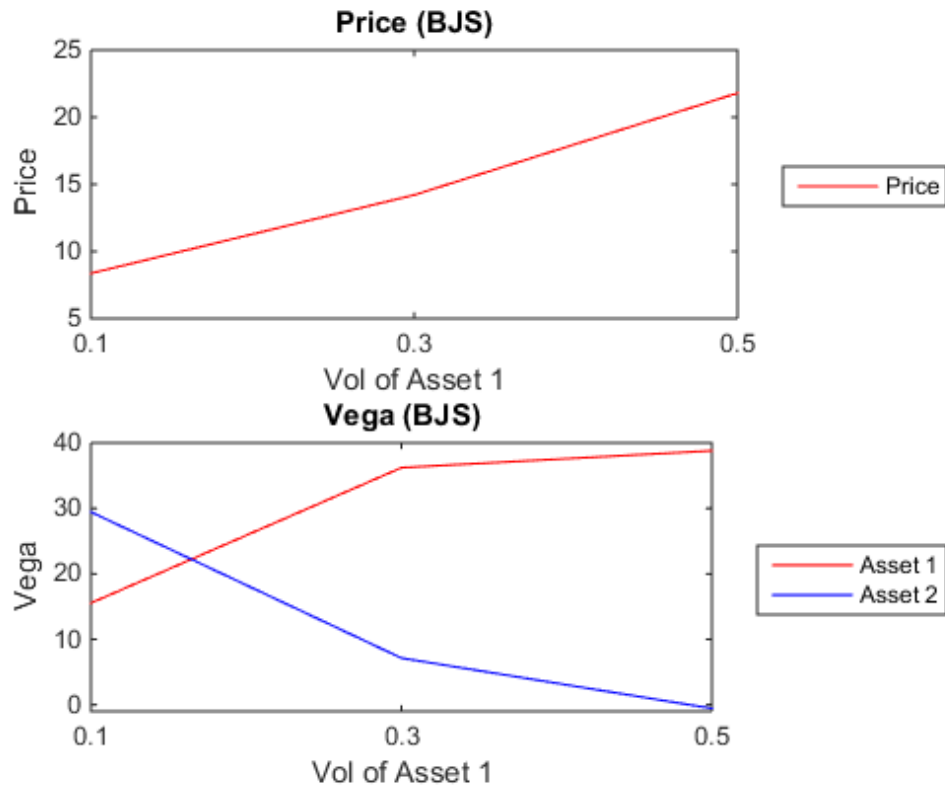
```
figure;
```

```

% Plot price for BJS model
subplot(2, 1, 1);
plot(PriceBJS, 'Color', 'red');
title('Price (BJS)');
legend('Price', 'Location', 'EastOutside');
xlabel('Vol of Asset 1');
ax = gca;
ax.XTick = 1:3;
ax.XTickLabel = Vol1;
ylabel('Price');

% Plot of vega for BJS model
subplot(2, 1, 2);
plot(VegaBJS(:,1), 'Color', 'red');
hold on;
plot(VegaBJS(:,2), 'Color', 'blue');
hold off;
title('Vega (BJS)');
legend('Asset 1', 'Asset 2', 'Location', 'EastOutside');
xlabel('Vol of Asset 1');
ax = gca;
ax.XTick = 1:3;
ax.XTickLabel = Vol1;
ax.YLim = [-1 40];
ylabel('Vega');

```



### Summary

In this example, European and American spread options were priced and analyzed using various techniques. The Financial Instruments Toolbox™ provides functions for two types of closed form solutions (Kirk, BJS), the finite difference method, and the Monte Carlo simulation method. The closed form solutions are well suited for pricing and sensitivity calculation of European spread options because they are fast. However, they cannot price American spread options. The finite difference method and Monte Carlo method can price both European and American options. However, they are not as fast in pricing European spread options as compared to closed form solutions.

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## Hedging Strategies Using Spread Options

This example shows different hedging strategies to minimize exposure in the Energy market using Crack Spread Options.

### Understanding Crack Spread Options

In the petroleum industry, refiners are concerned about the difference between their input costs (crude oil) and output prices (refined products - gasoline, heating oil, diesel fuel, etc). The differential between these two underlying commodities is referred to as a Crack Spread. It represents the profit margin between crude oil and the refined products.

A Spread option is an option on the spread where the holder has the right, but not the obligation, to enter into a spot or forward spread contract. Crack Spread Options are often used to protect against declines in the crack spread or to monetise volatility or price expectations on the spread.

### Example 1: Protecting Margins using a 1:1 Crack Spread Option

A marketer is interested in protecting his gasoline margin since current prices are strong. A crack spread option strategy will be used to maintain profits for the following season. In March the June WTI crude oil futures is at \$91.10 per barrel and RBOB gasoline futures contract is at \$2.72 per gallon. The marketer's strategy is a long crack call involving purchasing RBOB gasoline futures and selling crude oil futures.

```
OldFormat = get(0, 'format');
format bank

% Price and volatility of RBOB gasoline
Price1gallon = 2.72;           % $/gallon
Price1 = Price1gallon * 42;   % $/barrel
Vol1 = 0.39;

% Price and volatility of WTI crude oil
Price2 = 91.10;               % $/barrel
Vol2 = 0.34;

% Assume the following data
% Spread Option
Strike = 20;
OptSpec = 'call';
Settle = '01-March-2013';
Maturity = '01-June-2013';
```



```
Corr = 0.45;      % Correlation of underlying commodities
```

Define RateSpec and StockSpec

```
% Define RateSpec
Rate = 0.035;
Compounding = -1;
Basis = 1;
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
    'EndDates', Maturity, 'Rates', Rate, 'Compounding', ...
    Compounding, 'Basis', Basis);
```

```
% Define StockSpec for the two assets
```

```
StockSpec1 = stockspec(Vol1, Price1);
StockSpec2 = stockspec(Vol2, Price2);
```

Price the Crack Spread Option

```
% Use the function 'spreadbybjs' in the Financial Instruments Toolbox(TM) to
% price the spread option using the Bjerksund and Stensland model.
```

```
Price = spreadbybjs(RateSpec, StockSpec1, StockSpec2, Settle, ...
    Maturity, OptSpec, Strike, Corr)
```

```
Price =
```

```
9.91
```

The 1:1 implied current crack spread between these two underlyings is \$23.14 per barrel.

```
CrackSpread = Price1 - Price2      % $/barrel
```

```
CrackSpread =
```

```
23.14
```

Suppose that by expiration day, June crude oil prices decrease to \$90.34 per barrel and gasoline prices rise to \$2.89 per gallon.

```
% The price changes cause the marketer's profit margin (the new implied crack
% spread) to increase from $23.14/barrel to $31.04/barrel:
```

$$\text{NewCrackSpread} = (2.89 * 42) - 90.34$$

$$\text{NewCrackSpread} =$$

$$31.04$$

Since the marketer purchased a long crack call on the \$20 call, the option is now in the money by \$11.04

$$(\text{NewCrackSpread} - \text{Strike})$$

$$\text{ans} =$$

$$11.04$$

The marketer paid \$9.91 from the long crack call, this protects the margin by \$1.13.

$$(\text{NewCrackSpread} - \text{Strike} - \text{Price})$$

$$\text{ans} =$$

$$1.13$$

This strategy provides the marketer protection during spread increase scenarios.

#### **Example 2: Creating a Floor with Crack Spread Options**

A refiner is interested in covering its fixed and operating costs, but still profit from a favorable move in the market. In March the May WTI crude oil futures is at \$99.43 per barrel and RBOB gasoline futures contract is at \$3.04 per gallon. The refiner believes that the spread between those commodities of \$28.25 per barrel is favorable. Of this, \$11 corresponds to operating and fixed costs, and \$17.25 is the net refining margin. The refiner's strategy is to sell the crack spread by selling 10 RBOB gasoline futures and buying 10 crude oil futures.

```
% Price and volatility of RBOB gasoline
Price1gallon = 3.04;           % $/gallon
Price1 = Price1gallon * 42;    % $/barrel
Vol1 = 0.35;
```

```

Div1 = 0.0783;

% Price and volatility of WTI crude oil
Price2 = 99.43;      % $/barrel
Vol2 = 0.38;
Div2 = 0.0571;

% The refiner purchases 10 May RBOB gasoline crack spread puts with a strike
% price of $25.

% Assume the following data
% Spread Option
Strike = 25;
OptSpec = 'put';
Settle = '01-March-2013';
Maturity = '01-May-2013';
Corr = 0.30;      % Correlation of underlying commodities

Define RateSpec and StockSpec

% Define RateSpec
Rate = 0.035;
Compounding = -1;
Basis = 1;
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
    'EndDates', Maturity, 'Rates', Rate, 'Compounding', ...
    Compounding, 'Basis', Basis);

% Define StockSpec for the two assets
StockSpec1 = stockspec(Vol1, Price1, 'Continuous', Div1);
StockSpec2 = stockspec(Vol2, Price2, 'Continuous', Div2);

Price the Crack Spread Option

% Use the function 'spreadbyfd' in the Financial Instruments Toolbox(TM)
% to price the American spread option using the finite difference method.

Price = spreadbyfd(RateSpec, StockSpec1, StockSpec2, Settle, ...
    Maturity, OptSpec, Strike, Corr, 'AmericanOpt', 1)

Price =

```

6.61

By expiration, if option is exercised, the refiner would have hedged the cost of purchasing 10000 barrels of crude oil with the revenue of selling 10000 barrels of RBOB gasoline. The futures contract represents 1000 barrels of crude oil and 42000 gallons of gasoline.

```
CostOfHedge = Price * 10000    % Option premium
```

```
% The hedge cost $66386 to implement and guarantees that neither a fall in  
% RBOB gasoline prices or an increase in WTI crude oil prices will diminish  
% the refining margin below $25.
```

```
ProfitMargin = 14 * 10000    %$  
CrackingMargin = ProfitMargin - CostOfHedge
```

```
% This strategy allows a cracking margin of $73613.
```

```
CostOfHedge =
```

```
66122.24
```

```
ProfitMargin =
```

```
140000.00
```

```
CrackingMargin =
```

```
73877.76
```

Another strategy for the refiner could be to buy the \$22 puts at a price of \$5.38.

```
StrikeNew = 22;
```

```
PriceNew = spreadbyfd(RateSpec, StockSpec1, StockSpec2, Settle, ...  
                    Maturity, OptSpec, StrikeNew, Corr, 'AmericanOpt', 1)
```

```
% This time the hedge would have cost $53823, but it also guarantees a $11  
% per barrel or $56176 cracking margin.
```

```
NewCostOfHedge = PriceNew * 10000    % Option premium
```

```
NewProfitMargin = 11 * 10000
CrackingMargin = NewProfitMargin - NewCostOfHedge
```

```
PriceNew =
    5.36
```

```
NewCostOfHedge =
    53570.97
```

```
NewProfitMargin =
    110000.00
```

```
CrackingMargin =
    56429.03
```

### Example 3: Using Collars to Reduce the Cost of Hedging

A refiner is concerned about its cost of hedging and decides to use a collar strategy. In April the crack spread is trading at \$4.23 per barrel. The refiner is not convinced to lock in this margin, but also wants to protect against price changes causing the refinery margin to decrease less than \$4 per barrel.

```
% Price and volatility of heating oil
Price1gallon = 2.52;      % $/gallon
Price1 = Price1gallon * 42; % $/barrel
Vol1 = 0.38;
Div1 = 0.0762;
```

```
% Price and volatility of WTI crude oil
Price2 = 101.61;      % $/barrel
Vol2 = 0.34;
Div2 = 0.1169;
```

```
% To accomplish the collar strategy the refiner sells a call spread option
% with a strike of $4.50 and uses the premium income to offset the cost of
```

```
% purchasing a put spread option with a strike of $4. This allows the
% refiner to benefit if market prices move up and protects it if market
% prices move down.
```

```
% Assume the following data
```

```
Strike = [4.50;4];
OptSpec = {'call';'put'};
Settle = '01-April-2013';
Maturity = '01-June-2013';
Corr = 0.35;          % Correlation of underlying commodities
```

```
Define RateSpec and StockSpec
```

```
% Define RateSpec
```

```
Rate = 0.035;
Compounding = -1;
Basis = 1;
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
    'EndDates', Maturity, 'Rates', Rate, 'Compounding', ...
    Compounding, 'Basis', Basis);
```

```
% Define StockSpec for the two assets
```

```
StockSpec1 = stockspec(Vol1, Price1, 'Continuous', Div1);
StockSpec2 = stockspec(Vol2, Price2, 'Continuous', Div2);
```

```
Price the Crack Spread Options
```

```
% Use the function 'spreadbybjs' in the Financial Instruments Toolbox(TM) to
% price the spread options using the Bjerksund and Stensland model.
```

```
Price = spreadbybjs(RateSpec, StockSpec1, StockSpec2, Settle, ...
    Maturity, OptSpec, Strike, Corr)
```

```
% The collar strategy allows the refiner to reduced the cost of the hedge
% to $0.63:
```

```
% CostOfHedge = Premium of Call - Premium of Put
CostOfHedge = Price(1) - Price(2)
```

```
Price =
```

```
7.06
6.43
```

CostOfHedge =

0.63

The refiner is protected if the crack spread narrows to less than \$4. If the crack spread widens to more than \$4.50, the refiner will not benefit over this amount if he has hedged 100% of all its market exposure.

```
set(0, 'format', OldFormat);
```

## Pricing Swing Options using the Longstaff-Schwartz Method

This example shows how to price a swing option using a Monte Carlo simulation and the Longstaff-Schwartz method [6]. A risk-neutral simulation of the underlying natural gas price is conducted using a mean-reverting model. The simulation results are used to price a swing option based on the Longstaff-Schwartz method. This approach uses a regression technique to approximate the continuation value of the option. A comparison is made between a polynomial and spline basis to fit the regression. Finally, the resulting prices are analyzed against lower and upper price boundaries derived from standard European and American options.

### Overview of Swing Options

Swing options are popular financial instruments in the energy market, which provide flexibility in the volume of the delivered asset. In order for energy consumers to protect themselves against fluctuations in energy prices, they want to lock in a price by purchasing a forward contract, called the baseload forward contract. However, consumers do not know exactly how much energy will be used in the future, and energy commodities such as electricity and gas cannot easily be stored. Therefore, the consumer wants the flexibility to change the amount of energy that is delivered at each delivery date. Swing options provide this flexibility. Thus, the full contract is composed of two parts: the baseload forward contract, and the swing option component.

Swing options are generally over-the-counter (OTC) contracts that can be highly customized. Therefore, there are many different types of constraints and penalties (see [5] for more details). In this example, a swing option is priced where the only constraint is the daily volume, which is known as the Daily Contract Quantity (DCQ). When a swing right is exercised, the volume cannot go below the minimum DCQ ( $\text{minDCQ}$ ), or go above the maximum DCQ ( $\text{maxDCQ}$ ).

There are several methods to price swing options, such as finite differences, simulation, and dynamic programming based on trees [5]. This example uses the simulation based approach with the Longstaff-Schwartz method. The benefit of the simulation based approach is that the dynamics used to simulate the underlying asset price is separated from the pricing algorithm. In the finite difference and tree based methods, the pricing algorithm must be changed in order to consider pricing with a different underlying price dynamic.

### Risk-Neutral Simulation of Natural Gas Price



In this example, natural gas is used as the underlying asset with the following mean-reverting dynamic [8]:

$$dS_t = \kappa(\mu - \log(S_t))S_t dt + \sigma S_t dW_t$$

where  $W_t$  is a standard Brownian motion. Applying Ito's Lemma to the logarithm of the price leads to an Orstein-Uhlenbeck process:

$$dX_t = \kappa(\theta - X_t)dt + \sigma dW_t$$

where  $X_t = \log(S_t)$ ,  $\kappa > 0$ , and  $\theta$  is defined as:

$$\theta = \mu - \frac{\sigma^2}{2\kappa}$$

$\theta$  is the mean-reversion level that determines the value at which the simulated values will revert to in the long run.  $\kappa$  is the mean-reversion speed that determines how fast this reversion occurs.  $\sigma$  is the volatility of  $X$ . We first proceed by simulating the logarithm of the price. Afterwards, the exponential of the simulated values are taken to obtain the prices.

The length of the simulation is for a one year period, with the initial price of 3.9 dollars per MMBtu. The Monte Carlo simulation is conducted for 1,000 trials, with daily periods. In practice, these parameters are calibrated against market data. In this example,  $\kappa = 1.2$ ,  $\theta = 1.7$ , and  $\sigma = 59\%$ . The HWV object from the Financial Toolbox™ is used to simulate the mean-reverting dynamics of the natural gas price.

```
% Settlement date
Settle = '01-Jun-2014';

% Maturity Date
Maturity = '01-Jun-2015';

% Actual/Actual basis
Basis = 0;

% Initial log(price in $/MMBtu)
X0 = log(3.9);
```

```
% Volatility of log(price)
Sigma = 0.59;

% Number of trials in the Monte Carlo simulation
NumTrials = 1000;

% Number of periods (daily)
NumPeriods = daysdif(Settle, Maturity, Basis);

% Daily time step
dt = 1/NumPeriods;

% Mean reversion speed of log(price)
Kappa = 1.2;

% Mean reversion level of log(price)
Theta = 1.7;

% Create HWV object
hwvobj = hwv(Kappa, Theta, Sigma, 'StartState', X0);
```

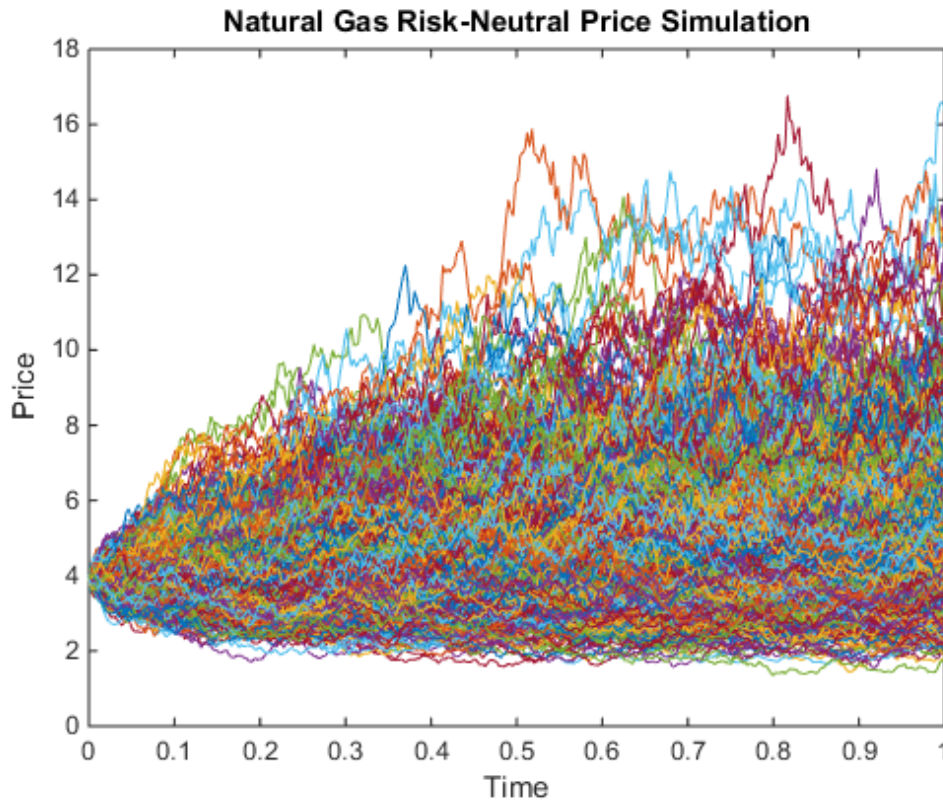
The simulation is run and plotted below.

```
% Set random number generator seed
savedState = rng(0, 'twister');

% Simulate gas prices
[Paths, Times] = hwvobj.simBySolution(NumPeriods, 'NTRIALS', NumTrials, ...
    'DeltaTime', dt);
Paths = squeeze(exp(Paths));

% Restore random number generator state
rng(savedState);

% Plot paths
figure;
plot(Times, Paths);
title('Natural Gas Risk-Neutral Price Simulation');
xlabel('Time');
ylabel('Price');
```



In this example, natural gas is used as the underlying asset with a mean-reverting dynamic. However, the Longstaff-Schwartz algorithm can be used for other underlying assets, such as electricity, with any underlying price dynamic.

### Pricing the Swing Option

We consider a swing option with five swing rights at the strike of \$4.69/MMBtu, which can be exercised daily between the day after the settlement date and the maturity date. The Daily Contract Quantity (DCQ) is 10,000 MMBtu, which is the average amount of natural gas that the consumer expects to purchase on a given day. The consumer has the flexibility to reduce the purchase amount (downswing) in one day to the minimum DCQ of 2,500 MMBtu, or increase the purchase (upswing) to 15,000 MMBtu. The continuously compounded annual risk-free rate is 1%.

RATESPEC is used to represent the interest-rate term structure. For the sake of simplicity, we consider a flat interest-rate term structure in this example. The values of RATESPEC can be modified to accommodate any interest-rate curve. The function HSWINGBYLS in this example assumes a daily exercise if the ExerciseDates input is empty.

```
% Define RateSpec
rfrate = 0.01;
Compounding = -1;
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
                    'EndDates', Maturity, 'Rates', rfrate, ...
                    'Compounding', Compounding, 'Basis', Basis);

% Daily exercise
% hswingbyls assumes daily exercise for empty ExerciseDates
ExerciseDates = [];

% Number of swings
NumSwings = 5;

% Daily Contract Quantity in MMBtu
DCQ = 10000;

% Minimum DCQ constraint in MMBtu
minDCQ = 2500;

% Maximum DCQ constraint in MMBtu
maxDCQ = 15000;

% Strike
Strike = 4.69;
```

The Longstaff-Schwartz method is a backward iteration algorithm, which steps backward in time from the maturity date. At each exercise date, the algorithm approximates the continuation value, which is the value of the option if it is not exercised. This is done by fitting a regression against the values of the simulated prices and the discounted future value of the option at the next exercise date. The future value of the option is known as the algorithm moves backward in time. The continuation value is compared to the sum of the payoff from immediate exercise (a downswing or upswing) and the continuation value of a swing option with one less swing right. If this sum is smaller, the option holder's optimal strategy is to not exercise on that date. The function HSWINGBYLS in this example uses this method to determine the optimal exercise strategy and the price for swing options [1,2,7].

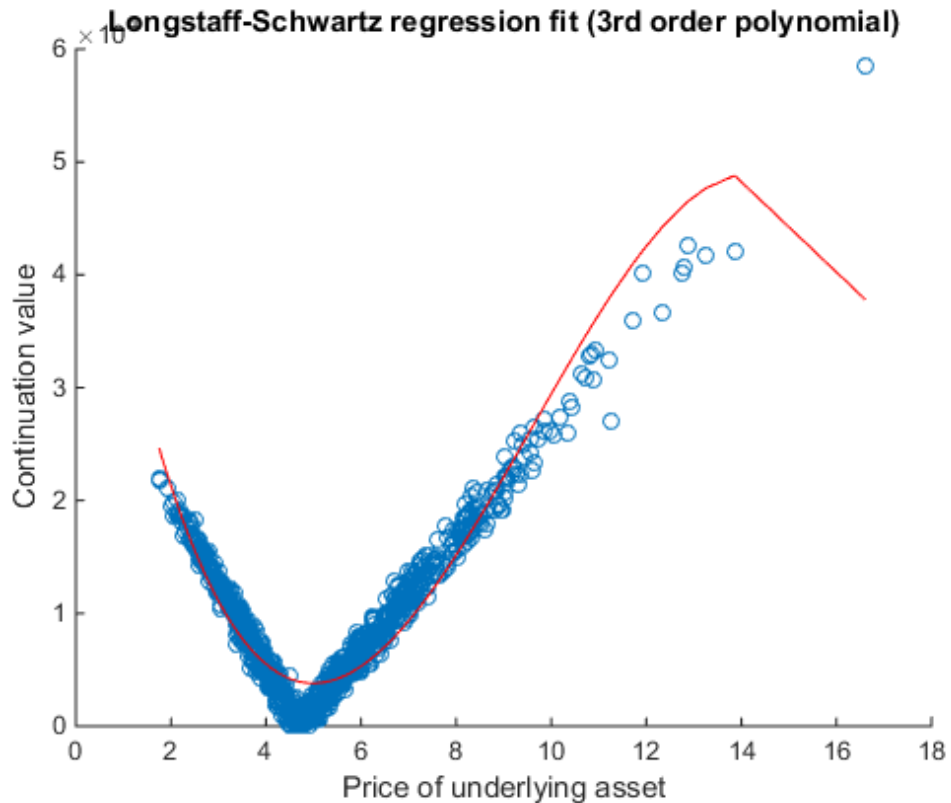
As discussed earlier, the only constraint considered in this example is the minimum and maximum DCQ. In this case, the optimal early exercise strategy is of a bang-bang type. This means that when it is optimal to upswing or downswing at a certain exercise date, the option holder should always exercise at the maximum or minimum DCQ to maximize profit. The bang-bang exercise would not be the optimal strategy if, for example, there is a terminal penalty based on volume. The pricing algorithm would then need to additionally keep track of all possible volume levels, which significantly adds to the runtime performance cost.

First, the swing option is priced using a 3rd order polynomial to fit the regression of the Longstaff-Schwartz method. The function HSWINGBYLS also generates a plot of the regression between the underlying price and the continuation value at the exercise date before maturity.

```
% Price swing option using 3rd order polynomial to fit Longstaff-Schwartz
% regression
tic;
useSpline = false;
SwingPrice = hswingbyls(Paths, Times, RateSpec, Settle, Maturity, ...
    Strike, ExerciseDates, NumSwings, DCQ, minDCQ, maxDCQ, useSpline, ...
    [], true)
lsPolyTime = toc;

SwingPrice =

    5.6943e+04
```



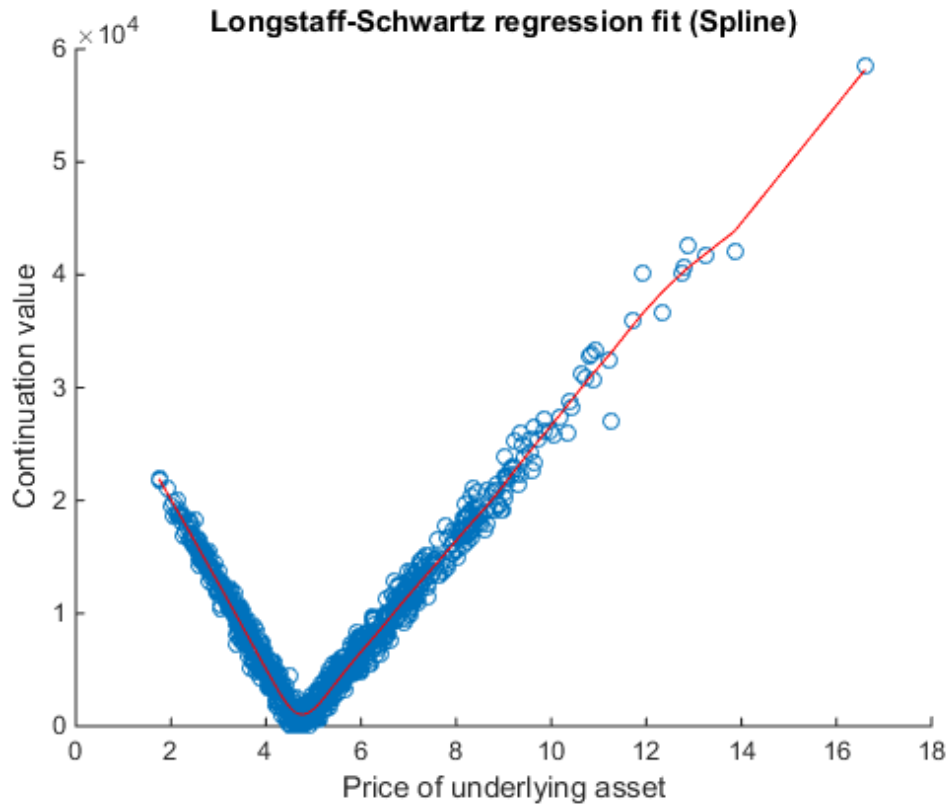
The above plot of the regression fit shows that the 3rd order polynomial does not fit the continuation value perfectly, especially near the hinge and at the extreme points. We now use the `CSAPS` function to fit the regression using a cubic smoothing spline with a smoothing parameter of 0.7. The Curve Fitting Toolbox™ is required to run the remainder of the example.

```
% Price swing option using smoothed splines to fit Longstaff-Schwartz
% regression
tic;
useSpline = true;
smoothingParam = 0.7;
SwingPriceSpline = hswingbyls(Paths, Times, RateSpec, Settle, Maturity, ...
    Strike, ExerciseDates, NumSwings, DCQ, minDCQ, maxDCQ, useSpline, ...
    smoothingParam, true)
```

```
lsSplineTime = toc;
```

```
SwingPriceSpline =
```

```
6.0729e+04
```



The plot of the regression shows that the cubic smoothing spline has a better fit against the data, thus obtaining a more accurate value for the continuation values. However, the below comparison shows that using a cubic smoothing spline takes longer than a 3rd order polynomial.

```
% Print comparison of running times
```

```
fprintf('Comparison of running times:\n\n');
fprintf('3rd order polynomial: %.2f sec\n', lsPolyTime);
fprintf('Spline           : %.2f sec\n\n', lsSplineTime);
```

Comparison of running times:

```
3rd order polynomial: 7.07 sec
Spline           : 16.30 sec
```

Also, it is important to note that the price represents solely the optionality component. Hence, the price of the baseload forward contract is not included in the above calculated price. Because we used a fixed strike price, the baseload contract has a non-zero value, which can be calculated by:

$$BaseLoadPrice = \sum_{i=1}^N e^{-rt_i} E(S_{t_i} - K)$$

where  $t_i, i = 1, \dots, N$ , are the exercise dates (see [3] for more details). The full price of the contract including the baseload and the swing option is calculated below using the swing option price from the smoothed cubic spline.

```
% Obtain discount factors
RS2 = intenvset(RateSpec, 'StartTimes', 0, 'EndTimes', Times(2:end));
D = intenvget(RS2, 'Disc');

% Calculate baseload price
BaseLoadPrice = DCQ.*mean(Paths(2:end,:) - Strike, 2)' * D;

% Calculate full contract price, based on results from cubic spline LS
FullContractPrice = BaseLoadPrice + SwingPriceSpline
```

```
FullContractPrice =
    1.2479e+05
```

#### Price Bounds

A lower bound for the swing option is a strip of European options, and the upper bound is a strip of American options [4]. Compared to European options, swing options have an early exercise premium at each exercise date, thus the price should be higher. The



price is lower than the American option strips, because only a single swing right can be exercised at each exercise date. More than one strip can be exercised in a single day using American options.

The prices for the strips of the lower and upper bounds are calculated below to check that the swing option prices are within these bounds. The European strip prices are calculated against the last five exercise dates.

```
% Obtain discount factor for the last NumSwings exercise dates
D = D(end-NumSwings+1:end);

% European lower bound
idx = size(Paths, 1):-1:(size(Paths, 1) - NumSwings + 1);
putEuro = D'*mean(max(Strike - Paths(idx,:), 0),2);
callEuro = D'*mean(max(Paths(idx,:) - Strike, 0),2);
lowerBound = ((DCQ-minDCQ).*putEuro+(maxDCQ-DCQ).*callEuro);

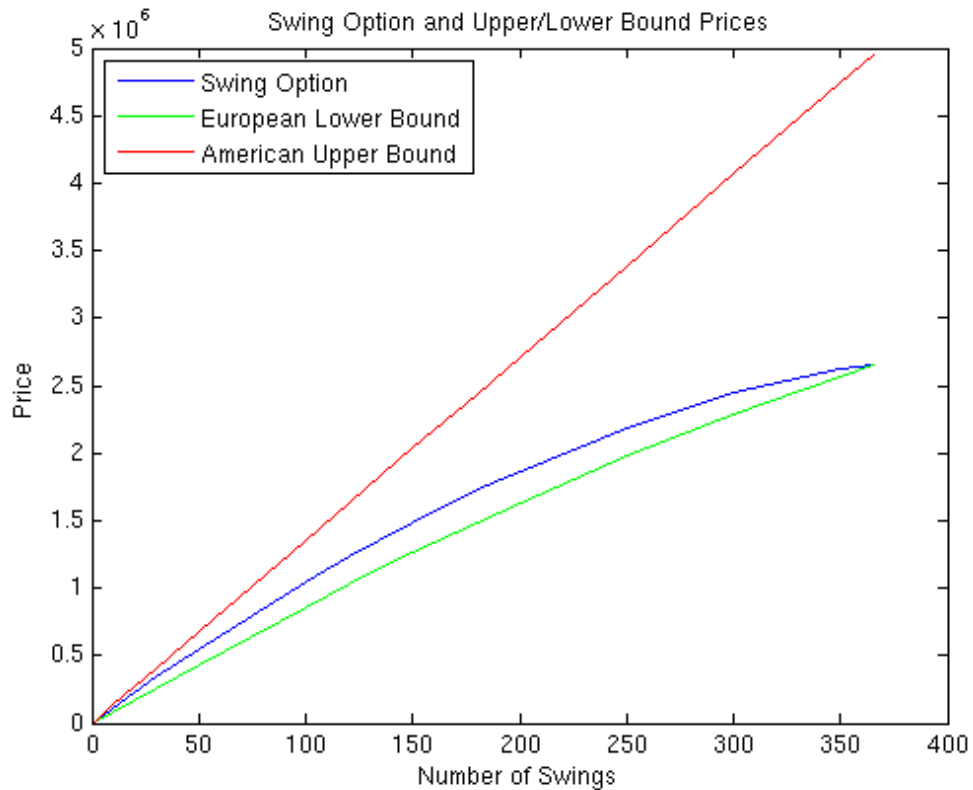
% American upper bound
[putAmer, callAmer] = hamericanPrice(Paths, Times, RateSpec, Strike);
upperBound = NumSwings.*((DCQ-minDCQ).*putAmer+(maxDCQ-DCQ).*callAmer);

% Print price and lower/upper bounds
fprintf('Comparison to lower and upper bounds:\n\n');
fprintf('Lower bound (European) : %.2f\n', lowerBound);
fprintf('Swing Option Price      : %.2f\n', SwingPriceSpline);
fprintf('Upper bound (American) : %.2f\n\n', upperBound);

Comparison to lower and upper bounds:

Lower bound (European) : 44412.14
Swing Option Price      : 60729.00
Upper bound (American) : 68181.42
```

The prices calculated using the Longstaff-Schwartz algorithm are within the lower and upper bounds. The below plot shows a comparison between the swing option and the upper and lower bounds as the number of swings increases, ceteris paribus. When the number of swings is one, the swing option is equivalent to an American option. In the case of daily exercise opportunity (`NumSwings = 365`), the swing option is equivalent to the strip of European options with daily maturity.



### Conclusion

The example shows the use of the Longstaff-Schwartz method to price a swing option where the underlying asset follows a mean-reverting dynamic. A 3rd order polynomial and a smoothed cubic spline are used to fit the regression in the Longstaff-Schwartz algorithm to approximate the continuation value. It was shown that the smoothed cubic spline fits the data better at the cost of slower performance. Finally, the resulting swing option prices were checked against the lower bound of a strip of European options and an upper bound of a strip of American options.

### References

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## Simulating Electricity Prices with Mean-Reversion and Jump-Diffusion

This example shows how to simulate electricity prices using a mean-reverting model with seasonality and a jump component. The model is calibrated under the real-world probability using historical electricity prices. The market price of risk is obtained from futures prices. A risk-neutral Monte Carlo simulation is conducted using the calibrated model and the market price of risk. The simulation results are used to price a Bermudan option with electricity prices as the underlying.

### Overview of the Model

Electricity prices exhibit jumps in prices at periods of high demand when additional, less efficient electricity generation methods are brought on-line to provide a sufficient supply of electricity. In addition, they have a prominent seasonal component, along with reversion to mean levels. Therefore, these characteristics should be incorporated into a model of electricity prices [2].

In this example, electricity price is modeled as:

$$\log(P_t) = f(t) + X_t$$

where  $P_t$  is the spot price of electricity. The logarithm of electricity price is modeled with two components:  $f(t)$  and  $X_t$ . The component  $f(t)$  is the deterministic seasonal part of the model, and  $X_t$  is the stochastic part of the model. Trigonometric functions are used to model  $f(t)$  as follows [3]:

$$f(t) = s_1 \sin(2\pi t) + s_2 \cos(2\pi t) + s_3 \sin(4\pi t) + s_4 \cos(4\pi t) + s_5$$

where  $s_i, i = 1, \dots, 5$  are constant parameters, and  $t$  is the annualized time factors. The stochastic component  $X_t$  is modeled as an Ornstein-Uhlenbeck process (mean-reverting) with jumps:

$$dX_t = (\alpha - \kappa X_t)dt + \sigma dW_t + J(\mu_J, \sigma_J)d\Pi(\lambda)$$

The parameters  $\alpha$  and  $\kappa$  are the mean-reversion parameters. Parameter  $\sigma$  is the volatility, and  $W_t$  is a standard Brownian motion. The jump size is  $J(\mu_J, \sigma_J)$ , with

normally distributed mean  $\mu_J$  and standard deviation  $\sigma_J$ . The Poisson process  $\Pi(\lambda)$  has a jump intensity of  $\lambda$ .

### Electricity Prices

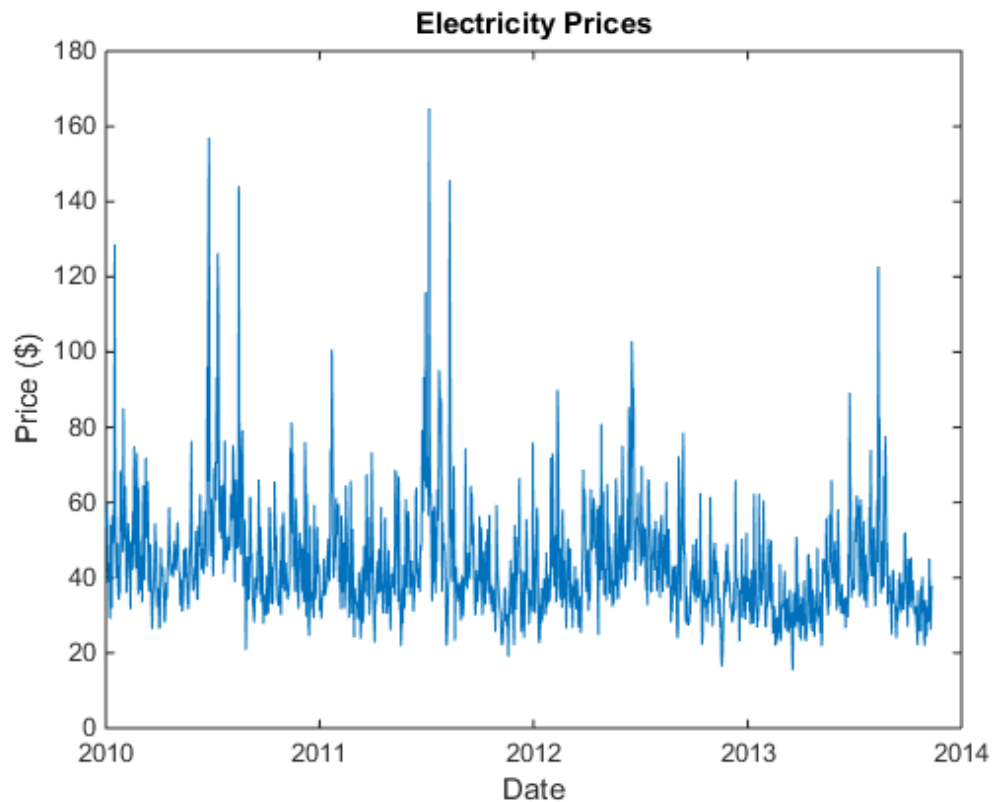
Sample electricity prices from January 1, 2010 to November 11, 2013 are loaded and plotted below. **Prices** contain the electricity prices, and **PriceDates** contain the dates associated with the prices. The logarithm of the prices and annual time factors are calculated.

```
% Load electricity prices and futures prices
load('electricity_prices.mat');

% Plot electricity prices
figure;
plot(PriceDates, Prices);
datetick();
title('Electricity Prices');
xlabel('Date');
ylabel('Price ($)');

% Obtain log of prices
logPrices = log(Prices);

% Obtain annual time factors from dates
PriceTimes = yearfrac(PriceDates(1), PriceDates);
```



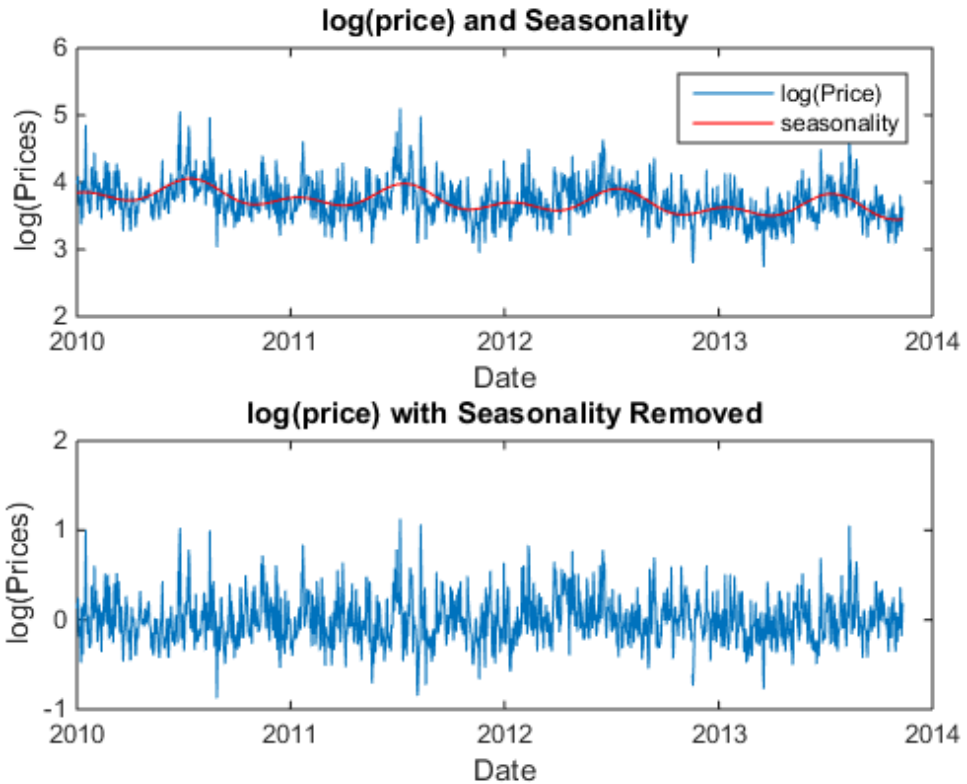
### Calibration

First, the deterministic seasonality part is calibrated using the least squares method. Since the seasonality function is linear with respect to the parameters  $s_i$ , the backslash operator (MLDIVIDE) is used. After the calibration, the seasonality is removed from the logarithm of price. The logarithm of price and seasonality trends are plotted below. Also, the de-seasonalized logarithm of price is plotted.

```
% Calibrate parameters for the seasonality model
seasonMatrix = @(t) [sin(2.*pi.*t) cos(2.*pi.*t) sin(4.*pi.*t) ...
    cos(4.*pi.*t) t ones(size(t, 1), 1)];
C = seasonMatrix(PriceTimes);
seasonParam = C \ logPrices;
```

```
% Plot log price and seasonality line
figure;
subplot(2, 1, 1);
plot(PriceDates, logPrices);
datetick();
title('log(price) and Seasonality');
xlabel('Date');
ylabel('log(Prices)');
hold on;
plot(PriceDates, C*seasonParam, 'r');
hold off;
legend('log(Price)', 'seasonality');

% Plot de-seasonalized log price
X = logPrices-C*seasonParam;
subplot(2, 1, 2);
plot(PriceDates, X);
datetick();
title('log(price) with Seasonality Removed');
xlabel('Date');
ylabel('log(Prices)');
```



The second stage is to calibrate the stochastic part. The model for  $X_t$  needs to be discretized in order to conduct the calibration. To discretize, we assume a Bernoulli process for the jump events. That is, there is at most one jump per day since we are calibrating against daily electricity prices. The discretized equation is:

$$X_t = \alpha\Delta t + \phi X_{t-1} + \sigma\xi$$

with probability  $(1 - \lambda\Delta t)$  and,

$$X_t = \alpha\Delta t + \phi X_{t-1} + \sigma\xi + \mu_J + \sigma_J\xi_J$$

with probability  $\lambda\Delta t$ , where  $\xi$  and  $\xi_J$  are independent standard normal random variables, and  $\phi = 1 - \kappa\Delta t$ . The density function of  $X_t$  given  $X_{t-1}$  is [1,4]:



$$f(X_t|X_{t-1}) = (\lambda\Delta t)N_1(X_t|X_{t-1}) + (1 - \lambda\Delta t)N_2(X_t|X_{t-1})$$

$$N_1(X_t|X_{t-1}) = (2\pi(\sigma^2 + \sigma_J^2))^{-\frac{1}{2}} \exp\left(\frac{-(X_t - \alpha\Delta t - \phi X_{t-1} - \mu_J)^2}{2(\sigma^2 + \sigma_J^2)}\right)$$

$$N_2(X_t|X_{t-1}) = (2\pi\sigma^2)^{-\frac{1}{2}} \exp\left(\frac{-(X_t - \alpha\Delta t - \phi X_{t-1})^2}{2\sigma^2}\right)$$

The parameters  $\theta = \{\alpha, \phi, \mu_J, \sigma^2, \sigma_J^2, \lambda\}$  can be calibrated by minimizing the negative log likelihood function:

$$\min_{\theta} - \sum_{t=1}^T \log(f(X_t|X_{t-1}))$$

$$\text{subject to } \phi < 1, \sigma^2 > 0, \sigma_J^2 > 0, 0 \leq \lambda\Delta t \leq 1$$

The first inequality constraint,  $\phi < 1$ , is equivalent to  $\kappa > 0$ . The volatilities  $\sigma$  and  $\sigma_J$  must be positive. In the last inequality,  $\lambda\Delta t$  is between 0 and 1, because it represents the probability of a jump occurring in  $\Delta t$  time. In this example, we take  $\Delta t$  to be one day. Consequently, there is at most 365 jumps in one year. The function MLE from the Statistics Toolbox™ is well suited to solve the above maximum likelihood problem.

```
% Prices at t, X(t)
Pt = X(2:end);

% Prices at t-1, X(t-1)
Pt_1 = X(1:end-1);

% Discretization for daily prices
dt = 1/365;

% PDF for discretized model
mrjpdf = @(Pt, a, phi, mu_J, sigmaSq, sigmaSq_J, lambda) ...
    lambda.*exp((- (Pt-a-phi.*Pt_1-mu_J).^2) ./ ...
    (2.*(sigmaSq+sigmaSq_J))).*(1/sqrt(2.*pi.*(sigmaSq+sigmaSq_J))) + ...
    (1-lambda).*exp((- (Pt-a-phi.*Pt_1).^2) / (2.*sigmaSq)).* ...
    (1/sqrt(2.*pi.*sigmaSq));

% Constraints:
% phi < 1 (k > 0)
% sigmaSq > 0
% sigmaSq_J > 0
% 0 <= lambda <= 1
lb = [-Inf -Inf -Inf 0 0 0];
ub = [Inf 1 Inf Inf Inf 1];
```

```
% Initial values
x0 = [0 0 0 var(X) var(X) 0.5];

% Solve maximum likelihood
params = mle(Pt, 'pdf', mrjpdf, 'start', x0, 'lowerbound', lb, 'upperbound', ub, ...
            'optimfun', 'fmincon');

% Obtain calibrated paramters
alpha = params(1)/dt
kappa = params(2)/dt
mu_J = params(3)
sigma = sqrt(params(4)/dt)
sigma_J = sqrt(params(5))
lambda = params(6)/dt

alpha =
    -20.1060

kappa =
    176.7465

mu_J =
    0.2044

sigma =
    3.0930

sigma_J =
    0.2659

lambda =
    98.3358
```

## Monte Carlo Simulation

The calibrated parameters and the discretized model allow us to simulate electricity prices under the real-world probability. The simulation is conducted for approximately 2 years with 10,000 trials. It exceeds 2 years to include all the dates in the last month of simulation. This is because the expected simulation prices for the futures contract expiry date is required in the next section to calculate the market price of risk. The seasonality is added back on the simulated paths. A plot for a single simulation path is plotted below.

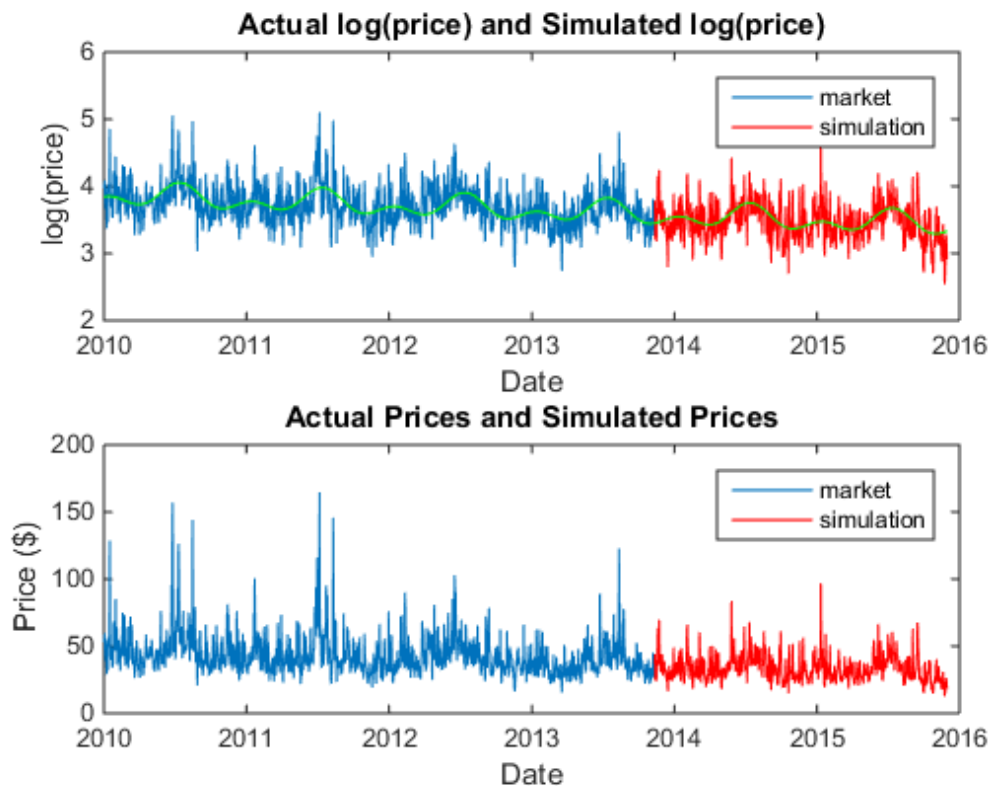
```
rng default;

% Simulate for about 2 years
nPeriods = 365*2+20;
nTrials = 10000;
n1 = randn(nPeriods,nTrials);
n2 = randn(nPeriods, nTrials);
j = binornd(1, lambda*dt, nPeriods, nTrials);
SimPrices = zeros(nPeriods, nTrials);
SimPrices(1,:) = X(end);
for i=2:nPeriods
    SimPrices(i,:) = alpha*dt + (1-kappa*dt)*SimPrices(i-1,:) + ...
        sigma*sqrt(dt)*n1(i,:) + j(i,:).*(mu_J+sigma_J*n2(i,:));
end

% Add back seasonality
SimPriceDates = daysadd(PriceDates(end),0:nPeriods-1);
SimPriceTimes = yearfrac(PriceDates(1), SimPriceDates);
CSim = seasonMatrix(SimPriceTimes);
logSimPrices = SimPrices + repmat(CSim*seasonParam,1,nTrials);

% Plot logarithm of Prices and simulated logarithm of Prices
figure;
subplot(2, 1, 1);
plot(PriceDates, logPrices);
hold on;
plot(SimPriceDates(2:end), logSimPrices(2:end,1), 'red');
seasonLine = seasonMatrix([PriceTimes; SimPriceTimes(2:end)])*seasonParam;
plot([PriceDates; SimPriceDates(2:end)], seasonLine, 'green');
hold off;
datetick();
title('Actual log(price) and Simulated log(price)');
xlabel('Date');
```

```
ylabel('log(price)');  
legend('market', 'simulation');  
  
% Plot prices and simulated prices  
PricesSim = exp(logSimPrices);  
subplot(2, 1, 2);  
plot(PriceDates, Prices);  
hold on;  
plot(SimPriceDates, PricesSim(:,1), 'red');  
hold off;  
datetick();  
title('Actual Prices and Simulated Prices');  
xlabel('Date');  
ylabel('Price ($)');  
legend('market', 'simulation');
```



## Calibration of the Market Price of Risk

Up to this point, the parameters were calibrated under the real-world probability. However, in order to price options, we need the simulation under the risk-neutral probability. To obtain this, we calculate the market price of risk from futures prices to derive the risk-neutral parameters. Suppose that there are monthly futures contracts available on the market, which are settled daily during the contract month. For example, such futures for the PJM electricity market is listed on the Chicago Mercantile Exchange [5].

The futures are settled daily during the contract month. Therefore, we obtain daily futures values by assuming the futures value is constant for the contract month. The expected futures prices from the real-world measure are also needed to calculate the market price of risk. This can be obtained from the simulation conducted in the previous section.

```
% Obtain daily futures prices
FutPricesDaily = zeros(size(SimPriceDates));
for i=1:nPeriods
    idx = find(year(SimPriceDates(i)) == year(FutExpiry) & ...
              month(SimPriceDates(i)) == month(FutExpiry));
    FutPricesDaily(i) = FutPrices(idx);
end

% Calculate expected futures price under real-world measure
SimPricesExp = mean(PricesSim, 2);
```

To calibrate the market price of risk against market futures values, we use the following equation:

$$\log\left(\frac{F_t}{E_t}\right) = -\sigma e^{-kt} \int_0^t e^{ks} m_s ds$$

where  $F_t$  is the observed futures value at time  $t$ , and  $E_t$  is the expected value under the real-world measure at time  $t$ . The equation was obtained using the same methodology as described in [3]. We assume that the market price of risk is fully driven by the Brownian motion. The market price of risk,  $m_t$ , can be solved by discretizing the above equation and solving a system of linear equations.

```
% Setup system of equations
t0 = yearfrac(PriceDates(1), FutValuationDate);
```

```

tz = SimPriceTimes-t0;
b = -log(FutPricesDaily(2:end) ./ SimPricesExp(2:end)) ./ ...
    (sigma.*exp(-kappa.*tz(2:end)));
A = (1/kappa).*(exp(kappa.*tz(2:end)) - exp(kappa.*tz(1:end-1)));
A = tril(repmat(A', size(A,1), 1));

% Precondition to stabilize numerical inversion
P = diag(1./diag(A));
b = P*b;
A = P*A;

% Solve for market price of risk
riskPremium = A\b;

```

#### Simulation of Risk-neutral Prices

Once  $m_t$  is obtained, risk-neutral simulation can be conducted using the following dynamics:

$$X_t = \alpha\Delta t + \phi X_{t-1} - \sigma m_{t-1}\Delta t + \sigma\xi$$

with probability  $(1 - \lambda\Delta t)$  and

$$X_t = \alpha\Delta t + \phi X_{t-1} - \sigma m_{t-1}\Delta t + \sigma\xi + \mu_J + \sigma_J\xi_J$$

with probability  $\lambda\Delta t$ .

```

nTrials = 10000;
n1 = randn(nPeriods, nTrials);
n2 = randn(nPeriods, nTrials);
j = binornd(1, lambda*dt, nPeriods, nTrials);

SimPrices = zeros(nPeriods, nTrials);
SimPrices(1,:) = X(end);
for i=2:nPeriods
    SimPrices(i,:) = alpha*dt + (1-kappa*dt)*SimPrices(i-1,:) + ...
        sigma*sqrt(dt)*n1(i,:) - sigma*dt*riskPremium(i-1) + ...
        j(i,:).*(mu_J+sigma_J*n2(i,:));
end

% Add back seasonality

```

```

CSim = seasonMatrix(SimPriceTimes);
logSimPrices = SimPrices + repmat(CSim*seasonParam,1,nTrials);

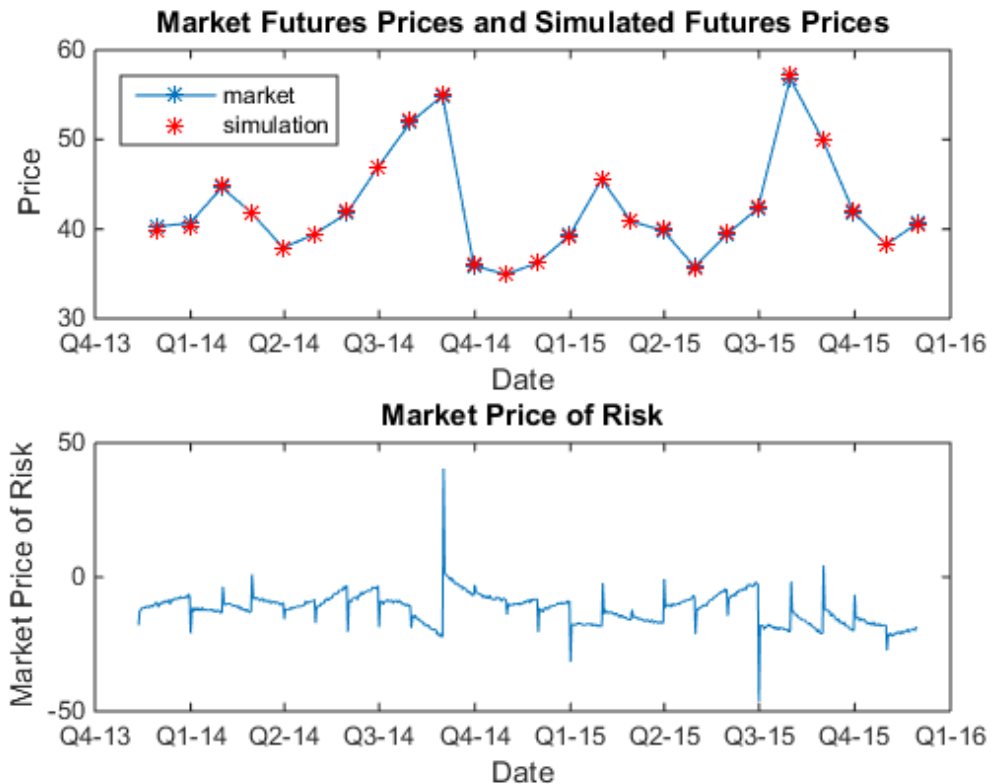
% Convert log(Price) to Price
PricesSim = exp(logSimPrices);
    
```

The expected values from the risk-neutral simulation are plotted against the market futures values. This confirms that the risk-neutral simulation closely reproduces the market futures values.

```

% Obtain expected values from the risk-neutral simulation
SimPricesExp = mean(PricesSim,2);
fexp = zeros(size(FutExpiry));
for i = 1:size(FutExpiry,1)
    idx = SimPriceDates == FutExpiry(i);
    if sum(idx)==1
        fexp(i) = SimPricesExp(idx);
    end
end

% Plot expected values from the simulation against market futures prices
figure;
subplot(2,1,1);
plot(FutExpiry, FutPrices(1:size(FutExpiry,1)),'-*');
hold on;
plot(FutExpiry, fexp, '*r');
datetick();
hold off;
title('Market Futures Prices and Simulated Futures Prices');
xlabel('Date');
ylabel('Price');
legend('market', 'simulation', 'Location', 'NorthWest');
subplot(2,1,2);
plot(SimPriceDates(2:end), riskPremium);
datetick();
title('Market Price of Risk');
xlabel('Date');
ylabel('Market Price of Risk');
    
```



### Pricing a Bermudan Option

The risk-neutral simulated values can be used as input into the function `OPTPRICEBYSIM` in the Financial Instruments Toolbox™ to price an European, Bermudan, or American option on electricity prices. Below, we price a two year Bermudan call option with two exercise opportunities. The first exercise is after one year, and the second is at the maturity of the option.

```
% Settle, maturity of option
Settle = FutValuationDate;
Maturity = addtodate(FutValuationDate, 2, 'year');

% Create interest rate term structure
riskFreeRate = 0.01;
```



```

Basis = 0;
Compounding = -1;
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
    'EndDates', Maturity, 'Rate', riskFreeRate, 'Compounding', ...
    Compounding, 'Basis', Basis);

% Cutoff simulation at maturity
endIdx = find(SimPriceDates == Maturity);
SimPrices = PricesSim(1:endIdx,:);
Times = SimPriceTimes(1:endIdx) - SimPriceTimes(1);

% Bermudan call option with strike 60, two exercise opportunities, after
% one year and at maturity.
OptSpec = 'call';
Strike = 60;
ExerciseTimes = [Times(366) Times(end)];
Price = optpricebysim(RateSpec, SimPrices, Times, OptSpec, Strike, ...
    ExerciseTimes)

Price =

    1.1588
    
```

## References

- [1] Escribano, Alvaro, Pena, Juan Ignacio, Villaplana, Pablo, Modeling Electricity Prices: International Evidence, Universidad Carlos III de Madrid, Working Paper 02-27, 2002.
- [2] Lucia, Julio J., Schwartz, Eduardo, Electricity Prices and Power Derivatives: Evidence from the Nordic Power Exchange, Review of Derivatives Research, Vol. 5, Issue 1, pp 5-50, 2002.
- [3] Seifert, Jan, Uhrig-Homburg, Marliese, Modelling Jumps in Electricity Prices: Theory and Empirical Evidence, Review of Derivatives Research, Vol. 10, pp 59-85, 2007.
- [4] Villaplana, Pablo, Pricing Power Derivatives: A Two-Factor Jump-Diffusion Approach, Universidad Carlos III de Madrid, Working Paper 03-18, 2003.
- [5] <http://www.cmegroup.com>

## Pricing Asian Options

This example shows how to price a European Asian option using four methods in the Financial Instruments Toolbox™: two closed form approximations (Levy and Kemna-Vorst), a lattice model (Cox-Ross-Rubinstein), and Monte Carlo simulation. All these methods involve some tradeoffs between numerical accuracy and computational efficiency. This example also demonstrates how variations in spot prices, volatility, and strike prices affect option prices on European Vanilla and Asian options.

### Overview of Asian Options

Asian options are securities with payoffs that depend on the average value of an underlying asset over a specific period of time. Underlying assets can be stocks, commodities, or financial indices.

Two types of Asian options are found in the market: average price options and average strike options. Average price options have a fixed strike value and the average used is the asset price. Average strike options have a strike equal to the average value of the underlying asset.

The payoff at maturity of an average price European Asian option is:

$\max(0, Savg - K)$  for a call

$\max(0, K - Savg)$  for a put

The payoff at maturity of an average strike European Asian option is:

$\max(0, St - Savg)$  for a call

$\max(0, Savg - St)$  for a put

where  $Savg$  is the average price of underlying asset,  $St$  is the price at maturity of underlying asset, and  $K$  is the strike price.

The average can be arithmetic or geometric.

### Pricing Asian Options Using Closed Form Approximations

The Financial Instruments Toolbox™ supports two closed form approximations for European Average Price options. The Levy model is based on the arithmetic mean of

the price of the underlying during the life of the option [1]. The Kemna-Vorst method provides a closed form pricing solution to geometric averaging options [2].

The pricing functions `asianbylevy` and `asianbykv` take an interest rate term structure and stock structure as inputs.

Consider the following example:

```
% Create RateSpec from the interest rate term structure
StartDates = '12-March-2014';
EndDates = '12-March-2020';
Rates = 0.035;
Compounding = -1;
Basis = 1;

RateSpec = intenvset('ValuationDate', StartDates, 'StartDates', StartDates, ...
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', ...
    Compounding, 'Basis', Basis);

% Define StockSpec with the underlying asset information
Sigma = 0.20;
AssetPrice = 100;

StockSpec = stockspec(Sigma, AssetPrice);

% Define the Asian option
Settle = '12-March-2014';
ExerciseDates = '12-March-2015';
Strike = 90;
OptSpec = 'call';

% Levy model approximation
PriceLevy = asianbylevy(RateSpec, StockSpec, OptSpec, Strike, Settle,...
    ExerciseDates);

% Kemna-Vorst closed form model
PriceKV = asianbykv(RateSpec, StockSpec, OptSpec, Strike, Settle,...
    ExerciseDates);

% Comparison of calculated prices for the geometric and arithmetic options
% using different closed form algorithms.
fprintf('Comparison of Asian Arithmetic and Geometric Prices:\n\n');
fprintf('Levy:           %f\n', PriceLevy);
fprintf('Kemna-Vorst:  %f\n', PriceKV);
```

Comparison of Asian Arithmetic and Geometric Prices:

Levy: 12.164734  
Kemna-Vorst: 11.862580

#### Computing Asian Options Prices Using the Cox-Ross-Rubinstein Model

In addition to closed form approximations, the Financial Instruments Toolbox™ supports pricing European Average Price options using CRR trees via the function `asianbycrr`.

The lattice pricing function `asianbycrr` takes an interest rate tree (`CRRTree`) and stock structure as inputs. We can price the previous options by building a `CRRTree` using the interest rate term structure and stock specification from the example above.

```
% Create the time specification of the tree
NPeriods = 20;
TreeValuationDate = '12-March-2014';
TreeMaturity = '12-March-2024';
TimeSpec = crrtimespec(TreeValuationDate, TreeMaturity, NPeriods);

% Build the tree
CRRTree = crrtree(StockSpec, RateSpec, TimeSpec);

% Price the European Asian option using the CRR lattice model.
% The function 'asianbycrr' computes prices of arithmetic and geometric
% Asian options.
AvgType = {'arithmetic'; 'geometric'};
AmericanOpt = 0;
PriceCRR20 = asianbycrr(CRRTree, OptSpec, Strike, Settle, ExerciseDates, ...
    AmericanOpt, AvgType);

% Increase the numbers of periods in the tree and compare results
NPeriods = 40;
TimeSpec = crrtimespec(TreeValuationDate, TreeMaturity, NPeriods);
CRRTree = crrtree(StockSpec, RateSpec, TimeSpec);

PriceCRR40 = asianbycrr(CRRTree, OptSpec, Strike, Settle, ExerciseDates, ...
    AmericanOpt, AvgType);

% Display prices
fprintf('Asian Prices using the CRR lattice model:\n\n');
fprintf('PriceArithmetic(CRR20): %f\n', PriceCRR20(1));
fprintf('PriceArithmetic(CRR40): %f\n', PriceCRR40(1));
fprintf('PriceGeometric (CRR20): %f\n', PriceCRR20(2));
```

```
fprintf('PriceGeometric (CRR40): %f\n', PriceCRR40(2));
```

Asian Prices using the CRR lattice model:

```
PriceArithmetic(CRR20): 11.934380
PriceArithmetic(CRR40): 12.047243
PriceGeometric (CRR20): 11.620899
PriceGeometric (CRR40): 11.732037
```

The results above compare the findings from calculating both geometric and arithmetic Asian options, using CRR trees with 20 and 40 levels. It can be seen that as the number of levels increases, the results approach the closed form solutions.

### Calculating Prices of Asian Options Using Monte Carlo Simulation

Another method to price European Average Price options with the Financial Instruments Toolbox™ is via Monte Carlo simulations.

The pricing function `asianbyls` takes an interest rate term structure and stock structure as inputs. The output and execution time of the Monte Carlo simulation depends on the number of paths (`NumTrials`) and the number of time periods per path (`NumPeriods`).

We can price the same options of previous examples using Monte Carlo.

```
% Simulation Parameters
```

```
NumTrials = 500;
NumPeriods = 200;
```

```
% Price the arithmetic option
```

```
PriceAMC = asianbyls(RateSpec, StockSpec, OptSpec, Strike, Settle,...
    ExerciseDates, 'NumTrials', NumTrials, ...
    'NumPeriods', NumPeriods);
```

```
% Price the geometric option
```

```
PriceGMC = asianbyls(RateSpec, StockSpec, OptSpec, Strike, Settle,...
    ExerciseDates, 'NumTrials', NumTrials, ...
    'NumPeriods', NumPeriods, 'AvgType', AvgType(2));
```

```
% Use the antithetic variates method to value the options
```

```
Antithetic = true;
PriceAMCAntithetic = asianbyls(RateSpec, StockSpec, OptSpec, Strike, Settle,...
    ExerciseDates, 'NumTrials', NumTrials, 'NumPeriods',...
    NumPeriods, 'Antithetic', Antithetic);
```

```

PriceGMCantithetic = asianbyls(RateSpec, StockSpec, OptSpec, Strike, Settle,...
    ExerciseDates,'NumTrials', NumTrials, 'NumPeriods',...
    NumPeriods, 'Antithetic', Antithetic,'AvgType', AvgType(2));

% Display prices
fprintf('Asian Prices using Monte Carlo Method:\n\n');
fprintf('Arithmetic Asian\n');
fprintf('Standard Monte Carlo:           %f\n', PriceAMC);
fprintf('Variate Antithetic Monte Carlo: %f\n\n', PriceAMCantithetic);
fprintf('Geometric Asian\n');
fprintf('Standard Monte Carlo:           %f\n', PriceGMC);
fprintf('Variate Antithetic Monte Carlo: %f\n', PriceGMCantithetic);

```

Asian Prices using Monte Carlo Method:

```

Arithmetic Asian
Standard Monte Carlo:           11.674673
Variate Antithetic Monte Carlo: 12.511805

```

```

Geometric Asian
Standard Monte Carlo:           11.758960
Variate Antithetic Monte Carlo: 12.069869

```

The use of variate antithetic accelerates the conversion process by reducing the variance.

We can create a plot to display the difference between the geometric Asian price using the Kemna-Vorst model, standard Monte Carlo and antithetic Monte Carlo.

```

nTrials = [50:5:100 110:10:250 300:50:500 600:100:2500]';
PriceKVVector = PriceKV * ones(size(nTrials));
PriceGMCVector = nan(size(nTrials));
PriceGMCantitheticVector = nan(size(nTrials));
TimeGMCantitheticVector = nan(length(nTrials),1);
TimeGMCVector = nan(length(nTrials),1);
idx = 1;
for iNumTrials = nTrials'
    PriceGMCVector(idx) = asianbyls(RateSpec, StockSpec, OptSpec, Strike, Settle,...
        ExerciseDates,'NumTrials', iNumTrials, 'NumPeriods',...
        NumPeriods, 'AvgType', AvgType(2));

    PriceGMCantitheticVector(idx) = asianbyls(RateSpec, StockSpec, OptSpec, Strike, Settle,...
        ExerciseDates,'NumTrials', iNumTrials, 'NumPeriods',...
        NumPeriods, 'Antithetic', Antithetic,'AvgType', AvgType(2));

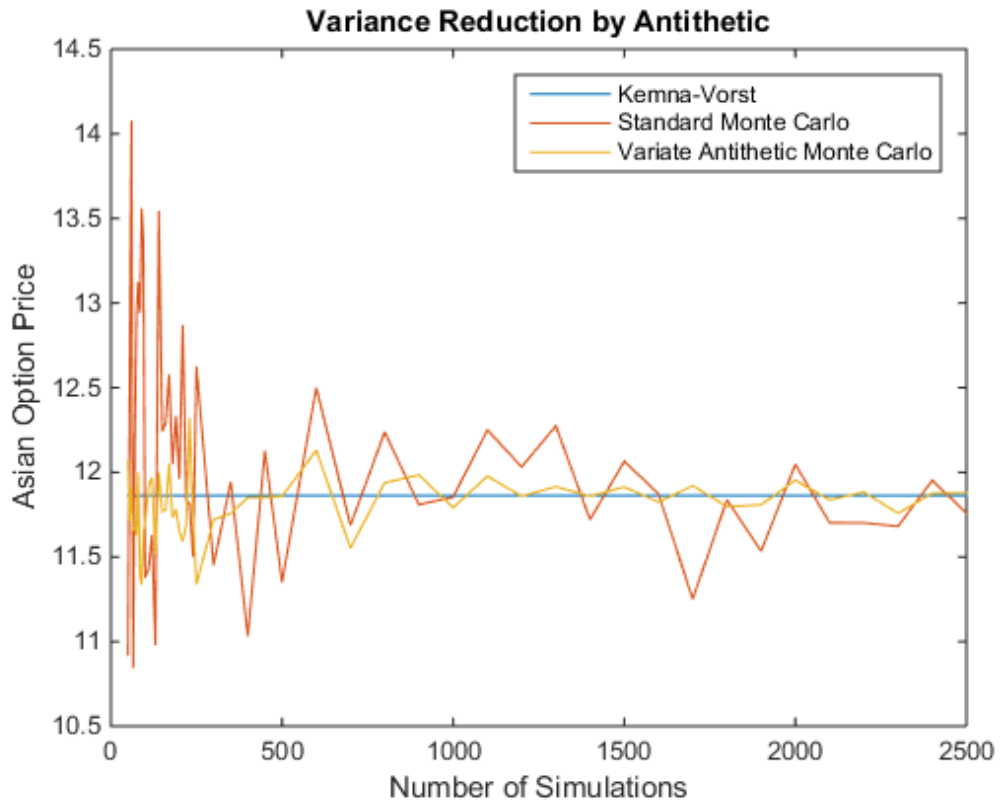
    idx = idx+1;
end

```

```

figure('menubar', 'none', 'numbertitle', 'off')
plot(nTrials, [PriceKVVector PriceGMCVector PriceGMCantitheticVector]);
title 'Variance Reduction by Antithetic'
xlabel 'Number of Simulations'
ylabel 'Asian Option Price'
legend('Kemna-Vorst', 'Standard Monte Carlo', 'Variate Antithetic Monte Carlo ', 'locat

```



The graph above shows how oscillation in simulated price is reduced through the use of variate antithetic.

### Compare Pricing Model Results

Prices calculated by the Monte Carlo method will vary depending on the outcome of the simulations. Increase NumTrials and analyze the results.

```

NumTrials = 2000;

PriceAMCAntithetic2000 = asianbyls(RateSpec, StockSpec, OptSpec, Strike, Settle, Exerc...
    'NumTrials', NumTrials, 'NumPeriods', NumPeriods, 'Antithetic', Antithetic);

PriceGMCAntithetic2000 = asianbyls(RateSpec, StockSpec, OptSpec, Strike, Settle,...
    ExerciseDates, 'NumTrials', NumTrials, 'NumPeriods',...
    NumPeriods, 'Antithetic', Antithetic, 'AvgType', AvgType(2));

% Comparison of calculated Asian call prices
fprintf('Comparison of Asian call prices:\n\n');
fprintf('Arithmetic Asian\n');
fprintf('Levy: %f\n', PriceLevy);
fprintf('Cox-Ross-Rubinstein: %f\n', PriceCRR40(1));
fprintf('Monte Carlo(500 trials): %f\n', PriceAMCAntithetic);
fprintf('Monte Carlo(2000 trials): %f\n\n', PriceAMCAntithetic2000);
fprintf('Geometric Asian\n');
fprintf('Kemna-Vorst: %f\n', PriceKV);
fprintf('Cox-Ross-Rubinstein: %f\n', PriceCRR40(2));
fprintf('Monte Carlo(500 trials): %f\n', PriceGMCAntithetic);
fprintf('Monte Carlo(2000 trials): %f\n', PriceGMCAntithetic2000);

```

Comparison of Asian call prices:

```

Arithmetic Asian
Levy: 12.164734
Cox-Ross-Rubinstein: 12.047243
Monte Carlo(500 trials): 12.511805
Monte Carlo(2000 trials): 11.998253

Geometric Asian
Kemna-Vorst: 11.862580
Cox-Ross-Rubinstein: 11.732037
Monte Carlo(500 trials): 12.069869
Monte Carlo(2000 trials): 11.864606

```

The table above contrast the results from closed approximation models against price simulations implemented via CRR trees and Monte Carlo.

#### Asian and Vanilla Call Options

Asian options are popular instruments since they tend to be less expensive than comparable Vanilla calls and puts. This is because the volatility in the average value of an underlier tends to be lower than the volatility of the value of the underlier itself.



The Financial Instruments Toolbox™ supports several algorithms for pricing vanilla options. Let's compare the price of Asian options against their Vanilla counterpart.

First, we compute the price of a European Vanilla Option using the Black Scholes model.

```
PriceBLS = optstockbybls(RateSpec, StockSpec, Settle, ExerciseDates,...
    OptSpec, Strike);
```

```
% Comparison of calculated call prices.
fprintf('Comparison of Vanilla and Asian Prices:\n\n');
fprintf('Vanilla BLS:           %f\n', PriceBLS);
fprintf('Asian Levy:           %f\n', PriceLevy);
fprintf('Asian Kemna-Vorst:      %f\n', PriceKV);
```

Comparison of Vanilla and Asian Prices:

```
Vanilla BLS:           15.743809
Asian Levy:           12.164734
Asian Kemna-Vorst:    11.862580
```

Both geometric and arithmetic Asians price lower than their Vanilla counterpart.

We can analyze options prices at different levels of the underlying asset. Using the Financial Instruments Toolbox™, it is possible to observe the effect of different parameters on the price of the options. Consider for example, the effect of variations in the price of the underlying asset.

```
StockPrices = (50:5:150)';
PriceBLS = nan(size(StockPrices));
PriceLevy = nan(size(StockPrices));
PriceKV = nan(size(StockPrices));
idx = 1;
for So = StockPrices';
    SP = stockspec(Sigma, So);
    PriceBLS(idx) = optstockbybls(RateSpec, SP, Settle, ExerciseDates,...
        OptSpec, Strike);

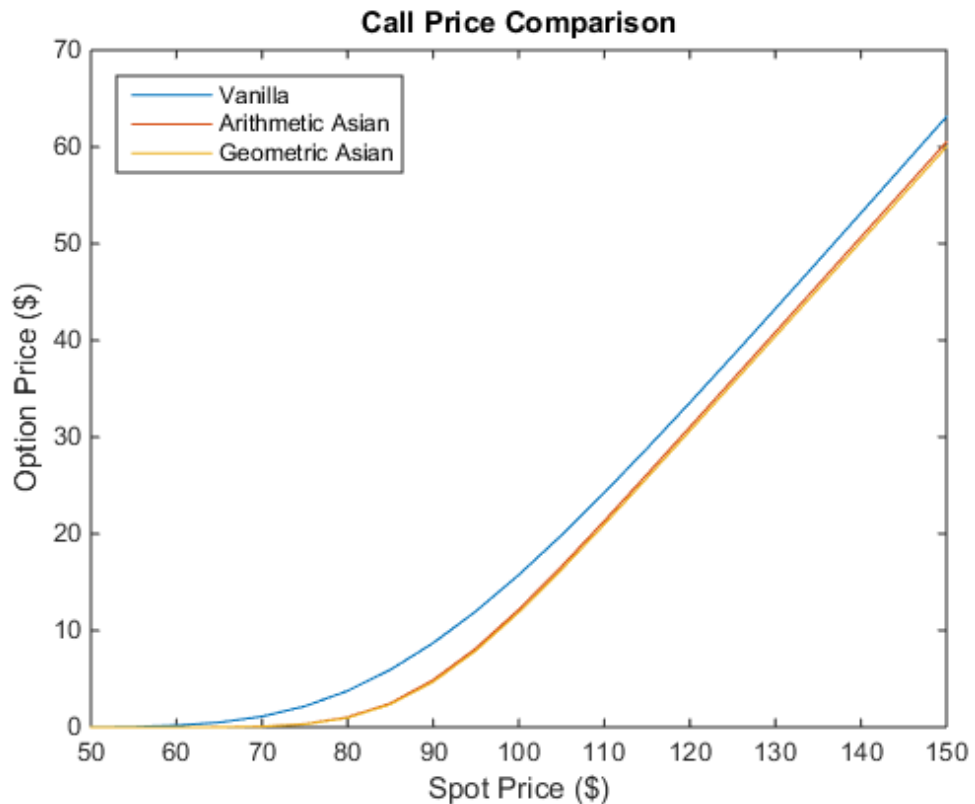
    PriceLevy(idx) = asianbylevy(RateSpec, SP, OptSpec, Strike, Settle,...
        ExerciseDates);

    PriceKV(idx) = asianbykv(RateSpec, SP, OptSpec, Strike, Settle,...
        ExerciseDates);
    idx = idx+1;
end
```

```

figure('menubar', 'none', 'numbertitle', 'off')
plot(StockPrices, [PriceBLS PriceLevy PriceKV]);
xlabel 'Spot Price ($)'
ylabel 'Option Price ($)'
title 'Call Price Comparison'
legend('Vanilla', 'Arithmetic Asian', 'Geometric Asian', 'location', 'northwest');

```



It can be observed that the price of the Asian option is cheaper than the price of the Vanilla option.

Additionally, it is possible to observe the effect of changes in the volatility of the underlying asset. The table below shows what happens to Asian and Vanilla option prices when the constant volatility changes.

Call Option (ITM)  
Strike = 90     AssetPrice = 100

Volatility	Levy	Kemna-Vorst	BLS
10%	11.3987	11.3121	13.4343
20%	12.1647	11.8626	15.7438
30%	13.6512	13.0338	18.8770
40%	15.4464	14.4086	22.2507

A comparison of the calculated prices show that Asian options are less sensitive to volatility changes, since averaging reduces the volatility of the value of the underlying asset. Also, Asian options that use arithmetic average are more expensive than those that use geometric average.

Now, examine the effect of strike on option prices.

```

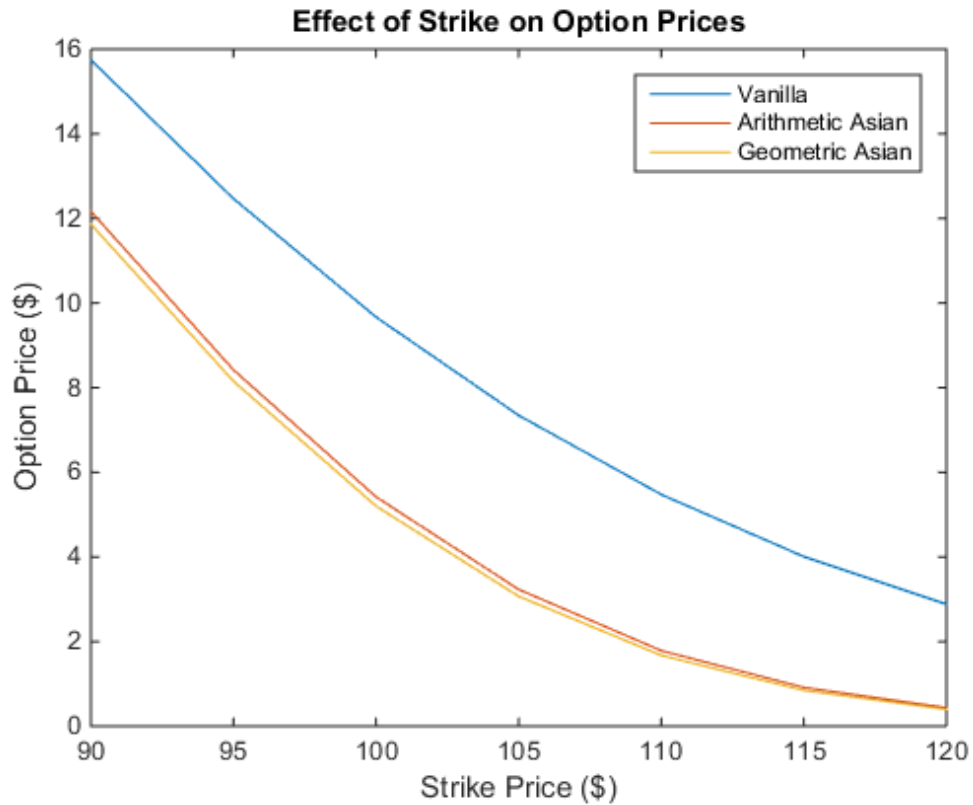
Strikes = (90:5:120)';
NStrike = length(Strikes);
PriceBLS = nan(size(Strikes));
PriceLevy = nan(size(Strikes));
PriceKV = nan(size(Strikes));
idx = 1;
for ST = Strikes';
    SP = stockspec(Sigma, AssetPrice);
    PriceBLS(idx) = optstockbybls(RateSpec, SP, Settle, ExerciseDates,...
                                OptSpec, ST);

    PriceLevy(idx) = asianbylevy(RateSpec, SP, OptSpec, ST, Settle,...
                                ExerciseDates);

    PriceKV(idx) = asianbykv(RateSpec, SP, OptSpec, ST, Settle,...
                             ExerciseDates);

    idx = idx+1;
end

figure('menubar', 'none', 'numbertitle', 'off')
plot(Strikes, [PriceBLS PriceLevy PriceKV]);
xlabel 'Strike Price ($)'
ylabel 'Option Price ($)'
title 'Effect of Strike on Option Prices'
legend('Vanilla', 'Arithmetic Asian', 'Geometric Asian', 'location', 'northeast');
```



The figure above displays the option price with respect to strike price. Since call option value decreases as strike price increases, the Asian call curve is under the Vanilla call curve. It can be observed that the Asian call option is less expensive than the Vanilla call.

### Hedging

Hedging is an insurance to minimize exposure to market movements on the value of a position or portfolio. As the underlying changes, the proportions of the instruments forming the portfolio may need to be adjusted to keep the sensitivities within the desired range. Delta measures the option price sensitivity to changes in the price of the underlying.

Assume that we have a portfolio of two options with the same strike and maturity. We can use the Financial Instruments Toolbox™ to compute Delta for the Vanilla and Average Price options.

```
OutSpec = 'Delta';

% Vanilla option using Black Scholes
DeltaBLS = optstocksensbybls(RateSpec, StockSpec, Settle, ExerciseDates,...
                             OptSpec, Strike, 'OutSpec', OutSpec);

% Asian option using Levy model
DeltaLevy = asiansensbylevy(RateSpec, StockSpec, OptSpec, Strike, Settle,...
                             ExerciseDates, 'OutSpec', OutSpec);

% Asian option using Kemna-Vorst method
DeltaLKV= asiansensbykv(RateSpec, StockSpec, OptSpec, Strike, Settle,...
                        ExerciseDates, 'OutSpec', OutSpec);

% Delta Comparison
fprintf('Comparison of Vanilla and Asian Delta:\n\n');
fprintf('Vanilla BLS:          %f\n', DeltaBLS);
fprintf('Asian Levy:          %f\n', DeltaLevy);
fprintf('Asian Kemna-Vorst: %f\n', DeltaLKV);
```

Comparison of Vanilla and Asian Delta:

```
Vanilla BLS:          0.788666
Asian Levy:          0.852806
Asian Kemna-Vorst: 0.844986
```

The following graph demonstrates the behavior of Delta for the Vanilla and Asian options as a function of the underlying price.

```
StockPrices = (40:5:120)';
NStockPrices = length(StockPrices);
DeltaBLS = nan(size(StockPrices));
DeltaLevy = nan(size(StockPrices));
DeltaKV = nan(size(StockPrices));

idx = 1;
for SPrices = StockPrices'
    SP = stockspec(Sigma, SPrices);
    DeltaBLS(idx) = optstocksensbybls(RateSpec, SP, Settle, ...
                                      ExerciseDates, OptSpec, Strike, 'OutSpec', OutSpec);
```

```

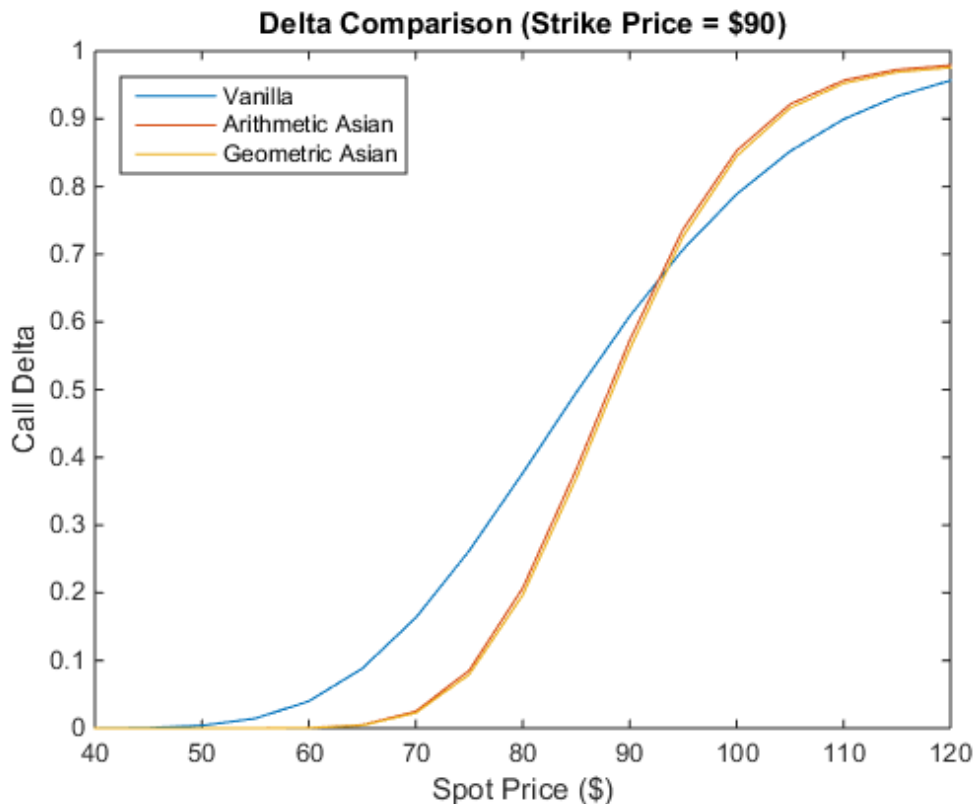
DeltaLevy(idx) = asiandeltalevy(RateSpec, SP, OptSpec, Strike,...
    Settle, ExerciseDates, 'OutSpec', OutSpec);

DeltaKV(idx) = asiandeltakv(RateSpec, SP, OptSpec, Strike, ...
    Settle, ExerciseDates, 'OutSpec', OutSpec);

    idx = idx+1;
end

figure('menubar', 'none', 'numbertitle', 'off')
plot(StockPrices, [DeltaBLS DeltaLevy DeltaKV]);
xlabel 'Spot Price ($)'
ylabel 'Call Delta'
title 'Delta Comparison (Strike Price = $90)'
legend('Vanilla', 'Arithmetic Asian', 'Geometric Asian', 'location', 'northwest');

```



A Vanilla, or Asian, in the money (ITM) call option is more sensitive to price movements than an out of the money (OTM) option. If the asset price is deep in the money, then it is more likely to be exercised. The opposite occurs for an out of the money option. Asian delta is lower for out of the money options and is higher for in the money options than its Vanilla European counterpart. The geometric Asian delta is lower than the arithmetic Asian delta.

### References

- [1] Levy, E., "Pricing European Average Rate Currency Options", *Journal of International Money and Finance*, 14, 474-491, (1992).
- [2] Kemna, A. & Vorst, A., "A Pricing Method for Options Based on Average Asset Values", *Journal of Banking and Finance*, 14, 113-129, (1990).

## Pricing Equity Derivatives Using Trees

In this section...
“Computing Instrument Prices” on page 3-104
“Computing Prices Using CRR” on page 3-105
“Computing Prices Using EQP” on page 3-107
“Computing Prices Using ITT” on page 3-109
“Examining Output from the Pricing Functions” on page 3-111
“Computing Instrument Sensitivities” on page 3-115
“Graphical Representation of Equity Derivative Trees” on page 3-118

### Computing Instrument Prices

The portfolio pricing functions `crrprice`, `eqpprice`, and `ittprice` calculate the price of any set of supported instruments based on a binary equity price tree or an implied trinomial price tree. These functions are capable of pricing the following instrument types:

- Vanilla stock options
  - American and European puts and calls
- Exotic options
  - Asian
  - Barrier
  - Compound
  - Lookback
  - Stock options (Bermuda put and call schedules)

The syntax for calling the function `crrprice` is:

```
[Price, PriceTree] = crrprice(CRRTree, InstSet, Options)
```

The syntax for `eqpprice` is:

```
[Price, PriceTree] = eqpprice(EQPtree, InstSet, Options)
```



The syntax for `ittprice` is:

```
Price = ittprice(ITTTree, ITTInstSet, Options)
```

These functions require two input arguments: the equity price tree and the set of instruments, `InstSet`, and allow a third optional argument.

### Required Arguments

`CRRTree` is a CRR equity price tree created using `crrtree`. `EQPTree` is an equal probability equity price tree created using `eqptree`. `ITTTree` is an ITT equity price tree created using `itttree`. See “Building Equity Binary Trees” on page 3-3 and “Building Implied Trinomial Trees” on page 3-8 to learn how to create these structures.

`InstSet` is a structure that represents the set of instruments to be priced independently using the model.

### Optional Argument

You can enter a third optional argument, `Options`, used when pricing barrier options. For more specific information, see Appendix B.

These pricing functions internally classify the instruments and call the appropriate individual instrument pricing function for each of the instrument types. The CRR pricing functions are `asianbycrr`, `barrierbycrr`, `compoundbycrr`, `lookbackbycrr`, and `optstockbycrr`. A similar set of functions exists for EQP and ITT pricing. You can also use these functions directly to calculate the price of sets of instruments of the same type. See the reference pages for these individual functions for further information.

## Computing Prices Using CRR

Consider the following example, which uses the portfolio and stock price data in the MAT-file `deriv.mat` included in the toolbox. Load the data into the MATLAB workspace.

```
load deriv.mat
```

Use the MATLAB `whos` command to display a list of the variables loaded from the MAT-file.

Name	Size	Bytes	Class	Attributes
BDTInstSet	1x1	15956	struct	

```

BDTTree          1x1          5138  struct
BKInstSet        1x1         15946  struct
BKTree           1x1          5904  struct
CRRInstSet       1x1         12434  struct
CRRTree          1x1          5058  struct
EQPInstSet       1x1         12434  struct
EQPTree          1x1          5058  struct
HJMInstSet       1x1         15948  struct
HJMTree          1x1          5838  struct
HWInstSet        1x1         15946  struct
HWTTree          1x1          5904  struct
ITTInstSet       1x1         12438  struct
ITTTree          1x1          8862  struct
ZeroInstSet      1x1         10282  struct
ZeroRateSpec     1x1          1580  struct

```

CRRTree and CRRInstSet are the required input arguments to call the function `corrprice`.

Use `instdisp` to examine the set of instruments contained in the variable `CRRInstSet`.

`instdisp(CRRInstSet)`

```

Index Type      OptSpec Strike Settle      ExerciseDates AmericanOpt Name  Quantity
1  OptStock call   105  01-Jan-2003  01-Jan-2005  1      Call1 10
2  OptStock put   105  01-Jan-2003  01-Jan-2006  0      Put1  5

Index Type      OptSpec Strike Settle      ExerciseDates AmericanOpt BarrierSpec Barrier Rebate Name  Quantity
3  Barrier call   105  01-Jan-2003  01-Jan-2006  1      ui      102  0      Barrier1 1

Index Type      UOptSpec UStrike USettle      UExerciseDates UAmericanOpt COptSpec CStrike CSettle      CExerciseDates
4  Compound call   130  01-Jan-2003  01-Jan-2006  1      put    5      01-Jan-2003  01-Jan-2005

Index Type      OptSpec Strike Settle      ExerciseDates AmericanOpt Name  Quantity
5  Lookback call   115  01-Jan-2003  01-Jan-2006  0      Lookback1 7
6  Lookback call   115  01-Jan-2003  01-Jan-2007  0      Lookback2 9

Index Type      OptSpec Strike Settle      ExerciseDates AmericanOpt AvgType  AvgPrice AvgDate Name  Quantity
7  Asian put    110  01-Jan-2003  01-Jan-2006  0      arithmetic NaN  NaN  Asian1 4
8  Asian put    110  01-Jan-2003  01-Jan-2007  0      arithmetic NaN  NaN  Asian2 6

```

---

**Note** Because of space considerations, the compound option above (Index 4) has been condensed to fit the page. The `instdisp` command displays all compound option fields on your computer screen.

---

The instrument set contains eight instruments:

- Two vanilla options (Call1, Put1)
- One barrier option (Barrier1)
- One compound option (Compound1)

- Two lookback options (Lookback1, Lookback2)
- Two Asian options (Asian1, Asian2)

Each instrument has a corresponding index that identifies the instrument prices in the price vector returned by `crrprice`.

Now use `crrprice` to calculate the price of each instrument in the instrument set.

```
Price = crrprice(CRRTree, CRRInstSet)
```

```
Price =
    8.2863
    2.5016
   12.1272
    3.3241
    7.6015
   11.7772
    4.1797
    3.4219
```

## Computing Prices Using EQP

Load the data into the MATLAB workspace.

```
load deriv.mat
```

Use the MATLAB `whos` command to display a list of the variables loaded from the MAT-file.

Name	Size	Bytes	Class	Attributes
BDTInstSet	1x1	15956	struct	
BDTTree	1x1	5138	struct	
BKInstSet	1x1	15946	struct	
BKTree	1x1	5904	struct	
CRRInstSet	1x1	12434	struct	
CRRTree	1x1	5058	struct	
EQPInstSet	1x1	12434	struct	
EQPTree	1x1	5058	struct	
HJMInstSet	1x1	15948	struct	
HJMTree	1x1	5838	struct	
HWInstSet	1x1	15946	struct	
HWTree	1x1	5904	struct	
ITTInstSet	1x1	12438	struct	
ITTTree	1x1	8862	struct	
ZeroInstSet	1x1	10282	struct	

```
ZeroRateSpec      1x1              1580  struct
```

`EQPtree` and `EQPInstSet` are the input arguments required to call the function `eqpprice`.

Use the command `instdisp` to examine the set of instruments contained in the variable `EQPInstSet`.

```
instdisp(EQPInstSet)
```

```

Index Type      OptSpec Strike Settle      ExerciseDates AmericanOpt Name      Quantity
1  OptStock call   105  01-Jan-2003  01-Jan-2005  1      Call1  10
2  OptStock put    105  01-Jan-2003  01-Jan-2006  0      Put1   5

Index Type      OptSpec Strike Settle      ExerciseDates AmericanOpt BarrierSpec Barrier Rebate Name      Quantity
3  Barrier call   105  01-Jan-2003  01-Jan-2006  1      ui      102    0      Barrier1 1

Index Type      UOptSpec UStrike USettle      UExerciseDates UAmericanOpt COptSpec CStrike CSettle      CExerciseDates
4  Compound call   130  01-Jan-2003  01-Jan-2006  1      put    5      01-Jan-2003  01-Jan-2005

Index Type      OptSpec Strike Settle      ExerciseDates AmericanOpt Name      Quantity
5  Lookback call   115  01-Jan-2003  01-Jan-2006  0      Lookback1 7
6  Lookback call   115  01-Jan-2003  01-Jan-2007  0      Lookback2 9

Index Type      OptSpec Strike Settle      ExerciseDates AmericanOpt AvgType      AvgPrice AvgDate Name      Quantity
7  Asian put      110  01-Jan-2003  01-Jan-2006  0      arithmetic NaN      NaN      Asian1 4
8  Asian put      110  01-Jan-2003  01-Jan-2007  0      arithmetic NaN      NaN      Asian2 6

>> instdisp(EQPInstSet)
Index Type      OptSpec Strike Settle      ExerciseDates AmericanOpt Name      Quantity
1  OptStock call   105  01-Jan-2003  01-Jan-2005  1      Call1  10
2  OptStock put    105  01-Jan-2003  01-Jan-2006  0      Put1   5

Index Type      OptSpec Strike Settle      ExerciseDates AmericanOpt BarrierSpec Barrier Rebate Name      Quantity
3  Barrier call   105  01-Jan-2003  01-Jan-2006  1      ui      102    0      Barrier1 1

Index Type      UOptSpec UStrike USettle      UExerciseDates UAmericanOpt COptSpec CStrike CSettle      CExerciseDates
4  Compound call   130  01-Jan-2003  01-Jan-2006  1      put    5      01-Jan-2003  01-Jan-2005

Index Type      OptSpec Strike Settle      ExerciseDates AmericanOpt Name      Quantity
5  Lookback call   115  01-Jan-2003  01-Jan-2006  0      Lookback1 7
6  Lookback call   115  01-Jan-2003  01-Jan-2007  0      Lookback2 9

Index Type      OptSpec Strike Settle      ExerciseDates AmericanOpt AvgType      AvgPrice AvgDate Name      Quantity
7  Asian put      110  01-Jan-2003  01-Jan-2006  0      arithmetic NaN      NaN      Asian1 4
8  Asian put      110  01-Jan-2003  01-Jan-2007  0      arithmetic NaN      NaN      Asian2 6

```

---

**Note** Because of space considerations, the compound option above (Index 4) has been condensed to fit the page. The `instdisp` command displays all compound option fields on your computer screen.

---

The instrument set contains eight instruments:

- Two vanilla options (`Call1`, `Put1`)
- One barrier option (`Barrier1`)
- One compound option (`Compound1`)
- Two lookback options (`Lookback1`, `Lookback2`)
- Two Asian options (`Asian1`, `Asian2`)

Each instrument has a corresponding index that identifies the instrument prices in the price vector returned by `eqpprice`.

Now use `eqpprice` to calculate the price of each instrument in the instrument set.

```
Price = eqpprice(EQPtree, EQPInstSet)
```

```
Price =
    8.4791
    2.6375
   12.2632
    3.5091
    8.7941
   12.9577
    4.7444
    3.9178
```

## Computing Prices Using ITT

Consider the following example, which uses the portfolio and stock price data in the MAT-file `deriv.mat` included in the toolbox. Load the data into the MATLAB workspace.

```
load deriv.mat
```

Use the MATLAB `whos` command to display a list of the variables loaded from the MAT-file.

Name	Size	Bytes	Class	Attributes
BDTInstSet	1x1	15956	struct	
BDTtree	1x1	5138	struct	
BKInstSet	1x1	15946	struct	
BKtree	1x1	5904	struct	
CRRInstSet	1x1	12434	struct	
CRRtree	1x1	5058	struct	

```

EQPInstSet      1x1      12434  struct
EQPTree         1x1      5058   struct
HJMInstSet     1x1      15948  struct
HJMTree        1x1      5838   struct
HWInstSet      1x1      15946  struct
HWTree         1x1      5904   struct
ITTInstSet     1x1      12438  struct
ITTree         1x1      8812   struct
ZeroInstSet    1x1      10282  struct
ZeroRateSpec   1x1      1580   struct

```

**ITTree** and **ITTInstSet** are the input arguments required to call the function **ittprice**. Use the command **instdisp** to examine the set of instruments contained in the variable **ITTInstSet**.

**instdisp(ITTInstSet)**

```

Index Type   OptSpec Strike Settle      ExerciseDates AmericanOpt Name  Quantity
1  OptStock call   105  01-Jan-2003  01-Jan-2005  1      Call1 10
2  OptStock put    105  01-Jan-2003  01-Jan-2006  0      Put1  5

Index Type   OptSpec Strike Settle      ExerciseDates AmericanOpt BarrierSpec Barrier Rebate Name  Quantity
3  Barrier call   105  01-Jan-2003  01-Jan-2006  1          ui      102  0      Barrier1 1

Index Type   UOptSpec UStrike USettle      UExerciseDates UAmericanOpt COptSpec CStrike CSettle      CExerciseDates
4  Compound call   130  01-Jan-2003  01-Jan-2006  1          put    5      01-Jan-2003  01-Jan-2005

Index Type   OptSpec Strike Settle      ExerciseDates AmericanOpt Name  Quantity
5  Lookback call   115  01-Jan-2003  01-Jan-2006  0      Lookback1 7
6  Lookback call   115  01-Jan-2003  01-Jan-2007  0      Lookback2 9

Index Type   OptSpec Strike Settle      ExerciseDates AmericanOpt AvgType  AvgPrice AvgDate Name  Quantity
7  Asian put    110  01-Jan-2003  01-Jan-2006  0      arithmetic NaN   NaN   Asian1 4
8  Asian put    110  01-Jan-2003  01-Jan-2007  0      arithmetic NaN   NaN   Asian2 6

>> instdisp(ITTInstSet)
Index Type   OptSpec Strike Settle      ExerciseDates AmericanOpt Name  Quantity
1  OptStock call   95  01-Jan-2006  31-Dec-2008  1      Call1 10
2  OptStock put    80  01-Jan-2006  01-Jan-2010  0      Put1  4

Index Type   OptSpec Strike Settle      ExerciseDates AmericanOpt BarrierSpec Barrier Rebate Name  Quantity
3  Barrier call   85  01-Jan-2006  31-Dec-2008  1          ui      115  0      Barrier1 1

Index Type   UOptSpec UStrike USettle      UExerciseDates UAmericanOpt COptSpec CStrike CSettle      CExerciseDates
4  Compound call   99  01-Jan-2006  01-Jan-2010  1          put    5      01-Jan-2006  01-Jan-2010

Index Type   OptSpec Strike Settle      ExerciseDates AmericanOpt Name  Quantity
5  Lookback call   85  01-Jan-2006  01-Jan-2008  0      Lookback1 7
6  Lookback call   85  01-Jan-2006  01-Jan-2010  0      Lookback2 9

Index Type   OptSpec Strike Settle      ExerciseDates AmericanOpt AvgType  AvgPrice AvgDate Name  Quantity
7  Asian call   55  01-Jan-2006  01-Jan-2008  0      arithmetic NaN   NaN   Asian1 5
8  Asian call   55  01-Jan-2006  01-Jan-2010  0      arithmetic NaN   NaN   Asian2 7

```

The instrument set contains eight instruments:

- Two vanilla options (Call1, Put1)

- One barrier option (`Barrier1`)
- One compound option (`Compound1`)
- Two lookback options (`Lookback1`, `Lookback2`)
- Two Asian options (`Asian1`, `Asian2`)

Each instrument has a corresponding index that identifies the instrument prices in the price vector returned by `ittprice`.

Now use `ittprice` to calculate the price of each instrument in the instrument set.

```
Price = ittprice(ITTTree, ITTInstSet)
```

```
Price =
    1.650
   10.68
    2.407
    3.229
    0.542
    6.184
    3.205
    6.607
```

## Examining Output from the Pricing Functions

The prices in the output vector `Price` correspond to the prices at observation time zero (`tObs = 0`), which is defined as the valuation date of the equity tree. The instrument indexing within `Price` is the same as the indexing within `InstSet`.

In the CRR example, the prices in the `Price` vector correspond to the instruments in this order.

```
InstNames = instget(CRRInstSet, 'FieldName', 'Name')
```

```
InstNames =
Call1
Put1
Barrier1
Compound1
Lookback1
Lookback2
Asian1
```

Asian2

Consequently, in the `Price` vector, the fourth element, 3.3241, represents the price of the fourth instrument (`Compound1`), and the sixth element, 11.7772, represents the price of the sixth instrument (`Lookback2`).

In the ITT example, the prices in the `Price` vector correspond to the instruments in this order.

```
InstNames = instget(ITTInstSet, 'FieldName', 'Name')
```

```
InstNames =
```

```
Call1  
Put1  
Barrier1  
Compound1  
Lookback1  
Lookback2  
Asian1  
Asian2
```

Consequently, in the `Price` vector, the first element, 1.650, represents the price of the first instrument (`Call1`), and the eighth element, 6.607, represents the price of the eighth instrument (`Asian2`).

#### Price Tree Output for CRR

If you call a pricing function with two output arguments, for example:

```
[Price, PriceTree] = crrprice(CRRTree, CRRInstSet)
```

you generate a price tree structure along with the price information.

This price tree structure `PriceTree` holds all pricing information.

```
PriceTree =  
FinObj: 'BinPriceTree'  
PTree: {[8x1 double] [8x2 double] [8x3 double] [8x4 double] [8x5 double]}  
tObs: [0 1 2 3 4]  
dObs: [731582 731947 732313 732678 733043]
```

The first field of this structure, `FinObj`, indicates that this structure represents a price tree. The second field, `PTree`, is the tree holding the prices of the instruments in each node of the tree. Finally, the third and fourth fields, `tObs` and `dObs`, represent the



observation time and date of each level of `Ptree`, with `tObs` using units in terms of compounding periods.

Using the command-line interface, you can directly examine `PriceTree.PTree`, the field within the `PriceTree` structure that contains the price tree with the price vectors at every state. The first node represents `tObs = 0`, corresponding to the valuation date.

```
PriceTree.PTree{1}
```

```
ans =
8.2863
2.5016
12.1272
3.3241
7.6015
11.7772
4.1797
3.4219
```

With this interface, you can observe the prices for all instruments in the portfolio at a specific time.

The function `eqpprice` also returns a price tree that you can examine in the same way.

### Price Tree Output for ITT

If you call a pricing function with two output arguments, for example:

```
[Price, PriceTree] = ittprice(ITTTree, ITTInstSet)
```

you generate a price tree structure along with the price information.

This price tree structure `PriceTree` holds all pricing information.

```
PriceTree =
  FinObj: 'TrinPriceTree'
  PTree: {[8x1 double] [8x3 double] [8x5 double] [8x7 double] [8x9 double]}
  tObs: [0 1 2 3 4]
  dObs: [732678 733043 733408 733773 734139]
```

The first field of this structure, `FinObj`, indicates that this structure represents a trinomial price tree. The second field, `Ptree` is the tree holding the prices of the instruments in each node of the tree. Finally, the third and fourth fields, `tObs` and `dObs`, represent the observation time and date of each level of `Ptree`, with `tObs` using units in terms of compounding periods.

Using the command-line interface, you can directly examine `PriceTree.PTree`, the field within the `PriceTree` structure that contains the price tree with the price vectors at every state. The first node represents `tObs = 0`, corresponding to the valuation date.

```
PriceTree.PTree{1}
```

```
ans =
```

```
1.6506
10.6832
2.4074
3.2294
0.5426
6.1845
3.2052
6.6074
```

With this interface, you can observe the prices for all instruments in the portfolio at a specific time.

#### Prices for Lookback and Asian Options for Equity Trees

Lookback options and Asian options are path dependent, and, as such, there are no unique prices for any node except the root node. Consequently, the corresponding values for lookback and Asian options in the price tree are set to `NaN`, the only exception being the root node. This becomes apparent if you examine the prices in the second node (`tObs = 1`) of the CRR price tree:

```
PriceTree.PTree{2}
```

```
ans =
```

```
11.9176      0
0.9508      7.1914
16.4600      2.6672
2.5896      5.0000
NaN          NaN
NaN          NaN
NaN          NaN
NaN          NaN
```

Examining the prices in the second node (`tObs = 1`) of the ITT price tree displays:

```
PriceTree.PTree{2}
```

```
ans =
    3.9022         0         0
    6.3736    13.3743    22.1915
    5.6914         0         0
    2.7663     3.8594     5.0000
    NaN         NaN         NaN
    NaN         NaN         NaN
    NaN         NaN         NaN
    NaN         NaN         NaN
```

## Computing Instrument Sensitivities

Sensitivities can be reported either as dollar price changes or percentage price changes. The delta, gamma, and vega sensitivities that the toolbox computes are dollar sensitivities.

The functions `crrsens`, `eqpsens`, and `ittsens` compute the delta, gamma, and vega sensitivities of instruments using a stock tree. They also optionally return the calculated price for each instrument. The sensitivity functions require the same two input arguments used by the pricing functions (`CRRTree` and `CRRInstSet` for CRR, `EQPTree` and `EQPInstSet` for EQP, and `ITTTree` and `ITTInstSet` for ITT).

As with the instrument pricing functions, the optional input argument `Options` is also allowed. You would include this argument if you want a sensitivity function to generate a price for a barrier option as one of its outputs and want to control the method that the toolbox uses to perform the pricing operation. See Appendix B or the `derivset` function for more information.

For path-dependent options (lookback and Asian), delta and gamma are computed by finite differences in calls to `crrprice`, `eqpprice`, and `ittprice`. For the other options (stock option, barrier, and compound), delta and gamma are computed from the CRR, EQP, and ITT trees and the corresponding option price tree. (See Chriss, Neil, *Black-Scholes and Beyond*, pp. 308-312.)

### CRR Sensitivities Example

The calling syntax for the sensitivity function is:

```
[Delta, Gamma, Vega, Price] = crrsens(CRRTree, InstSet, Options)
```

Using the example data in `deriv.mat`, calculate the sensitivity of the instruments.

```
load deriv.mat
[Delta, Gamma, Vega, Price] = crrsens(CRRTree, CRRInstSet);
```

You can conveniently examine the sensitivities and the prices by arranging them into a single matrix.

```
format bank
All = [Delta, Gamma, Vega, Price]
```

```
All =
```

0.59	0.04	53.45	8.29
-0.31	0.03	67.00	2.50
0.69	0.03	67.00	12.13
-0.12	-0.01	-98.08	3.32
-0.40	-45926.32	88.18	7.60
-0.42	-112143.15	119.19	11.78
0.60	45926.32	49.21	4.18
0.82	112143.15	41.71	3.42

As with the prices, each row of the sensitivity vectors corresponds to the similarly indexed instrument in `CRRInstSet`. To view the per-dollar sensitivities, divide each dollar sensitivity by the corresponding instrument price.

```
All = [Delta ./ Price, Gamma ./ Price, Vega ./ Price, Price]
```

```
All =
```

0.07	0.00	6.45	8.29
-0.12	0.01	26.78	2.50
0.06	0.00	5.53	12.13
-0.04	-0.00	-29.51	3.32
-0.05	-6041.77	11.60	7.60
-0.04	-9522.02	10.12	11.78
0.14	10987.98	11.77	4.18
0.24	32771.92	12.19	3.42

#### ITT Sensitivities Example

The calling syntax for the sensitivity function is:

```
[Delta, Gamma, Vega, Price] = ittens(ITTTree, ITTInstSet, Options)
```

Using the example data in `deriv.mat`, calculate the sensitivity of the instruments.

```
load deriv.mat
```

```
warning('off', 'fininst:itttree:Extrapolation');
[Delta, Gamma, Vega, Price] = ittSENS(ITTTree, ITTInstSet);
```

You can conveniently examine the sensitivities and the prices by arranging them into a single matrix.

```
format bank
All = [Delta, Gamma, Vega, Price]
```

```
All =
```

0.24	0.03	19.35	1.65
-0.43	0.02	49.69	10.68
0.35	0.04	12.29	2.41
-0.07	0.00	6.73	3.23
0.63	142945.66	38.90	0.54
0.60	22703.21	68.92	6.18
0.32	-142945.66	18.48	3.21
0.67	-22703.21	17.75	6.61

As with the prices, each row of the sensitivity vectors corresponds to the similarly indexed instrument in `ITTInstSet`.

---

**Note:** In this example, the extrapolation warnings are turned off before calculating the sensitivities to avoid displaying many warnings on the Command Window as the sensitivities are calculated.

---

If the extrapolation warnings are turned on

```
warning('on', 'fininst:itttree:Extrapolation');
and ittSENS is rerun, the extrapolation warnings scroll as the command executes:
```

```
[Delta, Gamma, Vega, Price] = ittSENS(ITTTree, ITTInstSet)
```

```
Warning: The option set specified in StockOptSpec was too narrow for the generated tree.
This makes extrapolation necessary. The list of options outside of the
range of those specified in StockOptSpec are:
```

```
Option Type: 'call'   Maturity: 01-Jan-2007   Strike=66.3529
Option Type: 'put'   Maturity: 01-Jan-2007   Strike=50.0061
Option Type: 'put'   Maturity: 01-Jan-2008   Strike=50.0061
Option Type: 'put'   Maturity: 31-Dec-2008   Strike=50.0061
Option Type: 'call'  Maturity: 01-Jan-2010   Strike=155.0141
Option Type: 'put'   Maturity: 01-Jan-2010   Strike=50.006
> In itttree>InterpOptPrices at 675
> In itttree at 277
In stocktreesens>stocktreedeltagamma_PD at 127
```

```
In stocktreesens at 83
In ittzens at 81

Warning: The option set specified in StockOptSpec was too narrow for the generated tree.
This made extrapolation necessary. Below is a list of the options that were outside of the
range of those specified in StockOptSpec.

Option Type: 'call'   Maturity: 01-Jan-2007   Strike=66.3367
Option Type: 'put'   Maturity: 01-Jan-2007   Strike=37.6773
Option Type: 'call'   Maturity: 01-Jan-2008   Strike=66.3367
Option Type: 'put'   Maturity: 01-Jan-2008   Strike=28.3951
Option Type: 'call'   Maturity: 31-Dec-2008   Strike=66.3367
Option Type: 'call'   Maturity: 01-Jan-2010   Strike=66.3367
Option Type: 'put'   Maturity: 01-Jan-2010   Strike=16.1276

> In itttree>InterpOptPrices at 675
In itttree at 277
In stocktreesens>stocktreedeltagamma_PD at 131
In stocktreesens at 83
In ittzens at 81

Warning: The option set specified in StockOptSpec was too narrow for the generated tree.
This made extrapolation necessary. Below is a list of the options that were outside of the
range of those specified in StockOptSpec.

Option Type: 'call'   Maturity: 01-Jan-2007   Strike=67.2897
Option Type: 'put'   Maturity: 01-Jan-2007   Strike=37.1528
Option Type: 'put'   Maturity: 01-Jan-2008   Strike=27.6066
Option Type: 'put'   Maturity: 31-Dec-2008   Strike=20.5132
Option Type: 'call'   Maturity: 01-Jan-2010   Strike=164.0157
Option Type: 'put'   Maturity: 01-Jan-2010   Strike=15.2424

> In itttree>InterpOptPrices at 675
In itttree at 277
In stocktreesens>stocktreevega at 191
In stocktreesens at 92
In ittzens at 81
```

These warnings are a consequence of having to extrapolate to find the option price of the tree nodes. In this example, the set of inputs options was too narrow for the shift in the tree nodes introduced by the disturbance used to calculate the sensitivities. As a consequence extrapolation for some of the nodes was needed. Since the input data is quite close the extrapolated data, the error introduced by extrapolation is fairly low.

## Graphical Representation of Equity Derivative Trees

You can use the function `treeviewer` to display a graphical representation of a tree, allowing you to examine interactively the prices and rates on the nodes of the tree until maturity. The graphical representations of CRR, EQP, and LR trees are equivalent to Black-Derman-Toy (BDT) trees, given that they are all binary recombining trees. The graphical representations of ITT trees are equivalent to Hull-White (HW) trees, given that they are all trinomial recombining trees. See “Graphical Representation of Trees” on page 2-128 for an overview on the use of `treeviewer` with CRR trees, EQP trees, LR

trees, and ITT trees and their corresponding option price trees. Follow the instructions for BDT trees.

## Equity Derivatives Using Closed-Form Solutions

**In this section...**

- “Introduction” on page 3-120
- “Black-Scholes Model” on page 3-120
- “Black Model” on page 3-121
- “Roll-Geske-Whaley Model” on page 3-122
- “Bjerk Sund-Stensland 2002 Model” on page 3-123
- “Pricing Using the Black-Scholes Model” on page 3-123
- “Pricing Using the Black Model” on page 3-125
- “Pricing Using the Roll-Geske-Whaley Model” on page 3-126
- “Pricing Using the Bjerk Sund-Stensland Model” on page 3-127

### Introduction

Financial Instruments Toolbox software supports four types of closed-form solutions and analytical approximations to calculate price and sensitivities (greeks) of vanilla options:

- Black-Scholes model
- Black model
- Roll-Geske-Whaley model
- Bjerk Sund-Stensland 2002 model

### Black-Scholes Model

The Black-Scholes model is one of the most commonly used models to price European calls and puts. It serves as a basis for many closed-form solutions used for pricing options. The standard Black-Scholes model is based on the following assumptions:

- There are no dividends paid during the life of the option.
- The option can only be exercised at maturity.
- The markets operate under a Markov process in continuous time.
- No commissions are paid.



- The risk-free interest rate is known and constant.
- Returns on the underlying stocks are log-normally distributed.

---

**Note:** The Black-Scholes model implemented in Financial Instruments Toolbox software allows dividends. The following three dividend methods are supported:

- Cash dividend
- Continuous dividend yield
- Constant dividend yield

However, not all Black-Scholes closed-form pricing functions support all three dividend methods. For more information on specifying the dividend methods, see `stockspec`.

---

Closed-form solutions based on a Black-Scholes model support the following tasks.

Task	Function
Price European options with different dividends using the Black-Scholes option pricing model.	<code>optstockbybls</code>
Calculate European option prices and sensitivities using the Black-Scholes option pricing model.	<code>optstocksensbybls</code>
Calculate implied volatility on European options using the Black-Scholes option pricing model.	<code>impvbybls</code>
Price European simple chooser options using Black-Scholes model.	<code>chooserbybls</code>

For an example using the Black-Scholes model, see “Pricing Using the Black-Scholes Model” on page 3-123.

## Black Model

Use the Black model for pricing European options on physical commodities, forwards or futures. The Black model supported by Financial Instruments Toolbox software is a special case of the Black-Scholes model. The Black model uses a forward price as an underlier in place of a spot price. The assumption is that the forward price at maturity of the option is log-normally distributed.

Closed-form solutions for a Black model support the following tasks.

<b>Task</b>	<b>Function</b>
Price European options on futures using the Black option pricing model.	optstockbyblk
Calculate European option prices and sensitivities on futures using the Black option pricing model.	optstocksensbyblk
Calculate implied volatility for European options using the Black option pricing model.	impvbyblk

For an example using the Black model, see “Pricing Using the Black Model” on page 3-125.

## Roll-Geske-Whaley Model

Use the Roll-Geske-Whaley approximation method to price American call options paying a single cash dividend. This model is based on the modification of the observed stock price for the present value of the dividend and also supports a compound option to account for the possibility of early exercise. The Roll-Geske-Whaley model has drawbacks due to an escrowed dividend price approach which may lead to arbitrage. For further explanation, see *Options, Futures, and Other Derivatives* by John Hull.

Closed-form solutions for a Roll-Geske-Whaley model support the following tasks.

<b>Task</b>	<b>Function</b>
Price American call options with a single cash dividend using the Roll-Geske-Whaley option pricing model.	optstockbyrgw
Calculate American call prices and sensitivities using the Roll-Geske-Whaley option pricing model.	optstocksensbyrgw
Calculate implied volatility for American call options using the Roll-Geske-Whaley option pricing model.	impvbyrgw

For an example using the Roll-Geske-Whaley model, see “Pricing Using the Roll-Geske-Whaley Model” on page 3-126.

## Bjerk Sund-Stensland 2002 Model

Use the Bjerk Sund-Stensland 2002 model for pricing American puts and calls with continuous dividend yield. This model works by dividing the time to maturity of the option in two separate parts, each with its own flat exercise boundary (trigger price). The Bjerk Sund-Stensland 2002 method is a generalization of the Bjerk Sund and Stensland 1993 method and is considered to be computationally efficient. For further explanation, see *Closed Form Valuation of American Options* by Bjerk Sund and Stensland.

Closed-form solutions for a Bjerk Sund-Stensland 2002 model support the following tasks.

Task	Function
Price American options with continuous dividend yield using the Bjerk Sund-Stensland 2002 option pricing model.	optstockbybjs
Calculate American options prices and sensitivities using the Bjerk Sund-Stensland 2002 option pricing model.	optstocksensbybjs
Calculate implied volatility for American options using the Bjerk Sund-Stensland 2002 option pricing model.	impvbybjs

For an example using the Bjerk Sund-Stensland 2002 model, see “Pricing Using the Bjerk Sund-Stensland Model” on page 3-127.

## Pricing Using the Black-Scholes Model

Consider a European stock option with an exercise price of \$40 on January 1, 2008 that expires on July 1, 2008. Assume the underlying stock pays dividends of \$0.50 on March 1 and June 1. The stock is trading at \$40 and has a volatility of 30% per annum. The risk-free rate is 4% per annum. Using this data, calculate the price of a call and a put option on the stock using the Black-Scholes option pricing model:

```
Strike = 40;
AssetPrice = 40;
Sigma = .3;
Rates = 0.04;
Settle = 'Jan-01-08';
Maturity = 'Jul-01-08';
```

```
Div1 = 'March-01-2008';  
Div2 = 'Jun-01-2008';
```

Create RateSpec and StockSpec:

```
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, 'EndDates',...  
Maturity, 'Rates', Rates, 'Compounding', -1);  
StockSpec = stockspec(Sigma, AssetPrice, {'cash'}, 0.50, {Div1, Div2});
```

Define two options, one call and one put:

```
OptSpec = {'call'; 'put'};
```

Calculate the price of the European options:

```
Price = optstockbybls(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike)  
  
Price =  
  
    3.2063  
    3.4027
```

The first element of the `Price` vector represents the price of the call (\$3.21); the second is the price of the put (\$3.40). Use the function `optstocksensbybls` to compute six sensitivities for the Black-Scholes model: `delta`, `gamma`, `vega`, `lambda`, `rho`, and `theta` and the `price` of the option.

The selection of output parameters and their order is determined by the optional input parameter `OutSpec`. This parameter is a cell array of strings, each one specifying a desired output parameter. The order in which these output parameters are returned by the function is the same as the order of the strings contained in `OutSpec`.

As an example, consider the same options as the previous example. To calculate their `Delta`, `Rho`, `Price`, and `Gamma`, build the cell array `OutSpec` as follows:

```
OutSpec = {'delta', 'rho', 'price', 'gamma'};  
  
[Delta, Rho, Price, Gamma] = optstocksensbybls(RateSpec, StockSpec, Settle,...  
Maturity, OptSpec, Strike, 'OutSpec', OutSpec)  
  
Delta =  
  
    0.5328  
   -0.4672
```

```
Rho =
    8.7902
   -10.8138
```

```
Price =
    3.2063
    3.4027
```

```
Gamma =
    0.0480
    0.0480
```

## Pricing Using the Black Model

Consider two European call options on a futures contract with exercise prices of \$20 and \$25 that expire on September 1, 2008. Assume that on May 1, 2008 the contract is trading at \$20 and has a volatility of 35% per annum. The risk-free rate is 4% per annum. Using this data, calculate the price of the call futures options using the Black model:

```
Strike = [20; 25];
AssetPrice = 20;
Sigma = .35;
Rates = 0.04;
Settle = 'May-01-08';
Maturity = 'Sep-01-08';
```

Create RateSpec and StockSpec:

```
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
    'EndDates', Maturity, 'Rates', Rates, 'Compounding', -1);
StockSpec = stockspec(Sigma, AssetPrice);
```

Define the call option:

```
OptSpec = {'call'};
```

Calculate price and all sensitivities of the European futures options:

```
OutSpec = {'All'}

[Delta, Gamma, Vega, Lambda, Rho, Theta, Price] = optstocksensbyblk(RateSpec,...
StockSpec, Settle, Maturity, OptSpec, Strike, 'OutSpec', OutSpec);

Price =

    1.5903
    0.3037
```

The first element of the `Price` vector represents the price of the call with an exercise price of \$20 (\$1.59); the second is the price of the call with an exercise price of \$25 (\$2.89).

The function `impvbyblk` is used to compute the implied volatility using the Black option pricing model. Assuming that the previous European call futures are trading at \$1.5903 and \$0.3037, you can calculate their implied volatility:

```
Volatility = impvbyblk(RateSpec, StockSpec, Settle, Maturity,...
OptSpec, Strike, Price);
```

As expected, you get volatilities of 35%. If the call futures were trading at \$1.50 and \$0.50 in the market, the implied volatility would be 33% and 42%:

```
Volatility = impvbyblk(RateSpec, StockSpec, Settle, Maturity,...
OptSpec, Strike, [1.50;0.5])

Volatility =

    0.3301
    0.4148
```

## Pricing Using the Roll-Geske-Whaley Model

Consider two American call options, with exercise prices of \$110 and \$100 on June 1, 2008, that expire on June 1, 2009. Assume the underlying stock pays dividends of \$0.001 on December 1, 2008. The stock is trading at \$80 and has a volatility of 20% per annum. The risk-free rate is 6% per annum. Using this data, calculate the price of the American calls using the Roll-Geske-Whaley option pricing model:

```
AssetPrice = 80;
Settle = 'Jun-01-2008';
Maturity = 'Jun-01-2009';
Strike = [110; 100];
```

```
Rate = 0.06;
Sigma = 0.2;
```

```
DivAmount = 0.001;
DivDate = 'Dec-01-2008';
```

Create RateSpec and StockSpec:

```
StockSpec = stockspec(Sigma, AssetPrice, {'cash'}, DivAmount, DivDate);
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
'EndDates', Maturity, 'Rates', Rate, 'Compounding', -1);
```

Calculate the call prices:

```
Price = optstockbyrgw(RateSpec, StockSpec, Settle, Maturity, Strike)

Price =

    0.8398
    2.0236
```

The first element of the `Price` vector represents the price of the call with an exercise price of \$110 (\$0.84); the second is the price of the call with an exercise price of \$100 (\$2.02).

## Pricing Using the Bjerk Sund-Stensland Model

Consider four American stock options (two calls and two puts) with an exercise price of \$100 that expire on July 1, 2008. Assume the underlying stock pays a continuous dividend yield of 4% as of January 1, 2008. The stock has a volatility of 20% per annum and the risk-free rate is 8% per annum. Using this data, calculate the price of the American calls and puts assuming the following current prices of the stock: \$80, \$90 (for the calls) and \$100 and \$110 (for the puts):

```
Settle = 'Jan-1-2008';
Maturity = 'Jul-1-2008';
Strike = 100;
AssetPrice = [80; 90; 100; 110];
DivYield = 0.04;
```

```
Rate = 0.08;
Sigma = 0.20;
```

Create RateSpec and StockSpec:

```
StockSpec = stockspeg(Sigma, AssetPrice, {'continuous'}, DivYield);  
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...  
'EndDates', Maturity, 'Rates', Rate, 'Compounding', -1);
```

Define the option type:

```
OptSpec = {'call'; 'call'; 'put'; 'put'};
```

Compute the option prices:

```
Price = optstockbybjs(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike)
```

```
Price =  
    0.4144  
    2.1804  
    4.7253  
    1.7164
```

The first two elements of the `Price` vector represent the price of the calls (\$0.41 and \$2.18), the last two elements represent the price of the put options (\$4.72 and \$1.72). Use the function `optstocksensbybjs` to compute six sensitivities for the Bjerksund-Stensland model: `delta`, `gamma`, `vega`, `lambda`, `rho`, and `theta` and the price of the option. The selection of output parameters and their order is determined by the optional input parameter `OutSpec`. This parameter is a cell array of strings, each one specifying a desired output parameter. The order in which these output parameters are returned by the function is the same as the order of the strings contained in `OutSpec`. As an example, consider the same options as the previous example. To calculate their `delta`, `gamma`, and `price`, build the cell array `OutSpec` as follows:

```
OutSpec = {'delta', 'gamma', 'price'};
```

The outputs of `optstocksensbybjs` will be in the same order as in `OutSpec`.

```
[Delta ,Gamma, Price]= optstocksensbybjs(RateSpec, StockSpec, Settle,...  
Maturity, OptSpec, Strike, 'OutSpec', OutSpec)
```

```
Delta =  
    0.0843  
    0.2912  
    0.4803  
    0.2261
```



Gamma =

0.0136  
0.0267  
0.0304  
0.0217

Price =

0.4144  
2.1804  
4.7253  
1.7164

For more information on the Bjerksund-Stensland model, see “Closed-Form Solutions Modeling” on page C-9.

## Pricing European Call Options Using Different Equity Models

This example illustrates how the Financial Instruments Toolbox™ can be used to price European vanilla call options using different equity models.

The example compares call option prices using the Cox-Ross-Rubinstein model, the Leisen-Reimer model and the Black-Scholes closed formula.

### Define the Call Instrument

Consider a European call option, with an exercise price of \$30 on January 1, 2010. The option expires on Sep 1, 2010. Assume that the underlying stock provides no dividends. The stock is trading at \$25 and has a volatility of 35% per annum. The annualized continuously compounded risk-free rate is 1.11% per annum.

```
% Option
Settle = 'Jan-01-2010';
Maturity = 'Sep-01-2010';
Strike = 30;
OptSpec = 'call';
```

```
% Stock
AssetPrice = 25;
Sigma = .35;
```

### Create the Interest Rate Term Structure

```
StartDates = '01 Jan 2010';
EndDates = '01 Jan 2013';
Rates = 0.0111;
ValuationDate = '01 Jan 2010';
Compounding = -1;
```

```
RateSpec = intenvset('Compounding',Compounding,'StartDates', StartDates,...
                    'EndDates', EndDates, 'Rates', Rates, 'ValuationDate', ValuationDate);
```

### Create the Stock Structure

Suppose we wish to create two scenarios. The first one assumes that AssetPrice is currently \$25, the option is out of the money (OTM). The second scenario assumes that the option is at the money (ATM), and therefore AssetPriceATM = 30.

```
AssetPriceATM = 30;
```

```
StockSpec = stockspeg(Sigma, AssetPrice);
StockSpecATM = stockspeg(Sigma, AssetPriceATM);
```

### Price the Options Using the Black-Scholes Closed Formula

Use the function 'optstockbybls' in the Financial Instruments Toolbox to compute the price of the European call options.

```
% Price the option with AssetPrice = 25
PriceBLS = optstockbybls(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike);

% Price the option with AssetPrice = 30
PriceBLSATM = optstockbybls(RateSpec, StockSpecATM, Settle, Maturity, OptSpec, Strike)
```

### Build the Cox-Ross-Rubinstein Tree

```
% Create the time specification of the tree
NumPeriods = 15;

CRRTIMEspec = crrtimespec(ValuationDate, Maturity, NumPeriods);

% Build the tree
CRRTree = crrtree(StockSpec, RateSpec, CRRTIMEspec);
CRRTreeATM = crrtree(StockSpecATM, RateSpec, CRRTIMEspec);
```

### Build the Leisen-Reimer Tree

```
% Create the time specification of the tree
LRTimeSpec = lrtimespec(ValuationDate, Maturity, NumPeriods);

% Use the default method 'PP1' (Peizer-Pratt method 1 inversion) to build
% the tree
LRTree = lrtree(StockSpec, RateSpec, LRTimeSpec, Strike);
LRTreeATM = lrtree(StockSpecATM, RateSpec, LRTimeSpec, Strike);
```

### Price the Options Using the Cox-Ross-Rubinstein (CRR) Model

```
PriceCRR = optstockbycrr(CRRTree, OptSpec, Strike, Settle, Maturity);
PriceCRRATM = optstockbycrr(CRRTreeATM, OptSpec, Strike, Settle, Maturity);
```

### Price the Options Using the Leisen-Reimer (LR) Model

```
PriceLR = optstockbylr(LRTree, OptSpec, Strike, Settle, Maturity);
PriceLRATM = optstockbylr(LRTreeATM, OptSpec, Strike, Settle, Maturity);
```

### Compare BLS, CRR and LR Results

```
printf('PriceBLS: %f\nPriceCRR: %f\nPriceLR:%f\n', PriceBLS, ...
      PriceCRR, PriceLR)
```

```
printf('\t== ATM ==\nPriceBLS ATM: %f\nPriceCRR ATM: %f\nPriceLR ATM:%f\n', Pri
      PriceCRRATM, PriceLRATM)
```

```
ans =
```

```
PriceBLS: 1.275075
PriceCRR: 1.294979
PriceLR: 1.275838
```

```
ans =
```

```
== ATM ==
PriceBLS ATM: 3.497891
PriceCRR ATM: 3.553938
PriceLR ATM: 3.498571
```

### Convergence of CRR and LR Models to a BLS Solution

The following tables compare call option prices using the CRR and LR models against the results obtained with the Black-Scholes formula.

While the CRR binomial model and the Black-Scholes model converge as the number of time steps gets large and the length of each step gets small, this convergence, except for at the money options, is anything but smooth or uniform.

The tables below show that the Leisen-Reimer model reduces the size of the error with even as few steps of 45.

Strike = 30, Asset Price = 30

#Steps	LR	CRR
15	3.4986	3.5539
25	3.4981	3.5314
45	3.4980	3.5165

65	3.4979	3.5108
85	3.4979	3.5077
105	3.4979	3.5058
201	3.4979	3.5020
501	3.4979	3.4996
999	3.4979	3.4987

Strike = 30,      Asset Price = 25

#Steps	LR	CRR
15	1.2758	1.2950
25	1.2754	1.2627
45	1.2751	1.2851
65	1.2751	1.2692
85	1.2751	1.2812
105	1.2751	1.2766
201	1.2751	1.2723
501	1.2751	1.2759
999	1.2751	1.2756

### Analyze the Effect of the Number of Periods on the Price of the Options

The following graphs show how convergence changes as the number of steps in the binomial calculation increases, as well as the impact on convergence to changes to the stock price. Observe that the Leisen-Reimer model removes the oscillation and produces estimates close to the Black-Scholes model using only a small number of steps.

```
NPoints = 300;
```

```
% Cox-Ross-Rubinstein
```

```
NumPeriodCRR = 5 : 1 : NPoints;
```

```
NbStepCRR = length(NumPeriodCRR);
```

```
PriceCRR = nan(NbStepCRR,1);
```

```
PriceCRRATM = PriceCRR;
```

```
for i = 1 : NbStepCRR
```

```
    CRRTTimeSpec = crrtimespec(ValuationDate, Maturity, NumPeriodCRR(i));
```

```
    CRRT = crrtree(StockSpec, RateSpec, CRRTTimeSpec);
```

```
    PriceCRR(i) = optstockbycrr(CRRT, OptSpec, Strike, ValuationDate, Maturity) ;
```

```
    CRRTATM = crrtree(StockSpecATM, RateSpec, CRRTTimeSpec);
```

```
    PriceCRRATM(i) = optstockbycrr(CRRTATM, OptSpec, Strike, ValuationDate, Maturity) ;
```

```
end;
```

```

% Now with Leisen-Reimer
NumPeriodLR = 5 : 2 : NPoints;
NbStepLR = length(NumPeriodLR);
PriceLR = nan(NbStepLR, 1);
PriceLRATM = PriceLR;

for i = 1 : NbStepLR
    LRTimeSpec = lrtimespec(ValuationDate, Maturity, NumPeriodLR(i));
    LRT = lrtree(StockSpec, RateSpec, LRTimeSpec, Strike);
    PriceLR(i) = optstockbylr(LRT, OptSpec, Strike, ValuationDate, Maturity) ;

    LRTATM = lrtree(StockSpecATM, RateSpec, LRTimeSpec, Strike);
    PriceLRATM(i) = optstockbylr(LRTATM, OptSpec, Strike, ValuationDate, Maturity) ;
end;

```

First scenario: Out of the Money call option

```

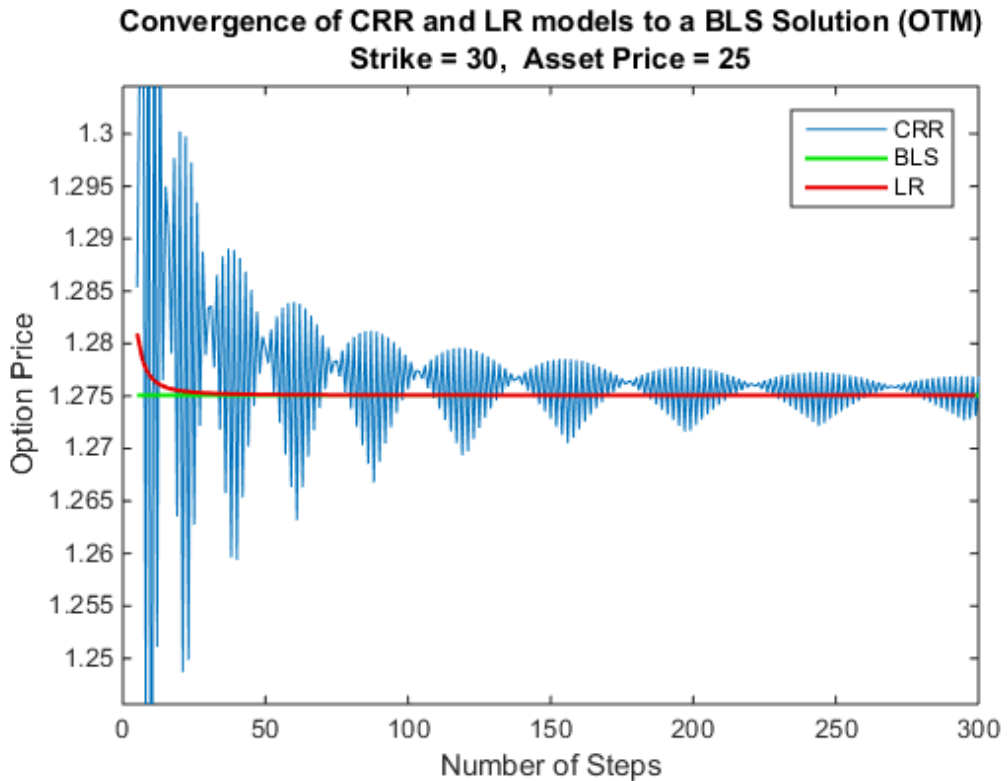
% For Cox-Ross-Rubinstein
plot(NumPeriodCRR, PriceCRR);
hold on;
plot(NumPeriodCRR, PriceBLS*ones(NbStepCRR,1), 'Color', [0 0.9 0], 'linewidth', 1.5);

% For Leisen-Reimer
plot(NumPeriodLR, PriceLR, 'Color', [0.9 0 0], 'linewidth', 1.5);

% Concentrate in the area of interest by clipping on the Y axis at 5x the
% LR Price:
YLimDelta = 5*abs(PriceLR(1) - PriceBLS);
ax = gca;
ax.YLim = [PriceBLS-YLimDelta PriceBLS+YLimDelta];

% Annotate Plot
titleString = sprintf('\nConvergence of CRR and LR models to a BLS Solution (OTM)\nStr:
title(titleString)
ylabel('Option Price')
xlabel('Number of Steps')
legend('CRR', 'BLS', 'LR', 'Location', 'NorthEast')

```



Second scenario: At the Money call option

```
% For Cox-Ross-Rubinstein
figure;
plot(NumPeriodCRR, PriceCRRATM);
hold on;
plot(NumPeriodCRR, PriceBLSATM*ones(NbStepCRR,1), 'Color',[0 0.9 0], 'linewidth', 1.5);

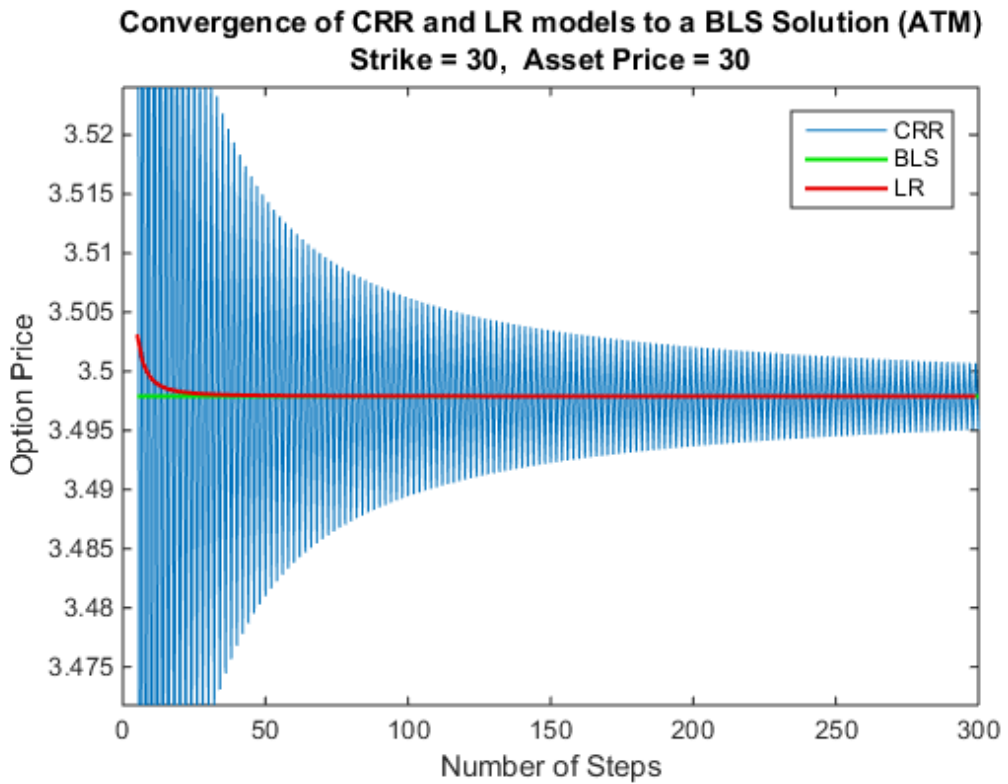
% For Leisen-Reimer
plot(NumPeriodLR, PriceLRATM, 'Color',[0.9 0 0], 'linewidth', 1.5);

% Concentrate in the area of interest by clipping on the Y axis at 5x the
% LR Price:
YLimDelta = 5*abs(PriceLRATM(1) - PriceBLSATM);
```

```

ax = gca;
ax.YLim = [PriceBLSATM-YLimDelta PriceBLSATM+YLimDelta];
% Annotate Plot
titleString = sprintf('\nConvergence of CRR and LR models to a BLS Solution (ATM)\nStr:
title(titleString)
ylabel('Option Price')
xlabel('Number of Steps')
legend('CRR', 'BLS', 'LR', 'Location', 'NorthEast')

```





# Hedging Portfolios

---

- “Hedging” on page 4-2
- “Hedging Functions” on page 4-3
- “Pricing and Hedging a Portfolio Using the Black-Karasinski Model” on page 4-15
- “Specifying Constraints with ConSet” on page 4-29
- “Hedging with Constrained Portfolios” on page 4-34

# Hedging

Hedging is an important consideration in modern finance. Whether or not to hedge, how much portfolio insurance is adequate, and how often to rebalance a portfolio are important considerations for traders, portfolio managers, and financial institutions alike.

If there were no transaction costs, financial professionals would prefer to rebalance portfolios continually, thereby minimizing exposure to market movements. However, in practice, the transaction costs associated with frequent portfolio rebalancing may be expensive. Therefore, traders and portfolio managers must carefully assess the cost required to achieve a particular portfolio sensitivity (for example, maintaining delta, gamma, and vega neutrality). Thus, the hedging problem involves the fundamental tradeoff between portfolio insurance and the cost of such insurance coverage.

# Hedging Functions

## In this section...

“Introduction” on page 4-3

“Hedging with hedgeopt” on page 4-4

“Self-Financing Hedges with hedgeslf” on page 4-11

## Introduction

Financial Instruments Toolbox software offers two functions for assessing the fundamental hedging tradeoff, `hedgeopt` and `hedgeslf`.

The first function, `hedgeopt`, addresses the most general hedging problem. It allocates an optimal hedge to satisfy either of two goals:

- Minimize the cost of hedging a portfolio given a set of target sensitivities.
- Minimize portfolio sensitivities for a given set of maximum target costs.

`hedgeopt` allows investors to modify portfolio allocations among instruments according to either of the goals. The problem is cast as a constrained linear least-squares problem. For additional information about `hedgeopt`, see “Hedging with hedgeopt” on page 4-4.

The second function, `hedgeslf`, attempts to allocate a self-financing hedge among a portfolio of instruments. In particular, `hedgeslf` attempts to maintain a constant portfolio value consistent with reduced portfolio sensitivities (that is, the rebalanced portfolio is hedged against market moves and is closest to being self-financing). If `hedgeslf` cannot find a self-financing hedge, it rebalances the portfolio to minimize overall portfolio sensitivities. For additional information on `hedgeslf`, see “Self-Financing Hedges with hedgeslf” on page 4-11.

The examples in this section consider the *delta*, *gamma*, and *vega* sensitivity measures. In this toolbox, when you work with *interest-rate derivatives*, delta is the price sensitivity measure of shifts in the forward yield curve, gamma is the delta sensitivity measure of shifts in the forward yield curve, and vega is the price sensitivity measure of shifts in the volatility process. See `bdtsens` or `hjmsens` for details on the computation of sensitivities for interest-rate derivatives.

For *equity exotic options*, the underlying instrument is the stock price instead of the forward yield curve. Consequently, delta now represents the price sensitivity measure of shifts in the stock price, gamma is the delta sensitivity measure of shifts in the stock price, and vega is the price sensitivity measure of shifts in the volatility of the stock. See `crrsens`, `eqpsens`, or `ittsens` for details on the computation of sensitivities for equity derivatives.

For examples showing the computation of sensitivities for interest-rate based derivatives, see “Computing Instrument Sensitivities” on page 2-51. Likewise, for examples showing the computation of sensitivities for equity exotic options, see “Computing Instrument Sensitivities” on page 3-115.

---

**Note** The delta, gamma, and vega sensitivities that the toolbox calculates are dollar sensitivities.

---

### Hedging with `hedgeopt`

---

**Note** The numerical results in this section are displayed in the MATLAB bank format. Although the calculations are performed in floating-point double precision, only two decimal places are displayed.

---

To illustrate the hedging facility, consider the portfolio `HJMInstSet` obtained from the example file `deriv.mat`. The portfolio consists of eight instruments: two bonds, one bond option, one fixed-rate note, one floating-rate note, one cap, one floor, and one swap.

Both hedging functions require some common inputs, including the current portfolio holdings (allocations), and a matrix of instrument sensitivities. To create these inputs, load the example portfolio into memory

```
load deriv.mat;
```

compute price and sensitivities

```
[Delta, Gamma, Vega, Price] = hjmsens(HJMTree, HMJInstSet);
```

```
Warning: Not all cash flows are aligned with the tree. Result will be approximated.
```

and extract the current portfolio holdings.

```
Holdings = instget(HJMIInstSet, 'FieldName', 'Quantity');
```

For convenience place the delta, gamma, and vega sensitivity measures into a matrix of sensitivities.

```
Sensitivities = [Delta Gamma Vega];
```

Each row of the **Sensitivities** matrix is associated with a different instrument in the portfolio, and each column with a different sensitivity measure.

To summarize the portfolio information

```
disp([Price Holdings Sensitivities])
```

98.72	100.00	-272.65	1029.90	0.00
97.53	50.00	-347.43	1622.69	-0.04
0.05	-50.00	-8.08	643.40	34.07
98.72	80.00	-272.65	1029.90	0.00
100.55	8.00	-1.04	3.31	0
6.28	30.00	294.97	6852.56	93.69
0.05	40.00	-47.16	8459.99	93.69
3.69	10.00	-282.05	1059.68	0.00

The first column above is the dollar unit price of each instrument, the second is the holdings of each instrument (the quantity held or the number of contracts), and the third, fourth, and fifth columns are the dollar delta, gamma, and vega sensitivities, respectively.

The current portfolio sensitivities are a weighted average of the instruments in the portfolio.

```
TargetSens = Holdings' * Sensitivities
```

```
TargetSens =
```

-61910.22	788946.21	4852.91
-----------	-----------	---------

### Maintaining Existing Allocations

To illustrate using `hedgeopt`, suppose that you want to maintain your existing portfolio. The first form of `hedgeopt` minimizes the cost of hedging a portfolio given a set of target sensitivities. If you want to maintain your existing portfolio composition and exposure, you should be able to do so without spending any money. To verify this, set the target sensitivities to the current sensitivities.

```
[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price, ...
```

```
Holdings, [], [], [], TargetSens)
Sens =
      -61910.22      788946.21      4852.91
Cost =
      0
Quantity' =
      100.00
       50.00
      -50.00
       80.00
        8.00
       30.00
       40.00
       10.00
```

Portfolio composition and sensitivities are unchanged, and the cost associated with doing nothing is zero. The cost is defined as the change in portfolio value. This number cannot be less than zero because the rebalancing cost is defined as a nonnegative number.

If `Value0` and `Value1` represent the portfolio value before and after rebalancing, respectively, the zero cost can also be verified by comparing the portfolio values.

```
Value0 = Holdings' * Price
```

```
Value0 =
      23674.62
```

```
Value1 = Quantity * Price
```

```
Value1 =
      23674.62
```

### Partially Hedged Portfolio

Building on the example in “Maintaining Existing Allocations” on page 4-5, suppose you want to know the cost to achieve an overall portfolio dollar sensitivity of `[-23000 -3300 3000]`, while allowing trading only in instruments 2, 3, and 6 (holding the

positions of instruments 1, 4, 5, 7, and 8 fixed). To find the cost, first set the target portfolio dollar sensitivity.

```
TargetSens = [-23000 -3300 3000];
```

Then, specify the instruments to be fixed.

```
FixedInd = [1 4 5 7 8];
```

Finally, call `hedgeopt`

```
[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price,...
Holdings, FixedInd, [], [], TargetSens);
```

and again examine the results.

```
Sens =
```

```
    -23000.00    -3300.00     3000.00
```

```
Cost =
```

```
    19174.02
```

```
Quantity' =
```

```
    100.00
   -141.03
    137.26
     80.00
     8.00
   -57.96
     40.00
     10.00
```

Recompute `Value1`, the portfolio value after rebalancing.

```
Value1 = Quantity * Price
```

```
Value1 =
```

```
    4500.60
```

As expected, the cost, \$19174.02, is the difference between `Value0` and `Value1`, \$23674.62 — \$4500.60. Only the positions in instruments 2, 3, and 6 have been changed.

### Fully Hedged Portfolio

The example in “Partially Hedged Portfolio” on page 4-6 illustrates a partial hedge, but perhaps the most interesting case involves the cost associated with a fully hedged portfolio (simultaneous delta, gamma, and vega neutrality). In this case, set the target sensitivity to a row vector of 0s and call `hedgeopt` again. The following example uses data from “Hedging with hedgeopt” on page 4-4.

```
TargetSens = [0 0 0];  
[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price, ...  
Holdings, FixedInd, [], [], TargetSens);
```

Examining the outputs reveals that you have obtained a fully hedged portfolio

```
Sens =  
  
          -0.00          -0.00          -0.00
```

but at an expense of over \$20,000.

```
Cost =  
  
    23055.90
```

The positions required to achieve a fully hedged portfolio

```
Quantity' =  
  
    100.00  
   -182.36  
    -19.55  
     80.00  
      8.00  
   -32.97  
     40.00  
     10.00
```

result in the new portfolio value

```
Value1 = Quantity * Price
```

```
Value1 =
```



618.72

### Minimizing Portfolio Sensitivities

The examples in “Fully Hedged Portfolio” on page 4-8 illustrate how to use `hedgeopt` to determine the minimum cost of hedging a portfolio given a set of target sensitivities. In these examples, portfolio target sensitivities are treated as equality constraints during the optimization process. You tell `hedgeopt` what sensitivities you want, and it tells you what it will cost to get those sensitivities.

A related problem involves minimizing portfolio sensitivities for a given set of maximum target costs. For this goal, the target costs are treated as inequality constraints during the optimization process. You tell `hedgeopt` the most you are willing spend to insulate your portfolio, and it tells you the smallest portfolio sensitivities you can get for your money.

To illustrate this use of `hedgeopt`, compute the portfolio dollar sensitivities along the entire cost frontier. From the previous examples, you know that spending nothing replicates the existing portfolio, while spending \$23,055.90 completely hedges the portfolio.

Assume, for example, you are willing to spend as much as \$50,000, and want to see what portfolio sensitivities will result along the cost frontier. Assume that the same instruments are held fixed, and that the cost frontier is evaluated from \$0 to \$50,000 at increments of \$1000.

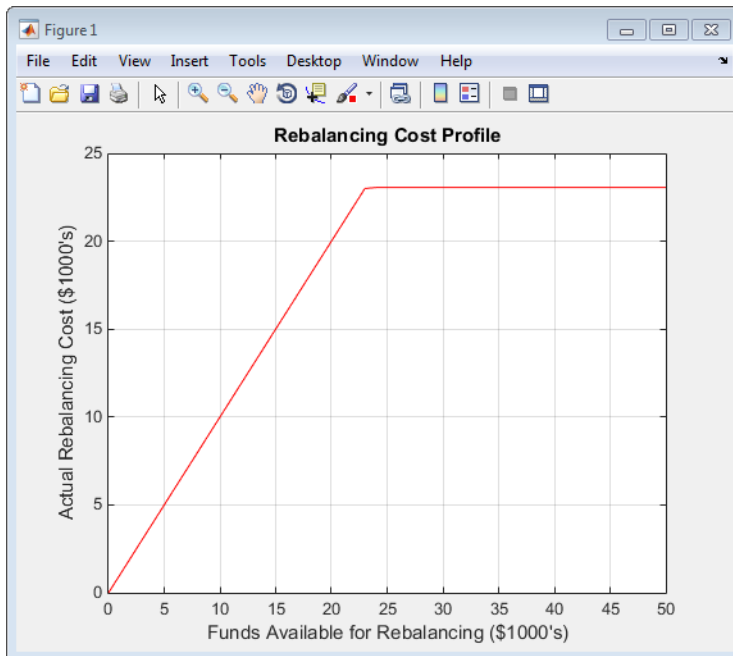
```
MaxCost = [0:1000:50000];
```

Now, call `hedgeopt`.

```
[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price, ...
Holdings, FixedInd, [], MaxCost);
```

With this data, you can plot the required hedging cost versus the funds available (the amount you are willing to spend)

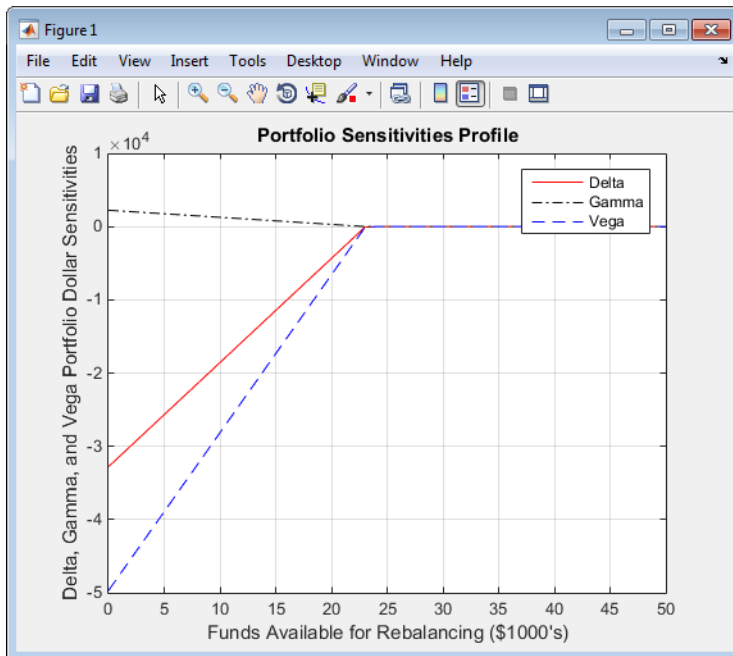
```
plot(MaxCost/1000, Cost/1000, 'red'), grid
xlabel('Funds Available for Rebalancing ($1000's)')
ylabel('Actual Rebalancing Cost ($1000's)')
title ('Rebalancing Cost Profile')
```



### Rebalancing Cost Profile

and the portfolio dollar sensitivities versus the funds available.

```
figure
plot(MaxCost/1000, Sens(:,1), '-red')
hold('on')
plot(MaxCost/1000, Sens(:,2), '-.black')
plot(MaxCost/1000, Sens(:,3), '--blue')
grid
xlabel('Funds Available for Rebalancing ($1000's)')
ylabel('Delta, Gamma, and Vega Portfolio Dollar Sensitivities')
title('Portfolio Sensitivities Profile')
legend('Delta', 'Gamma', 'Vega', 0)
```



### Funds Available for Rebalancing

## Self-Financing Hedges with hedgeslf

The figures Rebalancing Cost Profile and Funds Available for Rebalancing indicate that there is no benefit because the funds available for hedging exceed \$23,055.90, the point of maximum expense required to obtain simultaneous delta, gamma, and vega neutrality. You can also find this point of delta, gamma, and vega neutrality using `hedgeslf`.

```
[Sens, Value1, Quantity] = hedgeslf(Sensitivities, Price, ...
Holdings, FixedInd);
```

```
Sens =
```

```
-0.00
-0.00
-0.00
```

```
Value1 =
```

```

618.72
Quantity =
    100.00
   -182.36
    -19.55
     80.00
      8.00
   -32.97
    40.00
    10.00

```

Similar to `hedgeopt`, `hedgeslf` returns the portfolio dollar sensitivities and instrument quantities (the rebalanced holdings). However, in contrast, the second output parameter of `hedgeslf` is the value of the rebalanced portfolio, from which you can calculate the rebalancing cost by subtraction.

```

Value0 - Value1
ans =
    23055.90

```

In this example, the portfolio is clearly not self-financing, so `hedgeslf` finds the best possible solution required to obtain zero sensitivities.

There is, in fact, a third calling syntax available for `hedgeopt` directly related to the results shown above for `hedgeslf`. Suppose, instead of directly specifying the funds available for rebalancing (the most money you are willing to spend), you want to simply specify the number of points along the cost frontier. This call to `hedgeopt` samples the cost frontier at 10 equally spaced points between the point of minimum cost (and potentially maximum exposure) and the point of minimum exposure (and maximum cost).

```

[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price,...
Holdings, FixedInd, 10)
Sens =
   -32784.46    2231.83   -49694.33
   -29141.74    1983.85   -44172.74
   -25499.02    1735.87   -38651.14
   -21856.30    1487.89   -33129.55
   -18213.59    1239.91   -27607.96

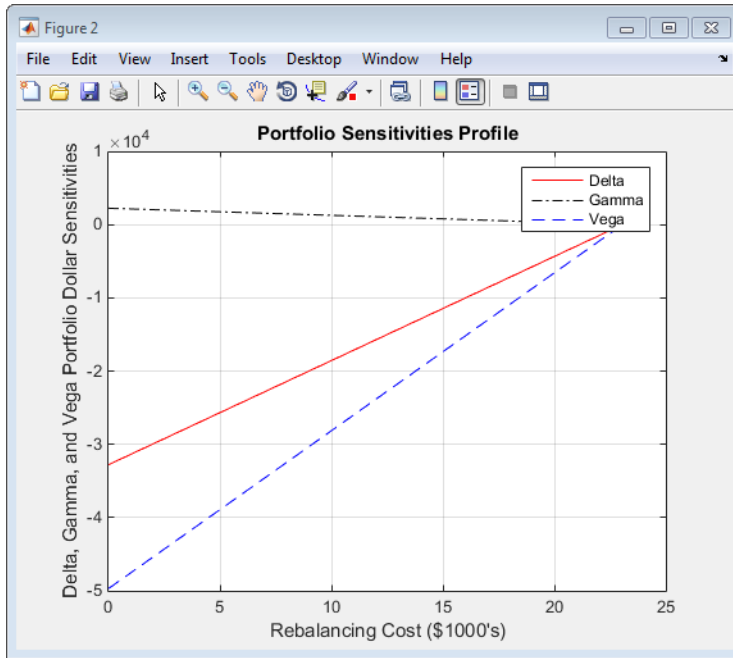
```

-14570.87	991.93	-22086.37
-10928.15	743.94	-16564.78
-7285.43	495.96	-11043.18
-3642.72	247.98	-5521.59
0.00	-0.00	0.00

```
Cost =
    0.00
   2561.77
   5123.53
   7685.30
  10247.07
  12808.83
  15370.60
  17932.37
  20494.14
  23055.90
```

Now plot this data.

```
figure
plot(Cost/1000, Sens(:,1), '-red')
hold('on')
plot(Cost/1000, Sens(:,2), '-.black')
plot(Cost/1000, Sens(:,3), '--blue')
grid
xlabel('Rebalancing Cost ($1000's)')
ylabel('Delta, Gamma, and Vega Portfolio Dollar Sensitivities')
title('Portfolio Sensitivities Profile')
legend('Delta', 'Gamma', 'Vega', 0)
```



### Rebalancing Cost

In this calling form, `hedgeopt` calls `hedgeslf` internally to determine the maximum cost needed to minimize the portfolio sensitivities (\$23,055.90), and evenly samples the cost frontier between \$0 and \$23,055.90.

Note that both `hedgeopt` and `hedgeslf` cast the optimization problem as a constrained linear least squares problem. Depending on the instruments and constraints, neither function is guaranteed to converge to a solution. In some cases, the problem space may be unbounded, and additional instrument equality constraints, or user-specified constraints, may be necessary for convergence. See “Hedging with Constrained Portfolios” on page 4-34 for additional information.

## Pricing and Hedging a Portfolio Using the Black-Karasinski Model

This example illustrates how MATLAB® can be used to create a portfolio of interest rate derivatives securities, and price it using the Black-Karasinski interest rate model. The example also shows some hedging strategies to minimize exposure to market movements.

### Create the Interest Rate Term Structure Based on Reported Data

The structure `RateSpec` is an interest rate term structure that defines the initial rate specification from which the tree rates are derived. Use the information of annualized zero coupon rates in the table below to populate the `RateSpec` structure.

From	To	Rate
27 Feb 2007	27 Feb 2008	0.0493
27 Feb 2007	27 Feb 2009	0.0459
27 Feb 2007	27 Feb 2010	0.0450
27 Feb 2007	27 Feb 2012	0.0446
27 Feb 2007	27 Feb 2014	0.0445
27 Feb 2007	27 Feb 2017	0.0450
27 Feb 2007	27 Feb 2027	0.0473

This data could be retrieved from the Federal Reserve Statistical Release page by using the Datafeed Toolbox™. In this case, the Datafeed Toolbox™ will connect to FRED® and pull back the rates of the following treasury notes.

Terms	Symbol
=====	=====
1	= DGS1
2	= DGS2
3	= DGS3
5	= DGS5
7	= DGS7
10	= DGS10
20	= DGS20

Create connection object:

```
c = fred;
```

Create symbol fetch list:

```
FredNames = { ...
    'DGS1'; ... % 1 Year
```

```
'DGS2'; ... % 2 Year
'DGS3'; ... % 3 Year
'DGS5'; ... % 5 Year
'DGS7'; ... % 7 Year
'DGS10'; ... % 10 Year
'DGS20'}; % 20 Year
```

Define Terms:

```
Terms = [ 1; ... % 1 Year
          2; ... % 2 Year
          3; ... % 3 Year
          5; ... % 5 Year
          7; ... % 7 Year
          10; ... % 10 Year
          20]; % 20 Year
```

Set StartDate to Feb 27, 2007:

```
StartDate = datenum('Feb-27-2007');
FredRet = fetch(c,FredNames,StartDate);
```

Set ValuationDate based on StartDate:

```
ValuationDate = StartDate;
EndDates = [];
Rates =[];
```

Create EndDates:

```
for idx = 1:length(FredRet)

%Pull the rates associated with Feb 27, 2007. All the Fred Rates come
%back as percents
Rates = [Rates; ...
         FredRet(idx).Data(1,2) / 100];

%Determine the EndDates by adding the Term to the year of the
%StartDate
EndDates = [EndDates; ...
            round(datenum(...
                year(StartDate)+ Terms(idx,1), ...
                month(StartDate),...
                day(StartDate)), ...
            'dd-mmm-yyyy')];
```



```

        day(StartDate))]);
end

```

Use the function 'intenvset' to create the RateSpec with the following data:

```

Compounding = 1;
StartDate = '27-Feb-2007';
Rates = [0.0493; 0.0459; 0.0450; 0.0446; 0.0446; 0.0450; 0.0473];
EndDates = {'27-Feb-2008'; '27-Feb-2009'; '27-Feb-2010'; '27-Feb-2012';...
            '27-Feb-2014'; '27-Feb-2017'; '27-Feb-2027'};
ValuationDate = StartDate;

RateSpec = intenvset('Compounding',Compounding,'StartDates', StartDate,...
                    'EndDates', EndDates, 'Rates', Rates, 'ValuationDate', ValuationDate);

```

```

RateSpec =

    FinObj: 'RateSpec'
  Compounding: 1
        Disc: [7x1 double]
        Rates: [7x1 double]
    EndTimes: [7x1 double]
  StartTimes: [7x1 double]
    EndDates: [7x1 double]
  StartDates: 733100
ValuationDate: 733100
          Basis: 0
  EndMonthRule: 1

```

### Specify the Volatility Model

Create the structure VolSpec that specifies the volatility process with the following data.

```

Volatility = [0.011892; 0.01563; 0.02021; 0.02125; 0.02165; 0.02065; 0.01803];
Alpha = [0.0001];
VolSpec = bkvolspec(ValuationDate, EndDates, Volatility, EndDates(end), Alpha);

```

```

VolSpec =

    FinObj: 'BKVolspec'
ValuationDate: 733100

```

```
VolDates: [7x1 double]
VolCurve: [7x1 double]
AlphaCurve: 1.0000e-04
AlphaDates: 740405
VolInterpMethod: 'linear'
```

### Specify the Time Structure of the Tree

The structure `TimeSpec` specifies the time structure for an interest rate tree. This structure defines the mapping between the observation times at each level of the tree and the corresponding dates.

```
TimeSpec = bktimespec(ValuationDate, EndDates)
```

```
TimeSpec =
    FinObj: 'BKTimeSpec'
ValuationDate: 733100
    Maturity: [7x1 double]
    Compounding: -1
    Basis: 0
    EndMonthRule: 1
```

### Create the BK Tree

Use the previously computed values for `RateSpec`, `VolSpec` and `TimeSpec` to create the BK tree.

```
BKTree = bktree(VolSpec, RateSpec, TimeSpec)
```

```
BKTree =
    FinObj: 'BKFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
    tObs: [0 1 2 3 5 7 10]
    dObs: [733100 733465 733831 734196 734926 735657 736753]
    CFlowT: {1x7 cell}
    Probs: {1x6 cell}
    Connect: {1x6 cell}
```

```
FwdTree: {1x7 cell}
```

Observe the Interest Rate Tree

Visualize the interest rate evolution along the tree by looking at the output structure BKTREE. The function 'bktree' returns an inverse discount tree, which you can convert into an interest rate tree with the 'cvtree' function.

```
BKTreeR = cvtree(BKTree)
```

```
BKTreeR =
```

```
    FinObj: 'BKRateTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
      tObs: [0 1 2 3 5 7 10]
      dObs: [733100 733465 733831 734196 734926 735657 736753]
    CFlowT: {1x7 cell}
    Probs: {1x6 cell}
    Connect: {1x6 cell}
    RateTree: {1x7 cell}
```

Look at the upper, middle and lower branch paths of the tree:

```
OldFormat = get(0, 'format');
format short
```

```
%Rate at root node:
```

```
RateRoot = trintreepath(BKTreeR, 0)
```

```
%Rates along upper branch:
```

```
RatePathUp = trintreepath(BKTreeR, [1 1 1 1 1 1])
```

```
%Rates along middle branch:
```

```
RatePathMiddle = trintreepath(BKTreeR, [2 2 2 2 2 2])
```

```
%Rates along lower branch:
```

```
RatePathDown = trintreepath(BKTreeR, [3 3 3 3 3 3])
```

```
RateRoot =
```

```
0.0481
```

```
RatePathUp =
```

```
0.0481  
0.0425  
0.0446  
0.0478  
0.0510  
0.0554  
0.0619
```

```
RatePathMiddle =
```

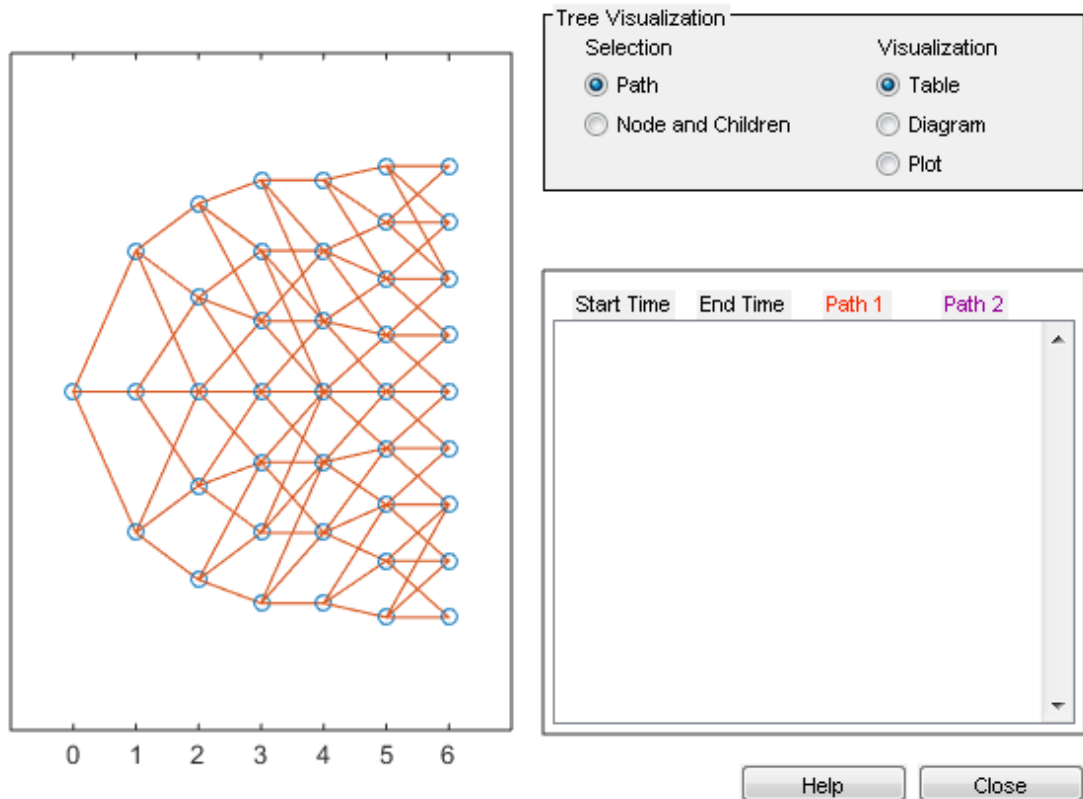
```
0.0481  
0.0416  
0.0423  
0.0430  
0.0436  
0.0448  
0.0483
```

```
RatePathDown =
```

```
0.0481  
0.0408  
0.0401  
0.0387  
0.0373  
0.0363  
0.0377
```

You can also display a graphical representation of the tree to examine interactively the rates on the nodes of the tree until maturity. The function `treeviewer` displays the structure of the rate tree in the left window. The tree visualization in the right window is blank, but by selecting `Table/Diagram` and clicking on the nodes you can examine the rates along the paths.

```
treeviewer(BKTreeR);
```



### Create an Instrument Portfolio

Create a portfolio consisting of two bonds instruments and an option on the 5% Bond.

```
% Two Bonds
CouponRate = [0.04;0.05];
Settle = '27 Feb 2007';
Maturity = {'27 Feb 2009';'27 Feb 2010'};
Period = 1;

% American Option on the 5% Bond
OptSpec = {'call'};
Strike = 98;
ExerciseDates = '27 Feb 2010';
```

```

AmericanOpt = 1;

InstSet = instadd('Bond', CouponRate, Settle, Maturity, Period);
InstSet = instadd(InstSet, 'OptBond', 2, OptSpec, Strike, ExerciseDates, AmericanOpt);

% Assign Names and Holdings
Holdings = [10; 15; 3];
Names = {'4% Bond'; '5% Bond'; 'Option 98'};

InstSet = instsetfield(InstSet, 'Index', 1:3, 'FieldName', {'Quantity'}, 'Data', Holdings);
InstSet = instsetfield(InstSet, 'Index', 1:3, 'FieldName', {'Name'}, 'Data', Names );

```

Examine the set of instruments contained in the variable InstSet.

```
instdisp(InstSet)
```

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate
1	Bond	0.04	27-Feb-2007	27-Feb-2009	1	0	1	NaN
2	Bond	0.05	27-Feb-2007	27-Feb-2010	1	0	1	NaN

Index	Type	UnderInd	OptSpec	Strike	ExerciseDates	AmericanOpt	Quantity	Name
3	OptBond	2	call	98	27-Feb-2010	1	3	Option 98

### Price the Portfolio Using the BK Model

Calculate the price of each instrument in the portfolio.

```
[Price, PTree] = bkprice(BKTree, InstSet)
```

```
Price =
```

```

98.8843
101.3476
3.3476

```

```
PTree =
```

```

FinObj: 'BKPriceTree'
PTree: {1x8 cell}
AITree: {1x8 cell}
tObs: [0 1 2 3 5 7 10 20]
Connect: {1x6 cell}

```

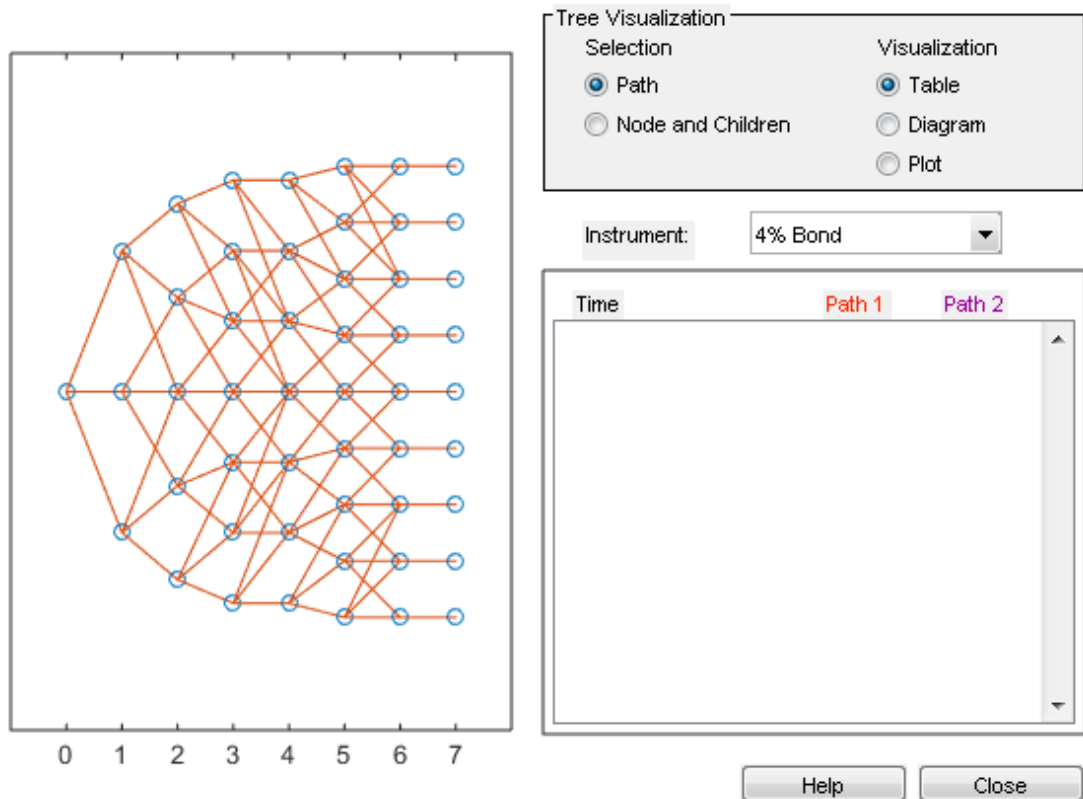
```
Probs: {1x6 cell}
```

The prices in the output vector `Price` correspond to the prices at observation time zero (`tObs = 0`), which is defined as the Valuation Date of the interest-rate tree.

In the `Price` vector, the first element, 98.884, represents the price of the first instrument (4% Bond); the second element, 101.347, represents the price of the second instrument (5% Bond), and 3.347 represents the price of the American call option.

You can also display a graphical representation of the price tree to examine the prices on the nodes of the tree until maturity.

```
treeviewer(PTree,InstSet);
```



### Add More Instruments to the Existing Portfolio

Add instruments to the existing portfolio: cap, floor, floating rate note, vanilla swap and a puttable and callable bond.

```
% Cap
StrikeC =0.035;
InstSet = instadd(InstSet,'Cap', StrikeC, Settle, '27 Feb 2010');

% Floor
StrikeF =0.05;
InstSet = instadd(InstSet,'Floor', StrikeF, Settle, '27 Feb 2009');

% Floating Rate Note
InstSet = instadd(InstSet,'Float', 30, Settle, '27 Feb 2009');

% Vanilla Swap
LegRate =[0.04 5];
InstSet = instadd(InstSet,'Swap', LegRate, Settle, '27 Feb 2010');

% Puttable and Callable Bonds
InstSet = instadd(InstSet,'OptEmBond', CouponRate, Settle, '27 Feb 2010', {'put';'call'};
                Strike, '27 Feb 2010','AmericanOpt', 1, 'Period', 1);

% Process Names and Holdings
Holdings = [15 ;5 ;8; 7; 9; 4];
Names = {'3.5% Cap';'5% Floor';'30BP Float';'4%/5BP Swap'; 'PuttBond'; 'CallBond' };

InstSet = instsetfield(InstSet, 'Index',4:9, 'FieldName', {'Quantity'}, 'Data', Holdings);
InstSet = instsetfield(InstSet, 'Index',4:9, 'FieldName', {'Name'}, 'Data', Names );
```

Examine the set of instruments contained in the variable InstSet.

```
instdisp(InstSet)
```

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate
1	Bond	0.04	27-Feb-2007	27-Feb-2009	1	0	1	NaN
2	Bond	0.05	27-Feb-2007	27-Feb-2010	1	0	1	NaN

Index	Type	UnderInd	OptSpec	Strike	ExerciseDates	AmericanOpt	Quantity	Name
3	OptBond	2	call	98	27-Feb-2010	1	3	Option 98

Index	Type	Strike	Settle	Maturity	CapReset	Basis	Principal	Quantity	Name
4	Cap	0.035	27-Feb-2007	27-Feb-2010	1	0	100	15	3.5%



Index	Type	Strike	Settle	Maturity	FloorReset	Basis	Principal	Quantity	Na
5	Floor	0.05	27-Feb-2007	27-Feb-2009	1	0	100	5	5
Index	Type	Spread	Settle	Maturity	FloatReset	Basis	Principal	EndMonthRu	
6	Float	30	27-Feb-2007	27-Feb-2009	1	0	100	1	
Index	Type	LegRate	Settle	Maturity	LegReset	Basis	Principal	LegType	En
7	Swap	[0.04 5]	27-Feb-2007	27-Feb-2010	[NaN]	0	100	[NaN]	1
Index	Type	CouponRate	Settle	Maturity	OptSpec	Strike	ExerciseDates		
8	OptEmBond	0.04	27-Feb-2007	27-Feb-2010	put	98	27-Feb-2007	2	
9	OptEmBond	0.05	27-Feb-2007	27-Feb-2010	call	98	27-Feb-2007	2	

## Hedging

The idea behind hedging is to minimize exposure to market movements. As the underlying changes, the proportions of the instruments forming the portfolio may need to be adjusted to keep the sensitivities within the desired range.

Calculate sensitivities using the BK model

```
[Delta, Gamma, Vega, Price] = bksens(BKTree, InstSet);
```

Get the current portfolio holdings.

```
Holdings = instget(InstSet, 'FieldName', 'Quantity');
```

Create a matrix of sensitivities

```
Sensitivities = [Delta Gamma Vega];
```

Each row of the Sensitivities matrix is associated with a different instrument in the portfolio, and each column with a different sensitivity measure.

Display the information

```
format bank
disp([Price Holdings Sensitivities])
```

98.88	10.00	-185.46	528.44	0.01
101.35	15.00	-277.50	1044.93	0.03
3.35	3.00	-223.50	11845.22	0.03
2.77	15.00	250.00	2926.95	-0.03
0.75	5.00	-132.97	11564.31	0.01

100.56	8.00	-0.80	2.02	0.00
-1.53	7.00	-272.07	1027.74	0.03
98.60	9.00	-168.94	21705.60	0.03
98.00	4.00	-54.00	-10800.29	0

The first column above is the dollar unit price of each instrument, the second is the number of contracts of each instrument, and the third, fourth, and fifth columns are the dollar delta, gamma, and vega sensitivities.

The current portfolio sensitivities are a weighted average of the instruments in the portfolio.

`TargetSens = Holdings' * Sensitivities`

`TargetSens =`

`-7249.76      317579.35      0.86`

### Obtain a Neutral Sensitivity Portfolio

Suppose you want to obtain a delta, gamma and vega neutral portfolio. The function `hedgeslf` finds the reallocation in a portfolio of financial instruments closest to being self-financing (maintaining constant portfolio value).

`[Sens, Value1, Quantity]= hedgeslf(Sensitivities, Price,Holdings)`

`Sens =`

`0.00  
0  
-0.00`

`Value1 =`

`4637.56`

`Quantity =`

`10.00`

```

5.59
-3.21
8.63
-14.68
9.74
-4.31
12.48
8.80

```

The function `hedgeslf` returns the portfolio dollar sensitivities (`Sens`), the value of the rebalanced portfolio (`Value1`) and the new allocation for each instrument (`Quantity`). If `Value0` and `Value1` represent the portfolio value before and after rebalancing, you can verify the cost by comparing the portfolio values.

```
Value0 = Holdings' * Price
```

```
Value0 =
```

```
4637.56
```

In this example, the portfolio is fully hedged (simultaneous delta, gamma, and vega neutrality) and self-financing (the values of the portfolio before and after balancing (`Value0` and `Value1`) are the same).

### Adding Constraints to Hedge a Portfolio

Suppose that you want to place upper and lower bounds on the individual instruments in the portfolio. Let's say that you want to bound the position of all instruments to within +/- 11 contracts.

Applying these constraints disallows the current positions in the fifth and eighth instruments. All other instruments are currently within the upper/lower bounds.

```

% Specify the lower and upper bounds
LowerBounds = [-11 -11 -11 -11 -11 -11 -11 -11 -11];
UpperBounds = [ 11  11  11  11  11  11  11  11  11];

% Use the function portcons to build the constraints
ConSet = portcons('AssetLims', LowerBounds, UpperBounds);

% Apply the constraints to the portfolio

```

```
[Sens, Value, Quantity1] = hedgeslf(Sensitivities, Price, Holdings, [], ConSet)
```

```
Sens =
```

```
      0  
     0.00  
    -0.00
```

```
Value =
```

```
4637.56
```

```
Quantity1 =
```

```
    2.56  
   11.00  
  -6.59  
    3.60  
  -4.67  
   11.00  
 -11.00  
   11.00  
   11.00
```

Observe that `hedgeslf` enforces the bounds on the fifth and eighth instruments, and the portfolio continues to be fully hedged and self-financing.

```
set(0, 'format', OldFormat);
```

## Specifying Constraints with ConSet

### In this section...

“Introduction” on page 4-29

“Setting Constraints” on page 4-29

“Portfolio Rebalancing” on page 4-31

### Introduction

Both `hedgeopt` and `hedgeslf` accept an optional input argument, `ConSet`, that allows you to specify a set of linear inequality constraints for instruments in your portfolio. The examples in this section are brief. For additional information regarding portfolio constraint specifications, refer to “Analyzing Portfolios”.

### Setting Constraints

For the first example of setting constraints, return to the fully hedged portfolio example that used `hedgeopt` to determine the minimum cost of obtaining simultaneous delta, gamma, and vega neutrality (target sensitivities all 0). Recall that when `hedgeopt` computes the cost of rebalancing a portfolio, the input target sensitivities you specify are treated as equality constraints during the optimization process. The situation is reproduced next for convenience.

```
TargetSens = [0 0 0];
[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price,...
Holdings, FixedInd, [], [], TargetSens);
```

The outputs provide a fully hedged portfolio

```
Sens =
      -0.00      -0.00      -0.00
```

at an expense of over \$23,000.

```
Cost =
 23055.90
```

The positions required to achieve this fully hedged portfolio are

```
Quantity' =
```

```
100.00
-182.36
-19.55
80.00
8.00
-32.97
40.00
10.00
```

Suppose now that you want to place some upper and lower bounds on the individual instruments in your portfolio. You can specify these constraints, along with a variety of general linear inequality constraints, with Financial Toolbox function `portcons`.

As an example, assume that, in addition to holding instruments 1, 4, 5, 7, and 8 fixed as before, you want to bound the position of all instruments to within +/- 180 contracts (for each instrument, you cannot short or long more than 180 contracts). Applying these constraints disallows the current position in the second instrument (short 182.36). All other instruments are currently within the upper/lower bounds.

You can generate these constraints by first specifying the lower and upper bounds vectors and then calling `portcons`.

```
LowerBounds = [-180 -180 -180 -180 -180 -180 -180 -180];
UpperBounds = [ 180  180  180 180 180 180 180 180];
ConSet = portcons('AssetLims', LowerBounds, UpperBounds);
```

To impose these constraints, call `hedgeopt` with `ConSet` as the last input.

```
[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price,...
Holdings, FixedInd, [], [], TargetSens, ConSet);
```

Examine the outputs and see that they are all set to `NaN`, indicating that the problem, given the constraints, is not solvable. Intuitively, the results mean that you cannot obtain simultaneous delta, gamma, and vega neutrality with these constraints at any price.

To see how close you can get to portfolio neutrality with these constraints, call `hedgeslf`.

```
[Sens, Value1, Quantity] = hedgeslf(Sensitivities, Price,...
Holdings, FixedInd, ConSet);
```

```
Sens =
```

```

-352.43
 21.99
-498.77

Value1 =

      855.10

Quantity =

      100.00
     -180.00
     -37.22
       80.00
        8.00
     -31.86
       40.00
       10.00

```

`hedges1f` enforces the lower bound for the second instrument, but the sensitivity is far from neutral. The cost to obtain this portfolio is

```

Value0 - Value1

ans =

      22819.52

```

## Portfolio Rebalancing

As a final example of user-specified constraints, rebalance the portfolio using the second hedging goal of `hedgeopt`. Assume that you are willing to spend as much as \$20,000 to rebalance your portfolio, and you want to know what minimum portfolio sensitivities you can get for your money. In this form, recall that the target cost (\$20,000) is treated as an inequality constraint during the optimization process.

For reference, startup `hedgeopt` without any user-specified linear inequality constraints.

```

[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price,...
Holdings, FixedInd, [], 20000);

Sens =

```

```

      -4345.36      295.81      -6586.64
Cost =
      20000.00

Quantity' =
      100.00
      -151.86
      -253.47
      80.00
      8.00
      -18.18
      40.00
      10.00

```

This result corresponds to the \$20,000 point along the Portfolio Sensitivities Profile shown in the figure Rebalancing Cost.

Assume that, in addition to holding instruments 1, 4, 5, 7, and 8 fixed as before, you want to bound the position of all instruments to within +/- 150 contracts (for each instrument, you cannot short more than 150 contracts and you cannot long more than 150 contracts). These bounds disallow the current position in the second and third instruments (-151.86 and -253.47). All other instruments are currently within the upper/lower bounds.

As before, you can generate these constraints by first specifying the lower and upper bounds vectors and then calling `portcons`.

```

LowerBounds = [-150 -150 -150 -150 -150 -150 -150 -150];
UpperBounds = [ 150 150 150 150 150 150 150 150];
ConSet = portcons('AssetLims', LowerBounds, UpperBounds);

```

To impose these constraints, again call `hedgeopt` with `ConSet` as the last input.

```

[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price, ...
Holdings, FixedInd, [], 20000, [], ConSet);

Sens =
      -8818.47      434.43      -4010.79

Cost =
      19876.89

```



Quantity' =

```
100.00
-150.00
-150.00
 80.00
  8.00
-28.32
 40.00
 10.00
```

With these constraints, **hedgeopt** enforces the lower bound for the second and third instruments. The cost incurred is \$19,876.89.

## Hedging with Constrained Portfolios

### In this section...

“Overview” on page 4-34

“Example: Fully Hedged Portfolio” on page 4-34

“Example: Minimize Portfolio Sensitivities” on page 4-36

“Example: Under-Determined System” on page 4-37

“Example: Portfolio Constraints with `hedgeslf`” on page 4-39

### Overview

Both hedging functions cast the optimization as a constrained linear least-squares problem. (See the function `lsqlin` in the Optimization Toolbox documentation for details.) In particular, `lsqlin` attempts to minimize the constrained linear least squares problem

$$\min_x \frac{1}{2} \|Cx - d\|_2^2 \quad \text{such that} \quad A \cdot x \leq b$$

$$A_{eq} \cdot x = beq$$

$$lb \leq x \leq ub$$

where  $C$ ,  $A$ , and  $A_{eq}$  are matrices, and  $d$ ,  $b$ ,  $beq$ ,  $lb$ , and  $ub$  are vectors. For Financial Instruments Toolbox software,  $x$  is a vector of asset holdings (contracts).

Depending on the constraint and the number of assets in the portfolio, a solution to a particular problem may or may not exist. Furthermore, if a solution is found, it may not be unique. For a unique solution to exist, the least squares problem must be sufficiently and appropriately constrained.

### Example: Fully Hedged Portfolio

Recall that `hedgeopt` allows you to allocate an optimal hedge by one of two goals:

- Minimize the cost of hedging a portfolio given a set of target sensitivities.
- Minimize portfolio sensitivities for a given set of maximum target costs.

As an example, reproduce the results for the fully hedged portfolio example.

```
TargetSens = [0 0 0];
FixedInd   = [1 4 5 7 8];
[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price, ...
Holdings, FixedInd, [], [], TargetSens);
```

Sens =

```
          -0.00          -0.00          -0.00
```

Cost =

```
23055.90
```

Quantity' =

```
  98.72
 -182.36
  -19.55
   80.00
    8.00
  -32.97
   40.00
   10.00
```

This example finds a unique solution at a cost of just over \$23,000. The matrix **C** (formed internally by `hedgeopt` and passed to `lsqlin`) is the asset **Price** vector expressed as a row vector.

```
C = Price' = [98.72 97.53 0.05 98.72 100.55 6.28 0.05 3.69]
```

The vector **d** is the current portfolio value `Value0 = 23674.62`. The example maintains, as closely as possible, a constant portfolio value subject to the specified constraints.

### Additional Constraints

In the absence of any additional constraints, the least squares objective involves a single equation with eight unknowns. This is an under-determined system of equations. Because such systems generally have an infinite number of solutions, you need to specify additional constraints to achieve a solution with practical significance.

The additional constraints can come from two sources:

- User-specified equality constraints
- Target sensitivity equality constraints imposed by `hedgeopt`

The example in “Fully Hedged Portfolio” on page 4-8 specifies five equality constraints associated with holding assets 1, 4, 5, 7, and 8 fixed. This reduces the number of unknowns from eight to three, which is still an under-determined system. However, when combined with the first goal of `hedgeopt`, the equality constraints associated with the target sensitivities in `TargetSens` produce an additional system of three equations with three unknowns. This additional system guarantees that the weighted average of the delta, gamma, and vega of assets 2, 3, and 6, together with the remaining assets held fixed, satisfy the overall portfolio target sensitivity needs in `TargetSens`.

Combining the least-squares objective equation with the three portfolio sensitivity equations provides an overall system of four equations with three unknown asset holdings. This is no longer an under-determined system, and the solution is as shown.

If the assets held fixed are reduced, for example, `FixedInd = [1 4 5 7]`, `hedgeopt` returns a no cost, fully hedged portfolio (`Sens = [0 0 0]` and `Cost = 0`).

If you further reduce `FixedInd` (for example, `[1 4 5]`, `[1 4]`, or even `[]`), `hedgeopt` always returns a no cost, fully hedged portfolio. In these cases, insufficient constraints result in an under-determined system. Although `hedgeopt` identifies no cost, fully hedged portfolios, there is nothing unique about them. These portfolios have little practical significance.

Constraints must be *sufficient* and *appropriately defined*. Additional constraints having no effect on the optimization are called *dependent constraints*. As a simple example, assume that parameter  $Z$  is constrained such that  $Z \leq 1$ . Furthermore, assume you somehow add another constraint that effectively restricts  $Z \leq 0$ . The constraint  $Z \leq 1$  now has no effect on the optimization.

### Example: Minimize Portfolio Sensitivities

To illustrate using `hedgeopt` to minimize portfolio sensitivities for a given maximum target cost, specify a target cost of \$20,000 and determine the new portfolio sensitivities, holdings, and cost of the rebalanced portfolio.

```
MaxCost = 20000;
[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price,...
Holdings, [1 4 5 7 8], [], MaxCost);
```

```

Sens =
      -4345.36      295.81     -6586.64

Cost =
      20000.00

Quantity' =
      100.00
     -151.86
     -253.47
       80.00
        8.00
     -18.18
       40.00
       10.00

```

This example corresponds to the \$20,000 point along the cost axis in the figures Rebalancing Cost Profile, Funds Available for Rebalancing, and Rebalancing Cost.

When minimizing sensitivities, the maximum target cost is treated as an inequality constraint; in this case, **MaxCost** is the most you are willing to spend to hedge a portfolio. The least-squares objective matrix **C** is the matrix transpose of the input asset sensitivities

**C** = Sensitivities'

a 3-by-8 matrix in this example, and **d** is a 3-by-1 column vector of zeros, **[0 0 0]'**.

Without any additional constraints, the least-squares objective results in an under-determined system of three equations with eight unknowns. By holding assets 1, 4, 5, 7, and 8 fixed, you reduce the number of unknowns from eight to three. Now, with a system of three equations with three unknowns, **hedgeopt** finds the solution shown.

### Example: Under-Determined System

Reducing the number of assets held fixed creates an under-determined system with meaningless solutions. For example, see what happens with only four assets constrained.

```
FixedInd = [1 4 5 7];
```

```
[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price,...
Holdings, FixedInd, [], MaxCost);
```

Sens =

```
      -0.00      -0.00      -0.00
```

Cost =

```
20000.00
```

Quantity' =

```
100.00
-149.31
-14.91
 80.00
  8.00
-34.64
 40.00
-32.60
```

You have spent \$20,000 (all the funds available for rebalancing) to achieve a fully hedged portfolio.

With an increase in available funds to \$50,000, you still spend all available funds to get another fully hedged portfolio.

```
MaxCost = 50000;
```

```
[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price,...
Holdings, FixedInd, [],MaxCost);
```

Sens =

```
      -0.00      0.00      0.00
```

Cost =

```
50000.00
```

Quantity' =

```
100.00
-473.78
-60.51
 80.00
```

```

8.00
-18.20
40.00
385.60

```

All solutions to an under-determined system are meaningless. You buy and sell various assets to obtain zero sensitivities, spending all available funds every time. If you reduce the number of fixed assets any further, this problem is insufficiently constrained, and you find no solution (the outputs are all NaN).

Note also that no solution exists whenever constraints are *inconsistent*. Inconsistent constraints create an infeasible solution space; the outputs are all NaN.

## Example: Portfolio Constraints with `hedgeslf`

The other hedging function, `hedgeslf`, attempts to minimize portfolio sensitivities such that the rebalanced portfolio maintains a constant value (the rebalanced portfolio is hedged against market moves and is closest to being self-financing). If a self-financing hedge is not found, `hedgeslf` tries to rebalance a portfolio to minimize sensitivities.

From a least-squares systems approach, `hedgeslf` first attempts to minimize cost in the same way that `hedgeopt` does. If it cannot solve this problem (a no cost, self-financing hedge is not possible), `hedgeslf` proceeds to minimize sensitivities like `hedgeopt`. Thus, the discussion of constraints for `hedgeopt` is directly applicable to `hedgeslf` as well.

To illustrate this hedging facility using equity exotic options, consider the portfolio `CRRInstSet` obtained from the example MAT-file `deriv.mat`. The portfolio consists of eight option instruments: two stock options, one barrier, one compound, two lookback, and two Asian.

The hedging functions require inputs that include the current portfolio holdings (allocations) and a matrix of instrument sensitivities. To create these inputs, start by loading the example portfolio into memory

```
load deriv.mat;
```

Next, compute the prices and sensitivities of the instruments in this portfolio.

```
[Delta, Gamma, Vega, Price] = crrsens(CRRTree, CRRInstSet);
```

Extract the current portfolio holdings (the quantity held or the number of contracts).

```
Holdings = instget(CRRInstSet, 'FieldName', 'Quantity');
```

For convenience place the delta, gamma, and vega sensitivity measures into a matrix of sensitivities.

```
Sensitivities = [Delta Gamma Vega];
```

Each row of the `Sensitivities` matrix is associated with a different instrument in the portfolio and each column with a different sensitivity measure.

```
disp([Price Holdings Sensitivities])
```

8.29	10.00	0.59	0.04	53.45
2.50	5.00	-0.31	0.03	67.00
12.13	1.00	0.69	0.03	67.00
3.32	3.00	-0.12	-0.01	-98.08
7.60	7.00	-0.40	-45926.32	88.18
11.78	9.00	-0.42	-112143.15	119.19
4.18	4.00	0.60	45926.32	49.21
3.42	6.00	0.82	112143.15	41.71

The first column contains the dollar unit price of each instrument, the second contains the holdings of each instrument, and the third, fourth, and fifth columns contain the delta, gamma, and vega dollar sensitivities, respectively.

Suppose that you want to obtain a delta, gamma and vega neutral portfolio using `hedgeslf`.

```
[Sens, Value1, Quantity]= hedgeslf(Sensitivities, Price, ...
Holdings)
```

```
Sens =
```

```
0.00
-0.00
0.00
```

```
Value1 =
```

```
313.93
```

```
Quantity =
```

```
10.00
7.64
-1.56
26.13
```



```

9.94
3.73
-0.75
8.11

```

`hedgeslf` returns the portfolio dollar sensitivities (`Sens`), the value of the rebalanced portfolio (`Value1`) and the new allocation for each instrument (`Quantity`).

If `Value0` and `Value1` represent the portfolio value before and after rebalancing, respectively, you can verify the cost by comparing the portfolio values.

```
Value0= Holdings' * Price
```

```
Value0 =
```

```
313.93
```

In this example, the portfolio is fully hedged (simultaneous delta, gamma, and vega neutrality) and self-financing (the values of the portfolio before and after balancing (`Value0` and `Value1`) are the same).

Suppose now that you want to place some upper and lower bounds on the individual instruments in your portfolio. By using Financial Toolbox function `portcons`, you can specify these constraints, along with a variety of general linear inequality constraints.

As an example, assume that, in addition to holding instrument 1 fixed as before, you want to bound the position of all instruments to within +/- 20 contracts (for each instrument, you cannot short or long more than 20 contracts). Applying these constraints disallows the current position in the fourth instrument (long 26.13). All other instruments are currently within the upper/lower bounds.

You can generate these constraints by first specifying the lower and upper bounds vectors and then calling `portcons`.

```
LowerBounds = [-20 -20 -20 -20 -20 -20 -20 -20];
UpperBounds = [20 20 20 20 20 20 20 20];
ConSet = portcons('AssetLims', LowerBounds, UpperBounds);
```

To impose these constraints, call `hedgeslf` with `ConSet` as the last input.

```
[Sens, Cost, Quantity1] = hedgeslf(Sensitivities, Price, ...
Holdings, 1, ConSet)
```

```
Sens =
```

-0.00  
0.00  
0.00

Cost =

313.93

Quantity1 =

10.00  
5.28  
10.98  
20.00  
20.00  
-6.99  
-20.00  
9.39

Observe that `hedges1f` enforces the upper bound on the fourth instrument, and the portfolio continues to be fully hedged and self-financing.

# Mortgage-Backed Securities

---

- “What Are Mortgage-Backed Securities?” on page 5-2
- “Fixed-Rate Mortgage Pool” on page 5-3
- “Prepayment Modeling with a Two Factor Hull White Model and a LIBOR Market Model” on page 5-16
- “Pricing Mortgage Backed Securities Using the Black-Derman-Toy Model” on page 5-38
- “Using Collateralized Mortgage Obligations (CMOs)” on page 5-45
- “Create PAC and Sequential CMO” on page 5-55

## What Are Mortgage-Backed Securities?

Mortgage-backed securities (MBSs) are a type of investment that represents ownership in a group of mortgages. Principal and interest from the individual mortgages are used to pay principal and interest on the MBS.

Ownership in a group of mortgages is typically represented by a *pass-through certificate* (PC). Most pass-through certificates are issued by the Government National Mortgage Agency, a branch of the United States government, or by one of two private corporations: Fannie Mae or Freddie Mac. With these certificates, homeowners' payments pass from the originating bank through the issuing agency to holders of the certificates. These agencies also frequently guarantee that the certificate holder receives timely payment of principal and interest from the PCs.

# Fixed-Rate Mortgage Pool

**In this section...**

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“Inputs to Functions” on page 5-3

“Generating Prepayment Vectors” on page 5-4

“Mortgage Prepayments” on page 5-6

“Risk Measurement” on page 5-8

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“Computing Option-Adjusted Spread” on page 5-10

“Prepayments with Fewer Than 360 Months Remaining” on page 5-12

“Pools with Different Numbers of Coupons Remaining” on page 5-14

## Introduction

Financial Instruments Toolbox software supports calculations involved with generic fixed-rate mortgage pools and balloon mortgages. Pass-through certificates typically have embedded call options in the form of prepayment. Prepayment is an excess payment applied to the principal of a PC. These accelerated payments reduce the effective life of a PC.

The toolbox comes with a standard Bond Market Association (PSA) prepayment model and can generate multiples of standard prepayment speeds. The Public Securities Association provides a set of uniform practices for calculating the characteristics of mortgage-backed securities when there is an assumed prepayment function.

Alternatively, aside from the standard PSA implementation in this toolbox, you can supply your own projected prepayment vectors. At this time, however, custom prepayment functionality that incorporates pool-specific information and interest rate forecasts are not available in this toolbox. If you plan to use custom prepayment vectors in your calculations, you presumably already own such a suite in MATLAB.

## Inputs to Functions

Because of the generic, all-purpose nature of the toolbox pass-through functions, you can fine-tune them to conform to a particular mortgage. Most functions require at least this set of inputs:

- Gross coupon rate
- Settlement date
- Issue (effective) date
- Maturity date

Typical optional inputs include standard prepayment speed (or customized vector), net coupon rate (if different from gross coupon rate), and payment delay in number of days.

All calculations are based on expected payment dates and actual cash flow to the investor. For example, when `GrossRate` and `CouponRate` differ as inputs to `mbsdurp`, the function returns a modified duration based on `CouponRate`. (A notable exception is `mbspassthrough`, which returns interest quantities based on the `GrossRate`.)

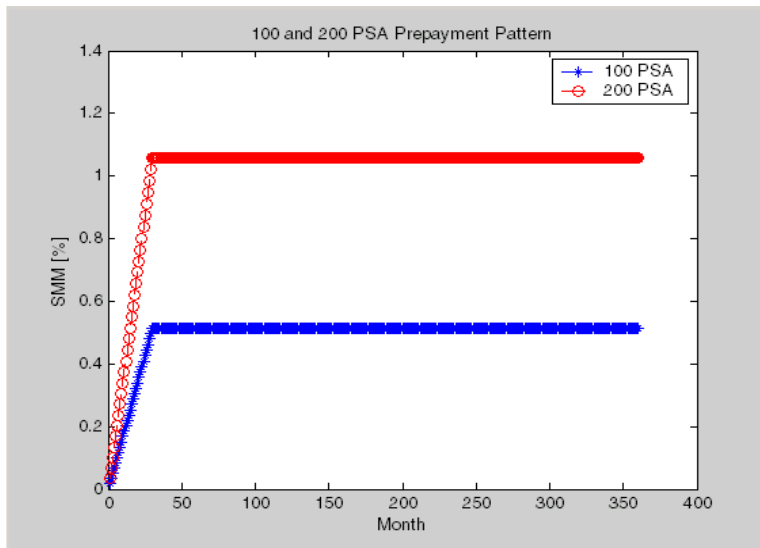
### Generating Prepayment Vectors

You can generate PSA multiple prepayment vectors quickly. To generate prepayment vectors of 100 and 200 PSA, type

```
PSASpeed = [100, 200];  
[CPR, SMM] = psaspeed2rate(PSASpeed);
```

This function computes two prepayment values: conditional prepayment rate (CPR) and single monthly mortality (SMM) rate. CPR is the percentage of outstanding principal prepaid in 1 year. SMM is the percentage of outstanding principal prepaid in 1 month. In other words, CPR is an annual version of SMM.

Since the entire 360-by-2 array is too long to show in this document, observe the SMM (100 and 200 PSA) plots, spaced one month apart, instead.



Prepayment assumptions form the basis upon which far more comprehensive MBS calculations are based. As an illustration observe the following example, which shows the use of the function `mbscfamounts` to generate cash flows and timings based on a set of standard prepayments.

Consider three mortgage pools that were sold on the issue date (which starts unamortized). The first two pools "balloon out" in 60 months, and the third is regularly amortized to the end. The prepayment speeds are assumed to be 100, 200, and 200 PSA, respectively.

```
Settle      = [datenum('1-Feb-2000');
              datenum('1-Feb-2000');
              datenum('1-Feb-2000')];

Maturity    = [datenum('1-Feb-2030')];

IssueDate   = datenum('1-Feb-2000');
GrossRate   = 0.08125;
CouponRate  = 0.075;
Delay       = 14;

PSASpeed    = [100, 200];
[CPR, SMM]  = psaspeed2rate(PSASpeed);
```

```

PrepayMatrix = ones(360,3);
PrepayMatrix(1:60,1:2) = SMM(1:60,1:2);
PrepayMatrix(:,3) = SMM(:,2);

[CFlowAmounts, CFlowDates, TFactors, Factors] = ...
mbscfamounts(Settle, Maturity, IssueDate, GrossRate, ...
CouponRate, Delay, [], PrepayMatrix);

```

The fourth output argument, `Factors`, indicates the fraction of the balance still outstanding at the beginning of each month. A snapshot of this argument in the MATLAB Variables editor illustrates the 60-month life of the first two of the mortgages with balloon payments and the continuation of the third mortgage until the end (360 months).

	59	60	61	62	63
1	0.7627	0.7580	0.7533	0	0
2	0.6021	0.5951	0.5882	0	0
3	0.6021	0.5951	0.5882	0.5813	0.5746

You can readily see that `mbscfamounts` is the building block of most fixed rate and balloon pool cash flows.

## Mortgage Prepayments

Prepayment is beneficial to the pass-through owner when a mortgage pool has been purchased at discount. The next example compares mortgage yields (compounded monthly) versus the purchase clean price with constant prepayment speed. The example illustrates that when you have purchased a pool at a discount, prepayment generates a higher yield with decreasing purchase price.

```

Price = [85; 90; 95];
Settle = datenum('15-Apr-2002');
Maturity = datenum('1 Jan 2030');
IssueDate = datenum('1-Jan-2000');
GrossRate = 0.08125;
CouponRate = 0.075;
Delay = 14;

```



Speed = 100;

Compute the mortgage and bond-equivalent yields.

```
[MYield, BEMBSYield] = mbsyield(Price, Settle, Maturity, ...  
IssueDate, GrossRate, CouponRate, Delay, Speed)
```

MYield =

```
0.1018  
0.0918  
0.0828
```

BEMBSYield =

```
0.1040  
0.0936  
0.0842
```

If for this same pool of mortgages, there was no prepayment (Speed = 0), the yields would decline to

MYield =

```
0.0926  
0.0861  
0.0802
```

BEMBSYield =

```
0.0944  
0.0877  
0.0815
```

Likewise, if the rate of prepayment doubled (Speed = 200), the yields would increase to

MYield =

```
0.1124  
0.0984  
0.0858
```

BEMBSYield =

```
0.1151  
0.1004
```

0.0873

For the same prepayment vector, deeper discount pools earn higher yields. For more information, see `mbsprice` and `mbsyield`.

### Risk Measurement

Financial Instruments Toolbox software provides the most basic risk measures of a pool portfolio:

- Modified duration
- Convexity
- Average life of pool

Consider the following example, which calculates the Macaulay and modified durations given the price of a mortgage pool.

```
Price = [95; 100; 105];
Settle = datenum('15-Apr-2002');
Maturity = datenum('1-Jan-2030');
IssueDate = datenum('1-Jan-2000');
GrossRate = 0.08125;
CouponRate = 0.075;
Delay = 14;
Speed = 100;
```

```
[YearDuration, ModDuration] = mbsdurp(Price, Settle, ...
Maturity, IssueDate, GrossRate, CouponRate, Delay, Speed)
```

```
YearDuration =
```

```
6.1341
6.3882
6.6339
```

```
ModDuration =
```

```
5.8863
6.1552
6.4159
```

Using Financial Instruments Toolbox functions, you can obtain modified duration and convexity from either price or yield, as long as you specify a prepayment vector or

an assumed prepayment speed. The toolbox risk-measurement functions (`mbsdurp`, `mbsdury`, `mbsconvp`, `mbsconvy`, and `mbswal`) adhere to the guidelines listed in the *PSA Uniform Practices* manual.

## Mortgage Pool Valuation

For accurate valuation of a mortgage pool, you must generate interest rate paths and use them with mortgage pool characteristics to properly value the pool. A widely used methodology is the option-adjusted spread (OAS). OAS measures the yield spread that is not directly attributable to the characteristics of a fixed-income investment.

### Calculating OAS

Prepayment alters the cash flows of an otherwise regularly amortizing mortgage pool. A comprehensive option-adjusted spread calculation typically begins with the generation of a set of paths of spot rates to predict prepayment. A path is collection of  $i$  spot-rate paths, with corresponding  $j$  cash flows on each of those paths.

The effect of the OAS on pool pricing is shown mathematically in the following equation, where  $K$  is the option-adjusted spread.

$$PoolPrice = \frac{1}{NumberofPaths} \times \sum_i^{NumberofPaths} \sum_j \frac{CF_{ij}}{(1 + zerorates_{ij} + K)^{T_{ij}}}$$

### Calculating Effective Duration

Alternatively, if you are more interested in the sensitivity of a mortgage pool to interest rate changes, use effective duration, which is a more appropriate measure. Effective duration is defined mathematically with the following equation.

$$Effective\ Duration = \frac{P(y + \Delta y) - P(y - \Delta y)}{2P(y)\Delta y}$$

### Calculating Market Price

The toolbox has all the components required to calculate OAS and effective duration if you supply prepayment vectors or assumptions. For OAS, given a prepayment vector, you can generate a set of cash flows with `mbscfamounts`. Discounting these cash flows with the reference curve and then adding OAS produces the market price. See “Computing

Option-Adjusted Spread” on page 5-10 for a discussion on the computation of option-adjusted spread.

Effective duration is a more difficult issue. While modified duration changes the discounting process (by changing the yield used to discount cash flows), effective duration must account for the change in cash flow because of the change in yield. A possible solution is to recompute prices using `mbsprice` for a small change in yield, in both the upwards and downwards directions. In this case, you must recompute the prepayment input. Internally, this alters the cash flows of the mortgage pool. Assuming that the OAS stays constant in all yield environments, you can apply a set of discounting factors to the cash flows in up and down yield environments to find the effective duration.

## Computing Option-Adjusted Spread

The option-adjusted spread (OAS) is an amount of extra interest added above (or below if negative) the reference zero curve. To compute the OAS, you must provide the zero curve as an extra input. You can specify the zero curve in any intervals and with any compounding method. (To minimize any error due to interpolation, keep the intervals as regular and frequent as possible.) You must supply a prepayment vector or specify a speed corresponding to a standard PSA prepayment vector.

One way to compute the appropriate zero curve for an agency is to look at its bond yields and bootstrap them from the shortest maturity onwards. You can do this with Financial Toolbox functions `zbtprice` and `zbtyield`.

The following example shows how to calculate an appropriate zero curve followed by computation of the pool's OAS. This example calculates the OAS of a 30-year fixed rate mortgage with about a 28-year weighted average maturity left, given an assumption of 0, 50, and 100 PSA prepayment speeds.

Create curve for `zerorates`.

```
Bonds = [datenum('11/21/2002') 0 100 0 2 1;
         datenum('02/20/2003') 0 100 0 2 1;
         datenum('07/31/2004') 0.03 100 2 3 1;
         datenum('08/15/2007') 0.035 100 2 3 1;
         datenum('08/15/2012') 0.04875 100 2 3 1;
         datenum('02/15/2031') 0.05375 100 2 3 1];

Yields = [0.0162;
          0.0163;
          0.0211;
          0.0328;
          0.0420;
          0.0501];
```

Since the above is Treasury data and not selected agency data, a term structure of spread is assumed. In this example, the spread declines proportionally from a maximum of 250 basis points at the shortest maturity.

```
Yields = Yields + 0.025 * (1./[1:6]');
```

Get parameters from Bonds matrix.

```
Settle = datenum('20-Aug-2002');
Maturity = Bonds(:,1);
CouponRate = Bonds(:,2);
Face = Bonds(:,3);
Period = Bonds(:,4);
Basis = Bonds(:,5);
EndMonthRule = Bonds(:,6);

[Prices, AccruedInterest] = bndprice(Yields, CouponRate, ...
Settle, Maturity, Period, Basis, EndMonthRule, [], [], [], [], ...
Face);
```

Use `zbtprice` to solve for zero rates.

```
[ZeroRatesP, CurveDatesP] = zbtprice(Bonds, Prices, Settle);
ZeroCompounding = 2*ones(size(ZeroRatesP));
ZeroMatrix = [CurveDatesP, ZeroRatesP, ZeroCompounding];
```

Use output from `zbtprice` to calculate the OAS.

```
Price = 95;
Settle = datenum('20-Aug-2002');
Maturity = datenum('2-Jan-2030');
IssueDate = datenum('2-Jan-2000');
GrossRate = 0.08125;
CouponRate = 0.075;
Delay = 14;
Interpolation = 1;
PrepaySpeed = [0; 50; 100];

OAS = mbsprice2oas(ZeroMatrix, Price, Settle, Maturity, ...
IssueDate, GrossRate, CouponRate, Delay, Interpolation, ...
PrepaySpeed)

OAS =

    26.0502
    28.6348
    31.2222
```

This example shows that one cash flow set is being discounted and solved for its OAS, as contrasted with the `NumberOfPaths` set of cash flows as shown in “Mortgage Pool Valuation” on page 5-9. Averaging the sets of cash flows resulting from all simulations into one average cash flow vector and solving for the OAS, discounts the averaged cash flows to have a present value of today's (average) price.

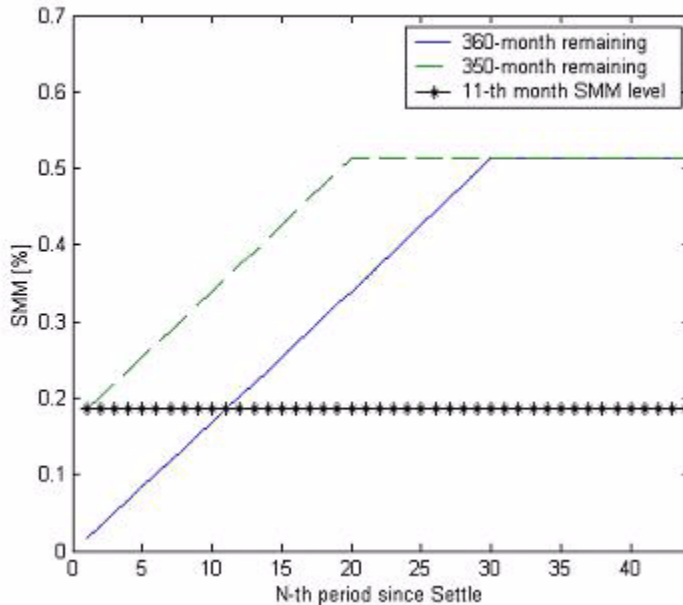
While this example uses the mortgage pool price (`mbsprice2oas`) to determine the OAS, you can also use yield to resolve it (`mbsyield2oas`). Also, there are reverse OAS functions that return prices and yields given OAS (`mbsoas2price` and `mbsoas2yield`).

The example also restates earlier examples that show discount securities benefit from higher level of prepayment, keeping everything else unchanged. The relation is reversed for premium securities.

### **Prepayments with Fewer Than 360 Months Remaining**

When fewer than 360 months remain in the pool, the applicable PSA prepayment vector is "seasoned" by the pool's age. (Elements in the 360-element prepayment vector that represent past payments are skipped. For example, on a 30-year mortgage that is 10 months old, only the final 350 prepayments are applied.)

Assume, for example, that you have two 30-year loans, one new and another 10 months old. Both have the same PSA speed of 100 and prepay using the vectors plotted below.



Still within the scope of relative valuation, you could also solve for the percentage of the standard PSA prepayment vector given the pool's arbitrary, user-supplied prepayment vector, such that the PSA speed gives the same Macaulay duration as the user-supplied prepayment vector.

If you supply a custom prepayment vector, you must account for the number of months remaining.

```

Price = 101;
Settle = datenum('1-Jan-2001');
Maturity = datenum('1-Jan-2030');
IssueDate = datenum('1-Jan-2000');
GrossRate = 0.08125;
PrepayMatrix = 0.005*ones(348,1);
CouponRate = 0.075;
Delay = 14;

ImpliedSpeed = mbsprice2speed(Price, Settle, Maturity, ...
IssueDate, GrossRate, PrepayMatrix, CouponRate, Delay)

ImpliedSpeed =

```

```
104.2543
```

Examine the prepayment input. The remaining 29 years require 348 monthly elements in the prepayment vector. Suppose then, keeping everything the same, you change `Settle` to February 14, 2003.

```
Settle = datenum('14-Feb-2003');
```

You can use `cpncount` to count all incoming coupons received after `Settle` by invoking

```
NumCouponsRemaining = cpncount(Settle, Maturity, 12, 1, [], ...  
IssueDate)
```

```
NumCouponsRemaining =  
323
```

The input 12 defines the monthly payment frequency, 1 defines the 30/360 basis, and `IssueDate` defines aging and determination-of-holder date. Thus, you must supply a 323-element vector to account for a prepayment corresponding to each monthly payment.

## Pools with Different Numbers of Coupons Remaining

Suppose one pool has two remaining coupons, and the other has three. MATLAB software expects the prepayment matrix to be in the following format:

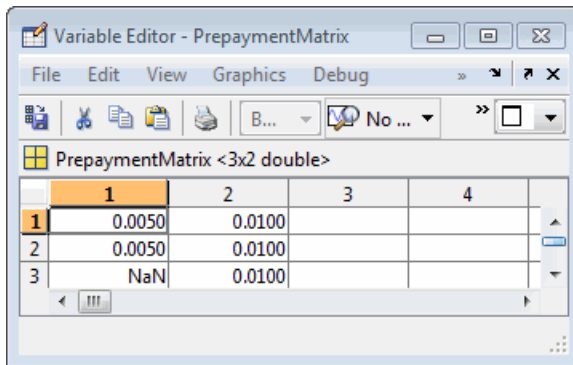
```
V11      V21  
V12      V22  
NaN      V23
```

$V_{ij}$  denotes the single monthly mortality (SMM) rate for pool  $i$  during the  $j$ th coupon period since `Settle`.

The use of `NaN` to pad the prepayment matrix is necessary because MATLAB cannot concatenate vectors of different lengths into a matrix. Also, it can serve as an error check against any unintended operation (any MATLAB operation that would return `NaN`).

For example, assume that the 2 month pool has a constant SMM of 0.5% and the 3 month has a constant SMM of 1% in every period. The prepayment matrix you would create is depicted below.





The image shows a MATLAB Variable Editor window titled "Variable Editor - PrepaymentMatrix". The window displays a 3x2 double matrix named "PrepaymentMatrix". The matrix has the following values:

	1	2	3	4
1	0.0050	0.0100		
2	0.0050	0.0100		
3	NaN	0.0100		

Create this input in whatever manner is best for you.

### Summary of Prepayment Data Vector Representation

- When you specify a PSA prepayment speed, MATLAB "seasons" the pool according to its age.
- When you specify your own prepayment matrix, identify the maximum number of coupons remaining using `cpncount`. Then supply the matrix elements up to the point when cash flow ceases to exist.
- When different length pools must exist in the same matrix, pad the shorter one(s) with NaN. Each column of the prepayment matrix corresponds to a specific pool.

## Prepayment Modeling with a Two Factor Hull White Model and a LIBOR Market Model

This example shows how to model prepayment in MATLAB® using functionality from the Financial Instruments Toolbox™. Specifically, a variation of the Richard and Roll prepayment model is implemented using a two factor Hull-White interest-rate model and a LIBOR Market Model to simulate future interest-rate paths. A mortgage-backed security is priced with both the custom and default prepayment models.

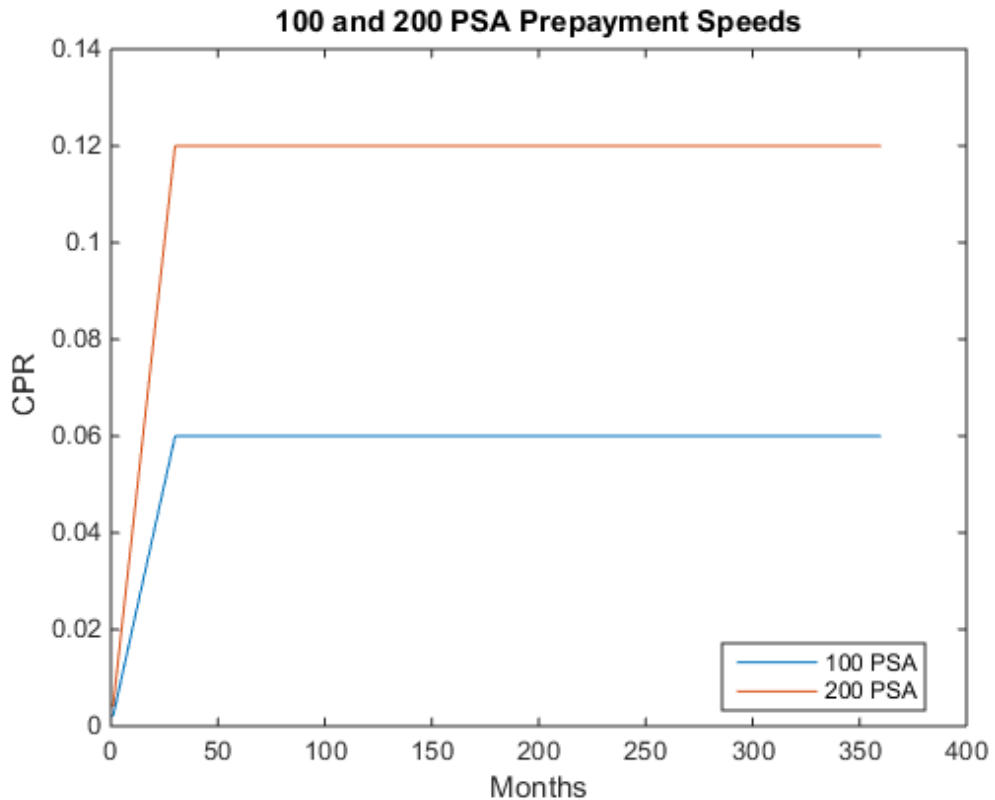
### Introduction

Prepayment modeling is crucial to the analysis of mortgage-backed securities (MBS). Prepayments by individual mortgage holders affect both the amount and timing of cash flows -- and for collateralized mortgage obligations (e.g.: interest-only securities), prepayment can greatly affect the value of the securities.

### PSA Model

The most basic prepayment model is the Public Securities Association (PSA) model, which assumes a ramp-up phase and then a constant conditional prepayment rate (CPR). The PSA model can be generated in MATLAB using the Financial Instruments Toolbox function `PSASPEED2RATE`

```
G2PP_CPR = psaspeed2rate([100 200]);  
figure  
plot(G2PP_CPR)  
title('100 and 200 PSA Prepayment Speeds')  
xlabel('Months')  
ylabel('CPR')  
ylim([0 .14])  
legend({'100 PSA', '200 PSA'}, 'Location', 'Best')
```



### Mortgage-Backed Security

The MBS analyzed in this example matures in 2020 and has the properties outlined in this section. Cash flows are generated for PSA prepayment speeds simply by entering the PSA speed as an input argument.

```
% Parameters for MBS passthrough to be priced
Settle = datenum('15-Dec-2007');
Maturity = datenum('15-Dec-2020');
IssueDate = datenum('15-Dec-2000');
GrossRate = .0475;
CouponRate = .045;
Delay = 14;
Period = 12;
```

```
Basis = 4;  
  
% Generate cash flows and dates for baseline case using 100 PSA  
[CFlowAmounts, CFlowDates] = mbscfamounts(Settle,Maturity, IssueDate,...  
    GrossRate, CouponRate, Delay,100);  
CFlowTimes = yearfrac(Settle,CFlowDates);  
NumCouponsRemaining = cpncount(Settle, Maturity, Period,Basis, 1, IssueDate);
```

### Richard and Roll Model

While prepayment modeling often involves quite complex and sophisticated modeling, often at the loan level, this example will use a slightly modified approach based on the model proposed by Richard and Roll in [6].

The Richard and Roll prepayment model involves the following factors:

- Refinancing incentive
- Seasonality (month of the year)
- Seasoning or age of the mortgage
- Burnout

Richard and Roll propose a multiplicative model of the following:

$$CPR = RefiIncentive * SeasoningMultiplier * SeasonalityMultiplier * BurnoutMultiplier$$

For the custom model in this example, the Burnout Multiplier, which describes the tendency of prepayment to slow when a significant number of homeowners have already refinanced, is ignored and the first three terms are used.

The refinancing incentive is a function of the ratio of the coupon-rate of the mortgage to the available mortgage rate at that particular point in time. For example, the Office of Thrift Supervision (OTS) proposes the following model:

$$Refi = .2406 - .1389 * \arctan\left(5.952 * \left(1.089 - \frac{CouponRate}{MortgageRate}\right)\right)$$

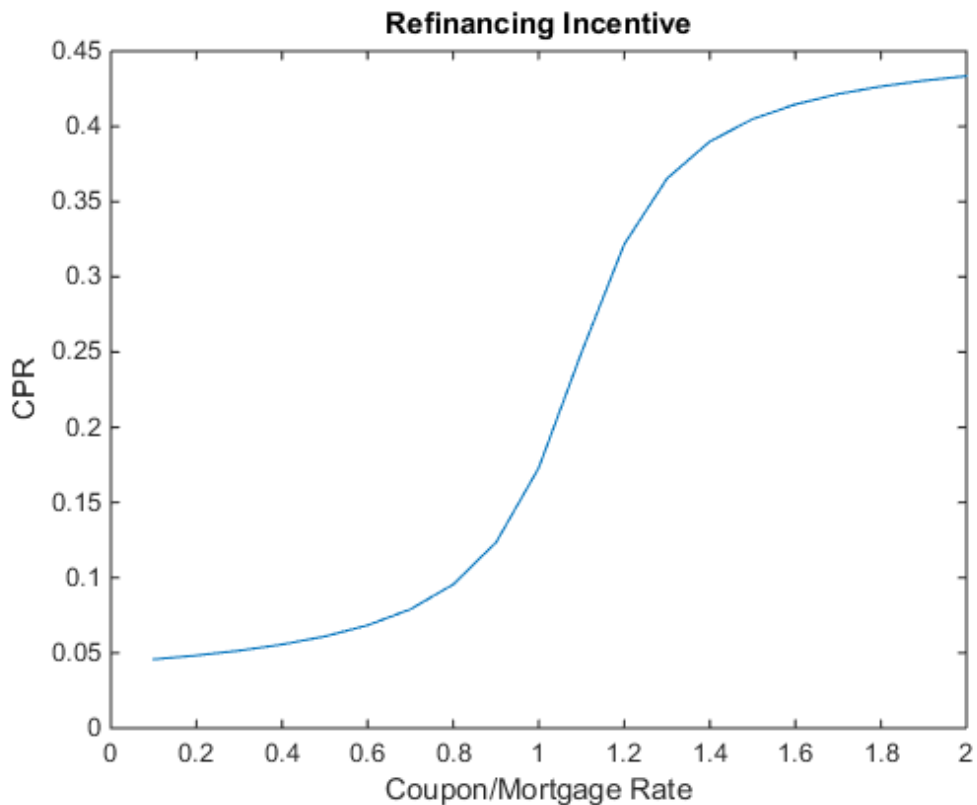
The refinancing incentive requires a simulation of future interest rates. This will be discussed later in this example.

```
C_M = .1:.1:2;
```

```

G2PP_Refi = .2406 - .1389 * atan(5.952*(1.089 - C_M));
figure
plot(C_M,G2PP_Refi)
xlabel('Coupon/Mortgage Rate')
ylabel('CPR')
title('Refinancing Incentive')

```



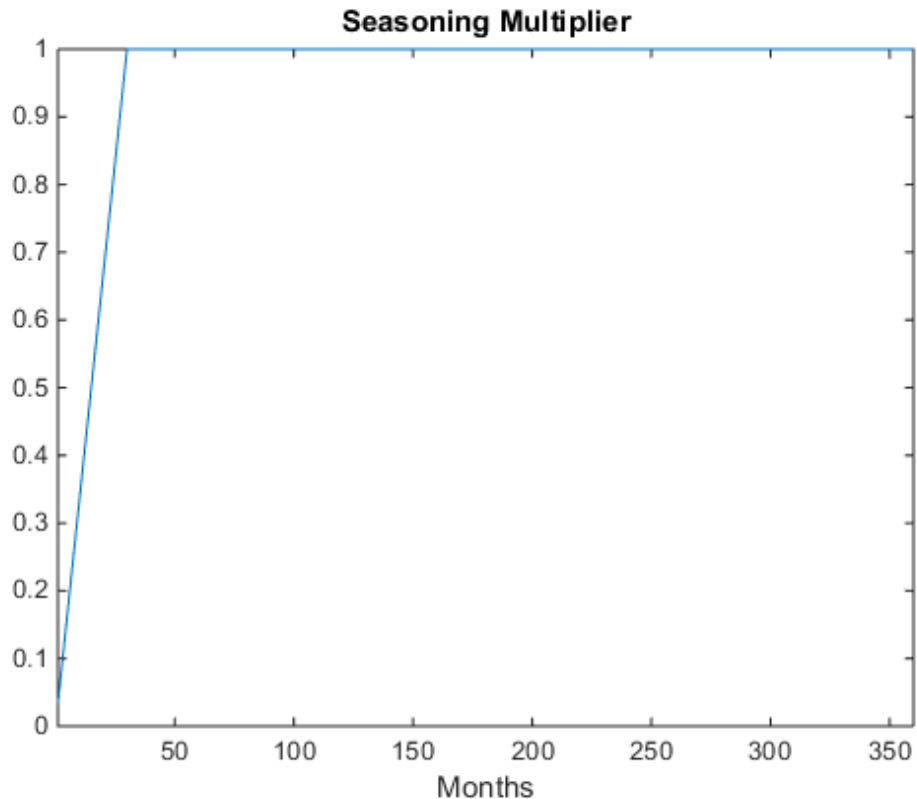
Seasoning captures the tendency of prepayment to ramp up at the beginning of a mortgage before leveling off. The OTS models the seasoning multiplier as follows:

```

Seasoning = ones(360,1);
Seasoning(1:29) = (1:29)/30;
figure
plot(Seasoning)

```

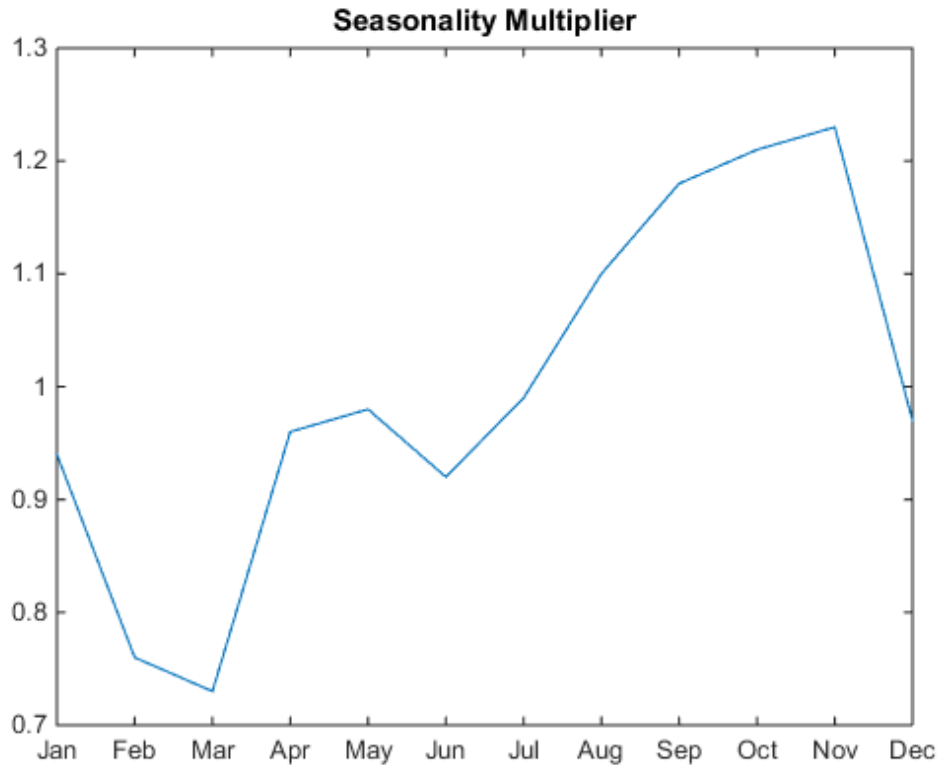
```
xlim([1 360])  
title('Seasoning Multiplier')  
xlabel('Months')
```



The seasonality multiplier simply models the seasonal behavior of prepayments -- this data is based on Figure 3 of [6], which applies to the behavior of Ginnie Mae 30-year, single-family MBSs.

```
Seasonality = [.94 .76 .73 .96 .98 .92 .99 1.1 1.18 1.21 1.23 .97];  
figure  
plot(Seasonality)  
xlim([1 12])  
ax = gca;  
ax.XTick = 1:12;
```

```
ax.XTickLabel = {'Jan', 'Feb', 'Mar', 'Apr', 'May', 'Jun', 'Jul', 'Aug', ...  
                'Sep', 'Oct', 'Nov', 'Dec'};  
title('Seasonality Multiplier')
```



### G2++ Interest-Rate Model

Since the refinancing incentive requires a simulation of future interest rates, an interest-rate model must be used. One choice is a two-factor additive Gaussian model, referred to as G2++ by Brigo and Mercurio [2].

The G2++ Interest Rate Model is:

$$r(t) = x(t) + y(t) + \varphi(t)$$

$$dx(t) = -ax(t)dt + \sigma dW_1(t)$$

$$dy(t) = -by(t)dt + \eta dW_2(t)$$

where  $dW_1(t)dW_2(t)$  is a two-dimensional Brownian motion with correlation  $\rho$

$$dW_1(t)dW_2(t) = \rho dt$$

$$\varphi(T) = f^M(0, T) + \frac{\sigma^2}{2a^2}(1 - e^{-aT})^2 + \frac{\eta^2}{2b^2}(1 - e^{-bT})^2 + \rho \frac{\sigma\eta}{ab}(1 - e^{-aT})(1 - e^{-bT})$$

and  $r(t)$  is the short rate,  $a$  and  $b$  are mean reversion constants and  $\sigma$  and  $\eta$  are volatility constants, and  $f^M(0, T)$  is the market forward rate, or the forward rate observed on the Settle date.

### LIBOR Market Model

The LIBOR Market Model (LMM) differs from short-rate models in that it evolves a set of discrete forward rates. Specifically, the lognormal LMM specifies the following diffusion equation for each forward rate:

$$\frac{dF_i(t)}{F_i} = -\mu_i dt + \sigma_i(t) dW_i$$

where

$dW$  is an  $N$  dimensional geometric Brownian motion with:

$$dW_i(t)dW_j(t) = \rho_{ij} dt$$

The LMM relates the drifts of the forward rates based on no-arbitrage arguments. Specifically, under the Spot LIBOR measure, the drifts are expressed as the following:

$$\mu_i(t) = -\sigma_i(t) \sum_{j=q(t)}^i \frac{\tau_j \rho_{i,j} \sigma_j(t) F_j(t)}{1 + \tau_j F_j(t)}$$

where



$\tau_i$  is the time fraction associated with the  $i$ th forward rate

$q(t)$  is an index function defined by the relation  $T_{q(t)-1} < t < T_{q(t)}$

and the Spot LIBOR numeraire is defined as the following:

$$B(t) = P(t, T_{q(t)}) \prod_{n=0}^{q(t)-1} (1 + \tau_n F_n(T_n))$$

Given the above, the choice with the LMM is how to model volatility and correlation.

The volatility of the rates can be modeled with a stochastic volatility, but for this example a deterministic volatility is used, and so a functional form needs to be specified. One of the most popular functional forms in the literature is the following:

$$\sigma_i(t) = \phi_i(a(T_i - t) + b)e^{c(T_i - t)} + d$$

where  $\phi$  adjusts the curve to match the volatility for the  $i^{\text{th}}$  forward rate.

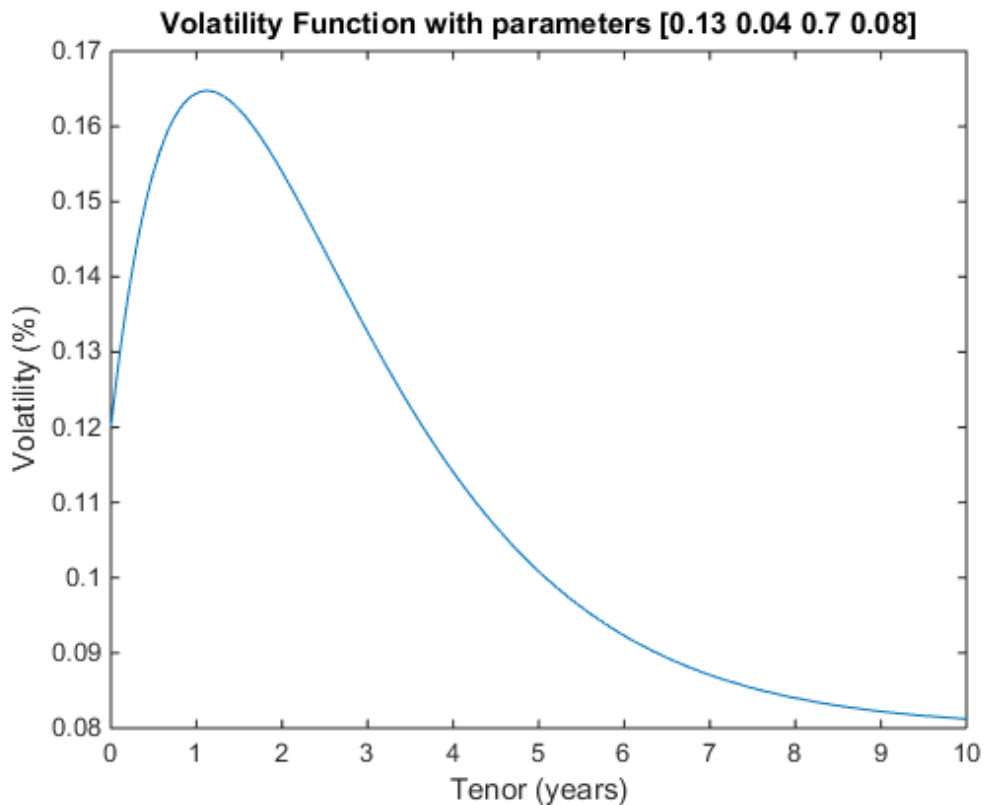
Similarly, the correlation between the forward rates needs to be specified. This can be estimated from historical data or fitted to option prices. For this example, the following functional form will be used:

$$\rho_{i,j} = e^{-\beta|i-j|}$$

Once the volatility and correlation are specified, the parameters need to be calibrated -- this can be done with historical or market data, typically swaptions or caps/floors. For this example, we simply use reasonable estimates for the correlation and volatility parameters.

```
% The volatility function to be used -- and one choice for the parameters
LMMVolFunc = @(a,t) (a(1)*t + a(2)).*exp(-a(3)*t) + a(4);
LMMVolParams = [.13 .04 .7 .08];
```

```
% Volatility specification
fplot(@(t) LMMVolFunc(LMMVolParams,t),[0 10])
title(['Volatility Function with parameters ' mat2str(LMMVolParams)])
ylabel('Volatility (%)')
xlabel('Tenor (years)')
```



### Calibration to Market Data

The parameters in the G2++ model can be calibrated to market data. Typically, the parameters are calibrated to observed interest-rate cap, floor and/or swaption data. For now, market cap data is used for calibration.

This data is hardcoded but could be imported into MATLAB with the Database Toolbox™ or Datafeed Toolbox™.

```
% Zero Curve -- this data is hardcoded for now but could be bootstrapped
% using the bootstrap method of IRDataCurve
ZeroTimes = [3/12 6/12 1 5 7 10 20 30]';
ZeroRates = [0.033 0.034 0.035 0.040 0.042 0.044 0.048 0.0475]';
ZeroDates = daysadd(Settle,360*ZeroTimes,1);
DiscountRates = zero2disc(ZeroRates,ZeroDates,Settle);
```

```

irdc = IRDataCurve('Zero',Settle,ZeroDates,ZeroRates);

figure
plot(ZeroDates,ZeroRates)
datetick
title(['US Zero Curve for ' datestr(Settle)])

% Cap Data
Reset = 2;
Notional = 100;
CapMaturity = daysadd(Settle,360*[1:5 7 10 15 20 25 30],1);
CapVolatility = [.28 .30 .32 .31 .30 .27 .23 .2 .18 .17 .165]';

% ATM strikes could be computed with SWAPBYZERO
Strike = [0.0353 0.0366 0.0378 0.0390 0.0402 0.0421 0.0439 ...
          0.0456 0.0471 0.0471 0.0471]';

% This could be computed with CAPBYBLK
BlackCapPrices = [0.1532 0.6416 1.3366 2.0290 2.7366 4.2960 6.5992 ...
                  9.6787 12.2580 14.0969 15.7873]';

figure
scatter(CapMaturity,CapVolatility)
datetick
title(['ATM Volatility for Caps on ' datestr(Settle)])

%
% To calibrate the model parameters, a parameter set will be found that
% minimizes the sum of the squared differences between the G2++ predicted
% Cap values and the observed Black Cap values. The Optimization Toolbox(TM)
% function LSQNONLIN is used in this example, although other approaches
% (e.g. Global Optimization) may also be applicable. The function CAPBYLG2F
% is used to compute analytic values for the caps given parameter values.
%
% Upper and lower bounds for the model parameters are set to be
% relatively constrained. As Brigo and Mercurio discuss, the correlation
% parameter,  $\rho$ , can often be close to -1 when fitting a G2++ model
% to interest-rate cap prices. Therefore,  $\rho$  is constrained
% to be between -.7 and .7 to ensure that the parameters represent a truly
% two-factor model. The remaining mean reversion and volatility
% parameters are constrained to be between 0 and .5. Calibration remains a
% complex task, and while the plot below indicates that the best fit
% parameters seem to do a reasonably good job of reproducing the Cap
% prices, it should be noted that the procedure outlined here simply

```

```
% represents one approach.

% Call to LSQNONLIN to calibrate parameters
objfun = @(x) BlackCapPrices - capbylg2f(irdc,x(1),x(2),x(3),x(4),x(5),Strike,CapMatur:
x0 = [.5 .05 .1 .01 -.1];
lb = [0 0 0 0 -.7];
ub = [.5 .5 .5 .5 .7];

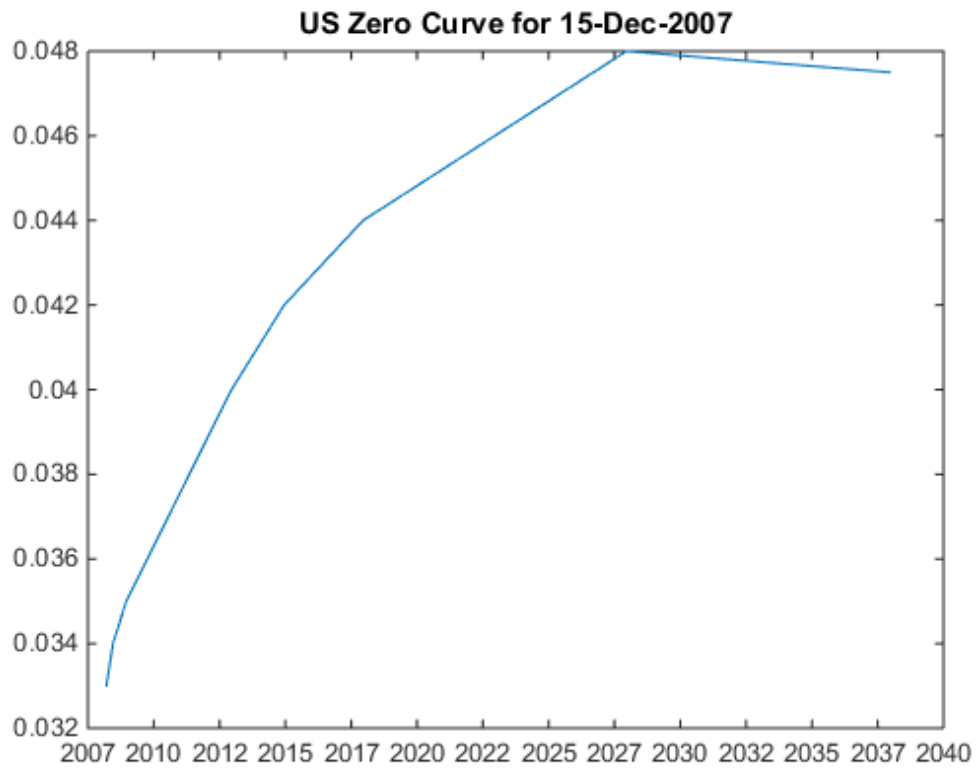
G2PP_Params = lsqnonlin(objfun,x0,lb,ub);

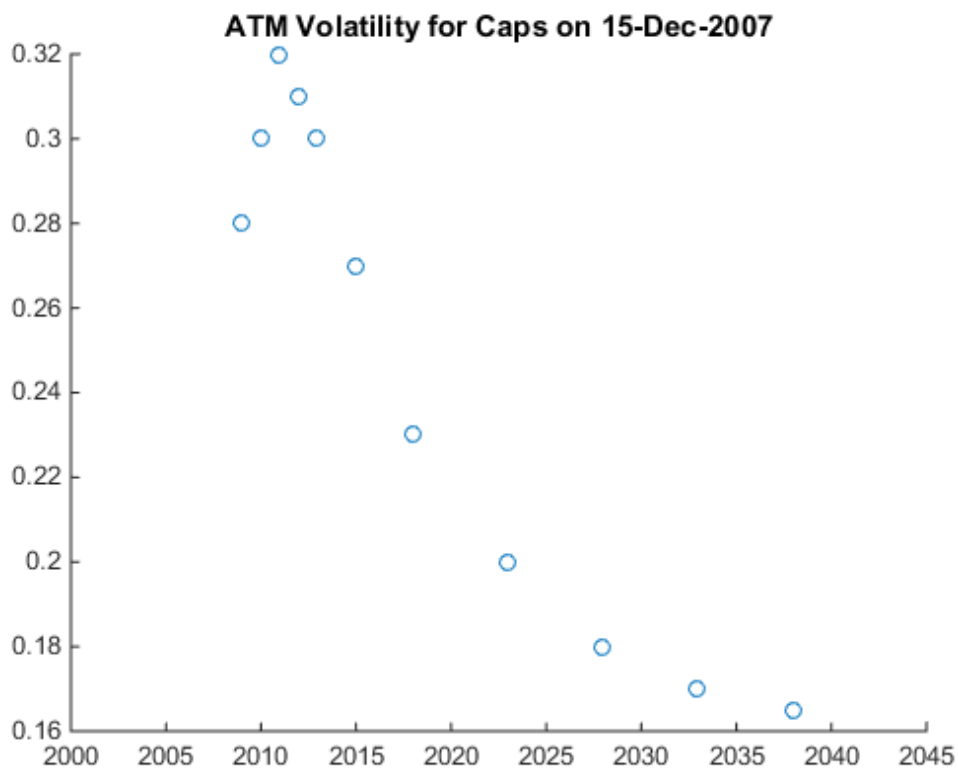
a = G2PP_Params(1);
b = G2PP_Params(2);
sigma = G2PP_Params(3);
eta = G2PP_Params(4);
rho = G2PP_Params(5);

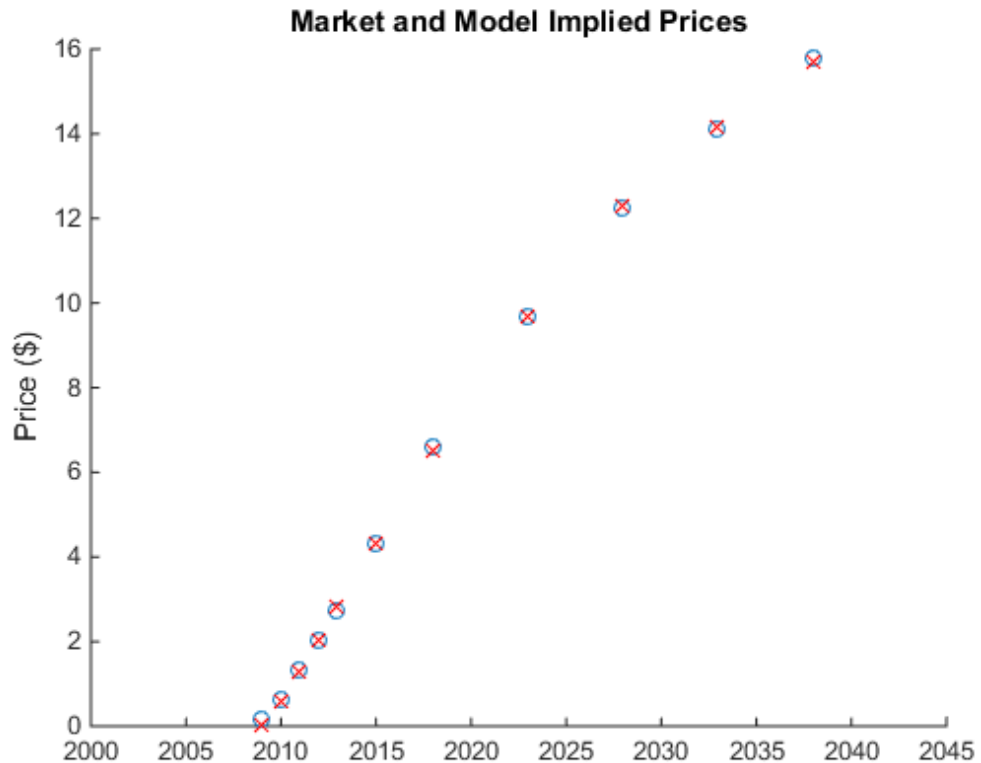
% Compare the results
figure
scatter(CapMaturity,BlackCapPrices)
hold on
scatter(CapMaturity,capbylg2f(irdc,a,b,sigma,eta,rho,Strike,CapMaturity),'rx')
datetick
title('Market and Model Implied Prices')
ylabel('Price ($)')
```

Local minimum possible.

lsqnonlin stopped because the final change in the sum of squares relative to its initial value is less than the default value of the function tolerance.







### G2++ Model Implementation

The LinearGaussian2F model can be used to specify the G2++ model and simulate future paths interest rates.

```
% G2++ model from Brigo and Mercurio with time homogeneous volatility
% parameters
G2PP = LinearGaussian2F(irdc,a,b,sigma,eta,rho);
```

### LIBOR Market Model Implementation

After the volatility and correlation have been calibrated, Monte Carlo simulation is used to evolve the rates forward in time. The LiborMarketModel object is used to simulate the forward rates.

While factor reduction is often used with the LMM to reduce computational complexity, there is no factor reduction in this example.

6M LIBOR rates are chosen to be evolved in this simulation. Since a monthly prepayment vector must be computed, interpolation is used to generate the intermediate rates. Simple linear interpolation is used.

```
numForwardRates = 46;

% Instead of being fit, VolPhi is simply hard-coded --
% representative of a declining volatility over time.
VolPhi = linspace(1.2,.8,numForwardRates-1)';

Beta = .08;
CorrFunc = @(i,j,Beta) exp(-Beta*abs(i-j));
CorrMat = CorrFunc(meshgrid(1:numForwardRates-1),meshgrid(1:numForwardRates-1),Beta);

VolFunc = cell(length(VolPhi),1);
for jdx = 1:length(VolPhi)
    VolFunc(jdx) = {@(t) VolPhi(jdx)*ones(size(t)).*(LMMVolParams(1)*t + ...
        LMMVolParams(2)).*exp(-LMMVolParams(3)*t) + LMMVolParams(4)};
end

LMM = LiborMarketModel(irdc,VolFunc,CorrMat);
```

### G2++ Monte Carlo Simulation

The various interest-rate paths can be simulated by calling the `simTermStructs` method.

One limitation to two-factor Gaussian models like this one is that it does not permit negative interest rates. This is a concern, particularly in low interest-rate environments. To handle this possibility, any interest-rate paths with negative rates are simply rejected.

```
nPeriods = NumCouponsRemaining;
nTrials = 100;
DeltaTime = 1/12;

% Generate factors and short rates
Tenor = [1/12 1 2 3 4 5 7 10 15 20 30];
G2PP_SimZeroRates = G2PP.simTermStructs(nPeriods,'NTRIALS',nTrials,...
    'Tenor',Tenor,'DeltaTime',DeltaTime);

SimDates = daysadd(Settle,360*DeltaTime*(0:nPeriods),1);

% Tenors that will be recovered for each simulation date. The stepsize is
```



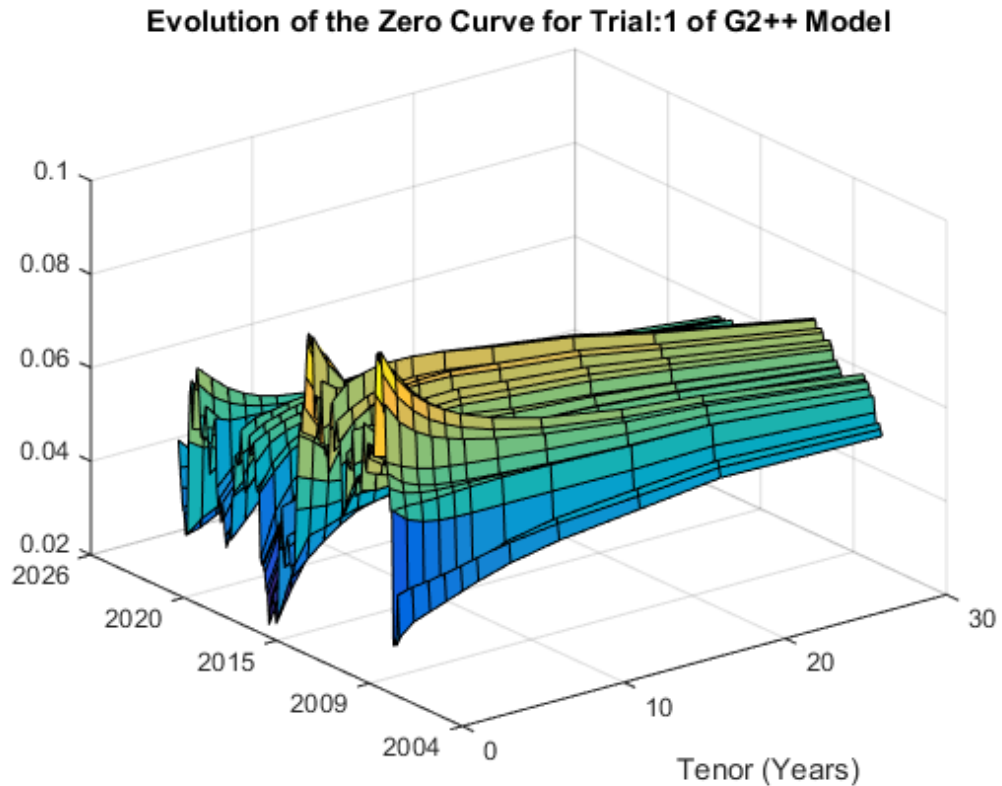
```

% included here to facilitate computing a discount factor for each
% simulation path.

% Remove any paths that go negative
NegIdx = squeeze(any(G2PP_SimZeroRates < 0,1),2);
G2PP_SimZeroRates(:, :, NegIdx) = [];
nTrials = size(G2PP_SimZeroRates,3);

% Plot evolution of one sample path
trialIdx = 1;
figure
surf(Tenor, SimDates, G2PP_SimZeroRates(:, :, trialIdx))
datetick y kepticks keeplimits
title(['Evolution of the Zero Curve for Trial:' num2str(trialIdx) ' of G2++ Model'])
xlabel('Tenor (Years)')

```



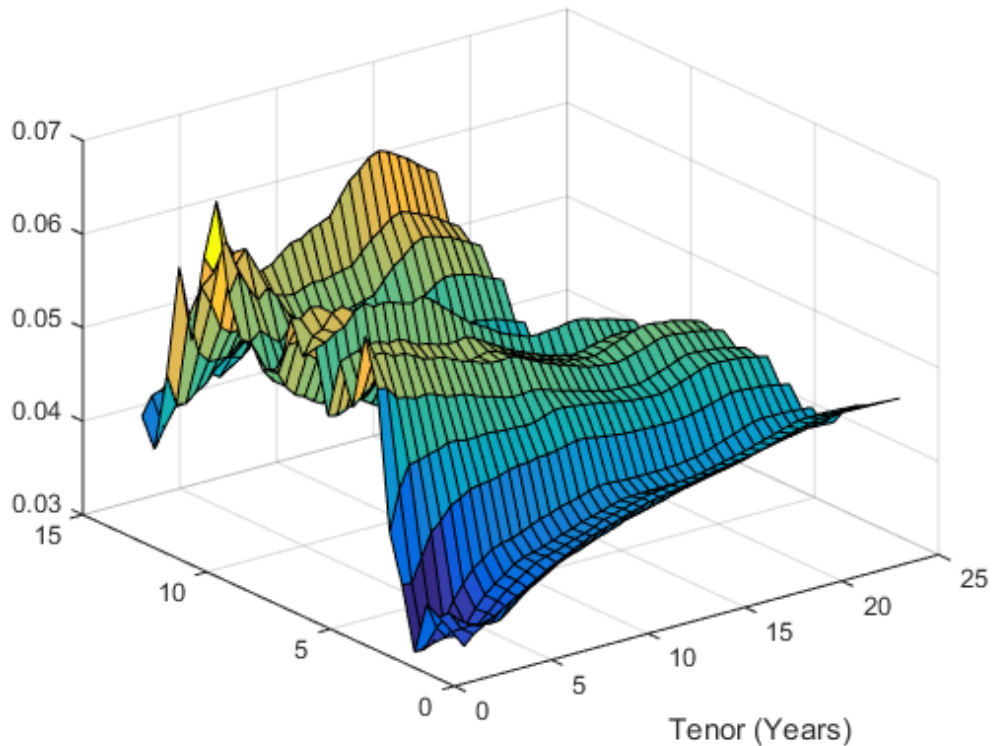
### LIBOR Market Model Simulation

The various interest-rate paths can be simulated by calling the `simTermStructs` method of the `LiborMarketModel` object.

```
LMMPeriod = 2; % Semi-annual rates
LMMNumPeriods = NumCouponsRemaining/12*LMMPeriod; % Number of semi-annual periods
LMMDeltaTime = 1/LMMPeriod;
LMMNTRIALS = 100;

% Simulate
[LMMZeroRates, LMMForwardRates] = LMM.simTermStructs(LMMNumPeriods, 'nTrials', LMMNTRIALS);
ForwardTimes = 1/2:1/2:numForwardRates/2;
LMMSimTimes = 0:1/LMMPeriod:LMMNumPeriods/LMMPeriod;

% Plot evolution of one sample path
trialIdx = 1;
figure
tmpPlotData = LMMZeroRates(:, :, trialIdx);
tmpPlotData(tmpPlotData == 0) = NaN;
surf(ForwardTimes, LMMSimTimes, tmpPlotData)
title(['Evolution of the Zero Curve for Trial:' num2str(trialIdx) ' of LIBOR Market Model'])
xlabel('Tenor (Years)')
```

**Evolution of the Zero Curve for Trial:1 of LIBOR Market Model****Compute Mortgage Rates from Simulation**

Once the interest-rate paths have been simulated, the mortgage rate needs to be computed -- one approach, discussed by [7], is to compute the mortgage rate from a combination of the 2-year and 10-year rates.

For this example, the following is used:

$$\text{MortgageRate} = .024 + .2 * \text{TwoYearRate} + .6 * \text{TenYearRate}$$

```
% Compute mortgage rates from interest rate paths
```

```

TwoYearRates = squeeze(G2PP_SimZeroRates(:,Tenor == 2,:));
TenYearRates = squeeze(G2PP_SimZeroRates(:,Tenor == 7,:));
G2PP_MortgageRates = .024 + .2*TwoYearRates + .6*TenYearRates;

LMMMortgageRates = squeeze(.024 + .2*LMMZeroRates(:,4,:) + .6*LMMZeroRates(:,20,:));
LMMDiscountFactors = squeeze(cumprod(1./(1 + LMMZeroRates(:,1,:)*.5)));

% Interpolate to get monthly mortgage rates
MonthlySimTimes = 0:1/12:LMMNumPeriods/LMMPeriod;
LMMMonthlyMortgageRates = zeros(nPeriods+1,LMMNTRIALS);
LMMMonthlyDF = zeros(nPeriods+1,LMMNTRIALS);
for trialidx = 1:LMMNTRIALS
    LMMMonthlyMortgageRates(:,trialidx) = interp1(LMMSimTimes,LMMMortgageRates(:,trialidx),MonthlySimTimes);
    LMMMonthlyDF(:,trialidx) = interp1(LMMSimTimes,LMMDiscountFactors(:,trialidx),MonthlySimTimes);
end

```

### Computing CPR and Generating and Valuing Cash Flows

Once the Mortgage Rates have been simulated, the CPR can be computed from the multiplicative model for each interest-rate path.

```

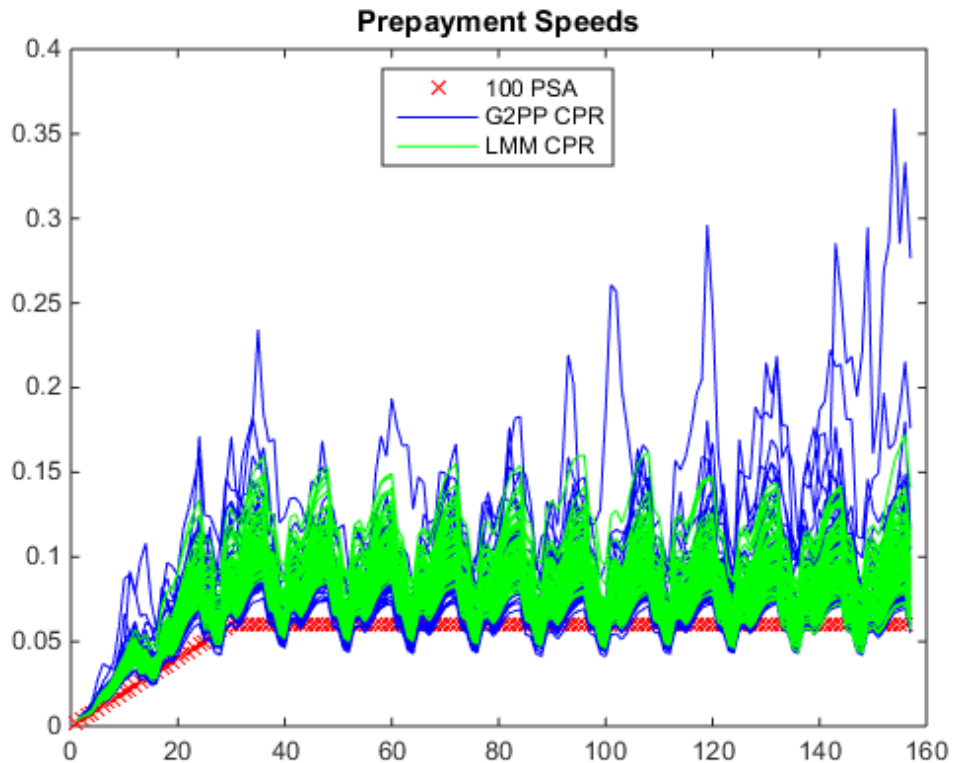
% Compute Seasoning and Refinancing Multipliers
Seasoning = ones(nPeriods+1,1);
Seasoning(1:30) = 1/30*(1:30);
G2PP_Refi = .2406 - .1389 * atan(5.952*(1.089 - CouponRate./G2PP_MortgageRates));
LMM_Refi = .2406 - .1389 * atan(5.952*(1.089 - CouponRate./LMMMonthlyMortgageRates));

% CPR is simply computed by evaluating the multiplicative model
G2PP_CPR = bsxfun(@times,G2PP_Refi,Seasoning.*(Seasonality(month(CFlowDates))));
LMM_CPR = bsxfun(@times,LMM_Refi,Seasoning.*(Seasonality(month(CFlowDates))));

% Compute single monthly mortality (SMM) from CPR
G2PP_SMM = 1 - (1 - G2PP_CPR).^(1/12);
LMM_SMM = 1 - (1 - LMM_CPR).^(1/12);

% Plot CPR's against 100 PSA
CPR_PSA100 = psaspeed2rate(100);
figure
PSA_handle = plot(CPR_PSA100(1:nPeriods),'rx');
hold on
G2PP_handle = plot(G2PP_CPR,'b');
LMM_handle = plot(LMM_CPR,'g');
title('Prepayment Speeds')
legend([PSA_handle(1) G2PP_handle(1) LMM_handle(1)],{'100 PSA','G2PP CPR','LMM CPR'},'Location','best')

```



### Generate Cash Flows and Compute Present Value

With a vector of single monthly mortalities (SMM) computed for each interest-rate path, cash flows for the MBS can be computed and discounted.

```
% Compute the baseline zero rate at each cash flow time
CFlowZero = interp1(ZeroTimes,ZeroRates,CFlowTimes,'linear','extrap');
```

```
% Compute DF for each cash flow time
CFlowDF_Zero = zero2disc(CFlowZero,CFlowDates,Settle);
```

```
% Compute the price of the MBS using the zero curve
Price_Zero = CFlowAmounts*CFlowDF_Zero';
```

```
% Generate the cash flows for each IR Path
```

```

G2PP_CFlowAmounts = mbscfamounts(Settle, ...
    repmat(Maturity,1,nTrials), IssueDate, GrossRate, CouponRate, Delay, [], G2PP_SMM(2));

% Compute the DF for each IR path
G2PP_CFlowDFSim = cumprod(exp(squeeze(-G2PP_SimZeroRates(:,1,:).*DeltaTime)));

% Present value the cash flows for each MBS
G2PP_Price_Ind = sum(G2PP_CFlowAmounts.*G2PP_CFlowDFSim',2);
G2PP_Price = mean(G2PP_Price_Ind);

% Repeat for LMM
LMM_CFlowAmounts = mbscfamounts(Settle, ...
    repmat(Maturity,1,LMMNTRIALS), IssueDate, GrossRate, CouponRate, Delay, [], LMM_SMM(2));

% Present value the cash flows for each MBS
LMM_Price_Ind = sum(LMM_CFlowAmounts.*LMMMonthlyDF',2);
LMM_Price = mean(LMM_Price_Ind);

```

The results from the different approaches can be compared. The number of trials for the G2++ model will typically be less than 100 due to the filtering out of any paths that produce negative interest rates.

Additionally, while the number of trials for the G2++ model in this example is set to be 100, it is often the case that a larger number of simulations need to be run to produce an accurate valuation.

```

fprintf('          # of Monte Carlo Trials: %8d\n'      , nTrials)
fprintf('          # of Time Periods/Trial: %8d\n\n'  , nPeriods)
fprintf('          MBS Price with PSA 100: %8.4f\n'    , Price_Zero)
fprintf(' MBS Price with Custom G2PP Prepayment Model: %8.4f\n\n', G2PP_Price)
fprintf(' MBS Price with Custom LMM Prepayment Model: %8.4f\n\n', LMM_Price)

          # of Monte Carlo Trials:          73
          # of Time Periods/Trial:         156

          MBS Price with PSA 100:          1.0187
MBS Price with Custom G2PP Prepayment Model: 0.9871

          MBS Price with Custom LMM Prepayment Model: 0.9993

```

## Conclusion

This example shows how to calibrate and simulate a G2++ interest-rate model and how to use the generated interest-rate paths in a prepayment model loosely based on the

Richard and Roll model. This example also provides a useful starting point to using the G2++ and LMM interest-rate models in other financial applications.

### **Bibliography**

This example is based on the following books, papers and journal articles:

- 1** Andersen, L. and V. Piterbarg (2010). *Interest Rate Modeling*, Atlantic Financial Press.
- 2** Brigo, D. and F. Mercurio (2001). *Interest Rate Models - Theory and Practice with Smile, Inflation and Credit* (2nd ed. 2006 ed.). Springer Verlag. ISBN 978-3-540-22149-4.
- 3** Hayre, L, ed., *Salomon Smith Barney Guide to Mortgage-Backed and Asset-Backed Securities*. New York: John Wiley & Sons, 2001b
- 4** Karpishpan, Y., O. Turel, and A. Hasha, *Introducing the Citi LMM Term Structure Model for Mortgages*, *The Journal of Fixed Income*, Volume 20 (2010) 44-58.
- 5** Rebonato, R., K. McKay, and R. White (2010). *The Sabr/Libor Market Model: Pricing, Calibration and Hedging for Complex Interest-Rate Derivatives*. John Wiley & Sons.
- 6** Richard, S. F., and R. Roll, 1989, "Prepayments on Fixed Rate Mortgage-Backed Securities" ,*Journal of Portfolio Management*.
- 7** Office of Thrift Supervision, "Net Portfolio Value Model Manual", March 2000.
- 8** Stein, H. J., Belikoff, A. L., Levin, K. and Tian, X., *Analysis of Mortgage Backed Securities: Before and after the Credit Crisis* (January 5, 2007). *Credit Risk Frontiers: Subprime Crisis, Pricing and Hedging, CVA, MBS, Ratings, and Liquidity*; Bielecki, Tomasz,; Damiano Brigo and Frederic Patras, eds., February 2011. Available at SSRN: <http://ssrn.com/abstract=955358>

## Pricing Mortgage Backed Securities Using the Black-Derman-Toy Model

This example illustrates how the Financial Toolbox™ and Financial Instruments Toolbox™ can be used to price a level mortgage backed security using the BDT model.

### Load the BDT Tree Stored in the Data File

```
load mbsexample.mat
```

### Observe the Interest Rate Tree

Visualize the interest rate evolution along the tree by looking at the output structure BDTTree. BDTTree returns an inverse discount tree, which you can convert into an interest rate tree with the cvtree function.

```
BDTTreeR = cvtree(BDTTree);
```

Look at the upper branch and lower branch paths of the tree:

```
OldFormat = get(0, 'format');  
format short
```

```
%Rate at root node:
```

```
RateRoot = treepath(BDTTreeR.RateTree, [0])
```

```
%Rates along upper branch:
```

```
RatePathUp = treepath(BDTTreeR.RateTree, [1 1 1 1 1])
```

```
%Rates along lower branch:
```

```
RatePathDown = treepath(BDTTreeR.RateTree, [2 2 2 2 2])
```

```
RateRoot =
```

```
0.0399
```

```
RatePathUp =
```

```
0.0399
```

```
0.0397
```

```
0.0391
```



```

0.0383
0.0373
0.0360

```

```
RatePathDown =
```

```

0.0399
0.0470
0.0550
0.0638
0.0734
0.0841

```

### Compute the Price Tree for the Non-Prepayable Mortgage

Let's say that we have a 3 year \$10000 level prepayable loan, with a mortgage interest rate of 4.64% semi-annually compounded.

```

MortgageAmount = 10000;
CouponRate = 0.0464;
Period = 2;
Settle='01-Jan-2007';
Maturity='01-Jan-2010';
Compounding = BDTTree.TimeSpec.Compounding;

```

```
format bank
```

```

% Use the function 'amortize.m' in the Financial Toolbox to calculate the mortgage
% payment of the loan (MP), the interest and principal components, and the
% outstanding principal balance.

```

```
NumPeriods = date2time(Settle,Maturity, Compounding)';
```

```
[Principal, InterestPayment, OutstandingBalance, MP] = amortize(CouponRate/Period, NumPeriods, MortgageAmount);
```

```
% Display Principal, Interest and Outstanding balances
```

```
PrincipalAmount = Principal'
```

```
InterestPaymentAmount = InterestPayment'
```

```
OutstandingBalanceAmount =OutstandingBalance'
```

```
CFlowAmounts = MP*ones(1,NumPeriods);
```

```
% The CFlowDates are the same as the tree level dates
```

```
CFlowDates= {'01-Jul-2007' , '01-Jan-2008' , '01-Jul-2008' , '01-Jan-2009' , '01-Jul-2009' , '01-Jan-2010'}
```

```
% Calculate the price of the non-prepayable mortgage
[PriceNonPrepayableMortgage, PriceTreeNonPrepayableMortgage] = cfbybdt(BDTTree, CFlowA
for iLevel = 2:length(PriceTreeNonPrepayableMortgage.PTree)
    PriceTreeNonPrepayableMortgage.PTree{iLevel}(:, :) = PriceTreeNonPrepayableMortgage.P
end

% Look at the price of the mortgage today (tObs = 0)
PriceNonPrepayableMortgage

% The value of the non-prepayable mortgage is $10017.47. This value exceeds
% the $10000 amount borrowed since the homeowner received not only $10000, but
% also a prepayment option.

% Look at the value of the mortgage on the last date, right after the last
% mortgage payment, is zero:
PriceTreeNonPrepayableMortgage.PTree{end};

% Visualize the price tree for the non-prepayable mortgage.
treeviewer(PriceTreeNonPrepayableMortgage)

PrincipalAmount =

    1572.59
    1609.07
    1646.40
    1684.60
    1723.68
    1763.67

InterestPaymentAmount =

    232.00
    195.52
    158.19
    119.99
    80.91
    40.92

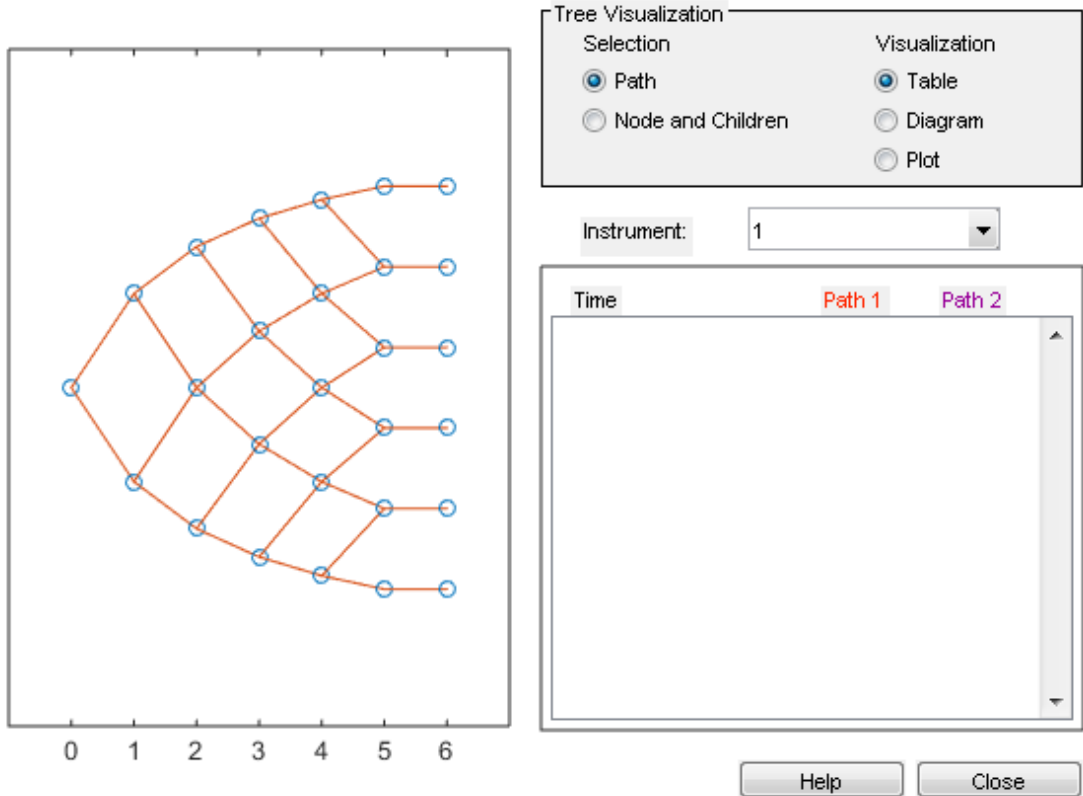
OutstandingBalanceAmount =

    8427.41
```

6818.34  
 5171.94  
 3487.35  
 1763.67  
 0.00

PriceNonPrepayableMortgage =

10017.47



**Compute the Price Tree of the Prepayment Option**

```
% The Prepayment option is like a call option on a bond.
%
% The exercise price or strike will be equal to the outstanding principal amount
% which has been calculated using the function 'amortize.m'.

OptSpec = 'call';
Strike = [MortgageAmount OutstandingBalance];
ExerciseDates =[Settle CFlowDates];
AmericanOpt = 0;
Maturity = CFlowDates(end);

% Compute the price of the prepayment option:
[PricePrepaymentOption, PriceTreePrepaymentOption] = prepaymentbybdt(BDTTree, OptSpec,
    0, Settle, Maturity,[], [], [], ...
    [], [], [], [], 0, [], CFlowAmounts);

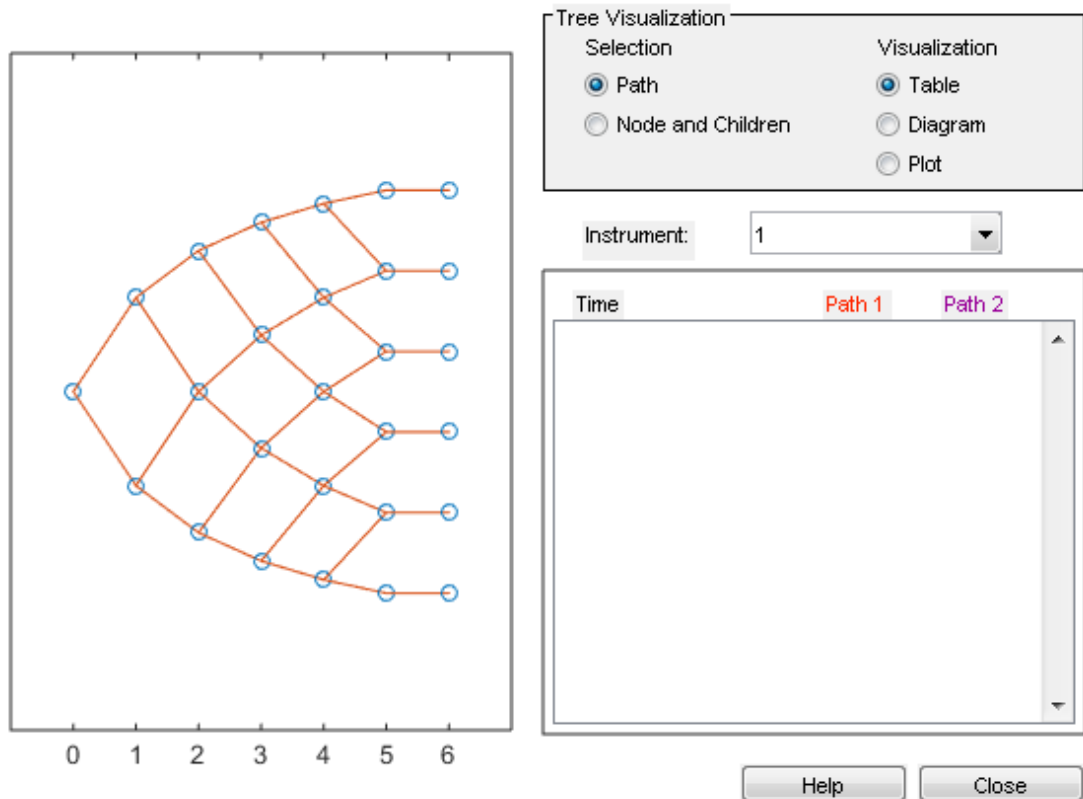
% Look at the price of the prepayment option today (tObs = 0)
PricePrepaymentOption

% The value of the prepayment option is $17.47 as expected.

% Visualize the price tree for the prepayment option
treeview(PriceTreePrepaymentOption)

PricePrepaymentOption =

    17.47
```



### Calculate the Price Tree of the Prepayable Mortgage.

```
% Compute the price of the prepayable mortgage.
```

```
PricePrepayableMortgage = PriceNonPrepayableMortgage - PricePrepaymentOption;
```

```
PriceTreePrepayableMortgage = PriceTreeNonPrepayableMortgage;
```

```
for iLevel = 1:length(PriceTreeNonPrepayableMortgage.PTree)
    PriceTreePrepayableMortgage.PTree{iLevel}(:, :) = PriceTreeNonPrepayableMortgage.PTree{iLevel}(:, :) - PriceTreePrepaymentOption.PTree{iLevel}(:, :);
end
```

```
% Look at the price of the prepayable mortgage today (tObs = 0)
```

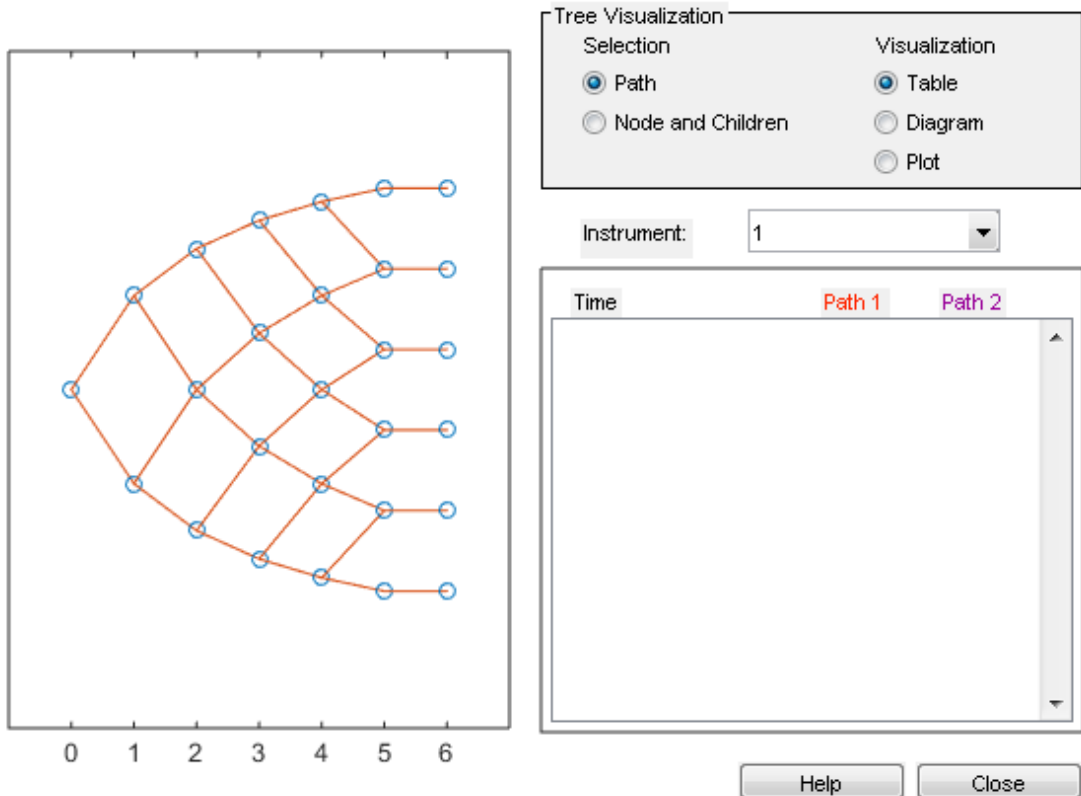
```
PricePrepayableMortgage
```

```
% The value of the prepayable mortgage is $10000 as expected.
```

```
% Visualize the price and price tree for the prepayable mortgage
treeviewer(PriceTreePrepayableMortgage)
set(0, 'format', OldFormat);
```

```
PricePrepayableMortgage =
```

```
10000.00
```



## Using Collateralized Mortgage Obligations (CMOs)

### In this section...

“What Are CMOs?” on page 5-45

“Prepayment Risk” on page 5-45

“CMO Workflow” on page 5-52

### What Are CMOs?

Financial Instruments Toolbox supports collateralized mortgage obligations (CMOs) to provide investors with a greater range of risk and return characteristics than mortgage-backed securities (MBS). In contrast to an MBS, which simply redirects principal and interest cash flows to investors on a pro rata basis, a CMO structures cash flows to different tranches, or slices, to create securities that are better tailored to specific investors.

For example, banks might be primarily concerned with *extension risk*, or the risk that their investment lengthens in time due to increasing interest rates, given that they typically have short-term deposits as liabilities. Insurance companies and pension funds might be concerned primarily with *contraction risk*, or the risk that their investment will pay off too soon, with liabilities that have much longer lives. A CMO structure addresses the interest-rate risk of extension or contraction with a blend of short-term and long-term CMO securities, called tranches.

### Prepayment Risk

Prepayment risk is the risk that the term of the security varies according to differing rates of repayment of principal by borrowers (repayments from refinancings, sales, curtailments, or foreclosures). In a CMO, you can structure the principal (and associated coupon) stream from the underlying mortgage pool collateral to allocate prepayment risk. If principal is prepaid faster than expected (for example, if mortgage rates fall and borrowers refinance), then the overall term of the mortgage pool collateral shortens.

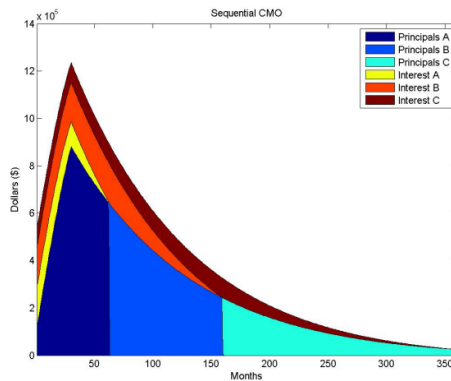
You cannot remove prepayment risk, but you can reallocate it among CMO tranches so that some tranches have some protection against this risk, and other tranches will absorb more of this risk. To facilitate this allocation of prepayment risk, CMOs are structured such that prepayments are allocated among tranches using a fixed set of rules. The most common schemes for prepayment tranching are:

- Sequential tranching, with or without, Z-bond tranching
- Schedule bond tranching
  - Planned amortization class (PAC) bonds
  - Target amortization class (TAC) bonds

Financial Instruments Toolbox supports these schemes for prepayment tranching for CMOs and tools for pricing and scheduling cash flows between the tranches, as well as analyzing the price and yield for CMOs. Financial Instruments Toolbox functionality for CMOs does not model credit risk. Therefore, this functionality is most appropriate for CMOs where credit risk is not an issue (for example, agency CMOs where the underlying mortgage pool collateral is insured for default by the agency Government-Sponsored Enterprises (GSEs), such as Fannie Mae and Freddie Mac).

### Sequential Tranches Without a Z-Bond

All available principal and interest payments go to the first sequential tranche, until its balance decrements to zero, then to the second, and so on. For example, consider the following example where all principal and interest from the underlying mortgage pool is repaid on tranche A first, then tranche B, then tranche C. Note that interest is paid on each tranche as long as the principal for the tranche has not been retired.



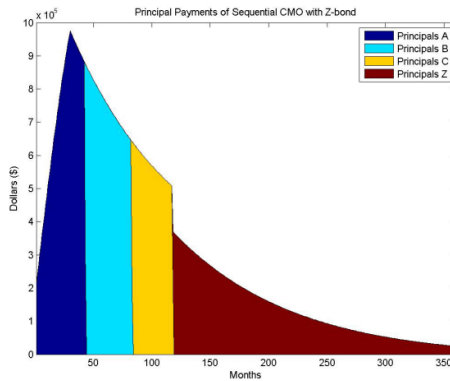
### Sequential Tranches With a Z-Bond

The Z-bond, also called an accrual bond, is a type of interest and principal pay rule. The Z-bond tranche supports other sequential pay tranches by not receiving an interest payment. The interest payment that would have accrued to the Z-bond tranche pays off the principal of other bonds, and the principal of the Z-bond tranche increases. The

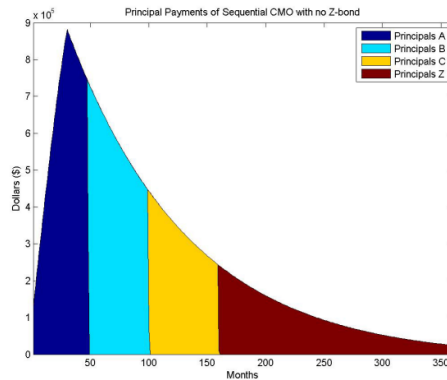


Z-bond tranche starts receiving interest and principal payments only after the other tranches in the CMO have been fully paid. The Z-bond tranche is used in a sequential-pay structure to accelerate the principal repayments of the sequential-pay bonds.

A Z-bond differs from other CMO instruments because it is not tranching principal but interest. The Z-bond receives no cash flows until all other securities have been paid off. In the interim, the interest that is owed to the Z-bond is accrued to its principal. The following chart demonstrates the difference between a Z-bond and a normal sequential pay tranche. Note that the C tranche pays off sooner with the Z-bond, because the interest cash flows to the Z-bond are being used to pay down the principal of the C tranche.



For comparison, the following graphic is the same sequential CMO with no Z-bond.



## PAC Tranches

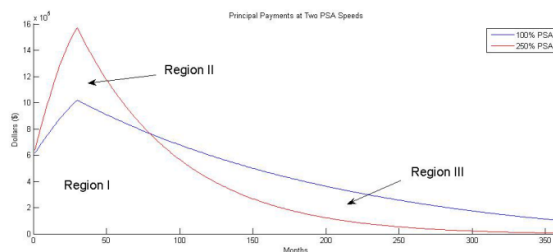
Planned amortization class (PAC) bonds help reduce the effects of prepayment risk. They are designed to produce more stable cash flows by redirecting prepayments from the underlying mortgage collateral to other classes (tranches) called companion or support classes. PAC bonds have a principal payment rate over a predetermined period of time. The PAC bond payment schedule is determined by two different prepayment rates, which together form a band (also called a collar). Early in the life of the CMO, the prepayment at the lower PSA yields a lower prepayment. Later in its life, the principal in the higher PSA declines enough that it yields a lower prepayment. The PAC tranche receives whichever rate is lower, so it will change prepayment at one PSA for the first part of its life, then switch to the other rate. The ability to stay on this schedule is maintained by a support bond, which absorbs excess prepayments, and receives less prepayments to prevent extension of average life.

However, the PAC is only protected from extension to the amount that prepayments are made on the underlying MBSs. If there is a sustained period of fast prepayments, then that might completely eliminate a PAC bond's outstanding support class. When the principal of the associated PAC bond is exhausted, the CMO is called a "busted PAC", or "busted collar". Alternatively, in times of slow prepayments, amortization of the support bonds is delayed if there is not enough principal for the currently paying PAC bond. This extends the average life of the class.

A PAC bond protects against both extension and contraction risk by:

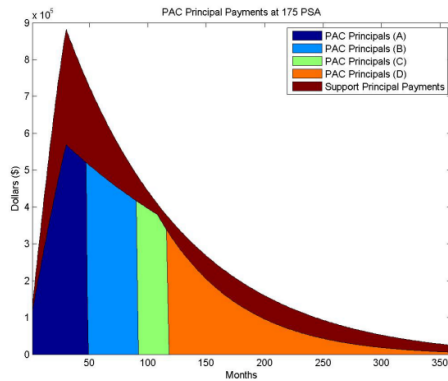
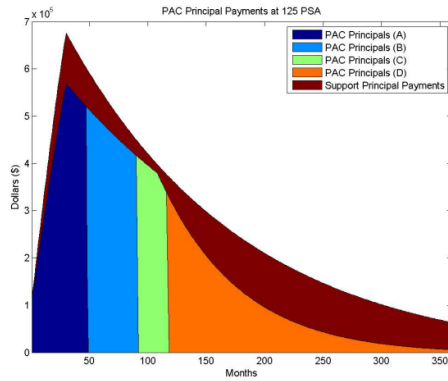
- Specifying a schedule of principal payments for the PAC bond
- Including support tranches that are allocated prepayments inside a specified prepayment band

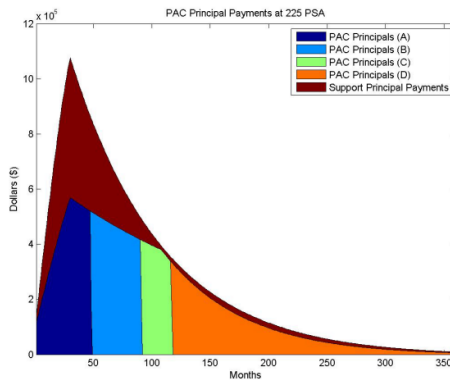
PAC bonds typically specify a band expressed using the PSA model. A PAC bond with a range of 100 to 250% has this principal schedule.



The principal repayment schedule is the minimum principal payment as Region 1 shows. Note that this is the principal payment schedule as long as the actual prepayment stays within the prepayment band of 100 to 250% PSA.

For example, for different prepayment speeds of 125%, 175%, and 225% PSA, the actual principal payments are shown in the following graphs. Note that at higher prepayment speeds, the support tranche is allocated principal earlier while the principal timing for the other tranches remains constant.

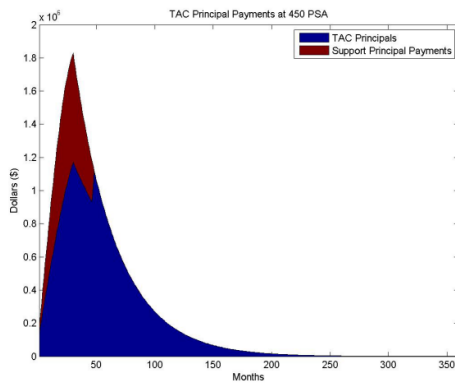
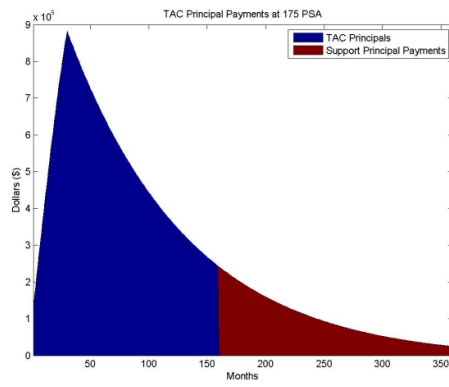
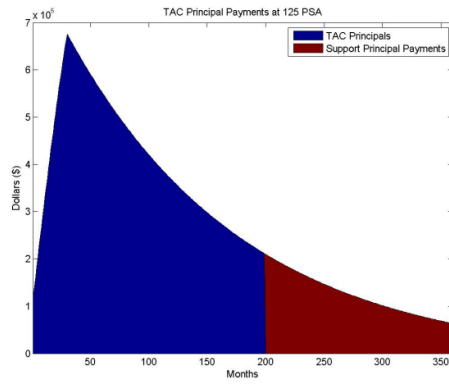




### TAC Tranches

Target amortization class (TAC) bonds are similar to PAC bonds, but they do not provide protection against extension of average life. Create the schedule of principal payments by using just a single PSA. TAC bonds pay a “targeted” principal payment schedule at a single, constant prepayment speed. As long as the underlying mortgage collateral does not prepay at a rate slower than this speed, the TAC bond payment schedule is met. TAC bonds can protect against increasing prepayments and early retirement of the TAC bond investment. If the principal cash flow from the mortgage collateral exceeds the TAC schedule, the excess is allocated to TAC companion (support) classes. Alternatively, if prepayments fall below the speed necessary to maintain the TAC schedule, the weighted average life of the TAC is extended. The TAC bond does not protect against low prepayment rates.

For example, here is a TAC structure rated for 125%, 175%, and 450% PSA.



Note that for prepayments below 175% PSA, the TAC bond extends like a normal sequential pay CMO. TAC bonds are appealing because they offer higher yields than comparable PAC bonds. The unaddressed risk from low prepayment rates generally does not concern investors as much as risk from high prepayment rates.

### CMO Workflow

In general, the CMO workflow is:

- 1 Calculate underlying mortgage cash flows.
- 2 Define CMO tranches
- 3 If using a PAC or TAC CMO, calculate the principal schedule.
- 4 Calculate cash flows for each tranche.
- 5 Analyze the CMO by computing price, yield, spread of CMO cash flows.

#### Calculate Underlying Mortgage Cash Flows

Underlying mortgage pool pass-through cash flows are calculated by the existing function `mbspassthrough`. The CMO cash flow functions require the principal payments (including prepayments) calculated from existing functions `mbspassthrough` or `mbscfamounts`.

```
principal = 10000000;
coupon = 0.06;
terms = 360;
psa = 150;

[principal_balance, monthly_payments, sched_principal_payments, ...
interest_payments, prepayments] = mbspassthrough(principal, ...
coupon, terms, terms, psa, []);

principal_payments = sched_principal_payments.' + prepayments.';
```

After determining principal payments for the underlying mortgage collateral, you can generate cash flows for a sequential CMO, with or without a Z-bond, by using `cmoseqcf`. For a PAC or TAC CMO, the cash flows are generated using `cmoschedcf`

#### Define CMO Tranches

Define CMO tranche; for example, define a CMO with 2 tranches:

```
TranchePrincipals = [500000; 500000];
TrancheCoupons = [0.06; 0.06];
```

### If Using a PAC or TAC CMO, Calculate Principal Schedule

Calculate the PAC/TAC principal balance schedule based on a band of PSA speeds. For scheduled CMOs (PAC/TAC), the CMO cash flow functions additionally take in the principal balance schedule calculated by the CMO schedule function `cmosched`.

```
speed = [100 300];
[balanceSchedule, initialBalance] = cmosched(principal, coupon,...
terms, terms, speed, TranchePrincipals(1));
```

### Calculate Cash Flows for Each Tranche

You can reuse the output from the cash flow generation functions to further divide the cash flows into tranches. For example, the output from `cmoschedcf` for a PAC tranche can be divided into sequential tranches by passing the principal cash flows of the PAC tranche into the `cmoschedcf` function. The output of the CMO cash flow functions are the principal and interest cash flows, as well as the principal balance.

```
[principal_balances, principal_cashflows, interest_cashflows] = cmoschedcf(principal_payments,...
TranchePrincipals, TrancheCoupons, balanceSchedule);
```

### Analyze CMO by Computing Price, Yield, and Spread of CMO Cash Flows

The outputs from the CMO functions (`cmoseqcf` and `cmoschedcf`) are cash flows. The functions used to analyze a CMO are based on these cash flows. To that end, you can use `cfbyzero`, `cfsread`, `cfyield`, and `cfprice` to compute prices, yield, and spreads for the CMO cash flows. In addition, using the following, you can calculate a weighted average life (WAL) for each tranche in the CMO:

$$WAL = \sum_{i=1}^n \frac{P_i t_i}{P}$$

where:

$P$  is the total principal.

$P_i$  is the principal repayment of the coupon  $i$ .

$\frac{P_i}{P}$  is the fraction of the principal repaid in coupon  $i$ .

$t_i$  is the time in years from the start to coupon  $i$ .

### **See Also**

cmosched | cmoschedcf | cmoseqcf | mbscfamounts | mbspassthrough

### **Related Examples**

- “Create PAC and Sequential CMO” on page 5-55
- “Fixed-Rate Mortgage Pool” on page 5-3

### **More About**

- “What Are Mortgage-Backed Securities?” on page 5-2



## Create PAC and Sequential CMO

This example shows how to use an underlying mortgage-backed security (MBS) pool for a 30-year fixed-rate mortgage of 6% to define a PAC bond, and then define a sequential CMO from the PAC bond. Analyze the CMO by comparing the CMO spread to a zero-rate curve for a 30-year Treasury bond and then calculate the weighted-average life (WAL) for the PAC bond.

### Step 1. Define the underlying mortgage pool.

```
principal = 100000000;
grossrate = 0.06;
coupon = 0.05;
originalTerm = 360;
termRemaining = 360;
speed = 100;
delay = 14;

Settle      = datenum('1-Jan-2011');
IssueDate   = datenum('1-Jan-2011');
Maturity    = addtodate(IssueDate, 360, 'month');
```

### Step 2. Calculate underlying pool cash flow.

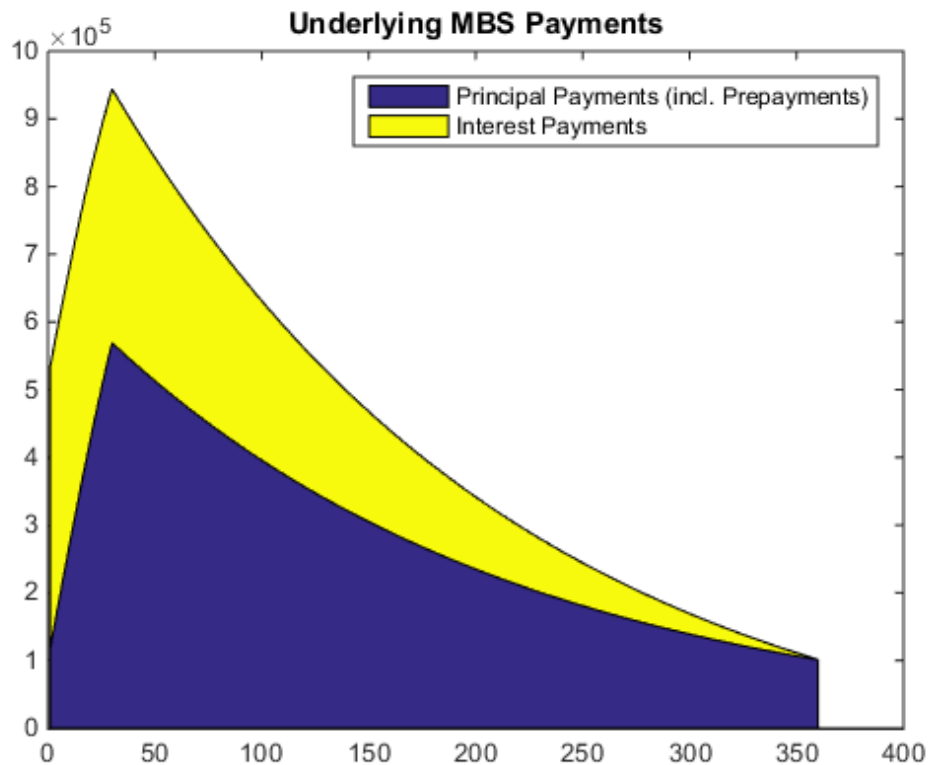
```
[CFlowAmounts, CFlowDates, ~, ~, ~, UnitPrincipal, UnitInterest, ...
UnitPrepayment] = mbscfamounts(Settle, Maturity, IssueDate, grossrate, ...
coupon, delay, speed, []);
```

### Step 3. Calculate prepayments.

```
principalPayments = UnitPrincipal * principal;
netInterest = UnitInterest * principal;
prepayments = UnitPrepayment * principal;
dates = CFlowDates' + delay;
```

### Step 4. Generate a plot for underlying MBS payments.

```
area([principalPayments'+prepayments', netInterest'])
title('Underlying MBS Payments');
legend('Principal Payments (incl. Prepayments)', 'Interest Payments')
```

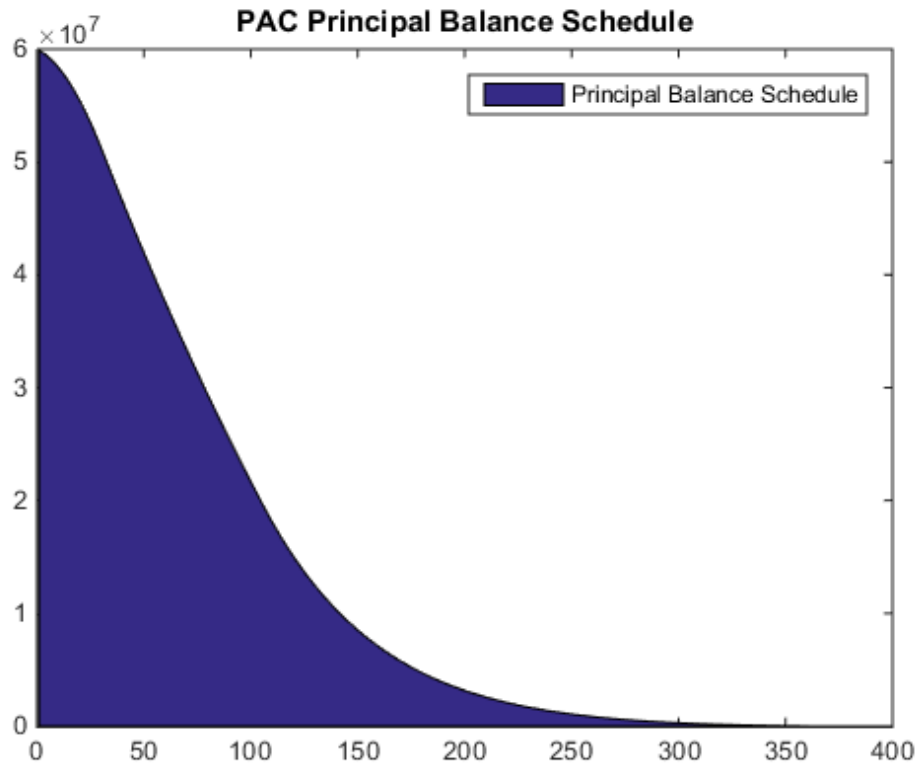


**Step 5. Calculate the PAC schedule.**

```
pacSpeed = [80 300];
[balanceSchedule, pacInitBalance] = ...
cmosched(principal, grossrate, originalTerm, termRemaining, ...
pacSpeed, []);
```

**Step 6. Generate a plot for the PAC principal balance schedule.**

```
figure;
area([pacInitBalance'; balanceSchedule'])
title('PAC Principal Balance Schedule');
legend('Principal Balance Schedule');
```



### Step 7. Calculate PAC cash flow.

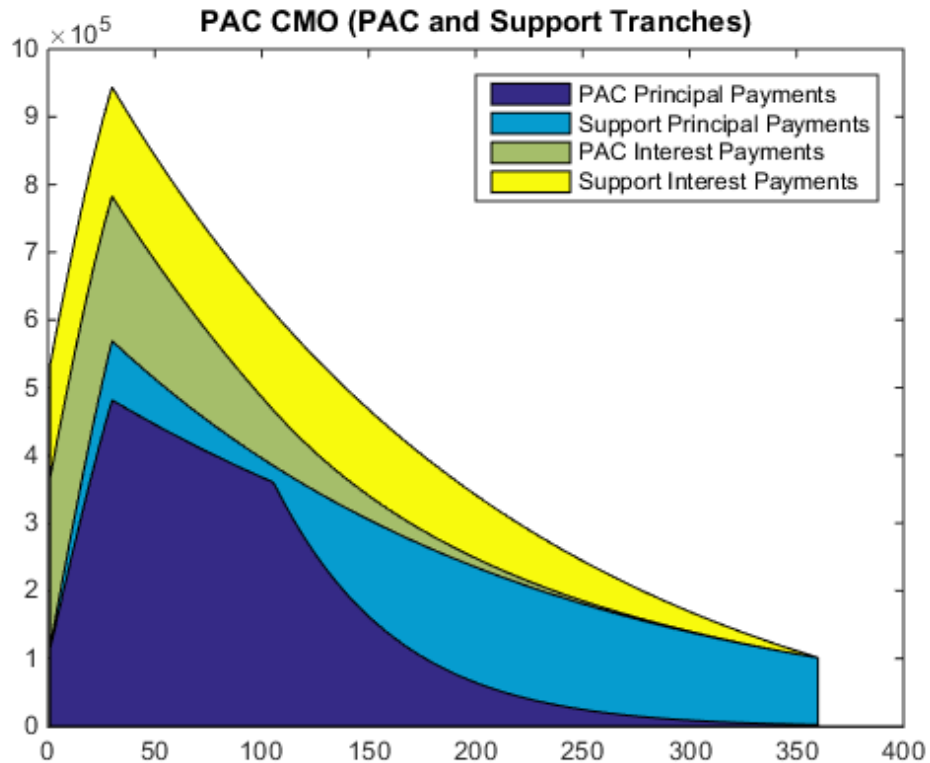
```
pacTranchePrincipals = [pacInitBalance; principal-pacInitBalance];
pacTrancheCoupons = [0.05; 0.05];
[pacBalances, pacPrincipals, pacInterests] = ...
cmoschedcf(principalPayments+prepayments, ...
pacTranchePrincipals, pacTrancheCoupons, balanceSchedule);
```

### Step 8. Generate a plot for the PAC CMO tranches.

Generate a plot for the PAC CMO tranches:

```
figure;
area([pacPrincipals' pacInterests']);
title('PAC CMO (PAC and Support Tranches)');
```

```
legend('PAC Principal Payments', 'Support Principal Payments', ...
      'PAC Interest Payments', 'Support Interest Payments');
```



### Step 9. Create sequential CMO from the PAC bond.

CMO tranches, A, B, C, and D

```
seqTranchePrincipals = ...
[20000000; 20000000; 10000000; pacInitBalance-50000000];
seqTrancheCoupons = [0.05; 0.05; 0.05; 0.05];
```

### Step 10. Calculate cash flows for each tranche.

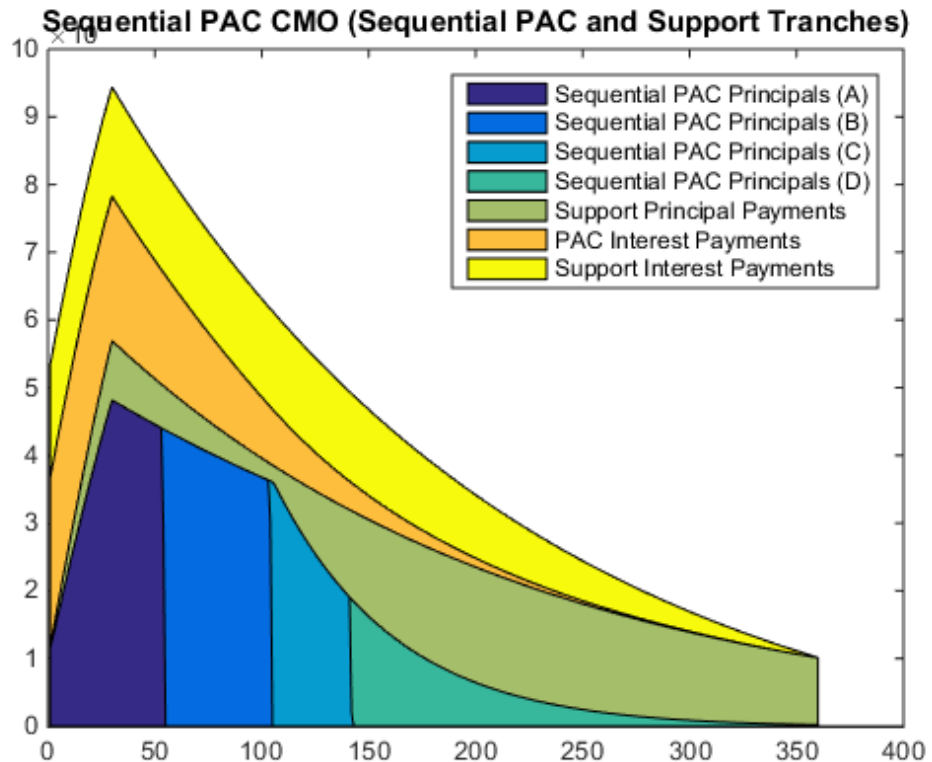
```
[seqBalances, seqPrincipals, seqInterests] = ...
cmoseqcf(pacPrincipals(1, :), seqTranchePrincipals, ...
```

```
seqTrancheCoupons, false);
```

### Step 11. Generate a plot for the sequential PAC CMO.

Generate a plot for the sequential PAC CMO:

```
figure
area([seqPrincipals' pacPrincipals(2, :)' pacInterests']);
title('Sequential PAC CMO (Sequential PAC and Support Tranches)');
legend('Sequential PAC Principals (A)', 'Sequential PAC Principals (B)', ...
'Sequential PAC Principals (C)', 'Sequential PAC Principals (D)', ...
'Support Principal Payments', 'PAC Interest Payments', ...
'Support Interest Payments');
```



### Step 12. Create the discount curve.

```
CurveSettle = datenum('1-Jan-2011');
ZeroRates = [0.01 0.03 0.10 0.19 0.45 0.81 1.76 2.50 3.18 4.09 4.38]'/100;
CurveTimes = [1/12 3/12 6/12 1 2 3 5 7 10 20 30]';
CurveDates = daysadd(CurveSettle, 360 * CurveTimes, 1);
zeroCurve = intenvset('Rates', ZeroRates, 'StartDates', CurveSettle, ...
'EndDates', CurveDates);
```

### Step 13. Price the CMO cash flows.

The cash flow for the sequential PAC principal A tranche is calculated using the cash flow functions `cfbyzero`, `cfyield`, `cfprice`, and `cfsread`.

```
cflows = seqPrincipals(1, :)+seqInterests(1, :);
cfdates = dates(2:end)';
price1 = cfbyzero(zeroCurve, cflows, cfdates, Settle, 4)
yield = cfyield(cflows, cfdates, price1, Settle, 'Basis', 4)
price2 = cfprice(cflows, cfdates, yield, Settle, 'Basis', 4)
spread = cfsread(zeroCurve, price2, cflows, cfdates, Settle, 'Basis', 4)
WAL = sum(cflows .* yearfrac(Settle, cfdates, 4)) / sum(cflows)
```

```
price1 =
    2.2109e+07
```

```
yield =
    0.0090
```

```
price2 =
    2.2109e+07
```

```
spread =
    8.5711e-13
```

```
WAL =
    2.5408
```

The weighted average life (WAL) for the sequential PAC principal A tranche is 2.54 years.

### **See Also**

cfbyzero | cfbyzero | cfprice | cfs spread | cfyield | cmosched | cmoschedcf  
| cmoseqcf | mbscfamounts

### **Related Examples**

- “Fixed-Rate Mortgage Pool” on page 5-3

### **More About**

- “Using Collateralized Mortgage Obligations (CMOs)” on page 5-45





# Debt Instruments

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- “Agency Option-Adjusted Spreads” on page 6-2
- “Using Zero-Coupon Bonds” on page 6-6
- “Stepped-Coupon Bonds” on page 6-10
- “Term Structure Calculations” on page 6-13

## Agency Option-Adjusted Spreads

Often bonds are issued with embedded options, which then makes standard price/yield or spread measures irrelevant. For example, a municipality concerned about the chance that interest rates may fall in the future might issue bonds with a provision that allows the bond to be repaid before the bond's maturity. This is a call option on the bond and must be incorporated into the valuation of the bond. Option-adjusted spread (OAS), which adjusts a bond spread for the value of the option, is the standard measure for valuing bonds with embedded options. Financial Instruments Toolbox software supports computing option-adjusted spreads for bonds with single embedded options using the agency model.

The Securities Industry and Financial Markets Association (SIFMA) has a simplified approach to compute OAS for agency issues (Government Sponsored Entities like Fannie Mae and Freddie Mac) termed "Agency OAS". In this approach, the bond has only one call date (European call) and uses Black's model (a variation on Black Scholes, [http://en.wikipedia.org/wiki/Black\\_model](http://en.wikipedia.org/wiki/Black_model)) to value the bond option. The price of the bond is computed as follows:

$$\text{Price}_{\text{Callable}} = \text{Price}_{\text{NonCallable}} - \text{Price}_{\text{Option}}$$

where

$\text{Price}_{\text{Callable}}$  is the price of the callable bond.

$\text{Price}_{\text{NonCallable}}$  is the price of the noncallable bond, i.e., price of the bond using `bndspread`.

$\text{Price}_{\text{Option}}$  is the price of the option, i.e., price of the option using Black's model.

The Agency OAS is the spread, when used in the previous formula, yields the market price. Financial Instruments Toolbox software supports these functions:

Agency OAS Functions	Purpose
<code>agencyoas</code>	Compute the OAS of the callable bond using the Agency OAS model.
<code>agencyprice</code>	Price the callable bond OAS using Agency using the OAS model.

## Computing the Agency OAS for Bonds

To compute the Agency OAS using `agencyoas`, you must provide the zero curve as the input `ZeroData`. You can specify the zero curve in any intervals and with any compounding method. You can do this using Financial Toolbox™ functions `zbtprice` and `zbtyield`. Or, you can use `IRDataCurve` to construct an `IRDataCurve` object, and then use the `getZeroRates` to convert to dates and data for use in the `ZeroData` input.

After creating the `ZeroData` input for `agencyoas`, you can then:

- 1 Assign parameters for `CouponRate`, `Settle`, `Maturity`, `Vol`, `CallDate`, and `Price`.
- 2 Compute the option-adjusted spread using `agencyoas` to derive the OAS output.

If you have the Agency OAS for the callable bond, you can use the OAS value as an input to `agencyprice` to determine the price for a callable bond.

In the following example, the Agency OAS is computed using `agencyoas` for a range of bond prices and the spread of an identically priced noncallable bond is calculated using `bndspread`.

```
%% Data
% Bond data -- note that there is only 1 call date
Settle = datenum('20-Jan-2010');
Maturity = datenum('30-Dec-2013');
Coupon = .022;
Vol = .5117;
CallDate = datenum('30-Dec-2010');
Period = 2;
Basis = 1;
Face = 100;

% Zero Curve data
ZeroTime = [.25 .5 1 2 3 4 5 7 10 20 30]';
ZeroDates = daysadd(Settle,360*ZeroTime,1);
ZeroRates = [.0008 .0017 .0045 .0102 .0169 .0224 .0274 .0347 .0414 .0530 .0740]';
ZeroData = [ZeroDates ZeroRates];
CurveCompounding = 2;
CurveBasis = 1;

Price = 94:104;
OAS = agencyoas(ZeroData, Price', Coupon, Settle,Maturity, Vol, CallDate,'Basis',Basis)
Spread = bndspread(ZeroData, Price', Coupon, Settle, Maturity)
plot(OAS,Price)
hold on
plot(Spread,Price,'r')
xlabel('Spread (bp)')
ylabel('Price')
title('AOAS and Spread for an Agency and Equivalent Noncallable Bond')
legend({'Callable Issue','Noncallable Issue'})
```

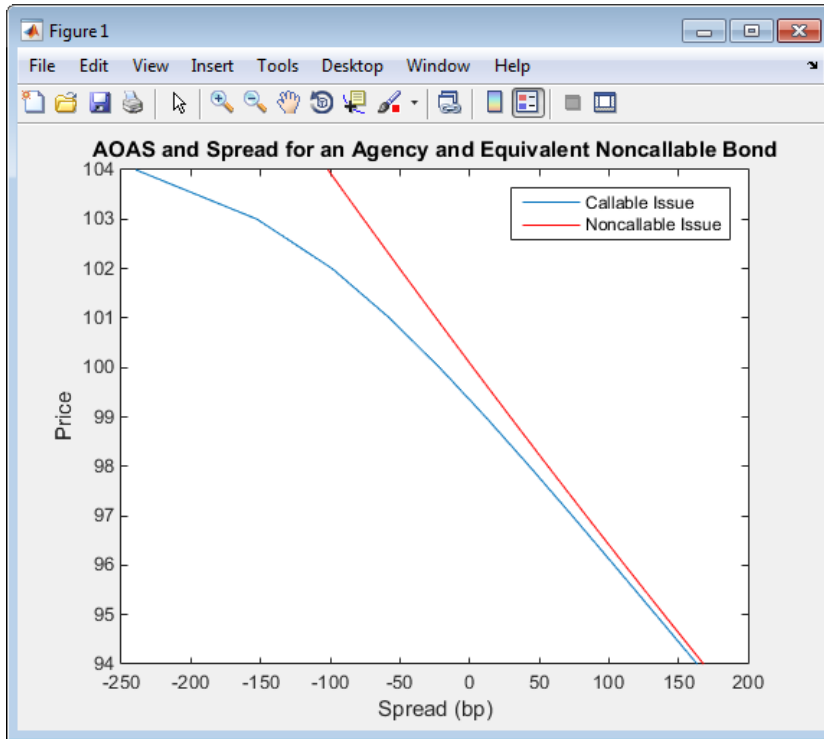
OAS =

163.4942  
133.7306  
103.8735  
73.7505  
43.1094  
11.5608  
-21.5412  
-57.3869  
-98.5675  
-152.5226  
-239.6462

Spread =

168.1412  
139.7047  
111.6123  
83.8561  
56.4286  
29.3227  
2.5314  
-23.9523  
-50.1348  
-76.0226  
-101.6218

The following plot demonstrates as the price increases, the value of the embedded option in the Agency issue increases, and the value of the issue itself does not increase as much as it would for a noncallable bond, illustrating the negative convexity of this issue:



## Using Zero-Coupon Bonds

### In this section...

“Introduction” on page 6-6

“Measuring Zero-Coupon Bond Function Quality” on page 6-6

“Pricing Treasury Notes” on page 6-7

“Pricing Corporate Bonds” on page 6-8

### Introduction

A zero-coupon bond is a corporate, Treasury, or municipal debt instrument that pays no periodic interest. Typically, the bond is redeemed at maturity for its full face value. It will be a security issued at a discount from its face value, or it may be a coupon bond stripped of its coupons and repackaged as a zero-coupon bond.

Financial Instruments Toolbox software provides functions for valuing zero-coupon debt instruments. These functions supplement existing coupon bond functions such as `bndprice` and `bndyield` that are available in Financial Toolbox software.

### Measuring Zero-Coupon Bond Function Quality

Zero-coupon function quality is measured by how consistent the results are with coupon-bearing bonds. Because the zero coupon's yield is bond-equivalent, comparisons with coupon-bearing bonds are possible.

In the textbook case, where time ( $t$ ) is measured continuously and the rate ( $r$ ) is continuously compounded, the value of a zero bond is the principal multiplied by  $e^{-rt}$ . In reality, the rate quoted is continuous and the basis can be variable, requiring a more consistent approach to meet the stricter demands of accurate pricing.

The following two examples

- “Pricing Treasury Notes” on page 6-7
- “Pricing Corporate Bonds” on page 6-8

show how the zero functions are consistent with supported coupon bond functions.

## Pricing Treasury Notes

A Treasury note can be considered to be a package of zeros. The toolbox functions that price zeros require a coupon bond equivalent yield. That yield can originate from any type of coupon paying bond, with any periodic payment, or any accrual basis. The next example shows the use of the toolbox to price a Treasury note and compares the calculated price with the actual price quotation for that day.

```
Settle = datenum('02-03-2003');
MaturityCpn = datenum('05-15-2009');
Period = 2;
Basis = 0;
```

```
% Quoted yield.
QYield = 0.03342;
```

```
% Quoted price.
QPriceACT = 112.127;
```

```
CouponRate = 0.055;
```

Extract the cash flow and compute price from the sum of zeros discounted.

```
[CFlows, CDates] = cfamounts(CouponRate, Settle, MaturityCpn, ...
Period, Basis);
MaturityofZeros = CDates;
```

Compute the price of the coupon bond identically as a collection of zeros by multiplying the discount factors to the corresponding cash flows.

```
PriceofZeros = CFlows * zeroprice(QYield, Settle, ...
MaturityofZeros, Period, Basis)/100;
```

The following table shows the intermediate calculations.

Cash Flows	Discount Factors	Discounted Cash Flows
-1.2155	1.0000	-1.2155
2.7500	0.9908	2.7246
2.7500	0.9745	2.6799
2.7500	0.9585	2.6359
2.7500	0.9427	2.5925
2.7500	0.9272	2.5499

Cash Flows	Discount Factors	Discounted Cash Flows
2.7500	0.9120	2.5080
2.7500	0.8970	2.4668
2.7500	0.8823	2.4263
2.7500	0.8678	2.3864
2.7500	0.8535	2.3472
2.7500	0.8395	2.3086
2.7500	0.8257	2.2706
102.7500	0.8121	83.4451
		Total 112.1263

Compare the quoted price and the calculated price based on zeros.

```
[QPriceACT PriceofZeros]
```

```
ans =
```

```
112.1270    112.1263
```

This example shows that `zeroprice` can satisfactorily price a Treasury note, a semiannual actual/actual basis bond, as if it were a composed of a series of zero-coupon bonds.

## Pricing Corporate Bonds

You can similarly price a corporate bond, for which there is no corresponding zero-coupon bond, as opposed to a Treasury note, for which corresponding zeros exist. You can create a synthetic zero-coupon bond and arrive at the quoted coupon-bond price when you later sum the zeros.

```
Settle = datenum('02-05-2003');
MaturityCpn = datenum('01-14-2009');
Period = 2;
Basis = 1;
% Quoted yield.
QYield = 0.05974;
% Quoted price.
QPrice30 = 99.382;
CouponRate = 0.05850;
```



Extract cash flow and compute price from the sum of zeros.

```
[CFlows, CDates] = cfamounts(CouponRate, Settle, MaturityCpn, ...
Period, Basis);
```

```
Maturity = CDates;
```

Compute the price of the coupon bond identically as a collection of zeros by multiplying the discount factors to the corresponding cash flows.

```
Price30 = CFlows * zeroprice(QYield, Settle, Maturity, Period, ...
Basis)/100;
```

Compare quoted price and calculated price based on zeros.

```
[QPrice30 Price30]
```

```
ans =
```

```
99.3820    99.3828
```

As a test of fidelity, intentionally giving the wrong basis, say actual/actual (**Basis = 0**) instead of 30/360, gives a price of 99.3972. Such a systematic error, if recurring in a more complex pricing routine, quickly adds up to large inaccuracies.

In summary, the zero functions in MATLAB software facilitate extraction of present value from virtually any fixed-coupon instrument, up to any period in time.

## Stepped-Coupon Bonds

### In this section...

“Introduction” on page 6-10

“Cash Flows from Stepped-Coupon Bonds” on page 6-10

“Price and Yield of Stepped-Coupon Bonds” on page 6-11

### Introduction

A stepped-coupon bond has a fixed schedule of changing coupon amounts. Like fixed coupon bonds, stepped-coupon bonds could have different periodic payments and accrual bases.

The functions `stepcpnprice` and `stepcpnyield` compute prices and yields of such bonds. An accompanying function `stepcpncfamounts` produces the cash flow schedules pertaining to these bonds.

### Cash Flows from Stepped-Coupon Bonds

Consider a bond that has a schedule of two coupons. Suppose the bond starts out with a 2% coupon that steps up to 4% in 2 years and onward to maturity. Assume that the issue and settlement dates are both March 15, 2003. The bond has a 5 year maturity. Use `stepcpncfamounts` to generate the cash flow schedule and times.

```
Settle      = datenum('15-Mar-2003');
Maturity    = datenum('15-Mar-2008');
ConvDates   = [datenum('15-Mar-2005')];
CouponRates = [0.02, 0.04];

[CFflows, CDates, CTimes] = stepcpncfamounts(Settle, Maturity, ...
ConvDates, CouponRates)
```

Notably, `ConvDates` has 1 less element than `CouponRates` because MATLAB software assumes that the first element of `CouponRates` indicates the coupon schedule between `Settle` (March 15, 2003) and the first element of `ConvDates` (March 15, 2005), shown diagrammatically below.

	Pay 2% from March 15, 2003		Pay 4% from March 15, 2003
--	----------------------------	--	----------------------------

Effective 2% on March 15, 2003		Effective 4% on March 15, 2005	
-----------------------------------	--	-----------------------------------	--

Coupon Dates	Semiannual Coupon Payment
15-Mar-03	0
15-Sep-03	1
15-Mar-04	1
15-Sep-04	1
15-Mar-05	1
15-Sep-05	2
15-Mar-06	2
15-Sep-06	2
15-Mar-07	2
15-Sep-07	2
15-Mar-08	102

The payment on March 15, 2005 is still a 2% coupon. Payment of the 4% coupon starts with the next payment, September 15, 2005. March 15, 2005 is the end of first coupon schedule, not to be confused with the beginning of the second.

In summary, MATLAB takes user input as the end dates of coupon schedules and computes the next coupon dates automatically.

The payment due on settlement (zero in this case) represents the accrued interest due on that day. It is negative if such amount is nonzero. Comparison with `cfamounts` in Financial Toolbox shows that the two functions operate identically.

## Price and Yield of Stepped-Coupon Bonds

The toolbox provides two basic analytical functions to compute price and yield for stepped-coupon bonds. Using the above bond as an example, you can compute the price when the yield is known.

You can estimate the yield to maturity as a number-of-year weighted average of coupon rates. For this bond, the estimated yield is:

$$\frac{(2 \times 2) + (4 \times 3)}{5}$$

or 3.33%. While definitely not exact (due to nonlinear relation of price and yield), this estimate suggests close to par valuation and serves as a quick first check on the function.

```
Yield = 0.0333;
```

```
[Price, AccruedInterest] = stepcpnprice(Yield, Settle, ...  
Maturity, ConvDates, CouponRates)
```

The price returned is 99.2237 (per \$100 notional), and the accrued interest is zero, consistent with our earlier assertions.

To validate that there is consistency among the stepped-coupon functions, you can use the above price and see if indeed it implies a 3.33% yield by using `stepcpnyield`.

```
YTM = stepcpnyield(Price, Settle, Maturity, ConvDates, ...  
CouponRates)
```

```
YTM =
```

```
0.0333
```

## Term Structure Calculations

### In this section...

“Introduction” on page 6-13

“Computing Spot and Forward Curves” on page 6-13

“Computing Spreads” on page 6-15

### Introduction

So far, a more formal definition of "yield" and its application has not been developed. In many situations when cash flow is available, discounting factors to the cash flows may not be immediately apparent. In other cases, what is relevant is often a *spread*, the difference between curves (also known as the term structure of spread).

All these calculations require one main ingredient, the Treasury spot, par-yield, or forward curve. Typically, the generation of these curves starts with a series of on-the-run and selected off-the-run issues as inputs.

MATLAB software uses these bonds to find spot rates one at a time, from the shortest maturity onwards, using bootstrap techniques. All cash flows are used to construct the spot curve, and rates between maturities (for these coupons) are interpolated linearly.

### Computing Spot and Forward Curves

For an illustration of how this works, observe the use of `zbtyield` (or equivalently `zbtprice`) on a portfolio of six Treasury bills and bonds.

Bills	Maturity Date	Current Yield
3 month	4/17/03	1.15
6 month	7/17/03	1.18

Notes/Bonds	Coupon	Maturity Date	Current Yield
2 year	1.750	12/31/04	1.68
5 year	3.000	11/15/07	2.97

Notes/Bonds	Coupon	Maturity Date	Current Yield
10 year	4.000	11/15/12	4.01
30 year	5.375	2/15/31	4.92

You can specify prices or yields to the bonds above to infer the spot curve. The function `zbtyield` accepts yields (bond-equivalent yield, to be exact).

To proceed, first assemble the above table into a variable called `Bonds`. The first column contains maturities, the second contains coupons, and the third contains notionals or face values of the bonds. (Note that bills have zero coupons.)

```
Bonds = [datenum('04/17/2003')    0      100;
          datenum('07/17/2003')    0      100;
          datenum('12/31/2004')    0.0175 100;
          datenum('11/15/2007')    0.03    100;
          datenum('11/15/2012')    0.04    100;
          datenum('02/15/2031')    0.05375 100];
```

Then specify the corresponding yields.

```
Yields = [0.0115;
          0.0118;
          0.0168;
          0.0297;
          0.0401;
          0.0492];
```

You are now ready to compute the spot curve for each of these six maturities. The spot curve is based upon a settlement date of January 17, 2003.

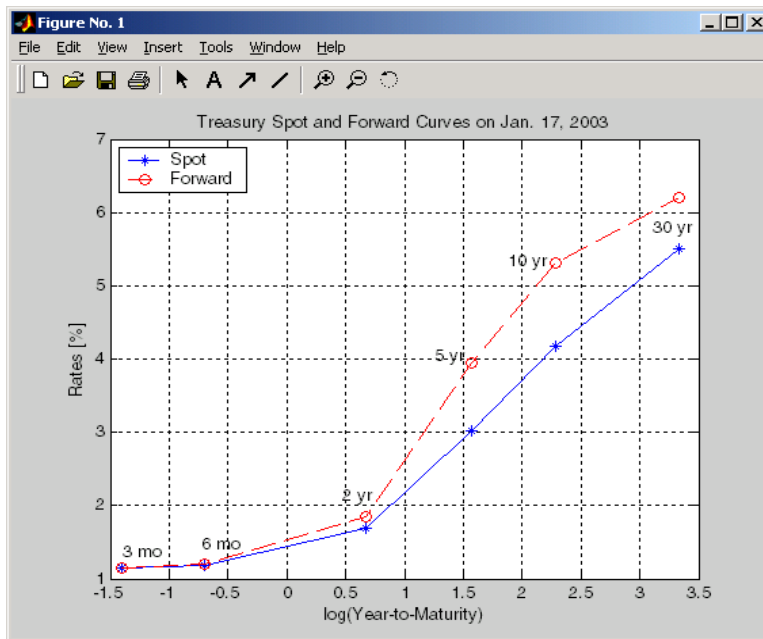
```
Settle = datenum('17-Jan-2003');
[ZeroRates, CurveDates] = zbtyield(Bonds, Yields, Settle)
```

This gets you the Treasury spot curve for the day.

You can compute the forward curve from this spot curve with `zero2fwd`.

```
[ForwardRates, CurveDates] = zero2fwd(ZeroRates, CurveDates, ...
Settle)
```

Here the notion of forward rates refers to rates between the maturity dates shown above, not to a certain period (forward 3 month rates, for example).



## Computing Spreads

Calculating the spread between specific, fixed forward periods (such as the Treasury-Eurodollar spread) requires an extra step. Interpolate the zero rates (or zero prices, instead) for the corresponding maturities on the interval dates. Then use the interpolated zero rates to deduce the forward rates, and thus the spread of Eurodollar forward curve segments versus the relevant forward segments from Treasury bills.

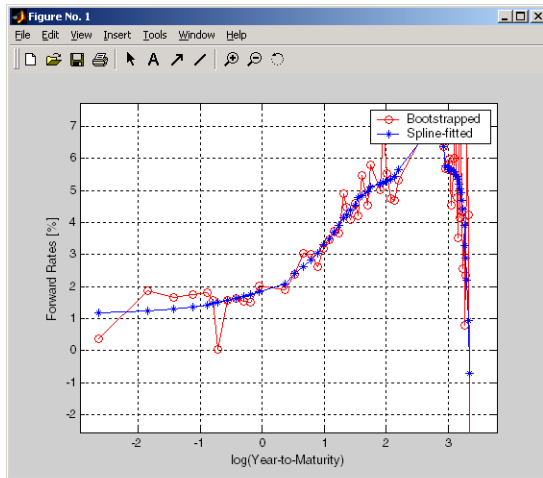
Additionally, the variety of curve functions (including `zero2fwd`) helps to standardize such calculations. For instance, by making both rates quoted with quarterly compounding and on an actual/360 basis, the resulting spread structure is fully comparable. This avoids the small inconsistency that occurs when directly comparing the bond-equivalent yield of a Treasury bill to the quarterly forward rates implied by Eurodollar futures.

### **Noise in Curve Computations**

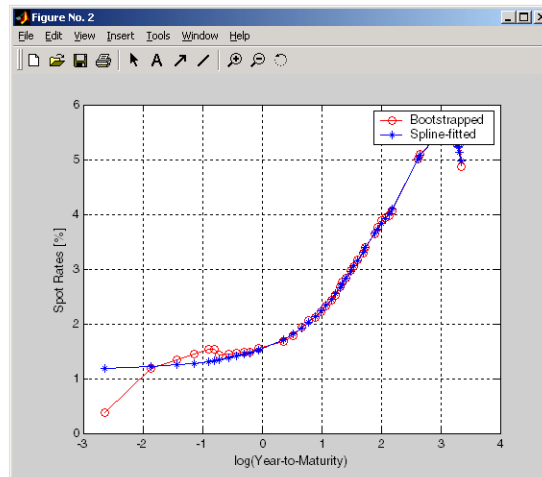
When introducing more bonds in constructing curves, noise may become a factor and may need some “smoothing” (with splines, for example); this helps obtain a smoother forward curve.

The following spot and forward curves are constructed from 67 Treasury bonds. The fitted and bootstrapped spot curve (bottom right figure) displays comparable stability. The forward curve (upper-left figure) contains significant noise and shows an improbable forward rate structure. The noise is not necessarily bad; it could uncover trading opportunities for a relative-value approach. Yet, a more balanced approach is desired when the bootstrapped forward curve oscillates this much and contains a negative rate as large as -10% (not shown in the plot because it is outside the limits).





**Implied Forward Curves.**  
**The jagged curve comes from direct bootstrapping.**  
**The smooth curve shows the effect of smoothing with splines.**



**Implied Spot Rate Curves.**  
**These curves correspond to the forward curve above.**

This example uses `termfit`, an example function from Financial Toolbox software that also requires the use of Curve Fitting Toolbox™ software.



# Derivative Securities

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- “Interest Rate Swaps” on page 7-2
- “Convertible Bond Valuation” on page 7-9
- “Bond Futures” on page 7-11
- “Managing Interest Rate Risk with Bond Futures” on page 7-16
- “Fitting the Diebold Li Model” on page 7-24

## Interest Rate Swaps

In this section...
“Swap Pricing Assumptions” on page 7-2
“Swap Pricing Example” on page 7-3
“Portfolio Hedging” on page 7-7

### Swap Pricing Assumptions

Financial Instruments Toolbox software contains the function `liborfloat2fixed`, which computes a fixed-rate par yield that equates the floating-rate side of a swap to the fixed-rate side. The solver sets the present value of the fixed side to the present value of the floating side without having to line up and compare fixed and floating periods.

#### Assumptions on Floating-Rate Input

- Rates are quarterly, for example, that of Eurodollar futures.
- Effective date is the first third Wednesday after the settlement date.
- All delivery dates are spaced 3 months apart.
- All periods start on the third Wednesday of delivery months.
- All periods end on the same dates of delivery months, 3 months after the start dates.
- Accrual basis of floating rates is actual/360.
- Applicable forward rates are estimated by interpolation in months when forward-rate data is not available.

#### Assumptions on Fixed-Rate Output

- Design allows you to create a bond of any coupon, basis, or frequency, based upon the floating-rate input.
- The start date is a valuation date, that is, a date when an agreement to enter into a contract by the settlement date is made.
- Settlement can be on or after the start date. If it is after, a forward fixed-rate contract results.
- Effective date is assumed to be the first third Wednesday after settlement, the same date as that of the floating rate.
- The end date of the bond is a designated number of years away, on the same day and month as the effective date.

- Coupon payments occur on anniversary dates. The frequency is determined by the period of the bond.
- Fixed rates are not interpolated. A fixed-rate bond of the same present value as that of the floating-rate payments is created.

## Swap Pricing Example

This example shows the use of the functions in computing the fixed rate applicable to a series of 2-, 5-, and 10-year swaps based on Eurodollar market data. According to the Chicago Mercantile Exchange (<http://www.cmegroup.com>), Eurodollar data on Friday, October 11, 2002, was as shown in the following table.

---

**Note** This example illustrates swap calculations in MATLAB software. Timing of the data set used was not rigorously examined and was assumed to be the proxy for the swap rate reported on October 11, 2002.

---

### Eurodollar Data on Friday, October 11, 2002

Month	Year	Settle
10	2002	98.21
11	2002	98.26
12	2002	98.3
1	2003	98.3
2	2003	98.31
3	2003	98.275
6	2003	98.12
9	2003	97.87
12	2003	97.575
3	2004	97.26
6	2004	96.98
9	2004	96.745
12	2004	96.515
3	2005	96.33

<b>Month</b>	<b>Year</b>	<b>Settle</b>
6	2005	96.135
9	2005	95.955
12	2005	95.78
3	2006	95.63
6	2006	95.465
9	2006	95.315
12	2006	95.16
3	2007	95.025
6	2007	94.88
9	2007	94.74
12	2007	94.595
3	2008	94.48
6	2008	94.375
9	2008	94.28
12	2008	94.185
3	2009	94.1
6	2009	94.005
9	2009	93.925
12	2009	93.865
3	2010	93.82
6	2010	93.755
9	2010	93.7
12	2010	93.645
3	2011	93.61
6	2011	93.56
9	2011	93.515
12	2011	93.47
3	2012	93.445
6	2012	93.41

Month	Year	Settle
9	2012	93.39

Using this data, you can compute 1-, 2-, 3-, 4-, 5-, 7-, and 10-year swap rates with the toolbox function `liborfloat2fixed`. The function requires you to input only Eurodollar data, the settlement date, and tenor of the swap. MATLAB software then performs the required computations.

To illustrate how this function works, first load the data contained in the supplied Excel® worksheet `EDdata.xls`.

```
[EDRawData, textdata] = xlsread('EDdata.xls');
```

Extract the month from the first column and the year from the second column. The rate used as proxy is the arithmetic average of rates on opening and closing.

```
Month = EDRawData(:,1);
Year = EDRawData(:,2);
IMMData = (EDRawData(:,4)+EDRawData(:,6))/2;
EDFutData = [Month, Year, IMMData];
```

Next, input the current date.

```
Settle = datenum('11-Oct-2002');
```

To compute for the 2 year swap rate, set the tenor to 2.

```
Tenor = 2;
```

Finally, compute the swap rate with `liborfloat2fixed`.

```
[FixedSpec, ForwardDates, ForwardRates] = ...
liborfloat2fixed(EDFutData, Settle, Tenor)
```

MATLAB returns a par-swap rate of 2.23% using the default setting (quarterly compounding and 30/360 accrual), and forward dates and rates data (quarterly compounded).

```
FixedSpec =
```

```
    Coupon: 0.0223
    Settle: '16-Oct-2002'
    Maturity: '16-Oct-2004'
```

```
    Period: 4
    Basis: 1

ForwardDates =

    731505
    731596
    731687
    731778
    731869
    731967
    732058
    732149

ForwardRates =

    0.0178
    0.0168
    0.0171
    0.0189
    0.0216
    0.0250
    0.0280
    0.0306
```

In the `FixedSpec` output, note that the swap rate actually goes forward from the third Wednesday of October 2002 (October 16, 2002), 5 days after the original `Settle` input (October 11, 2002). This, however, is still the best proxy for the swap rate on `Settle`, as the assumption merely starts the swap's effective period and does not affect its valuation method or its length.

The correction suggested by Hull and White improves the result by turning on convexity adjustment as part of the input to `liborfloat2fixed`. (See Hull, J., *Options, Futures, and Other Derivatives*, 4th Edition, Prentice-Hall, 2000.) For a long swap, for example, 5 years or more, this correction could prove to be large.

The adjustment requires additional parameters:

- `StartDate`, which you make the same as `Settle` (the default) by providing an empty matrix `[]` as input.
- `ConvexAdj` to tell `liborfloat2fixed` to perform the adjustment.
- `RateParam`, which provides the parameters `a` and `S` as input to the Hull-White short rate process.



- Optional parameters `InArrears` and `Sigma`, for which you can use empty matrices `[]` to accept the MATLAB defaults.
- `FixedCompound`, with which you can facilitate comparison with values cited in Table H15 of *Federal Reserve Statistical Release* by turning the default quarterly compounding into semiannual compounding, with the (default) basis of 30/360.

```
StartDate = [];
Interpolation = [];
ConvexAdj = 1;
RateParam = [0.03; 0.017];
FixedCompound = 2;
[FixedSpec, ForwardDaates, ForwardRates] = ...
liborfloat2fixed(EDFutData, Settle, Tenor, StartDate, ...
Interpolation, ConvexAdj, RateParam, [], [], FixedCompound)
```

This returns 2.21% as the 2-year swap rate, quite close to the reported swap rate for that date.

Analogously, the following table summarizes the solutions for 1-, 3-, 5-, 7-, and 10-year swap rates (convexity-adjusted and unadjusted).

#### Calculated and Market Average Data of Swap Rates on Friday, October 11, 2002

Swap Length (Years)	Unadjusted	Adjusted	Table H15	Adjusted Error (Basis Points)
1	1.80%	1.79%	1.80%	-1
2	2.24%	2.21%	2.22%	-1
3	2.70%	2.66%	2.66%	0
4	3.12%	3.03%	3.04%	-1
5	3.50%	3.37%	3.36%	+1
7	4.16%	3.92%	3.89%	+3
10	4.87%	4.42%	4.39%	+3

## Portfolio Hedging

You can use these results further, such as for hedging a portfolio. The `liborduration` function provides a duration-hedging capability. You can isolate assets (or liabilities) from interest-rate risk exposure with a swap arrangement.

Suppose you own a bond with these characteristics:

- \$100 million face value
- 7% coupon paid semiannually
- 5% yield to maturity
- Settlement on October 11, 2002
- Maturity on January 15, 2010
- Interest accruing on an actual/365 basis

Use of the `bnddury` function from Financial Toolbox software shows a modified duration of 5.6806 years.

To immunize this asset, you can enter into a pay-fixed swap, specifically a swap in the amount of notional principal ( $Ns$ ) such that  $Ns * SwapDuration + \$100M * 5.6806 = 0$  (or  $Ns = -100 * 5.6806 / SwapDuration$ ).

Suppose again, you choose to use a 5-, 7-, or 10-year swap (3.37%, 3.92%, and 4.42% from the previous table) as your hedging tool.

```
SwapFixRate = [0.0337; 0.0392; 0.0442];
Tenor = [5; 7; 10];
Settle = '11-Oct-2002';
PayFixDuration = liborduration(SwapFixRate, Tenor, Settle)
```

This gives a duration of -3.6835, -4.7307, and -6.0661 years for 5-, 7-, and 10-year swaps. The corresponding notional amount is computed by

```
Ns = -100*5.6806./PayFixDuration
```

```
Ns =
    154.2163
    120.0786
     93.6443
```

The notional amount entered in pay-fixed side of the swap instantaneously immunizes the portfolio.

## Convertible Bond Valuation

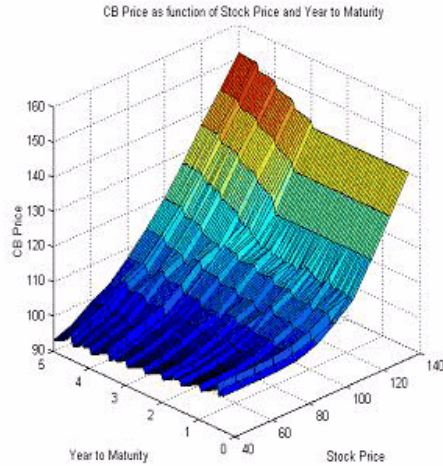
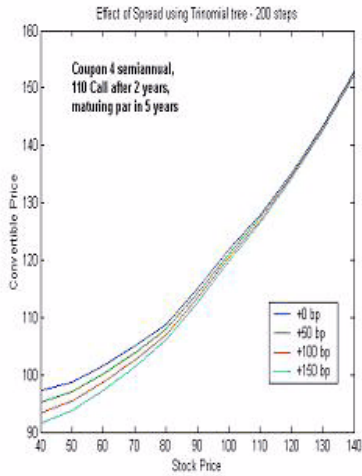
A convertible bond (CB) is a debt instrument that can be converted into a predetermined amount of a company's equity at certain times before the bond's maturity.

Financial Instruments Toolbox software uses a binomial and trinomial tree approach (`cbprice`) to value convertible bonds. The value of a convertible bond is determined by the uncertainty of the related stock. Once the stock evolution is modeled, backward discounting is computed.

The last column of such trees provides the data to decide which is more profitable: the debt notional (plus interest, if any) or the equivalent number of shares per the notional.

Where debt prevails, the toolbox discounts backward with the risk-free rate plus the spread reflecting the credit risk of the issuer. Where stock prevails, the toolbox discounts with the risk-free rate. The intrinsic value of a convertible bond is the sum of the (probability-adjusted) debt and stock portions from the last node. This is compared to current stock price, to see if voluntary or forced conversion may take place. Otherwise, its value is the intrinsic value. From here, the same discounting process is repeated after adjusting debt portion to be equal to 0 if any conversion takes place. Dividends and coupons are handled discretely, at the date they occur.

The approach is equivalent to solving a one-dimensional partial differential equation such as one described by Tsiveriotis and Fernandes. (See Tsiveriotis, K. and C. Fernandes (1998), "Valuing Convertible Bonds with Credit Risk," *The Journal of Fixed Income*, 8 (3), 95-102.) Using the same example of bond specifications that they use (4% annual coupon, payable twice a year, callable after 2 years at 110, and redeemable at par in 5 years), the toolbox gives results like theirs.



The figure on the left shows the bond "floor" of the convertible (a 5% yield, given a 4% coupon at about 97% par) when share prices are low.

The change of curvature located at the end of the second year is due to the activation of the embedded (soft) call feature (visible on the surface plot in the right figure).

Finally, there is the flat section when time is nearing expiration and share prices are high, indicating a delta of unity, a characteristic of in-the-money equity options embedded in a bond.

## Bond Futures

### In this section...

“Supported Bond Futures” on page 7-11

“Analysis of Bond Futures” on page 7-12

“Managing Present Value with Bond Futures” on page 7-14

### Supported Bond Futures

Bond futures are futures contracts where the commodity for delivery is a government bond. There are established global markets for government bond futures. Bond futures provide a liquid alternative for managing interest-rate risk.

In the U.S. market, the Chicago Mercantile Exchange (CME) offers futures on Treasury bonds and notes with maturities of 2, 5, 10, and 30 years. Typically, the following bond future contracts from the CME have maturities of 3, 6, 9, and 12 months:

- 30-year U.S. Treasury bond
- 10-year U.S. Treasury bond
- 5-year U.S. Treasury bond
- 2-year U.S. Treasury bond

The short position in a Treasury bond or note future contract must deliver to the long position in one of many possible existing Treasury bonds. For example, in a 30-year Treasury bond future, the short position must deliver a Treasury bond with at least 15 years to maturity. Because these bonds have different values, the bond future contract is standardized by computing a conversion factor. The conversion factor normalizes the price of a bond to a theoretical bond with a coupon of 6%. The price of a bond future contract is represented as:

$$\text{InvoicePrice} = \text{FutPrice} \times CF + AI$$

where:

*FutPrice* is the price of the bond future.

*CF* is the conversion factor for a bond to deliver in a futures contract.

*AI* is the accrued interest.

The short position in a futures contract has the option of which bond to deliver and, in the U.S. bond market, when in the delivery month to deliver the bond. The short position typically chooses to deliver the bond known as the Cheapest to Deliver (CTD). The CTD bond most often delivers on the last delivery day of the month.

Financial Instruments Toolbox software supports the following bond futures:

- U.S. Treasury bonds and notes
- German Bobl, Bund, Buxl, and Schatz
- UK gilts
- Japanese government bonds (JGBs)

The functions supporting all bond futures are:

Function	Purpose
<code>convfactor</code>	Calculates bond conversion factors for U.S. Treasury bonds, German Bobl, Bund, Buxl, and Schatz, U.K. gilts, and JGBs.
<code>bndfutprice</code>	Prices bond future given repo rates.
<code>bndfutimrepo</code>	Calculates implied repo rates for a bond future given price.

The functions supporting U.S. Treasury bond futures are:

Function	Purpose
<code>tfutbyprice</code>	Calculates future prices of Treasury bonds given the spot price.
<code>tfutbyyield</code>	Calculates future prices of Treasury bonds given current yield.
<code>tfutimrepo</code>	Calculates implied repo rates for the Treasury bond future given price.
<code>tfutpricebyrepo</code>	Calculates Treasury bond futures price given the implied repo rates.
<code>tfutyieldbyrepo</code>	Calculates Treasury bond futures yield given the implied repo rates.

## Analysis of Bond Futures

The following example demonstrates analyzing German Euro-Bund futures traded on Eurex. However, `convfactor`, `bndfutprice`, and `bndfutimrepo` apply to bond futures in the U.S., U.K., Germany, and Japan. The workflow for this analysis is:

- 1 Calculate bond conversion factors.
- 2 Calculate implied repo rates to find the CTD bond.
- 3 Price the bond future using the term implied repo rate.

### Calculating Bond Conversion Factors

Use conversion factors to normalize the price of a particular bond for delivery in a futures contract. When using conversion factors, the assumption is that a bond for delivery has a 6% coupon. Use `convfactor` to calculate conversion factors for all bond futures from the U.S., Germany, Japan, and U.K.

For example, conversion factors for Euro-Bund futures on Eurex are listed at [www.eurexchange.com](http://www.eurexchange.com). The delivery date for Euro-Bund futures is the 10th day of the month, as opposed to bond futures in the U.S., where the short position has the option of choosing when to deliver the bond.

For the 4% bond, compute the conversion factor with:

```
CF1 = convfactor('10-Sep-2009', '04-Jul-2018', .04, .06, 3)
```

```
CF1 =
```

```
0.8659
```

This syntax for `convfactor` works fine for bonds with standard coupon periods. However, some deliverable bonds have long or short first coupon periods. Compute the conversion factors for such bonds using the optional input parameters `StartDate` and `FirstCouponDate`. Specify all optional input arguments for `convfactor` as parameter/value pairs:

```
CF2 = convfactor('10-Sep-2009', '04-Jan-2019', .0375, 'Convention', 3, 'startdate', ...
datenum('14-Nov-2008'))
```

```
CF2 =
```

```
0.8426
```

### Calculating Implied Repo Rates to Find the CTD Bond

To determine the availability of the cheapest bond for deliverable bonds against a futures contract, compute the implied repo rate for each bond. The bond with the highest repo rate is the cheapest because it has the lowest initial value, thus yielding a higher return,

provided you deliver it with the stated futures price. Use `bndfutimprepo` to calculate repo rates:

```
% Bond Properties
CouponRate = [.0425;.0375;.035];
Maturity = [datenum('04-Jul-2018');datenum('04-Jan-2019');datenum('04-Jul-2019')];
CF = [0.882668;0.842556;0.818193];
Price = [105.00;100.89;98.69];

% Futures Properties
FutSettle = '09-Jun-2009';
FutPrice = 118.54;
Delivery = '10-Sep-2009';

% Note that the default for BDNFUTIMPREPO is for the bonds to be
% semi-annual with a day count basis of 0. Since these are German
% bonds, we need to have a Basis of 8 and a Period of 1
ImpRepo = bndfutimprepo(Price, FutPrice, FutSettle, Delivery, CF, ...
    CouponRate, Maturity,'Basis',8,'Period',1)

ImpRepo =

    0.0261
   -0.0022
   -0.0315
```

### Pricing Bond Futures Using the Term Implied Repo Rate

Use `bndfutprice` to perform price calculations for all bond futures from the U.S., Germany, Japan, and U.K. To price the bond, given a term repo rate:

```
% Assume a term repo rate of .0091;
RepoRate = .0091;
[FutPrice,AccrInt] = bndfutprice(RepoRate, Price(1), FutSettle,...
    Delivery, CF(1), CouponRate(1), Maturity(1),...
    'Basis',8,'Period',1)

FutPrice =

    118.0126

AccrInt =

    0.7918
```

### Managing Present Value with Bond Futures

The Present Value of a Basis Point (PVBP) is used to manage interest-rate risk. PVBP is a measure that quantifies the change in price of a bond given a one-basis point shift in interest rates. The PVBP of a bond is computed with the following:



$$PVBP_{Bond} = \frac{Duration \times MarketValue}{100}$$

The PVBP of a bond futures contract can be computed with the following:

$$PVBP_{Futures} = \frac{PVBP_{CTDBond}}{CTDConversionFactor}$$

Use `bnddurp` and `bnddury` from Financial Toolbox software to compute the modified durations of CTD bonds. For more information, see “Managing Interest Rate Risk with Bond Futures” on page 7-16 and “Fitting the Diebold Li Model” on page 7-24.

## Managing Interest Rate Risk with Bond Futures

This example shows how to hedge the interest rate risk of a portfolio using bond futures.

### Modifying the Duration of a Portfolio with Bond Futures

In managing a bond portfolio, you can use a benchmark portfolio to evaluate performance. Sometimes a manager is constrained to keep the portfolio's duration within a particular band of the duration of the benchmark. One way to modify the duration of the portfolio is to buy and sell bonds, however, there may be reasons why a portfolio manager wishes to maintain the existing composition of the portfolio (e.g., the current holdings reflect fundamental research/views about future returns). Therefore, another option for modifying the duration is to buy and sell bond futures.

Bond futures are futures contracts where the commodity to be delivered is a government bond that meets the standard outlined in the futures contract (e.g., the bond has a specified remaining time to maturity).

Since often many bonds are available, and each bond may have a different coupon, you can use a conversion factor to normalize the payment by the long to the short.

There exist well developed markets for government bond futures. Specifically, the Chicago Board of Trade offers futures on the following:

- 2 Year Note
- 3 Year Note
- 5 Year Note
- 10 Year Note
- 30 Year Bond

<http://www.cmegroup.com/trading/interest-rates/>

Eurex offers futures on the following:

- Euro-Schatz Futures 1.75 to 2.25
- Euro-Bobl Futures 4.5 to 5.5
- Euro-Bund Futures 8.5 to 10.5
- Euro-Buxl Futures 24.0 to 35

<http://www.eurexchange.com>

Bond futures can be used to modify the duration of a portfolio. Since bond futures derive their value from the underlying instrument, the duration of a bond futures contract is related to the duration of the underlying bond.

There are two challenges in computing this duration:

- Since there are many available bonds for delivery, the short in the contract has a choice in which bond to deliver.
- Some contracts allow the short flexibility in choosing the delivery date.

Typically, the bond used for analysis is the bond that is cheapest for the short to deliver (CTD).

One approach is to compute duration measures using the CTD's duration and the conversion factor.

For example, the Present Value of a Basis Point (PVBP) can be computed from the following:

$$PVBP_{Futures} = \frac{PVBP_{CTD}}{ConversionFactor_{CTD}}$$

$$PVBP_{CTD} = \frac{Duration_{CTD} * Price_{CTD}}{100}$$

Note that these definitions of duration for the futures contract are approximate, and do not account for the value of the delivery options for the short.

If the goal is to modify the duration of a portfolio, use the following:

$$NumContracts = \frac{(Dur_{Target} - Dur_{Initial}) * Value_{Portfolio}}{Dur_{CTD} * Price_{CTD} * ContractSize} * ConvFactor_{CTD}$$

Note that the contract size is typically for 100,000 face value of a bond -- so the contract size is typically 1000, as the bond face value is 100.

The following example assumes an initial duration, portfolio value, and target duration for a portfolio with exposure to the Euro interest rate. The June Euro-Bund Futures contract is used to modify the duration of the portfolio.

Note that typically futures contracts are offered for March, June, September and December.

```
% Assume the following for the portfolio and target
PortfolioDuration = 6.4;
PortfolioValue = 100000000;
BenchmarkDuration = 4.8;

% Deliverable Bunds -- note that these conversion factors may also be
% computed with the MATLAB(R) function CONVFACTOR
BondPrice = [106.46;108.67;104.30];
BondMaturity = datenum({'04-Jan-2018','04-Jul-2018','04-Jan-2019'});
BondCoupon = [.04;.0425;.0375];
ConversionFactor = [.868688;.880218;.839275];

% Futures data -- found from http://www.eurexchange.com
FuturesPrice = 122.17;
FuturesSettle = '23-Apr-2009';
FuturesDelivery = '10-Jun-2009';

% To find the CTD bond we can compute the implied repo rate
ImpliedRepo = bndfutimprepo(BondPrice,FuturesPrice,FuturesSettle,...
    FuturesDelivery,ConversionFactor,BondCoupon,BondMaturity);

% Note that the bond with the highest implied repo rate is the CTD
[CTDImpRepo,CTDIndex] = max(ImpliedRepo);

% Compute the CTD's Duration -- note the period and basis for German Bunds
Duration = bnddurp(BondPrice,BondCoupon,FuturesSettle,BondMaturity,1,8);

ContractSize = 1000;

% Use the formula above to compute the number of contracts to sell
NumContracts = (BenchmarkDuration - PortfolioDuration)*PortfolioValue./...
    (BondPrice(CTDIndex)*ContractSize*Duration(CTDIndex))*ConversionFactor(CTDIndex);

disp(['To achieve the target duration, ' num2str(abs(round(NumContracts))) ...
    ' Euro-Bund Futures must be sold.'])

To achieve the target duration, 180 Euro-Bund Futures must be sold.
```

### **Modifying the Key Rate Durations of a Portfolio with Bond Futures**

One of the shortcomings of using duration as a risk measure is that it assumes parallel shifts in the yield curve. While many studies have shown that this explains roughly

85% of the movement in the yield curve, changes in the slope or shape of the yield curve are not captured by duration -- and therefore, hedging strategies are not successful at addressing these dynamics.

One approach is to use key rate duration -- this is particularly relevant when using bond futures with multiple maturities, like Treasury futures.

The following example uses 2, 5, 10 and 30 year Treasury Bond futures to hedge the key rate duration of a portfolio.

Computing key rate durations requires a zero curve. This example uses the zero curve published by the Treasury and found at the following location:

<http://www.ustreas.gov/offices/domestic-finance/debt-management/interest-rate/yield.shtml>

Note that this zero curve could also be derived using the Interest Rate Curve functionality found in IRDataCurve and IRFunctionCurve.

```
% Assume the following for the portfolio and target, where the duration
% vectors are key rate durations at 2, 5, 10, and 30 years.
PortfolioDuration = [.5 1 2 6];
PortfolioValue = 100000000;
BenchmarkDuration = [.4 .8 1.6 5];

% The following are the CTD Bonds for the 30, 10, 5 and 2 year futures
% contracts -- these were determined using the procedure outlined in the
% previous section.
CTDCoupon = [4.75 3.125 5.125 7.5]'/100;
CTDMaturity = datenum({'3/31/2011', '08/31/2013', '05/15/2016', '11/15/2024'});
CTDConversion = [0.9794 0.8953 0.9519 1.1484]';
CTDPrice = [107.34 105.91 117.00 144.18]';

ZeroRates = [0.07 0.10 0.31 0.50 0.99 1.38 1.96 2.56 3.03 3.99 3.89]'/100;
ZeroDates = daysadd(FuturesSettle,[30 360 360*2 360*3 360*5 ...
    360*7 360*10 360*15 360*20 360*25 360*30],1);

% Compute the key rate durations for each of the CTD bonds.
CTDKRD = bndkrdr([ZeroDates ZeroRates], CTDCoupon,FuturesSettle,...
    CTDMaturity,'KeyRates',[2 5 10 30]);

% Note that the contract size for the 2 Year Note Future is $200,000
ContractSize = [2000;1000;1000;1000];
```

```
NumContracts = (bsxfun(@times,CTDPrice.*ContractSize./CTDConversion,CTDKRD))\...
    (BenchmarkDuration - PortfolioDuration)'*PortfolioValue;

sprintf(['To achieve the target duration, \n' ...
    num2str(-round(NumContracts(1))) ' 2 Year Treasury Note Futures must be sold, \n'
    num2str(-round(NumContracts(2))) ' 5 Year Treasury Note Futures must be sold, \n'
    num2str(-round(NumContracts(3))) ' 10 Year Treasury Note Futures must be sold, \n'
    num2str(-round(NumContracts(4))) ' Treasury Bond Futures must be sold, \n'])

ans =

To achieve the target duration,
24 2 Year Treasury Note Futures must be sold,
47 5 Year Treasury Note Futures must be sold,
68 10 Year Treasury Note Futures must be sold,
120 Treasury Bond Futures must be sold,
```

### Improving the Performance of a Hedge with Regression

An additional component to consider in hedging interest rate risk with bond futures, again related to movements in the yield curve, is that typically the yield curve moves more at the short end than at the long end.

Therefore, if a position is hedged with a future where the CTD bond has a maturity that is different than the portfolio this could lead to a situation where the hedge under- or over-compensates for the actual interest rate risk of the portfolio.

One approach is to perform a regression on historical yields at different maturities to determine a Yield Beta, which is a value that represents how much more the yield changes for different maturities.

This example shows how to use this approach with UK Long Gilt futures and historical data on Gilt Yields.

Market data on Gilt futures is found at the following:

<http://www.euronext.com>

Historical data on gilts is found at the following;

<http://www.dmo.gov.uk>

Note that while this approach does offer the possibility of improving the performance of a hedge, any analysis using historical data depends on historical relationships remaining consistent.

Also note that an additional enhancement takes into consideration the correlation between different maturities. While this approach is outside the scope of this example, you can use this to implement a minimum variance hedge.

```
% Assume the following for the portfolio and target
PortfolioDuration = 6.4;
PortfolioValue = 100000000;
BenchmarkDuration = 4.8;

% This is the CTD Bond for the Long Gilt Futures contract
CTDBondPrice = 113.40;
CTDBondMaturity = datenum('7-Mar-2018');
CTDBondCoupon = .05;
CTDConversionFactor = 0.9325024;

% Market data for the Long Gilt Futures contract
FuturesPrice = 120.80;
FuturesSettle = '23-Apr-2009';
FuturesDelivery = '10-Jun-2009';

CTDDuration = bnddurp(CTDBondPrice,CTDBondCoupon,FuturesSettle,CTDBondMaturity);

ContractSize = 1000;

NumContracts = (BenchmarkDuration - PortfolioDuration)*PortfolioValue./...
    (CTDBondPrice*ContractSize*CTDDuration)*CTDConversionFactor;

disp(['To achieve the target duration with a conventional hedge ' ...
    num2str(-round(NumContracts)) ...
    ' Long Gilt Futures must be sold.'])

To achieve the target duration with a conventional hedge 182 Long Gilt Futures must be
```

To improve the accuracy of this hedge, historical data is used to determine a relationship between the standard deviation of the yields. Specifically, standard deviation of yields is plotted and regressed vs bond duration. This relationship is then used to compute a Yield Beta for the hedge.

```
% Load data from XLS spreadsheet
load ukbonddata_20072008
```

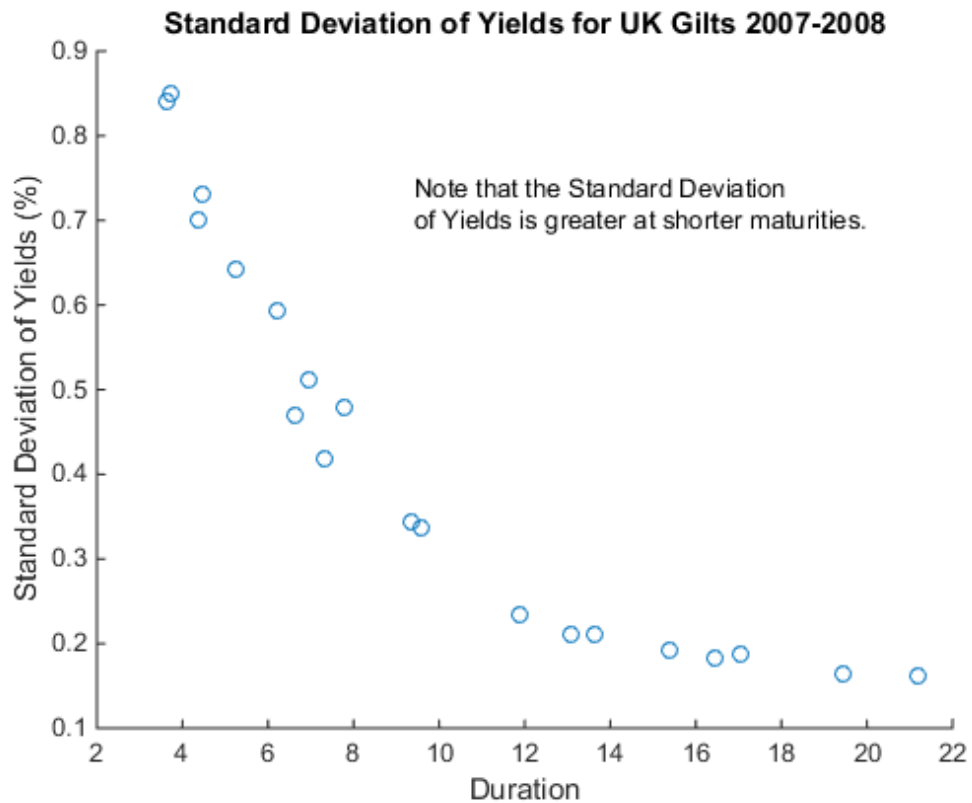
```

Duration = bnddury(Yield(1,:)','Coupon,Dates(1,:),Maturity);

scatter(Duration,100*std(Yield))
title('Standard Deviation of Yields for UK Gilts 2007-2008')
ylabel('Standard Deviation of Yields (%)')
xlabel('Duration')
annotation(gcf,'textbox',[0.4067 0.685 0.4801 0.0989],...
    'String',{'Note that the Standard Deviation',...
    'of Yields is greater at shorter maturities.'},...
    'FitBoxToText','off',...
    'EdgeColor','none');

stats = regstats(std(Yield),Duration);
YieldBeta = (stats.beta'*[1 PortfolioDuration]')./(stats.beta'*[1 CTDDuration]');

```





Now the Yield Beta is used to compute a new value for the number of contracts to be sold. Note that since the duration of the portfolio was less than the duration of the CTD Gilt, the number of futures to sell is actually greater than in the first case.

```
NumContracts = (BenchmarkDuration - PortfolioDuration)*PortfolioValue./...  
               (CTDBondPrice*ContractSize*CTDDuration)*CTDConversionFactor*YieldBeta;  
  
disp(['To achieve the target duration using a Yield Beta-modified hedge, ' ...  
      num2str(abs(round(NumContracts))) ...  
      ' Long Gilt Futures must be sold.'])
```

To achieve the target duration using a Yield Beta-modified hedge, 193 Long Gilt Futures

## Bibliography

This example is based on the following books and papers:

- [1] Burghardt, G., T. Belton, M. Lane and J. Papa. The Treasury Bond Basis. New York, NY: McGraw-Hill, 2005.
- [2] Krgin, D. Handbook of Global Fixed Income Calculations. New York, NY: John Wiley & Sons, 2002.
- [3] CFA Program Curriculum, Level III, Volume 4, Reading 31. CFA Institute, 2009.

## Fitting the Diebold Li Model

This example shows how to construct a Diebold Li model of the US yield curve for each month from 1990 to 2010 and how to forecast future yield curves by fitting an autoregressive model to the time series of each parameter.

The paper can be found here:

<http://www.ssc.upenn.edu/~fdiebold/papers/paper49/Diebold-Li.pdf>

### Load the Data

The data used are monthly Treasury yields from 1990 through 2010 for tenors of 1 Mo, 3 Mo, 6 Mo, 1 Yr, 2 Yr, 3 Yr, 5 Yr, 7 Yr, 10 Yr, 20 Yr, 30 Yr.

Daily data can be found here:

<http://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yieldAll>

Data is stored in a MATLAB® data file as a MATLAB dataset object.

```
load Data_USYieldCurve
```

```
% Extract data for the last day of each month
MonthYearMat = repmat((1990:2010)',1,12)';
EOMDates = lbusdate(MonthYearMat(:),repmat((1:12)',21,1));
MonthlyIndex = find(ismember(Dataset.Properties.ObsNames,datestr(EOMDates)));
Estimationdataset = Dataset(MonthlyIndex,:);
EstimationData = double(Estimationdataset);
```

### Diebold Li Model

Diebold and Li start with the Nelson Siegel model

$$y = \beta_0 + (\beta_1 + \beta_2) \frac{\tau}{m} (1 - e^{-\frac{m}{\tau}}) - \beta_2 e^{-\frac{m}{\tau}}$$

and rewrite it to be the following:

$$y_t(\tau) = \beta_{1t} + \beta_{2t} \left( \frac{1 - e^{-\lambda_t \tau}}{\lambda_t \tau} \right) + \beta_{3t} \left( \frac{1 - e^{-\lambda_t \tau}}{\lambda_t \tau} - e^{-\lambda_t \tau} \right)$$

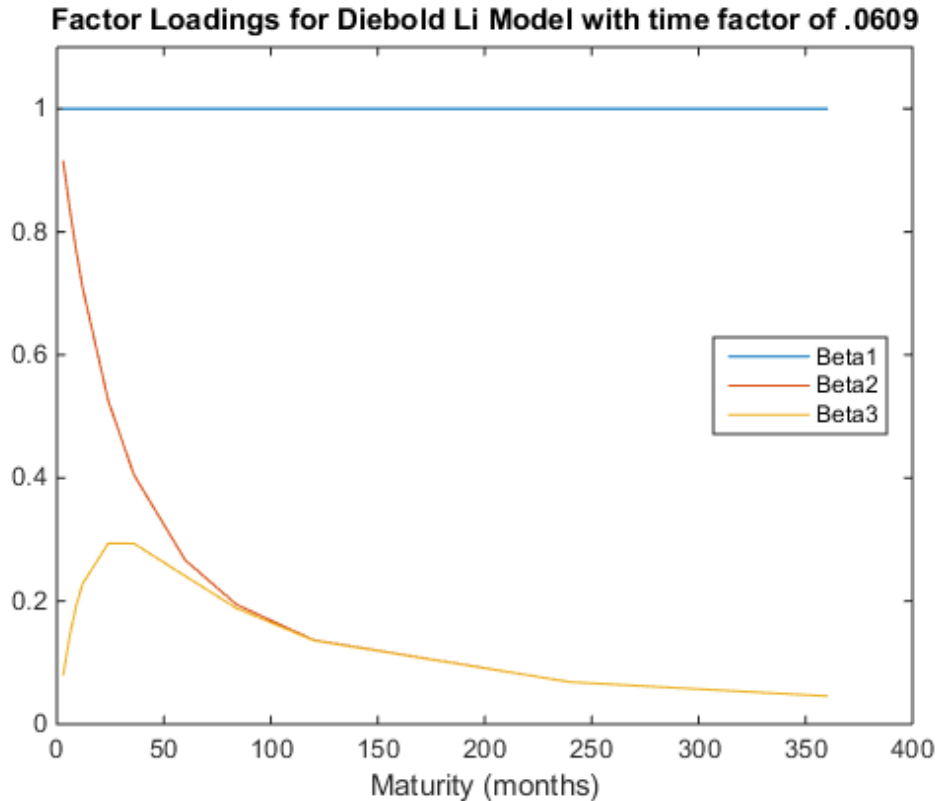
The above model allows the factors to be interpreted in the following way: Beta1 corresponds to the long term/level of the yield curve, Beta2 corresponds to the short term/slope, and Beta3 corresponds to the medium term/curvature.

Diebold and Li advocate setting the time factor, lambda, to maximize the loading on the medium term factor, Beta3, at 30 months. This also transforms the problem from a nonlinear fitting one to a simple linear regression.

```
% Explicitly set the time factor lambda
lambda_t = .0609;

% Construct a matrix of the factor loadings
% Tenors associated with data
TimeToMat = [3 6 9 12 24 36 60 84 120 240 360]';
X = [ones(size(TimeToMat)) (1 - exp(-lambda_t*TimeToMat))./(lambda_t*TimeToMat) ...
     ((1 - exp(-lambda_t*TimeToMat))./(lambda_t*TimeToMat) - exp(-lambda_t*TimeToMat))]

% Plot the factor loadings
plot(TimeToMat,X)
title('Factor Loadings for Diebold Li Model with time factor of .0609')
xlabel('Maturity (months)')
ylim([0 1.1])
legend({'Beta1', 'Beta2', 'Beta3'}, 'location', 'east')
```



### Fit the Model

A DieboldLi object has been developed to facilitate fitting the model from yield data. The DieboldLi object inherits from the IRCurve object, so the getZeroRates, getDiscountFactors, getParYields, getForwardRates and toRateSpec methods are all implemented. Additionally, the method fitYieldsFromBetas has been implemented to estimate the Beta parameters given a lambda parameter for observed market yields.

The DieboldLi object will be used to fit a Diebold Li model for each month from 1990 through 2010.

```
% Preallocate the Betas
Beta = zeros(size(EstimationData,1),3);
```

```

% Loop through and fit each end of month yield curve
for jdx = 1:size(EstimationData,1)
    tmpCurveModel = DieboldLi.fitBetasFromYields(EOMDates(jdx),lambda_t*12,daysadd(EOMD
    Beta(jdx,:) = [tmpCurveModel.Beta1 tmpCurveModel.Beta2 tmpCurveModel.Beta3];
end

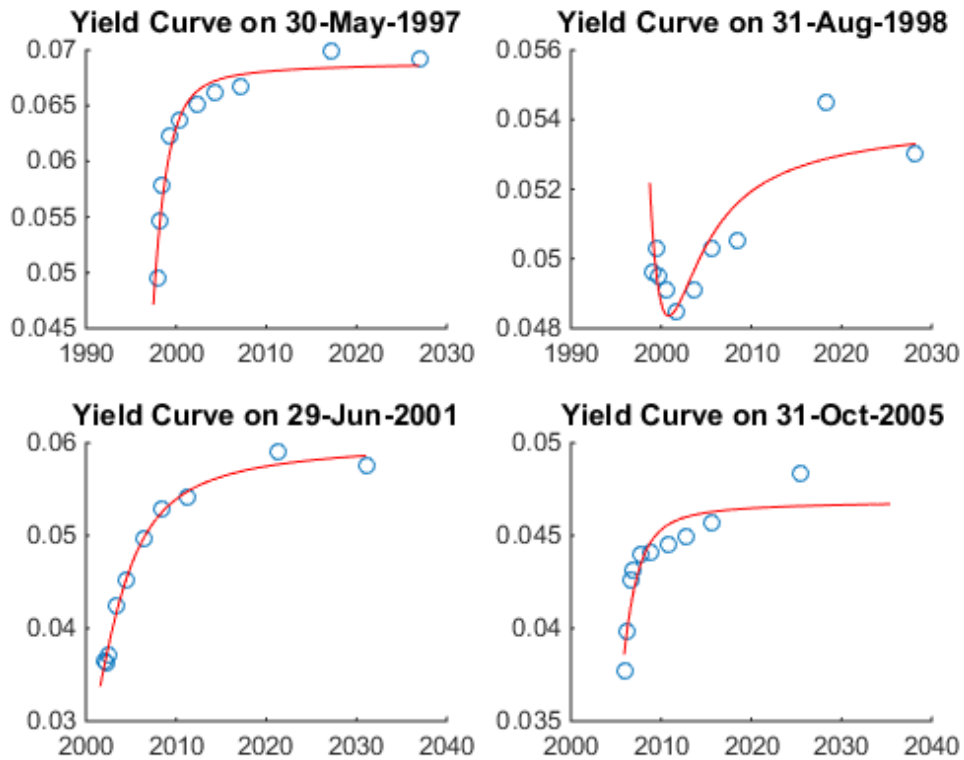
```

The Diebold Li fits on selected dates are included here

```

PlotSettles = datenum({'30-May-1997','31-Aug-1998','29-Jun-2001','31-Oct-2005'});
figure
for jdx = 1:length(PlotSettles)
    subplot(2,2,jdx)
    tmpIdx = find(strcmpi(EstimationDataset.Properties.ObsNames,datestr(PlotSettles(jdx)
    tmpCurveModel = DieboldLi.fitBetasFromYields(PlotSettles(jdx),lambda_t*12,...
        daysadd(PlotSettles(jdx),30*TimeToMat),EstimationData(tmpIdx,:)');
    scatter(daysadd(PlotSettles(jdx),30*TimeToMat),EstimationData(tmpIdx,:))
    hold on
    PlottingDates = (PlotSettles(jdx)+30:30:PlotSettles(jdx)+30*360)';
    plot(PlottingDates,tmpCurveModel.getParYields(PlottingDates),'r-')
    title(['Yield Curve on ' datestr(PlotSettles(jdx))])
    datetick
end

```



### Forecasting

The Diebold Li model can be used to forecast future yield curves. Diebold and Li propose fitting an AR(1) model to the time series of each Beta parameter. This fitted model can then be used to forecast future values of each parameter, and by extension, future yield curves.

For this example the MATLAB function REGRESS is used to estimate the parameters for an AR(1) model for each Beta.

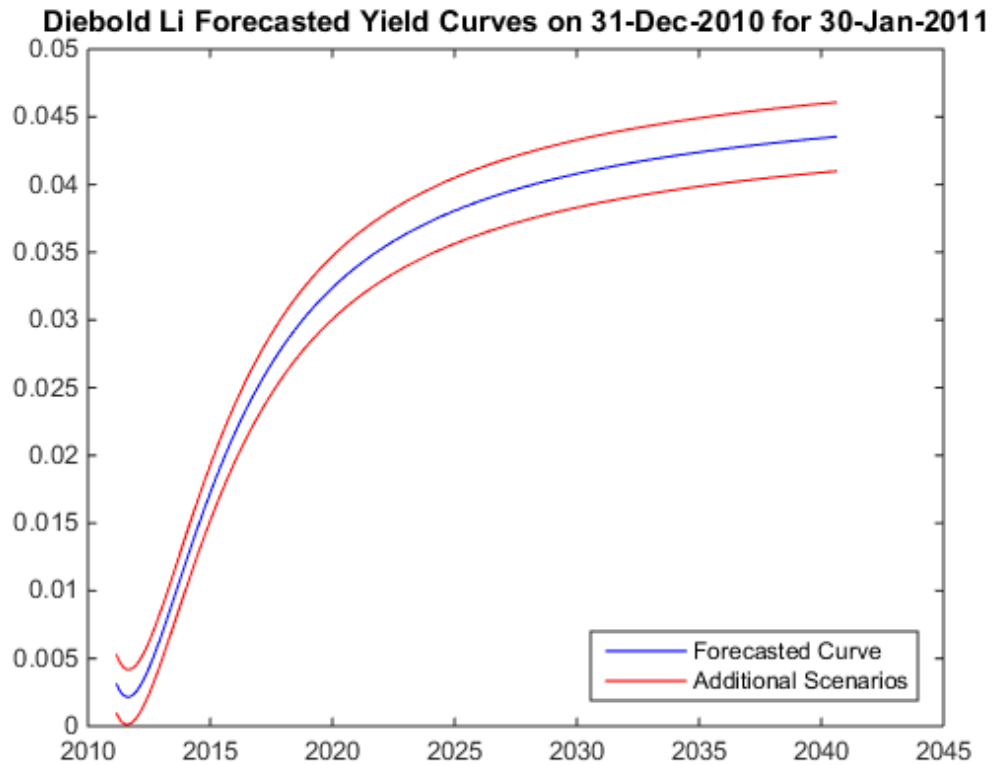
The confidence intervals for the regression fit are also used to generate two additional yield curve forecasts that serve as additional possible scenarios for the yield curve.

The MonthsLag variable can be adjusted to make different period ahead forecasts. For example, changing the value from 1 to 6 would change the forecast from a 1 month ahead to 6 month ahead forecast.

```
MonthsLag = 1;

[tmpBeta,bint] = regress(Beta(MonthsLag+1:end,1),[ones(size(Beta(MonthsLag+1:end,1)))
ForecastBeta(1,1) = [1 Beta(end,1)]*tmpBeta;
ForecastBeta_Down(1,1) = [1 Beta(end,1)]*bint(:,1);
ForecastBeta_Up(1,1) = [1 Beta(end,1)]*bint(:,2);
[tmpBeta,bint] = regress(Beta(MonthsLag+1:end,2),[ones(size(Beta(MonthsLag+1:end,2)))
ForecastBeta(1,2) = [1 Beta(end,2)]*tmpBeta;
ForecastBeta_Down(1,2) = [1 Beta(end,2)]*bint(:,1);
ForecastBeta_Up(1,2) = [1 Beta(end,2)]*bint(:,2);
[tmpBeta,bint] = regress(Beta(MonthsLag+1:end,3),[ones(size(Beta(MonthsLag+1:end,3)))
ForecastBeta(1,3) = [1 Beta(end,3)]*tmpBeta;
ForecastBeta_Down(1,3) = [1 Beta(end,3)]*bint(:,1);
ForecastBeta_Up(1,3) = [1 Beta(end,3)]*bint(:,2);

% Forecasted yield curve
figure
Settle = daysadd(EOMDates(end),30*MonthsLag);
DieboldLi_Forecast = DieboldLi('ParYield',Settle,[ForecastBeta lambda_t*12]);
DieboldLi_Forecast_Up = DieboldLi('ParYield',Settle,[ForecastBeta_Up lambda_t*12]);
DieboldLi_Forecast_Down = DieboldLi('ParYield',Settle,[ForecastBeta_Down lambda_t*12]);
PlottingDates = (Settle+30:30:Settle+30*360)';
plot(PlottingDates,DieboldLi_Forecast.getParYields(PlottingDates),'b-')
hold on
plot(PlottingDates,DieboldLi_Forecast_Up.getParYields(PlottingDates),'r-')
plot(PlottingDates,DieboldLi_Forecast_Down.getParYields(PlottingDates),'r-')
title(['Diebold Li Forecasted Yield Curves on ' datestr(EOMDates(end)) ' for ' datestr
legend({'Forecasted Curve','Additional Scenarios'},'location','southeast')
datetick
```



### Bibliography

This example is based on the following paper:

[1] Francis X. Diebold, Canlin Li, Forecasting the term structure of government bond yields, *Journal of Econometrics*, Volume 130, Issue 2, February 2006, Pages 337-364



# Credit Derivatives

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- “Counterparty Credit Risk and CVA” on page 8-15
- “First-to-Default Swaps” on page 8-37
- “Credit Default Swap Option” on page 8-49

## Credit Default Swap (CDS)

A credit default swap (CDS) is a contract that protects against losses resulting from credit defaults. The transaction involves two parties, the protection buyer and the protection seller, and also a reference entity, usually a bond. The protection buyer pays a stream of premiums to the protection seller, who in exchange offers to compensate the buyer for the loss in the bond's value if a credit event occurs. The stream of premiums is called the premium leg, and the compensation when a credit event occurs is called the protection leg. Credit events usually include situations in which the bond issuer goes bankrupt, misses coupon payments, or enters a restructuring process. Financial Instruments Toolbox software supports:

### CDS Functions

Function	Purpose
<code>cdsbootstrap</code>	Compute default probability parameters from CDS market quotes.
<code>cdsspread</code>	Compute breakeven spreads for the CDS contracts.
<code>cdsprice</code>	Compute the price for the CDS contracts.

### Bootstrapping a Default Probability Curve

In a typical workflow, pricing a new CDS contract involves first estimating a default probability term structure using `cdsbootstrap`. This requires market quotes of existing CDS contracts, or quotes of CDS indices (e.g., iTraxx). The estimated default probability curve is then used as input to `cdsspread` or `cdsprice`. If the default probability information is already known, `cdsbootstrap` can be bypassed and `cdsspread` or `cdsprice` can be called directly.

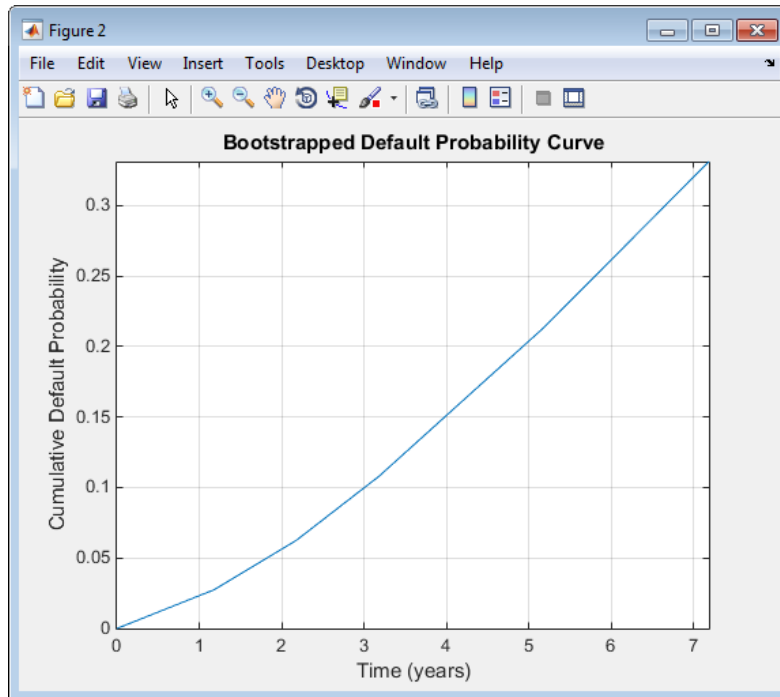
The market information in this example is provided in the form of running spreads of CDS contracts maturing on the CDS standard payment dates closest to 1, 2, 3, 5, and 7 years from the valuation date.

```
Settle = '17-Jul-2009'; % valuation date for the CDS
MarketDates = datenum({'20-Sep-10', '20-Sep-11', '20-Sep-12', '20-Sep-14', ...
    '20-Sep-16'});
MarketSpreads = [140 175 210 265 310]';
MarketData = [MarketDates MarketSpreads];
ZeroDates = datenum({'17-Jan-10', '17-Jul-10', '17-Jul-11', '17-Jul-12', ...
    '17-Jul-13', '17-Jul-14'});
ZeroRates = [1.35 1.43 1.9 2.47 2.936 3.311]'/100;
ZeroData = [ZeroDates ZeroRates];
```

```
[ProbData,HazData] = cdsbootstrap(ZeroData,MarketData,Settle);
```

The bootstrapped default probability curve is plotted against time, in years, from the valuation date.

```
ProbTimes = yearfrac(Settle,ProbData(:,1));
figure
plot([0; ProbTimes],[0; ProbData(:,2)])
grid on
axis([0 ProbTimes(end,1) 0 ProbData(end,2)])
xlabel('Time (years)')
ylabel('Cumulative Default Probability')
title('Bootstrapped Default Probability Curve')
```

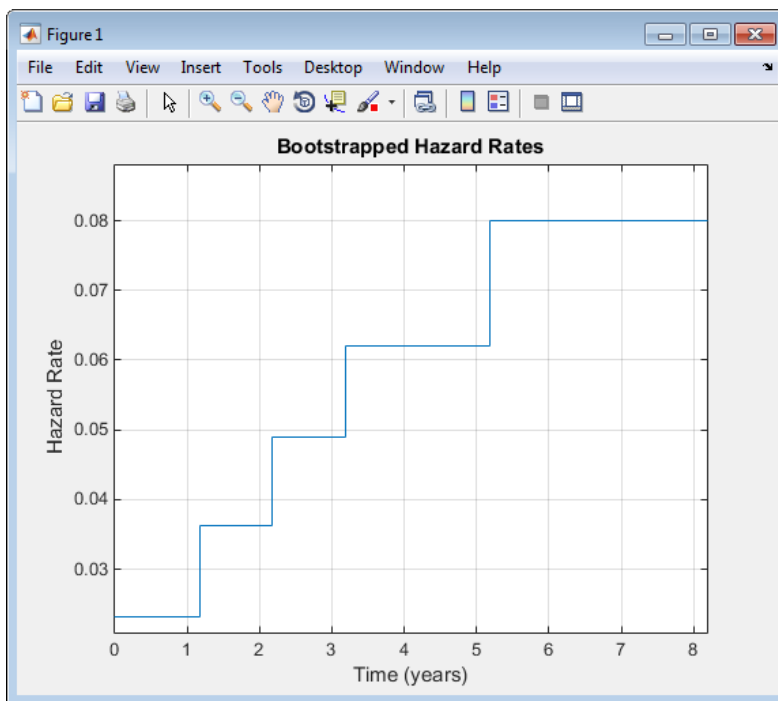


The associated hazard rates are returned as an optional output. The convention is that the first hazard rate applies from the settlement date to the first market date, the second hazard rate from the first to the second market date, etc., and the last hazard rate applies from the second-to-last market date onwards. The following plot displays the bootstrapped hazard rates, plotted against time, in years, from the valuation date:

```

HazTimes = yearfrac(Settle,HazData(:,1));
figure
stairs([0; HazTimes(1:end-1,1); HazTimes(end,1)+1],...
[HazData(:,2);HazData(end,2)])
grid on
axis([0 HazTimes(end,1)+1 0.9*HazData(1,2) 1.1*HazData(end,2)])
xlabel('Time (years)')
ylabel('Hazard Rate')
title('Bootstrapped Hazard Rates')

```



## Finding Breakeven Spread for New CDS Contract

The breakeven, or running, spread is the premium a protection buyer must pay, with no upfront payments involved, to receive protection for credit events associated to a given reference entity. Spreads are expressed in basis points (bp). There is a notional amount associated to the CDS contract to determine the monetary amounts of the premium payments.

New quotes for CDS contracts can be obtained with `cdsspread`. After obtaining a default probability curve using `cdsbootstrap`, you get quotes that are consistent with current market conditions.

In this example, instead of standard CDS payment dates, define new maturity dates. Using the period from 3 and 5 years (CDS standard dates), maturities are defined within this range spaced at quarterly intervals (measuring time from the valuation date):

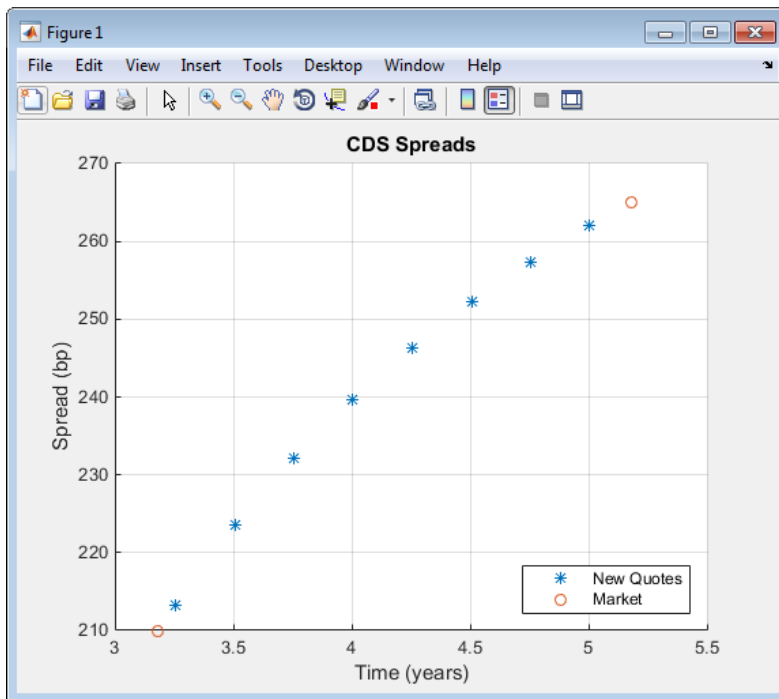
```
Settle = '17-Jul-2009'; % valuation date for the CDS
MarketDates = datenum({'20-Sep-10','20-Sep-11','20-Sep-12','20-Sep-14',...
'20-Sep-16'});
MarketSpreads = [140 175 210 265 310]';
MarketData = [MarketDates MarketSpreads];
ZeroDates = datenum({'17-Jan-10','17-Jul-10','17-Jul-11','17-Jul-12',...
'17-Jul-13','17-Jul-14'});
ZeroRates = [1.35 1.43 1.9 2.47 2.936 3.311]'/100;
ZeroData = [ZeroDates ZeroRates];

[ProbData,HazData] = cdsbootstrap(ZeroData,MarketData,Settle);

Maturity1 = datestr(daysadd('17-Jul-09',360*(3.25:0.25:5),1));
Spread1 = cdsspread(ZeroData,ProbData,Settle,Maturity1);

figure
scatter(yearfrac(Settle,Maturity1),Spread1,'*')
hold on
scatter(yearfrac(Settle,MarketData(3:4,1)),MarketData(3:4,2))
hold off
grid on
xlabel('Time (years)')
ylabel('Spread (bp)')
title('CDS Spreads')
legend('New Quotes','Market','location','SouthEast')
```

This plot displays the resulting spreads:

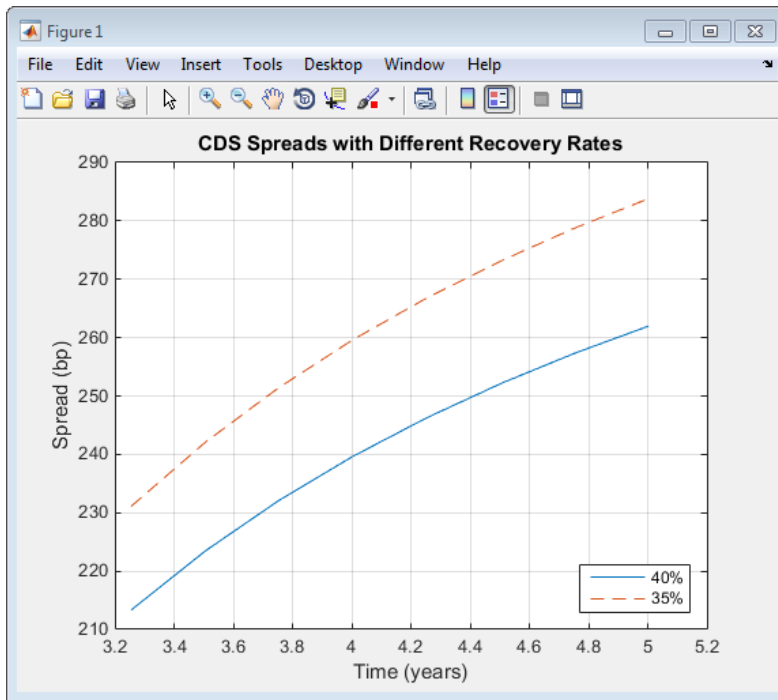


To evaluate the effect of the recovery rate parameter, instead of 40% (default value), use a recovery rate of 35%:

```
Spread1Rec35 = cdsspread(ZeroData,ProbData,Settle,Maturity1,...
'RecoveryRate',0.35);
```

```
figure
plot(yearfrac(Settle,Maturity1),Spread1,...
yearfrac(Settle,Maturity1),Spread1Rec35,'--')
grid on
xlabel('Time (years)')
ylabel('Spread (bp)')
title('CDS Spreads with Different Recovery Rates')
legend('40%', '35%', 'location', 'SouthEast')
```

The resulting plot shows that smaller recovery rates produce higher premia, as expected, since in the event of default, the protection payments will be higher:



## Valuing an Existing CDS Contract

The current value, or mark-to-market, of an existing CDS contract is the amount of money the contract holder would receive (if positive) or pay (if negative) to unwind this contract. The upfront of the contract is the current value expressed as a fraction of the notional amount of the contract, and it is commonly used to quote market values.

The value of existing CDS contracts is obtained with `cdsprice`. By default, `cdsprice` treats contracts as long positions. Whether a contract position is long or short is determined from a protection standpoint, that is, long means protection was bought, and short means protection was sold. In the following example, an existing CDS contract pays a premium that is lower than current market conditions. The price is positive, as expected, since it would be more costly to buy the same type of protection today.

```
Settle = '17-Jul-2009'; % valuation date for the CDS
MarketDates = datenum({'20-Sep-10','20-Sep-11','20-Sep-12','20-Sep-14',...
'20-Sep-16'});
MarketSpreads = [140 175 210 265 310]';
MarketData = [MarketDates MarketSpreads];
```

```

ZeroDates = datenum({'17-Jan-10','17-Jul-10','17-Jul-11','17-Jul-12',...
'17-Jul-13','17-Jul-14'});
ZeroRates = [1.35 1.43 1.9 2.47 2.936 3.311]'/100;
ZeroData = [ZeroDates ZeroRates];

[ProbData,HazData] = cdsbootstrap(ZeroData,MarketData,Settle);

Maturity2 = '20-Sep-2012';
Spread2 = 196;

[Price,AccPrem,PaymentDates,PaymentTimes,PaymentCF] = cdsprice(ZeroData,...
ProbData,Settle,Maturity2,Spread2);

fprintf('Dirty Price: %8.2f\n',Price);
fprintf('Accrued Premium: %8.2f\n',AccPrem);
fprintf('Clean Price: %8.2f\n',Price-AccPrem);
fprintf('\nPayment Schedule:\n\n');
fprintf('Date \t\t Time Frac \t Amount\n');
for k = 1:length(PaymentDates)
    fprintf('%s \t %5.4f \t %8.2f\n',datestr(PaymentDates(k)),...
PaymentTimes(k),PaymentCF(k));
end

```

This resulting payment schedule is:

```

Dirty Price: 41628.50
Accrued Premium: 15244.44
Clean Price: 26384.05

```

Payment Schedule:

Date	Time Frac	Amount
20-Sep-2009	0.1806	35388.89
20-Dec-2009	0.2528	49544.44
20-Mar-2010	0.2500	49000.00
20-Jun-2010	0.2556	50088.89
20-Sep-2010	0.2556	50088.89
20-Dec-2010	0.2528	49544.44
20-Mar-2011	0.2500	49000.00
20-Jun-2011	0.2556	50088.89
20-Sep-2011	0.2556	50088.89
20-Dec-2011	0.2528	49544.44
20-Mar-2012	0.2528	49544.44
20-Jun-2012	0.2556	50088.89
20-Sep-2012	0.2556	50088.89

Additionally, you can use `cdsprice` to value a portfolio of CDS contracts. In the following example, a simple hedged position with two vanilla CDS contracts, one long,



one short, with slightly different spreads is priced in a single call and the value of the portfolio is the sum of the returned prices:

```
[Price2,AccPrem2] = cdsprice(ZeroData,ProbData,Settle,...
repmat(datenum(Maturity2),2,1),[Spread2;Spread2+3],...
'Notional',[1e7; -1e7]);

fprintf('Contract \t Dirty Price \t Acc Premium \t Clean Price\n');
fprintf('    Long \t $ %9.2f \t $ %9.2f \t $ %9.2f \t\n',...
    Price2(1), AccPrem2(1), Price2(1) - AccPrem2(1));
fprintf('    Short \t $ %8.2f \t $ %8.2f \t $ %8.2f \t\n',...
    Price2(2), AccPrem2(2), Price2(2) - AccPrem2(2));
fprintf('Mark-to-market of hedged position: $ %8.2f\n',sum(Price2));
```

This resulting value of the portfolio is:

Contract	Dirty Price	Acc Premium	Clean Price
Long	\$ 41628.50	\$ 15244.44	\$ 26384.05
Short	\$ -32708.11	\$ -15477.78	\$ -17230.33
Mark-to-market of hedged position: \$			8920.39

## Converting from Running to Upfront

A CDS market quote is given in terms of a standard spread (usually 100 bp or 500 bp) and an upfront payment, or in terms of an equivalent running or breakeven spread, with no upfront payment. The functions `cdsbootstrap`, `cdsspread`, and `cdsprice` perform upfront to running or running to upfront conversions.

For example, to convert the market quotes to upfront quotes for a standard spread of 100 bp:

```
Settle = '17-Jul-2009'; % valuation date for the CDS
MarketDates = datenum({'20-Sep-10','20-Sep-11','20-Sep-12','20-Sep-14',...
'20-Sep-16'});
MarketSpreads = [140 175 210 265 310]';
MarketData = [MarketDates MarketSpreads];

ZeroDates = datenum({'17-Jan-10','17-Jul-10','17-Jul-11','17-Jul-12',...
'17-Jul-13','17-Jul-14'});
ZeroRates = [1.35 1.43 1.9 2.47 2.936 3.311]'/100;
ZeroData = [ZeroDates ZeroRates];

[ProbData,HazData] = cdsbootstrap(ZeroData,MarketData,Settle);

Maturity3 = MarketData(:,1);
Spread3Run = MarketData(:,2);
Spread3Std = 100*ones(size(Maturity3));
```

```
Price3 = cdsprice(ZeroData,ProbData,Settle,Maturity3,Spread3Std);
Upfront3 = Price3/1000000; % Standard notional of 10MM
display(Upfront3);
```

This resulting value is:

```
Upfront3 =

    0.0047
    0.0158
    0.0327
    0.0737
    0.1182
```

The conversion can be reversed to convert upfront quotes to market quotes:

```
ProbData3Upf = cdsbootstrap(ZeroData,[Maturity3 Upfront3 Spread3Std],Settle);
Spread3RunFromUpf = cdsspread(ZeroData,ProbData3Upf,Settle,Maturity3);
display([Spread3Run Spread3RunFromUpf]);
```

Comparing the results of this conversion to the original market spread demonstrates the reversal:

```
ans =

    140.0000    140.0000
    175.0000    175.0000
    210.0000    210.0000
    265.0000    265.0000
    310.0000    310.0000
```

Under the flat-hazard rate (FHR) quoting convention, a single market quote is used to calibrate a probability curve. This convention yields a single point in the probability curve, and a single hazard rate value. For example, assume a 4-year (standard dates) CDS contract with a current FHR-based running spread of 550 bp needs conversion to a CDS contract with a standard spread of 500 bp:

```
Maturity4 = datenum('20-Sep-13');
Spread4Run = 550;
ProbData4Run = cdsbootstrap(ZeroData,[Maturity4 Spread4Run],Settle);
Spread4Std = 500;
Price4 = cdsprice(ZeroData,ProbData4Run,Settle,Maturity4,Spread4Std);
Upfront4 = Price4/1000000;
fprintf('A running spread of %5.2f is equivalent to\n',Spread4Run);
fprintf('    a standard spread of %5.2f with an upfront of %8.7f\n',...
        Spread4Std,Upfront4);
```

A running spread of 550.00 is equivalent to

a standard spread of 500.00 with an upfront of 0.0167576

To reverse the conversion:

```

ProbData4Upf = cdsbootstrap(ZeroData,[Maturity4 Upfront4 Spread4Std],Settle);
Spread4RunFromUpf = cdsspread(ZeroData,ProbData4Upf,Settle,Maturity4);
fprintf('A standard spread of %5.2f with an upfront of %8.7f\n',...
    Spread4Std,Upfront4);
fprintf('    is equivalent to a running spread of %5.2f\n',Spread4RunFromUpf);

```

A standard spread of 500.00 with an upfront of 0.0167576  
is equivalent to a running spread of 550.00

As discussed in Beumee et. al., 2009 (see “Credit Derivatives” on page C-15), the FHR approach is a quoting convention only, and leads to quotes inconsistent with market data. For example, calculating the upfront for the 3-year (standard dates) CDS contract with a standard spread of 100 bp using the FHR approach and comparing the results to the upfront amounts previously calculated, demonstrates that the FHR-based approach yields a different upfront amount:

```

Maturity5 = MarketData(3,1);
Spread5Run = MarketData(3,2);
ProbData5Run = cdsbootstrap(ZeroData,[Maturity5 Spread5Run],Settle);
Spread5Std = 100;
Price5 = cdsprice(ZeroData,ProbData5Run,Settle,Maturity5,Spread5Std);
Upfront5 = Price5/10000000;
fprintf('Relative error of FHR-based upfront amount: %3.1f%%\n',...
    ((Upfront5-Upfront3(3))/Upfront3(3))*100);

```

Relative error of FHR-based upfront amount: -0.8%

## Bootstrapping from Inverted Market Curves

The following two examples demonstrate the behavior of bootstrapping with inverted CDS market curves, that is, market quotes with higher spreads for short-term CDS contracts. The first example is handled normally by `cdsbootstrap`:

```

Settle = '17-Jul-2009'; % valuation date for the CDS
MarketDates = datenum({'20-Sep-10','20-Sep-11','20-Sep-12','20-Sep-14',...
    '20-Sep-16'});

ZeroDates = datenum({'17-Jan-10','17-Jul-10','17-Jul-11','17-Jul-12',...
    '17-Jul-13','17-Jul-14'});
ZeroRates = [1.35 1.43 1.9 2.47 2.936 3.311]/100;
ZeroData = [ZeroDates ZeroRates];

MarketSpreadsInv1 = [750 650 550 500 450]';
MarketDataInv1 = [MarketDates MarketSpreadsInv1];
[ProbDataInv1,HazDataInv1] = cdsbootstrap(ZeroData,MarketDataInv1,Settle)

```

```
ProbDataInv1 =  
  
1.0e+05 *  
  
7.3440    0.0000  
7.3477    0.0000  
7.3513    0.0000  
7.3586    0.0000  
7.3659    0.0000
```

```
HazDataInv1 =  
  
1.0e+05 *  
  
7.3440    0.0000  
7.3477    0.0000  
7.3513    0.0000  
7.3586    0.0000  
7.3659    0.0000
```

In the second example, `cdsbootstrap` generates a warning:

```
MarketSpreadsInv2 = [800 550 400 250 100]';  
MarketDataInv2 = [MarketDates MarketSpreadsInv2];  
  
[ProbDataInv2,HazDataInv2] = cdsbootstrap(ZeroData,MarketDataInv2,Settle);  
  
Warning: Found non-monotone default probabilities (negative hazard rates)
```

A non-monotone bootstrapped probability curve implies negative default probabilities and negative hazard rates for certain time intervals. Extreme market conditions can lead to these types of situations. In these cases, you must assess the reliability and usefulness of the bootstrapped results.

The following plot illustrates these bootstrapped probability curves. The curves are concave, meaning that the marginal default probability decreases with time. This result is consistent with the market information that indicates a higher default risk in the short term. The second bootstrapped curve is non-monotone, as indicated by the warning.

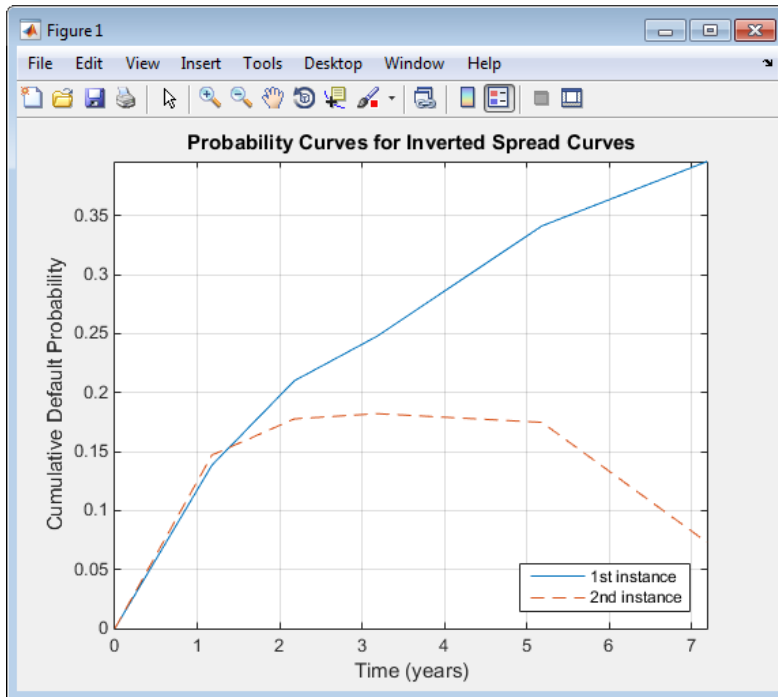
```
ProbTimes = yearfrac(Settle, MarketDates);  
figure  
plot([0; ProbTimes],[0; ProbDataInv1(:,2)])  
hold on  
plot([0; ProbTimes],[0; ProbDataInv2(:,2)],'--')
```

```

hold off
grid on
axis([0 ProbTimes(end,1) 0 ProbDataInv1(end,2)])
xlabel('Time (years)')
ylabel('Cumulative Default Probability')
title('Probability Curves for Inverted Spread Curves')
legend('1st instance', '2nd instance', 'location', 'SouthEast')

```

The resulting plot



Also in line with the previous plot, the hazard rates for these bootstrapped curves are decreasing because the short-term risk is higher. Some bootstrapped parameters in the second curve are negative, as indicated by the warning.

```

HazTimes = yearfrac(Settle, MarketDates);
figure
stairs([0; HazTimes(1:end-1,1); HazTimes(end,1)+1],...
       [HazDataInv1(:,2);HazDataInv1(end,2)])
hold on

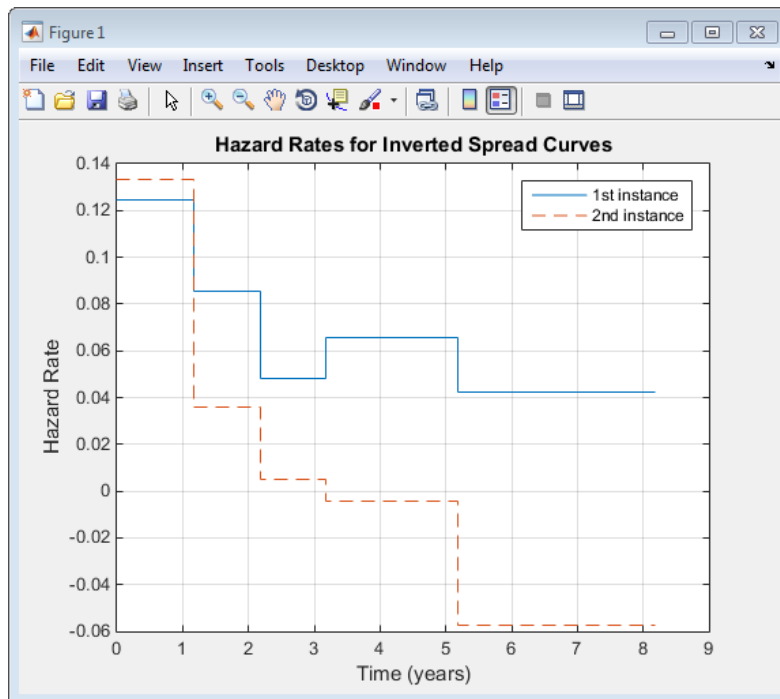
```

```

stairs([0; HazTimes(1:end-1,1); HazTimes(end,1)+1],...
      [HazDataInv2(:,2);HazDataInv2(end,2)], '--')
hold off
grid on
xlabel('Time (years)')
ylabel('Hazard Rate')
title('Hazard Rates for Inverted Spread Curves')
legend('1st instance', '2nd instance', 'location', 'NorthEast')

```

The resulting plot shows the hazard rates for both bootstrapped curves:



For further discussion on inverted curves, and their relationship to arbitrage, see O'Kane and Turnbull, 2003 ("Credit Derivatives" on page C-15).

## Counterparty Credit Risk and CVA

This example shows how to compute the unilateral credit value (valuation) adjustment (CVA) for a bank holding a portfolio of vanilla interest rate swaps with several counterparties. CVA is the expected loss on an over-the-counter contract or portfolio of contracts due to counterparty default. The CVA for a particular counterparty is defined as the sum over all points in time of the discounted expected exposure at each moment multiplied by the probability that the counterparty defaults at that moment, all multiplied by 1 minus the recovery rate. The CVA formula is:

$$CVA = (1 - R) \int_0^T discEE(t)dPD(t)$$

Where  $R$  is the recovery,  $discEE$  the discounted expected exposure at time  $t$ , and  $PD$  the default probability distribution.

The expected exposure is computed by first simulating many future scenarios of risk factors for the given contract or portfolio. Risk factors can be interest rates, as in this example, but will differ based on the portfolio and can include FX rates, equity or commodity prices, or anything that will affect the market value of the contracts. Once a sufficient set of scenarios has been simulated, the contract or portfolio can be priced on a series of future dates for each scenario. The result is a matrix, or "cube", of contract values.

These prices are converted into exposures after taking into account collateral agreements that the bank might have in place as well as netting agreements, as in this example, where the values of several contracts may offset each other, lowering their total exposure.

The contract values for each scenario are discounted to compute the discounted exposures. The discounted expected exposures can then be computed by a simple average of the discounted exposures at each simulation date.

Finally, counterparty default probabilities are typically derived from credit default swap (CDS) market quotes and the CVA for the counterparty can be computed according to the above formula. We assume that a counterparty default is independent of its exposure (no wrong-way risk).

For this example we will work with a portfolio of vanilla interest rate swaps with the goal of computing the CVA for a particular counterparty.

### Read Swap Portfolio

The portfolio of swaps is close to zero value at time  $t=0$ . Each swap is associated with a counterparty and may or may not be included in a netting agreement.

```
% Read swaps from spreadsheet
swapFile = 'cva-swap-portfolio.xls';
swapData = dataset('XLSFile', swapFile, 'Sheet', 'Swap Portfolio');

swaps = struct(...
    'Counterparty', [], ...
    'NettingID', [], ...
    'Principal', [], ...
    'Maturity', [], ...
    'LegRate', [], ...
    'LegType', [], ...
    'LatestFloatingRate', [], ...
    'FloatingResetDates', []);

swaps.Counterparty = swapData.CounterpartyID;
swaps.NettingID = swapData.NettingID;
swaps.Principal = swapData.Principal;
swaps.Maturity = swapData.Maturity;
swaps.LegType = [swapData.LegType ~swapData.LegType];
swaps.LegRate = [swapData.LegRateReceiving swapData.LegRatePaying];
swaps.LatestFloatingRate = swapData.LatestFloatingRate;
swaps.Period = swapData.Period;
swaps.LegReset = ones(size(swaps.LegType));

numSwaps = numel(swaps.Counterparty);

Create RateSpec from the Interest Rate Curve

Settle = datenum('14-Dec-2007');

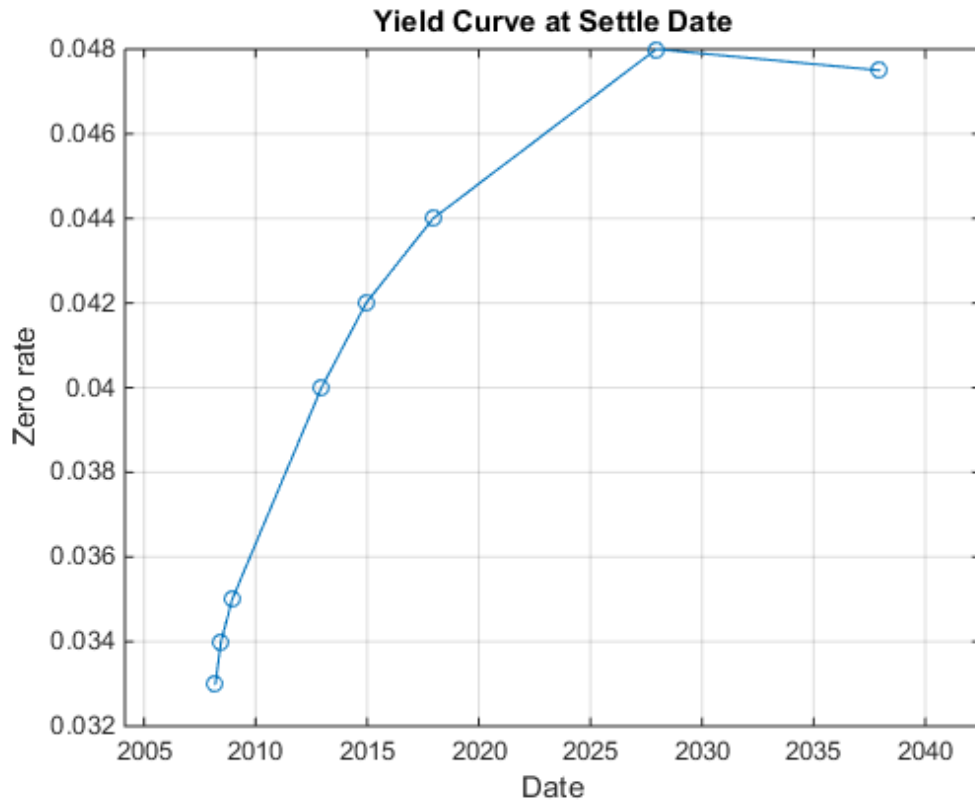
Tenor = [3 6 12 5*12 7*12 10*12 20*12 30*12]';
ZeroRates = [0.033 0.034 0.035 0.040 0.042 0.044 0.048 0.0475]';

ZeroDates = datemnth(Settle, Tenor);
Compounding = 2;
Basis = 0;
RateSpec = intenvset('StartDates', Settle, 'EndDates', ZeroDates, ...
    'Rates', ZeroRates, 'Compounding', Compounding, 'Basis', Basis);

figure;
plot(ZeroDates, ZeroRates, 'o-');
```



```
xlabel('Date');  
datetick('keeplimits');  
ylabel('Zero rate');  
grid on;  
title('Yield Curve at Settle Date');
```



### Set Changeable Simulation Parameters

We can vary here the number of simulated interest rate scenarios we generate. We set our simulation dates to be more frequent at first, then turning less frequent further in the future.

```
% Number of Monte Carlo simulations
```

```
numScenarios = 1000;  
  
% Compute monthly simulation dates, then quarterly dates later.  
simulationDates = datemnth(Settle,0:12);  
simulationDates = [simulationDates datemnth(simulationDates(end),3:3:74)]';  
numDates = numel(simulationDates);
```

### Compute Floating Reset Dates

For each simulation date, we compute previous floating reset date for each swap.

```
floatDates = cfdates(Settle-360,swaps.Maturity,swaps.Period);  
swaps.FloatingResetDates = zeros(numSwaps,numDates);  
for i = numDates:-1:1  
    thisDate = simulationDates(i);  
    floatDates(floatDates > thisDate) = 0;  
    swaps.FloatingResetDates(:,i) = max(floatDates,[],2);  
end
```

### Setup Hull-White Single Factor Model

The risk factor we will simulate to value our contracts is the zero curve. For this example we will model the interest rate term structure using the one-factor Hull-White model. This is a model of the short rate and is defined as:

$$dr = [\theta(t) - ar]dt + \sigma dz$$

where

- $dr$ : Change in the short rate after a small change in time,  $dt$
- $a$ : Mean reversion rate
- $\sigma$ : Volatility of the short rate
- $dz$ : A Weiner process (a standard normal process)
- $\theta(t)$ : Drift function defined as:

$$\theta(t) = F_t(0, t) + aF(0, t) + \frac{\sigma^2}{2a}(1 - e^{-2at})$$

$F(0, t)$ : Instantaneous forward rate at time  $t$

$F_t(0, t)$ : Partial derivative of  $F$  with respect to time

Once we have simulated a path of the short rate we generate a full yield curve at each simulation date using the formula:

$$R(t, T) = -\frac{1}{(T-t)} \ln A(t, T) + \frac{1}{(T-t)} B(t, T) r(t)$$

$$\ln A(t, T) = \ln \frac{P(0, T)}{P(0, t)} + B(t, T) F(0, t) - \frac{1}{4a^3} \sigma^2 (e^{-aT} - e^{-at})^2 (e^{2at} - 1)$$

$$B(t, T) = \frac{1 - e^{-a(T-t)}}{a}$$

$R(t, T)$ : Zero rate at time  $t$  for a period of  $T - t$

$P(t, T)$ : Price of a zero coupon bond at time  $t$  that pays one dollar at time  $T$

Each scenario contains the full term structure moving forward through time, modeled at each of our selected simulation dates.

Refer to "Calibrating the Hull-White Model Using Market Data" example in the Financial Instruments Toolbox™ Users' Guide for more details on Hull-White one-factor model calibration.

Alpha = 0.2;  
Sigma = 0.015;

hw1 = HullWhite1F(RateSpec, Alpha, Sigma);

### Simulate Scenarios

For each scenario, we simulate the future interest rate curve at each valuation date using the Hull-White one-factor interest rate model.

```
% Use reproducible random number generator (vary the seed to produce
% different random scenarios).
```

```
prevRNG = rng(0, 'twister');

dt = diff(yearfrac(Settle,simulationDates,1));
nPeriods = numel(dt);
scenarios = hw1.simTermStructs(nPeriods,...
    'nTrials',numScenarios,...
    'deltaTime',dt);

% Restore random number generator state
rng(prevRNG);

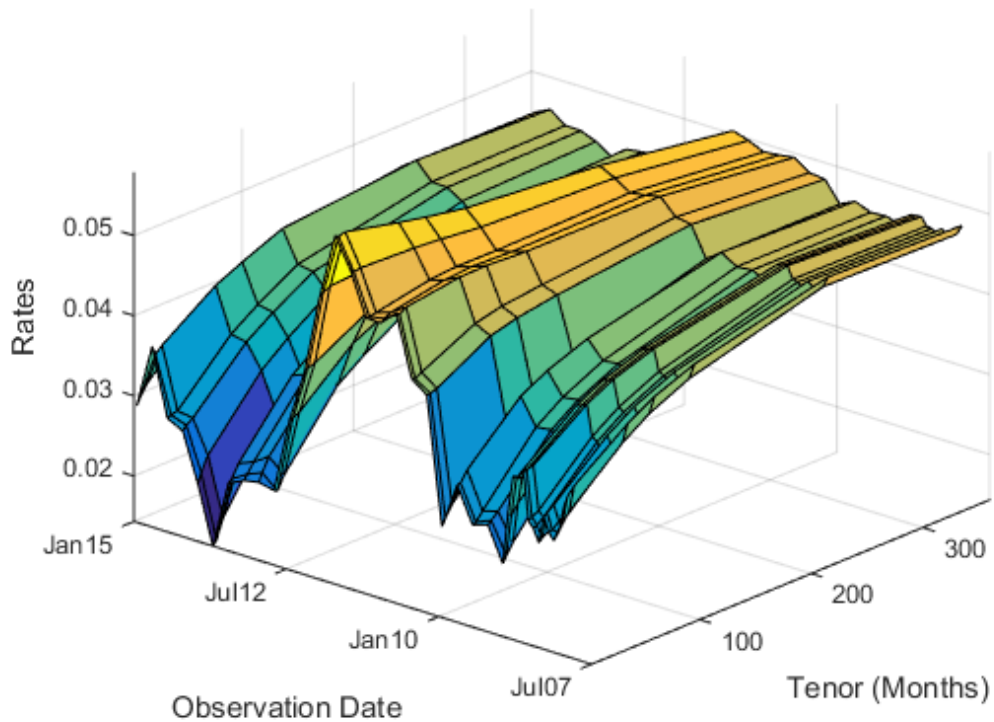
% Compute the discount factors through each realized interest rate
% scenario.
dfactors = ones(numDates,numScenarios);
for i = 2:numDates
    tenorDates = datemnth(simulationDates(i-1),Tenor);
    rateAtNextSimDate = interp1(tenorDates,squeeze(scenarios(i-1,:,:)),...
        simulationDates(i),'linear','extrap');
    % Compute D(t1,t2)
    dfactors(i,:) = zero2disc(rateAtNextSimDate,...
        repmat(simulationDates(i),1,numScenarios),simulationDates(i-1),-1,3);
end
dfactors = cumprod(dfactors,1);
```

### Inspect a Scenario

Create a surface plot of the yield curve evolution for a particular scenario.

```
i = 20;
figure;
surf(Tenor, simulationDates, scenarios(:,:,i))
axis tight
datetick('y','mmyy');
xlabel('Tenor (Months)');
ylabel('Observation Date');
zlabel('Rates');
ax = gca;
ax.View = [-49 32];
title(sprintf('Scenario %d Yield Curve Evolution\n',i));
```

### Scenario 20 Yield Curve Evolution



#### Compute Mark to Market Swap Prices

For each scenario the swap portfolio is priced at each future simulation date. Prices are computed using a price approximation function, `hswapapprox`. It is common in CVA applications to use simplified approximation functions when pricing contracts due to the performance requirements of these Monte Carlo simulations.

Since the simulation dates do not correspond to the swaps cash flow dates (where the floating rates are reset) we estimate the latest floating rate with the 1-year rate (all swaps have period 1 year) interpolated between the nearest simulated rate curves.

The swap prices are then aggregated into a "cube" of values which contains all future contract values at each simulation date for each scenario. The resulting cube of contract

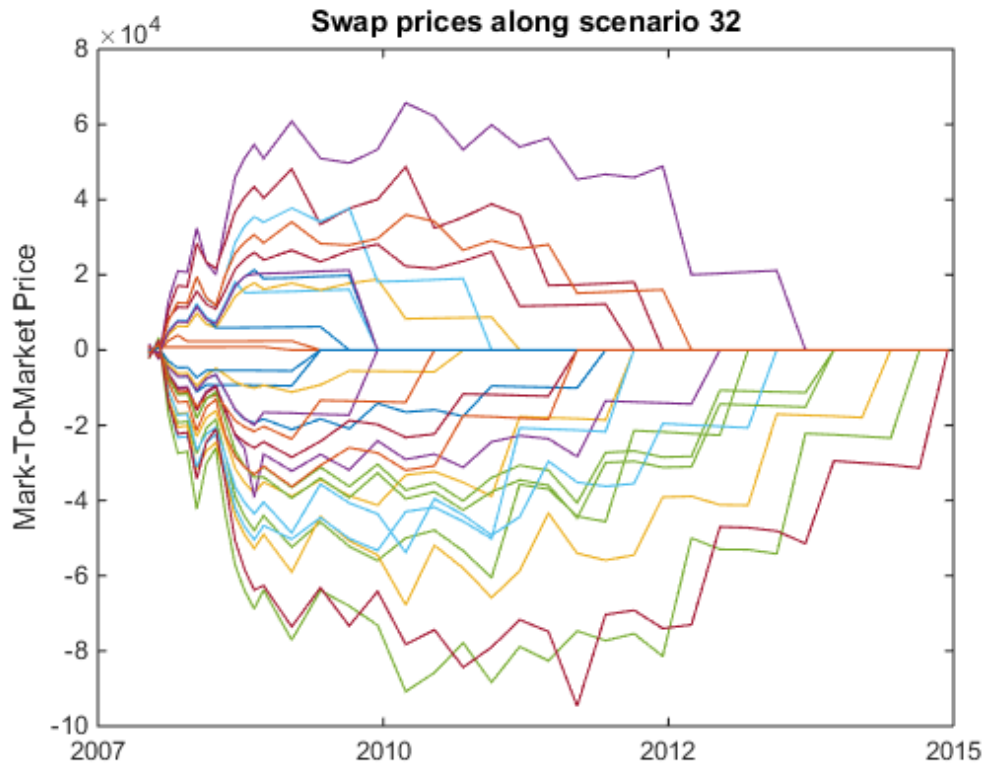
prices is a 3 dimensional matrix where each row represents a simulation date, each column an contract, and each "page" a different simulated scenario.

```
% Compute all mark-to-market values for this scenario. We use an  
% approximation function here to improve performance.  
values = hcomputeMTMValues(swaps,simulationDates,scenarios,Tenor);
```

### **Inspect Scenario Prices**

Create a plot of the evolution of all swap prices for a particular scenario.

```
i = 32;  
figure;  
plot(simulationDates, values(:, :, i));  
datetick;  
ylabel('Mark-To-Market Price');  
title(sprintf('Swap prices along scenario %d', i));
```

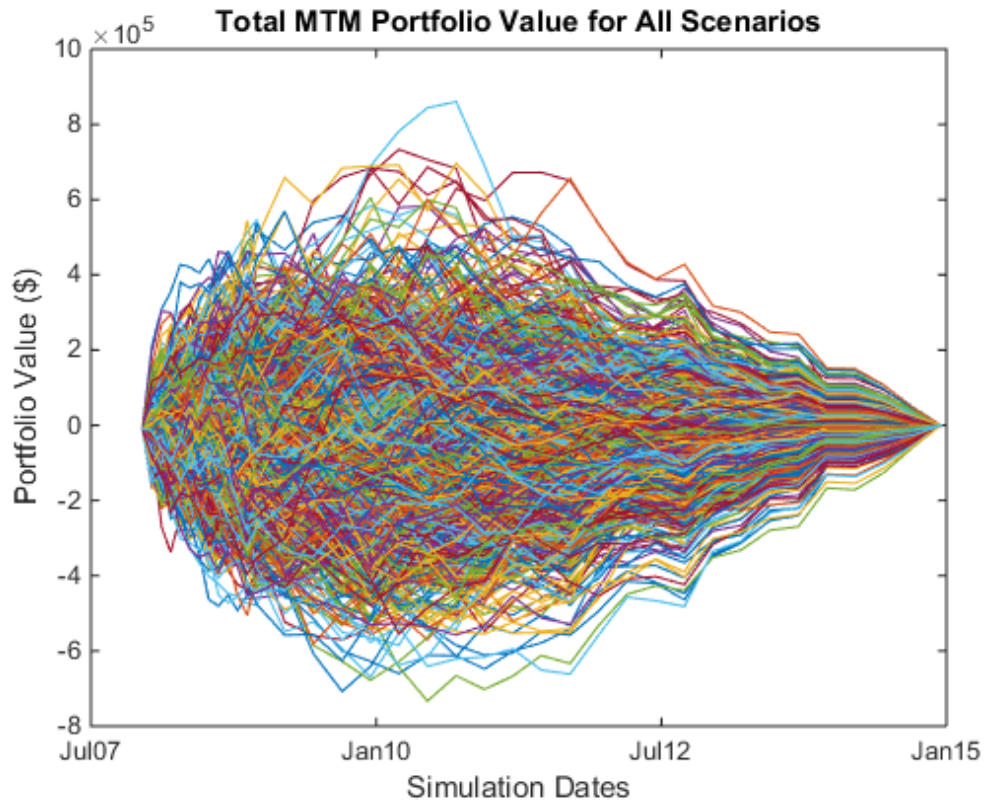


### Visualize Simulated Portfolio Values

We plot the total portfolio value for each scenario of our simulation. As each scenario moves forward in time the values of the contracts will move up or down depending on how the modeled interest rate term structure changes. As the swaps get closer to maturity, their values will begin to approach zero since the aggregate value of all remaining cash flows will decrease after each cash flow date.

```
% View portfolio value over time
figure;
totalPortValues = squeeze(sum(values, 2));
plot(simulationDates,totalPortValues);
title('Total MTM Portfolio Value for All Scenarios');
datetick('x','mmyy')
```

```
ylabel('Portfolio Value ($)')  
xlabel('Simulation Dates')
```



### Compute Exposure by Counterparty

The exposure of a particular contract (i) at time t is the maximum of the contract value ( $V_i$ ) and 0:

$$E_i(t) = \max\{V_i(t), 0\}$$

And the exposure for a particular counterparty is simply a sum of the individual contract exposures:



$$E_{cp}(t) = \sum E_i(t) = \sum \max\{V_i(t), 0\}$$

In the presence of netting agreements, however, contracts are aggregated together and can offset each other. Therefore the total exposure of all contracts in a netting agreement is:

$$E_{na}(t) = \max\{\sum V_i(t), 0\}$$

We compute these exposures for the entire portfolio as well as each counterparty at each simulation date using the `creditexposures` function.

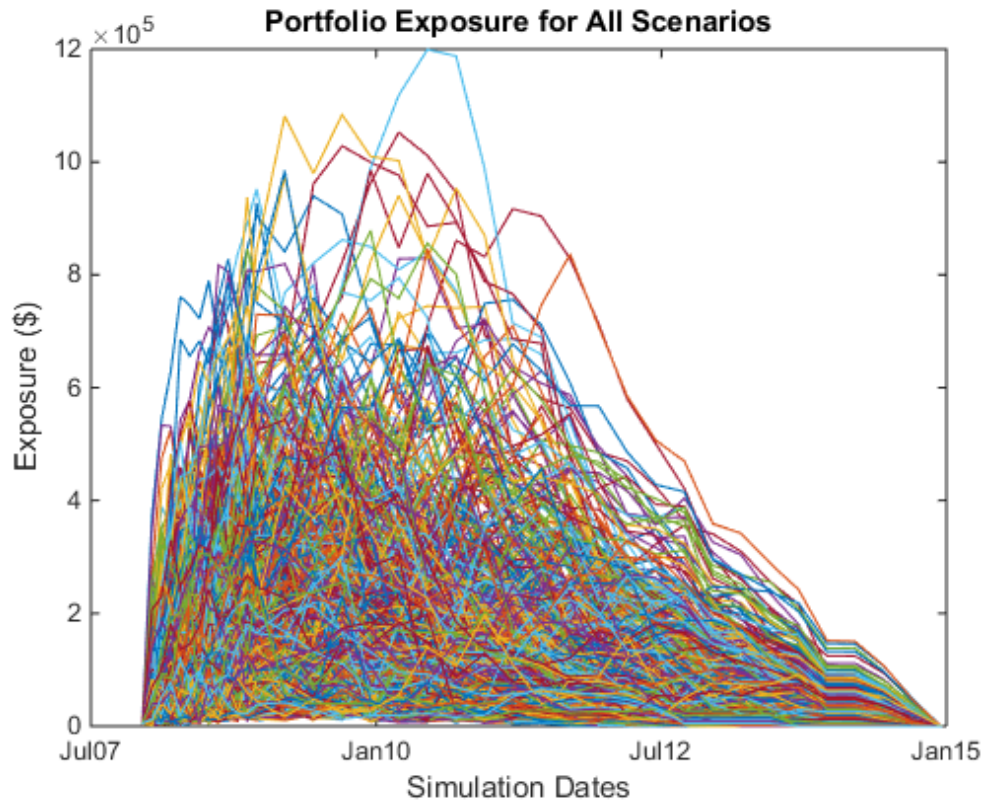
Unnetted contracts are indicated using a NaN in the `NettingID` vector. Exposure of an unnetted contract is equal to the market value of the contract if it has positive value, otherwise it is zero.

Contracts included in a netting agreement have their values aggregated together and can offset each other. See the references for more details on computing exposure from mark-to-market contract values.

```
[exposures, expcpty] = creditexposures(values,swaps.Counterparty,...
    'NettingID',swaps.NettingID);
```

We plot the total portfolio exposure for each scenario in our simulation. Similar to the plot of contract values, the exposures for each scenario will approach zero as the swaps mature.

```
% View portfolio exposure over time
figure;
totalPortExposure = squeeze(sum(exposures,2));
plot(simulationDates,totalPortExposure);
title('Portfolio Exposure for All Scenarios');
datetick('x','mmyy')
ylabel('Exposure ($)')
xlabel('Simulation Dates')
```



### Exposure Profiles

Several exposure profiles are useful when analyzing the potential future exposure of a bank to a counterparty. Here we compute several (non-discounted) exposure profiles per counterparty as well as for the entire portfolio.

- PFE : Potential Future Exposure : A high percentile (95%) of the distribution of exposures at any particular future date. Also called Peak Exposure (PE)
- MPFE : Maximum Potential Future Exposure : The maximum PFE across all dates
- EE : Expected Exposure : The mean (average) of the distribution of exposures at each date
- EPE : Expected Positive Exposure : Weighted average over time of the expected exposure

- **EffEE** : Effective Expected Exposure : The maximum expected exposure at any time,  $t$ , or previous time
- **EffEPE** : Effective Expected Positive Exposure : The weighted average of the effective expected exposure

For further definitions, see for example Basel II document in references.

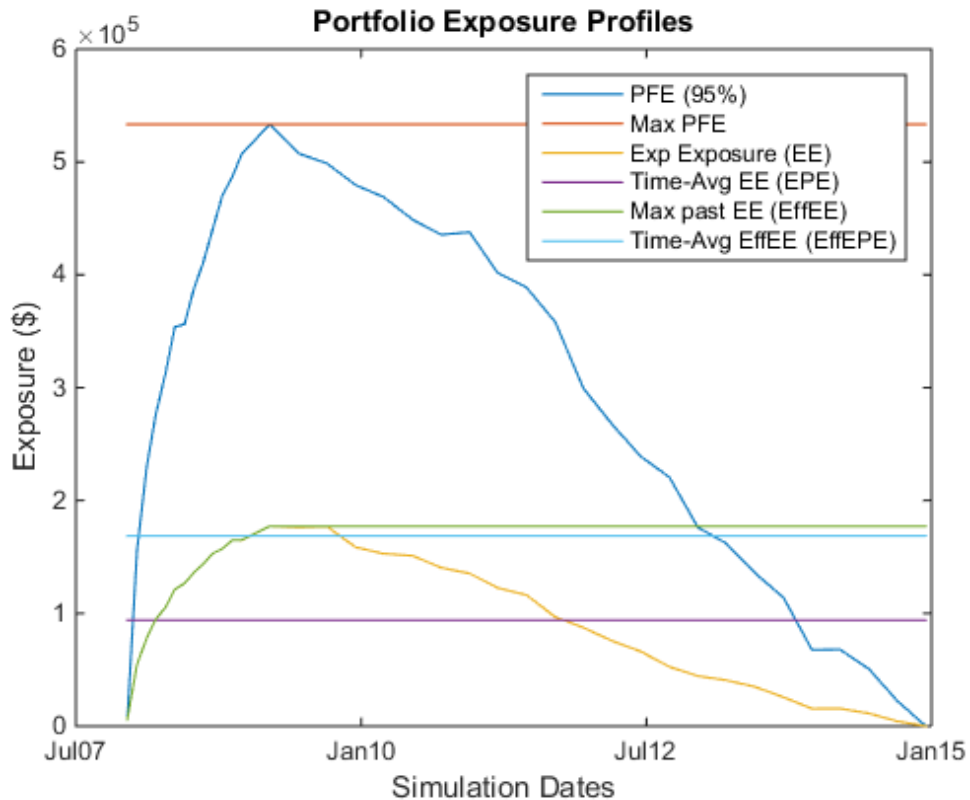
```
% Compute entire portfolio exposure
portExposures = sum(exposures,2);

% Compute exposure profiles for each counterparty and entire portfolio
cpProfiles = exposureprofiles(simulationDates,exposures);
portProfiles = exposureprofiles(simulationDates,portExposures);
```

We visualize the exposure profiles, first for the entire portfolio, then for a particular counterparty.

```
% Visualize portfolio exposure profiles
figure;
plot(simulationDates,portProfiles.PFE,...
      simulationDates,portProfiles.MPFE * ones(numDates,1),...
      simulationDates,portProfiles.EE,...
      simulationDates,portProfiles.EPE * ones(numDates,1),...
      simulationDates,portProfiles.EffEE,...
      simulationDates,portProfiles.EffEPE * ones(numDates,1));
legend({'PFE (95%)','Max PFE','Exp Exposure (EE)','Time-Avg EE (EPE)',...
       'Max past EE (EffEE)','Time-Avg EffEE (EffEPE)'});

datetick('x','mmyy')
title('Portfolio Exposure Profiles');
ylabel('Exposure ($)')
xlabel('Simulation Dates')
```



Visualize exposure profiles for a particular counterparty

```

cpIdx = find(expcpty == 5);
figure;
plot(simulationDates,cpProfiles(cpIdx).PFE,...
      simulationDates,cpProfiles(cpIdx).MPFE * ones(numDates,1),...
      simulationDates,cpProfiles(cpIdx).EE,...
      simulationDates,cpProfiles(cpIdx).EPE * ones(numDates,1),...
      simulationDates,cpProfiles(cpIdx).EffEE,...
      simulationDates,cpProfiles(cpIdx).EffEPE * ones(numDates,1));
legend({'PFE (95%)','Max PFE','Exp Exposure (EE)','Time-Avg EE (EPE)',...
       'Max past EE (EffEE)','Time-Avg EffEE (EffEPE)'});

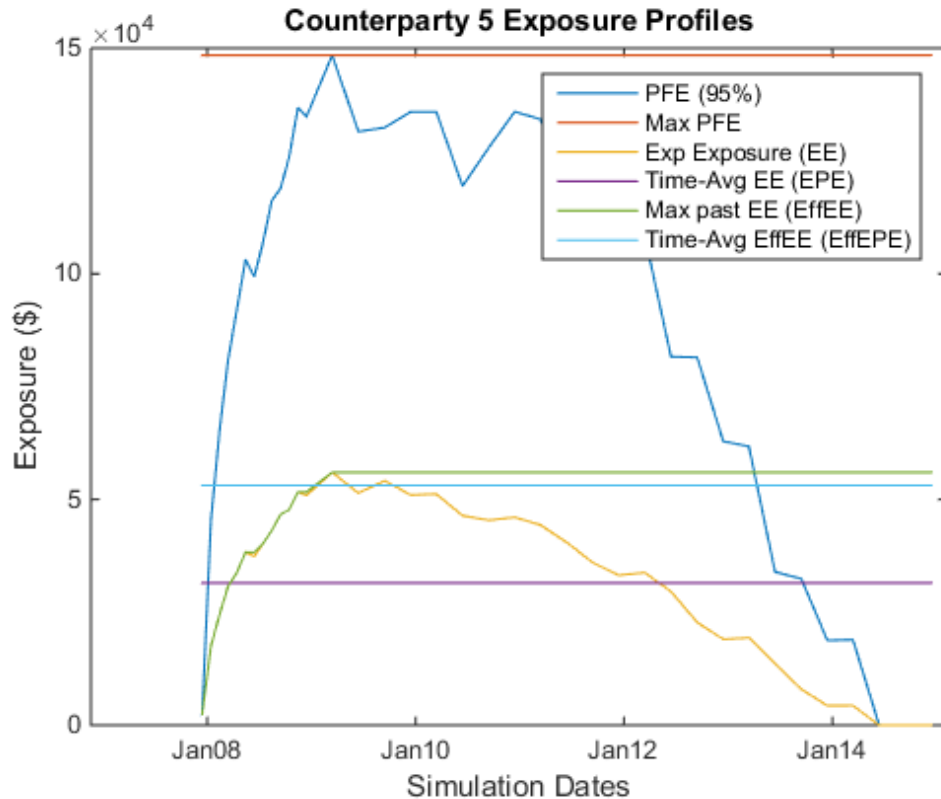
datetick('x','mmyy','keeplimits')

```

```

title(sprintf('Counterparty %d Exposure Profiles',cpIdx));
ylabel('Exposure ($)')
xlabel('Simulation Dates')

```



### Discounted Exposures

We compute the discounted expected exposures using the discount factors from each simulated interest rate scenario. The discount factor for a given valuation date in a given scenario is the product of the incremental discount factors from one simulation date to the next, along the interest rate path of that scenario.

```

% Get discounted exposures per counterparty, for each scenario
discExp = zeros(size(exposures));

```

```
for i = 1:numScenarios
    discExp(:, :, i) = bsxfun(@times, dfactors(:, i), exposures(:, :, i));
end

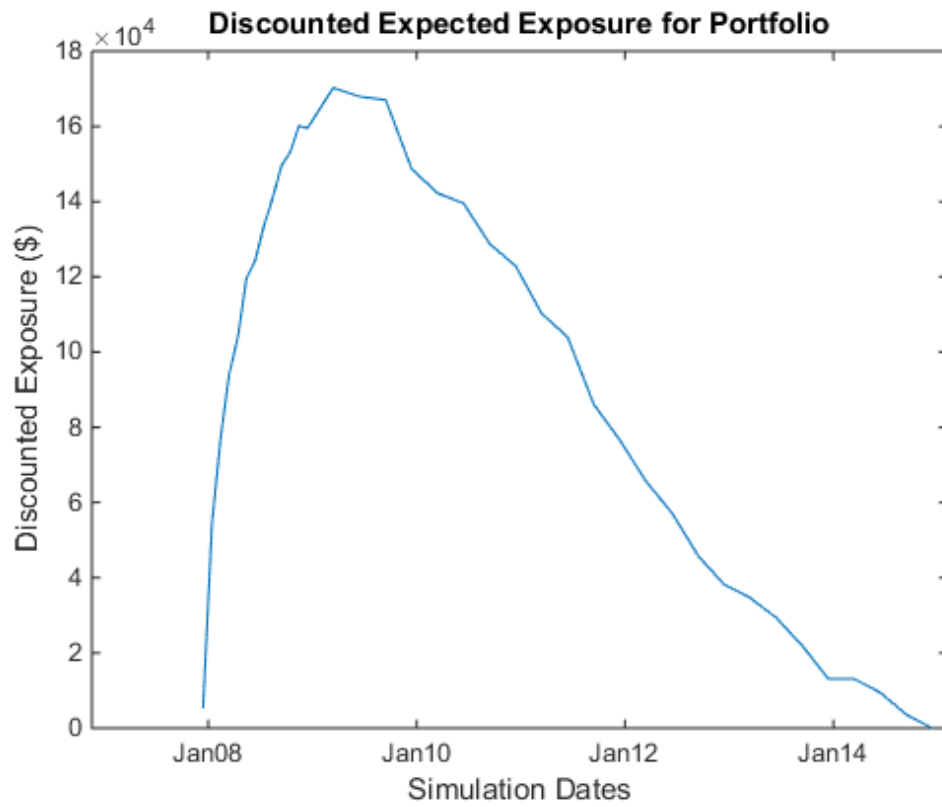
% Discounted expected exposure
discProfiles = exposureprofiles(simulationDates, discExp, ...
    'ProfileSpec', 'EE');
```

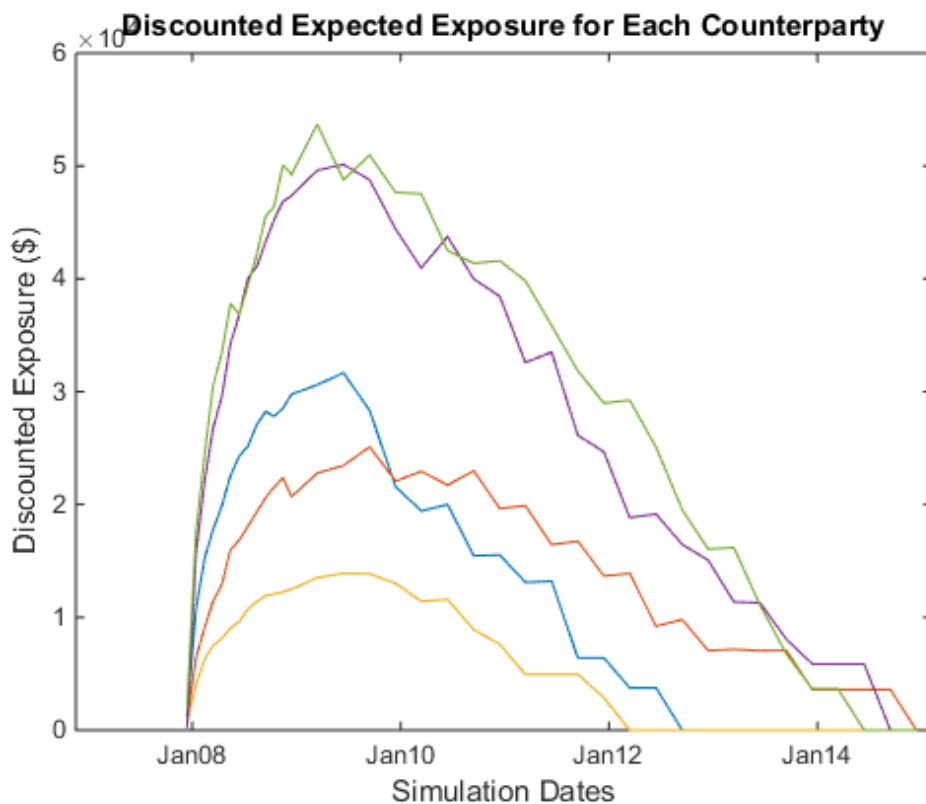
We plot the discounted expected exposures for the aggregate portfolio as well as for each counterparty.

```
% Aggregate the discounted EE for each counterparty into a matrix
discEE = [discProfiles.EE];

% Portfolio discounted EE
figure;
plot(simulationDates, sum(discEE, 2))
datetick('x', 'mmyy', 'keeplimits')
title('Discounted Expected Exposure for Portfolio');
ylabel('Discounted Exposure ($)');
xlabel('Simulation Dates')

% Counterparty discounted EE
figure;
plot(simulationDates, discEE)
datetick('x', 'mmyy', 'keeplimits')
title('Discounted Expected Exposure for Each Counterparty');
ylabel('Discounted Exposure ($)');
xlabel('Simulation Dates')
```





### Calibrating Probability of Default Curve for Each Counterparty

The default probability for a given counterparty is implied by the current market spreads of the counterparty's CDS. We use the function `cdsbootstrap` to generate the cumulative probability of default at each simulation date.

```
% Import CDS market information for each counterparty
CDS = dataset('XLSfile',swapFile,'Sheet','CDS Spreads') % #ok<NOPTS>
CDSDates = datenum(CDS.Date);
CDSSpreads = double(CDS(:,2:end));
```

```
ZeroData = [RateSpec.EndDates RateSpec.Rates];
```

```
% Calibrate default probabilities for each counterparty
```



```

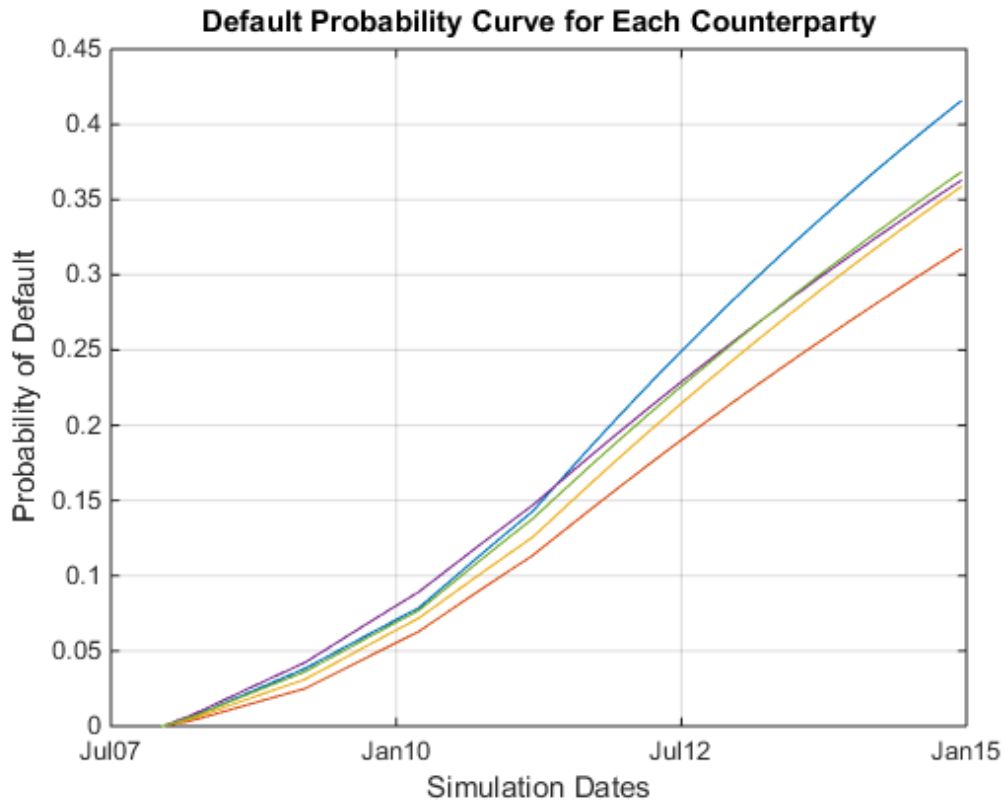
DefProb = zeros(length(simulationDates), size(CDSSpreads,2));
for i = 1:size(DefProb,2)
    probData = cdsbootstrap(ZeroData, [CSDDates CDSSpreads(:,i)],...
        Settle, 'probDates', simulationDates);
    DefProb(:,i) = probData(:,2);
end

% We plot of the cumulative probability of default for each counterparty.
figure;
plot(simulationDates,DefProb)
title('Default Probability Curve for Each Counterparty');
xlabel('Date');
grid on;
ylabel('Cumulative Probability')
datetick('x','mmyy')
ylabel('Probability of Default')
xlabel('Simulation Dates')

```

CDS =

Date	cp1	cp2	cp3	cp4	cp5
'3/20/2008'	140	85	115	170	140
'3/20/2009'	185	120	150	205	175
'3/20/2010'	215	170	195	245	210
'3/20/2011'	275	215	240	285	265
'3/20/2012'	340	255	290	320	310



### CVA Computation

The Credit Value (Valuation) Adjustment (CVA) formula is:

$$CVA = (1 - R) \int_0^T discEE(t)dPD(t)$$

Where  $R$  is the recovery,  $discEE$  the discounted expected exposure at time  $t$ , and  $PD$  the default probability distribution. This assumes the exposure is independent of default (no wrong-way risk), and it also assumes the exposures were obtained using risk-neutral probabilities.

Here we approximate the integral with a finite sum over the valuation dates as:

$$CVA(\text{approx}) = (1 - R) \sum_{i=2}^n \text{discEE}(t_i)(PD(t_i) - PD(t_{i-1}))$$

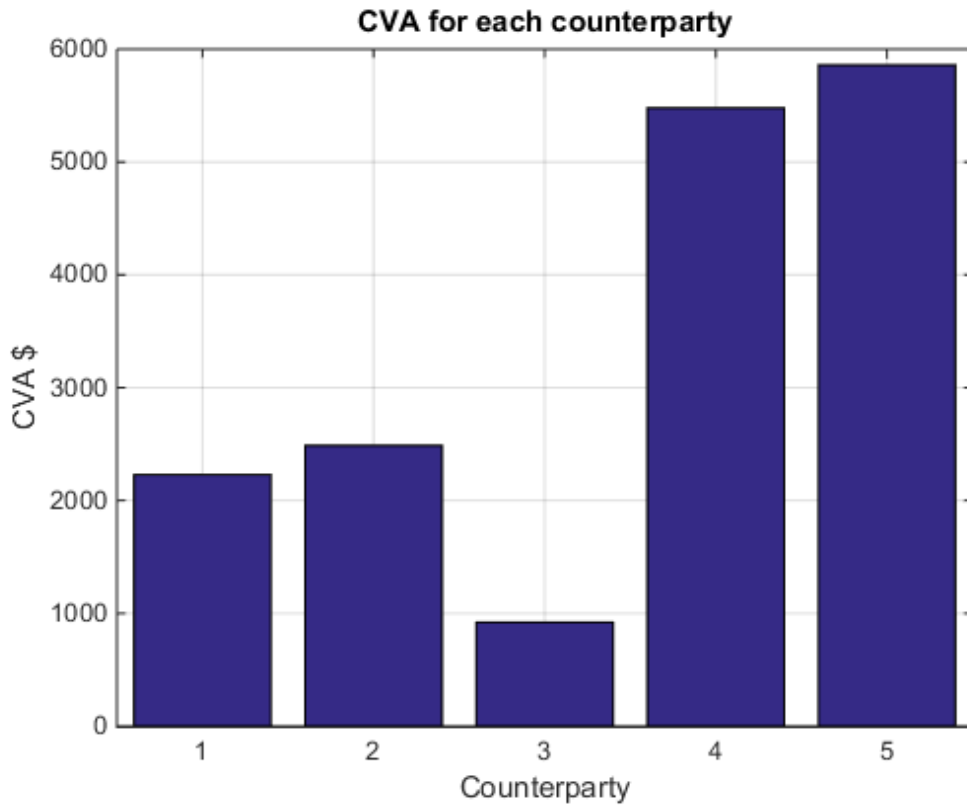
where  $t_1$  is today's date,  $t_2, \dots, t_n$  the future valuation dates.

We assume CDS info corresponds to counterparty with index `cpIdx`. The computed CVA is the present market value of our credit exposure to counterparty `cpIdx`. For this example we set the recovery rate at 40%.

```
Recovery = 0.4;
CVA = (1-Recovery) * sum(discEE(2:end,:) .* diff(DefProb));
for i = 1:numel(CVA)
    fprintf('CVA for counterparty %d = $%.2f\n',i,CVA(i));
end
```

```
figure;
bar(CVA);
title('CVA for each counterparty');
xlabel('Counterparty');
ylabel('CVA $');
grid on;
```

```
CVA for counterparty 1 = $2228.36
CVA for counterparty 2 = $2487.60
CVA for counterparty 3 = $920.39
CVA for counterparty 4 = $5478.50
CVA for counterparty 5 = $5859.30
```



**References**

- 1 Pykhtin, Michael, and Steven Zhu, *A Guide to Modeling Counterparty Credit Risk*, GARP, July/August 2007, issue 37, pp. 16-22.
- 2 Pykhtin, Michael, and Dan Rosen, *Pricing Counterparty Risk at the Trade Level and CVA*, 2010.
- 3 Basel II: <http://www.bis.org/publ/bcbs128.pdf> page 256

## First-to-Default Swaps

This example shows how to price first-to-default (FTD) swaps under the homogeneous loss assumption.

A first-to-default swap is an instrument that pays a predetermined amount when (and if) the first of a basket of credit instruments defaults. The credit instruments in the basket are usually bonds. If we assume that the loss amount following a credit event is the same for all credits in the basket, we are under the *homogeneous loss* assumption. This assumption makes models simpler, because any default in the basket triggers the same payment amount. This example is an implementation of the pricing methodology for these instruments, as described in O'Kane [2]. There are two steps in the methodology: a) Compute the survival probability for the basket numerically; b) Use this survival curve and standard single-name credit-default swap (CDS) functionality to find FTD spreads and to price existing FTD swaps.

### Fit Probability Curves to Market Data

Given CDS market quotes for each issuer in the basket, use `cdsbootstrap` to calibrate individual default probability curves for each issuer.

```
% Interest rate curve
ZeroDates = datenum({'17-Jan-10', '17-Jul-10', '17-Jul-11', '17-Jul-12', ...
'17-Jul-13', '17-Jul-14'});
ZeroRates = [1.35 1.43 1.9 2.47 2.936 3.311]'/100;
ZeroData = [ZeroDates ZeroRates];

% CDS spreads
% Each row in MarketSpreads corresponds to a different issuer; each
% column to a different maturity date (corresponding to MarketDates)
MarketDates = datenum({'20-Sep-10', '20-Sep-11', '20-Sep-12', '20-Sep-14', ...
'20-Sep-16'});
MarketSpreads = [
    160 195 230 285 330;
    130 165 205 260 305;
    150 180 210 260 300;
    165 200 225 275 295];
% Number of issuers equals number of rows in MarketSpreads
nIssuers = size(MarketSpreads,1);

% Settlement date
Settle = datenum('17-Jul-2009');
```

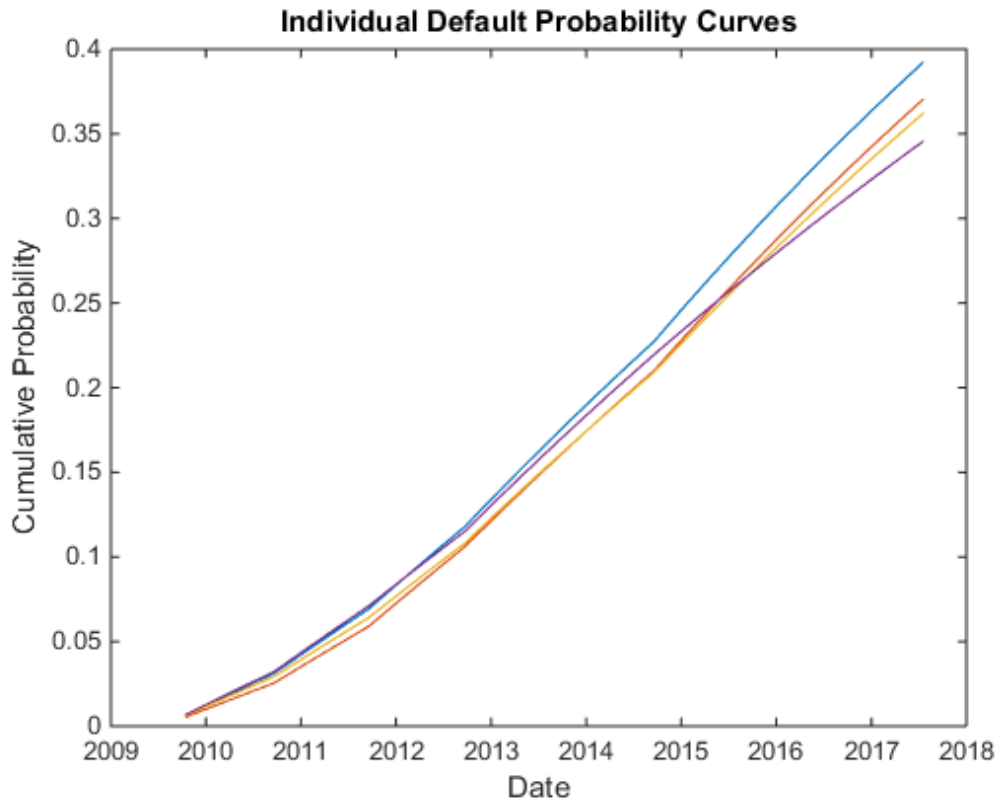
In practice, the time axis is discretized and the FTD survival curve is only evaluated at grid points. We use one point every three months. To request that `cdsbootstrap` returns default probability values over the specific grid points we want, use the optional argument 'ProbDates'. We add the original standard CDS market dates to the grid, otherwise the default probability information on those dates would be interpolated using the two closest dates on the grid, and the prices on market dates would be inconsistent with the original market data.

```
ProbDates = union(MarketDates,daysadd(Settle,360*(0.25:0.25:8),1));
nProbDates = length(ProbDates);
DefProb = zeros(nIssuers,nProbDates);

for ii = 1:nIssuers
    MarketData = [MarketDates MarketSpreads(ii,:)'];
    ProbData = cdsbootstrap(ZeroData,MarketData,Settle,...
        'ProbDates',ProbDates);
    DefProb(ii,:) = ProbData(:,2)';
end
```

These are the calibrated default probability curves for each credit in the basket.

```
figure
plot(ProbDates',DefProb)
datetick
title('Individual Default Probability Curves')
ylabel('Cumulative Probability')
xlabel('Date')
```



### Determine Latent Variable Thresholds

Latent variables are used in different credit risk contexts, with different interpretations. In some contexts, a latent variable is a proxy for a *change in the value of assets*, and the domain of this variable is binned, with each bin corresponding to a credit rating. The bins limits, or thresholds, are determined from credit migration matrices. In our context, the latent variable is associated to a *time to default*, and the thresholds determine bins in a discretized time grid where defaults may occur.

Formally, if the time to default of a particular issuer is denoted by  $\tau$ , and we know its default probability function  $P(t)$ , a latent variable  $A$  and corresponding thresholds  $C(t)$  satisfy

$$\Pr(\tau \leq t) = P(t) = \Pr(A \leq C(t))$$

or

$$\Pr(s \leq \tau \leq t) = P(t) - P(s) = \Pr(C(s) \leq A \leq C(t))$$

These relationships make latent variable approaches convenient for both simulations and analytical derivations. Both  $P(t)$  and  $C(t)$  are functions of time.

The choice of a distribution for the variable  $A$  determines the thresholds  $C(t)$ . In the standard latent variable model, the variable  $A$  is chosen to follow a standard normal distribution, from which

$$C(t) = \Phi^{-1}(P(t))$$

where  $\Phi$  is the cumulative standard normal distribution.

Use the previous formula to determine the *default-time thresholds*, or simply *default thresholds*, corresponding to the default probabilities previously obtained for the credits in the basket.

```
DefThresh = norminv(DefProb);
```

### Derive Survival Curve for the Basket

Following O'Kane [2], we use a one-factor latent variable model to derive expressions for the survival probability function of the basket.

Given parameters  $\beta_i$  for each issuer  $i$ , and given independent standard normal variables  $Z$  and  $\epsilon_i$ , the one-factor latent variable model assumes that the latent variable  $A_i$  associated to issuer  $i$  satisfies

$$A_i = \beta_i * Z + \sqrt{1 - \beta_i^2} * \epsilon_i$$

This induces a correlation between issuers  $i$  and  $j$  of  $\beta_i \beta_j$ . All latent variables  $A_i$  share the common factor  $Z$  as a source of uncertainty, but each latent variable also has an idiosyncratic source of uncertainty  $\epsilon_i$ . The larger the coefficient  $\beta_i$ , the more the latent variable resembles the common factor  $Z$ .



Using the latent variable model, we derive an analytic formula for the survival probability of the basket.

The probability that issuer  $i$  survives past time  $t_j$ , in other words, that its default time  $\tau_i$  is greater than  $t_j$  is

$$Pr(\tau_i > t_j) = 1 - Pr(A_i \leq C_i(t_j))$$

where  $C_i(t_j)$  is the default threshold computed above for issuer  $i$ , for the  $j$ -th date in the discretization grid.

Conditional on the value of the one-factor  $Z$ , the probability that all issuers survive past time  $t_j$  is

$$Pr(\text{No defaults by time } t_j | Z) = Pr(\tau_i > t_j \text{ for all } i | Z) = \prod_i [1 - Pr(A_i \leq C_i(t_j) | Z)]$$

where the product is justified because all the  $\epsilon_i$ 's are independent. Therefore, conditional on  $Z$ , the  $A_i$ 's are independent.

The unconditional probability of no defaults by time  $t_j$  is the integral over all values of  $Z$  of the previous conditional probability

$$Pr(\text{No defaults by time } t_j) = \int_Z \prod_i [1 - Pr(A_i \leq C_i(t_j) | Z)] \phi(Z) dZ$$

with  $\phi(Z)$  the standard normal density.

By evaluating this one-dimensional integral for each point  $t_j$  in the grid, we get a discretization of the survival curve for the whole basket, which is the FTD survival curve.

The latent variable model can also be used to simulate default times, which is the back engine of many pricing methodologies for credit instruments. Loeffler and Posch [1], for example, estimate the survival probability of a basket via simulation. In each simulated scenario a time to default is determined for each issuer. With some bookkeeping, the probability of having the first default on each bucket of the grid can be estimated from

the simulation. The simulation approach is also discussed in O'Kane [2]. Simulation is very flexible and applicable to many credit instruments. However, analytic approaches are preferred, when available, because they are much faster and more accurate than simulation.

To compute the FTD survival probabilities in our example, we set all betas to the square root of a target correlation. Then we loop over all dates in the time grid to compute the one dimensional integral that gives the survival probability of the basket.

Regarding implementation, the conditional survival probability as a function of a scalar  $Z$  would be

```
condProb=@(Z)prod(normcdf((-DefThresh(:,jj)+beta*Z)./sqrt(1-beta.^2)));
```

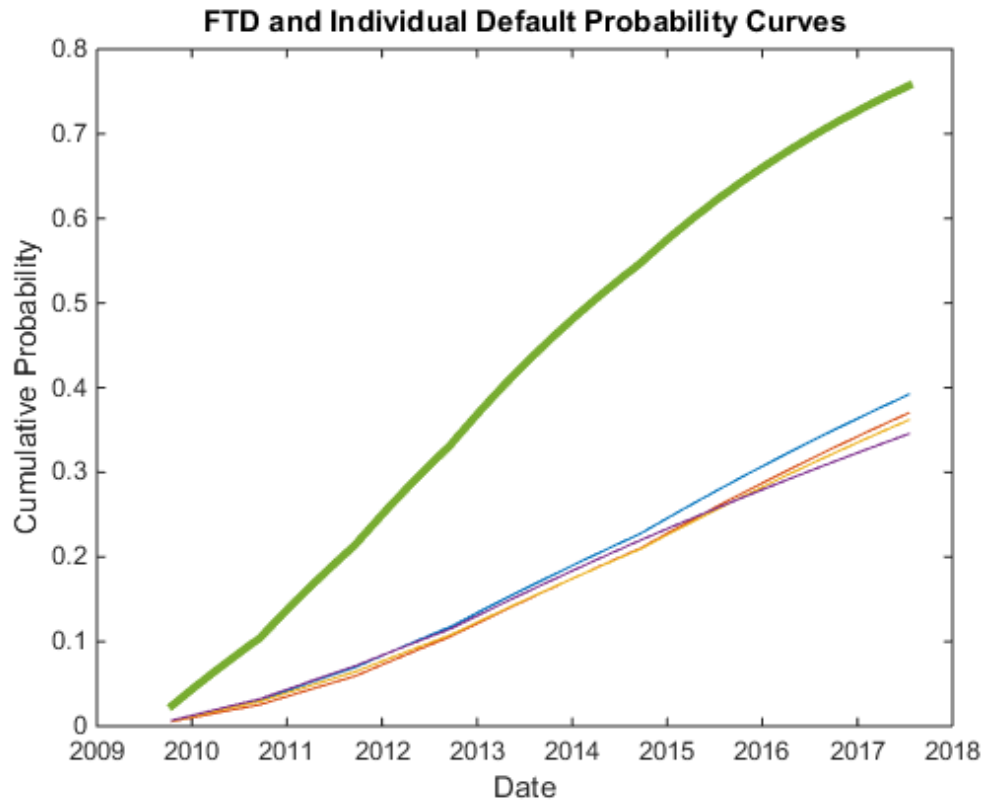
However, the integration function we use requires that the function handle of the integrand accepts vectors. Although a loop around the scalar version of the conditional probability would work, it is far more efficient to vectorize the conditional probability using `bsxfun`.

```
beta = sqrt(0.25)*ones(nIssuers,1);

FTDSurvProb = zeros(size(ProbDates));
for jj = 1:nProbDates
    % vectorized conditional probability as a function of Z
    vecCondProb = @(Z)prod(normcdf(bsxfun(@rdivide,...
        - repmat(DefThresh(:,jj),1,length(Z))+bsxfun(@times,beta,Z),...
        sqrt(1-beta.^2))));
    % truncate domain of normal distribution to [-5,5] interval
    FTDSurvProb(jj) = integral(@(Z)vecCondProb(Z).*normpdf(Z),-5,5);
end
FTDDefProb = 1-FTDSurvProb;
```

Compare the FTD probability to the default probabilities of the individual issuers.

```
figure
plot(ProbDates',DefProb)
datetick
hold on
plot(ProbDates,FTDDefProb,'LineWidth',3)
datetick
hold off
title('FTD and Individual Default Probability Curves')
ylabel('Cumulative Probability')
xlabel('Date')
```



### Find FTD Spreads and Price Existing FTD Swaps

Under the assumption that all instruments in the basket have the same recovery rate, or homogeneous loss assumption (see O'Kane in References), we get the spread for the FTD swap using the `cdsspread` function, but passing the FTD probability data just computed.

```
Maturity = MarketDates;
ProbDataFTD = [ProbDates, FTDDefProb];
FTDSpread = cdsspread(ZeroData, ProbDataFTD, Settle, Maturity);
```

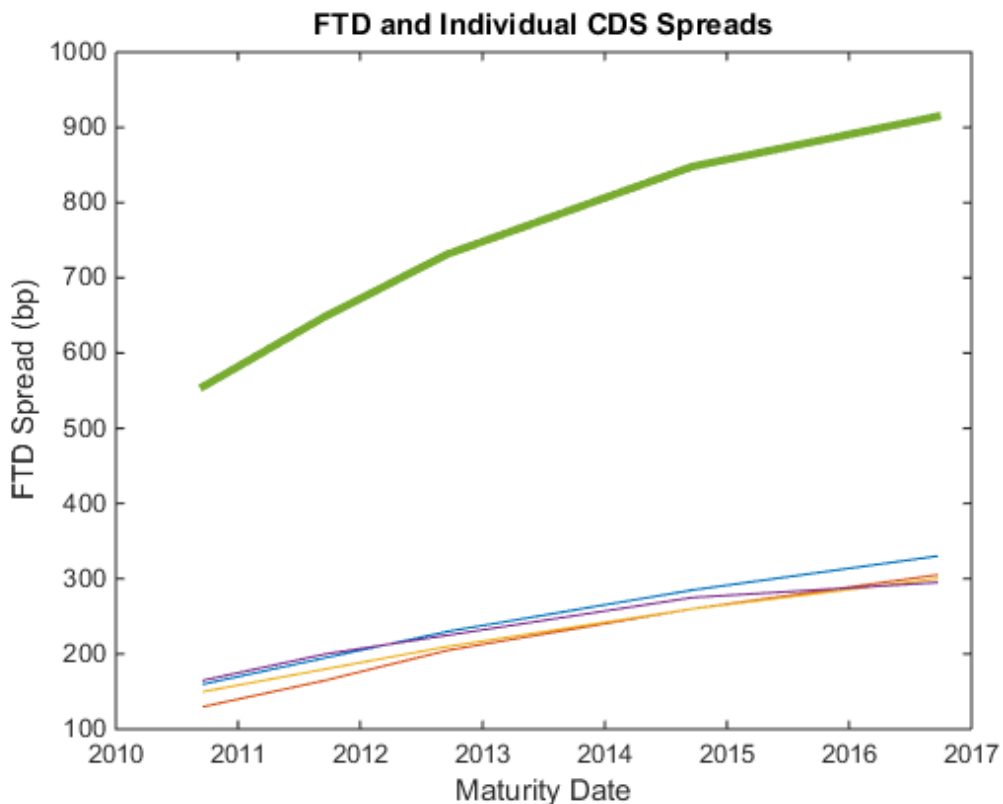
Compare the FTD spreads with the individual spreads.

figure

```

plot(MarketDates,MarketSpreads')
datetick
hold on
plot(MarketDates,FTDSpread,'LineWidth',3)
hold off
title('FTD and Individual CDS Spreads')
ylabel('FTD Spread (bp)')
xlabel('Maturity Date')

```



An existing FTD swap can be priced with `cdsprice`, using the same FTD probability.

```

Maturity0 = MarketDates(1); % Assume maturity on nearest market date
Spread0 = 540; % Spread of existing FTD contract
% Assume default values of recovery and notional

```

```
FTDPrice = cdsprice(ZeroData,ProbDataFTD,Settle,Maturity0,Spread0);
fprintf('Price of existing FTD contract: %g\n',FTDPrice)
```

```
Price of existing FTD contract: 17644.7
```

### Analyze Sensitivity to Correlation

To illustrate the sensitivity of the FTD spreads to model parameters, we calculate the market spreads for a range of correlation values.

```
corr = [0 0.01 0.10 0.25 0.5 0.75 0.90 0.99 1];
FTDSpreadByCorr = zeros(length(Maturity),length(corr));
FTDSpreadByCorr(:,1) = sum(MarketSpreads)';
FTDSpreadByCorr(:,end) = max(MarketSpreads)';

for ii = 2:length(corr)-1
    beta = sqrt(corr(ii))*ones(nIssuers,1);
    FTDSurvProb = zeros(length(ProbDates));
    for jj = 1:nProbDates
        % vectorized conditional probability as a function of Z
        condProb = @(Z)prod(normcdf(bsxfun(@divide,...
            - repmat(DefThresh(:,jj),1,length(Z))+bsxfun(@times,beta,Z),...
            sqrt(1-beta.^2))));
        % truncate domain of normal distribution to [-5,5] interval
        FTDSurvProb(jj) = integral(@(Z)condProb(Z).*normpdf(Z),-5,5);
    end
    FTDDefProb = 1-FTDSurvProb;
    ProbDataFTD = [ProbDates, FTDDefProb];
    FTDSpreadByCorr(:,ii) = cdsspread(ZeroData,ProbDataFTD,Settle,Maturity);
end
```

The FTD spreads lie in a band between the sum and the maximum of individual spreads. As the correlation increases to one, the FTD spreads decrease towards the maximum of the individual spreads in the basket (all credits default together). As the correlation decreases to zero, the FTD spreads approach the sum of the individual spreads (independent credits).

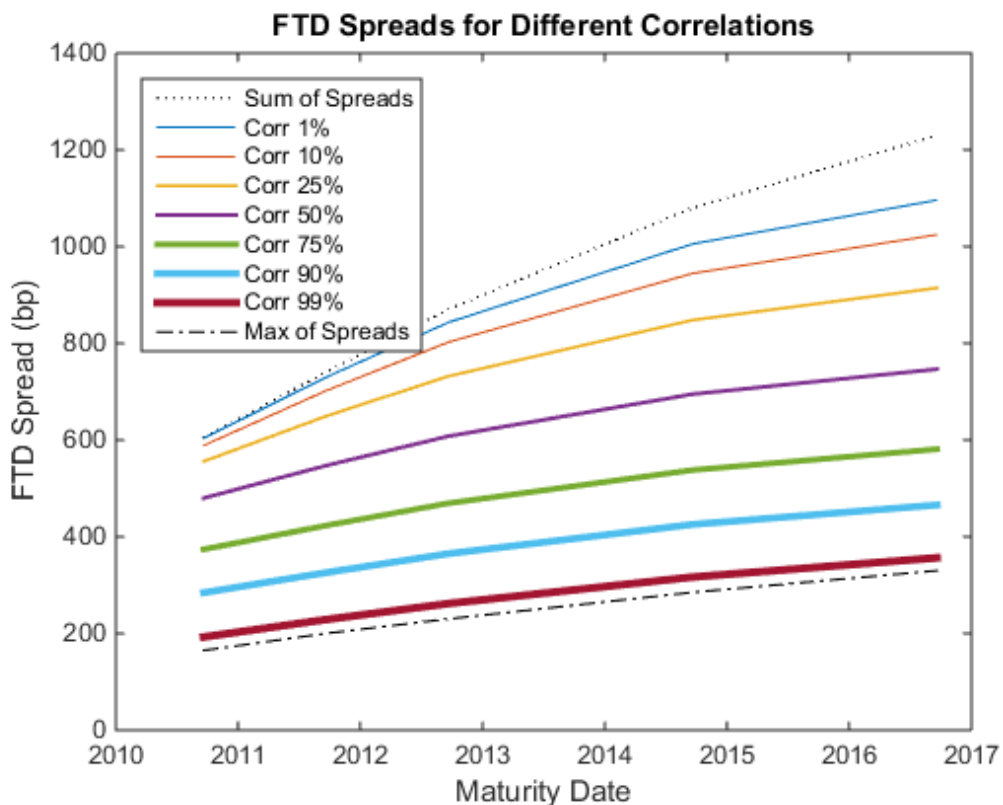
```
figure
legends = cell(1,length(corr));
plot(MarketDates,FTDSpreadByCorr(:,1),'k:');
legends{1} = 'Sum of Spreads';
datetick
hold on
for ii = 2:length(corr)-1
    plot(MarketDates,FTDSpreadByCorr(:,ii),'LineWidth',3*corr(ii))
```

```

legends{ii} = ['Corr ' num2str(corr(ii)*100) '%'];
end
plot(MarketDates,FTDSpreadByCorr(:,end),'k-.')
legends{end} = 'Max of Spreads';

hold off
title('FTD Spreads for Different Correlations')
ylabel('FTD Spread (bp)')
xlabel('Maturity Date')
legend(legends,'Location','NW')

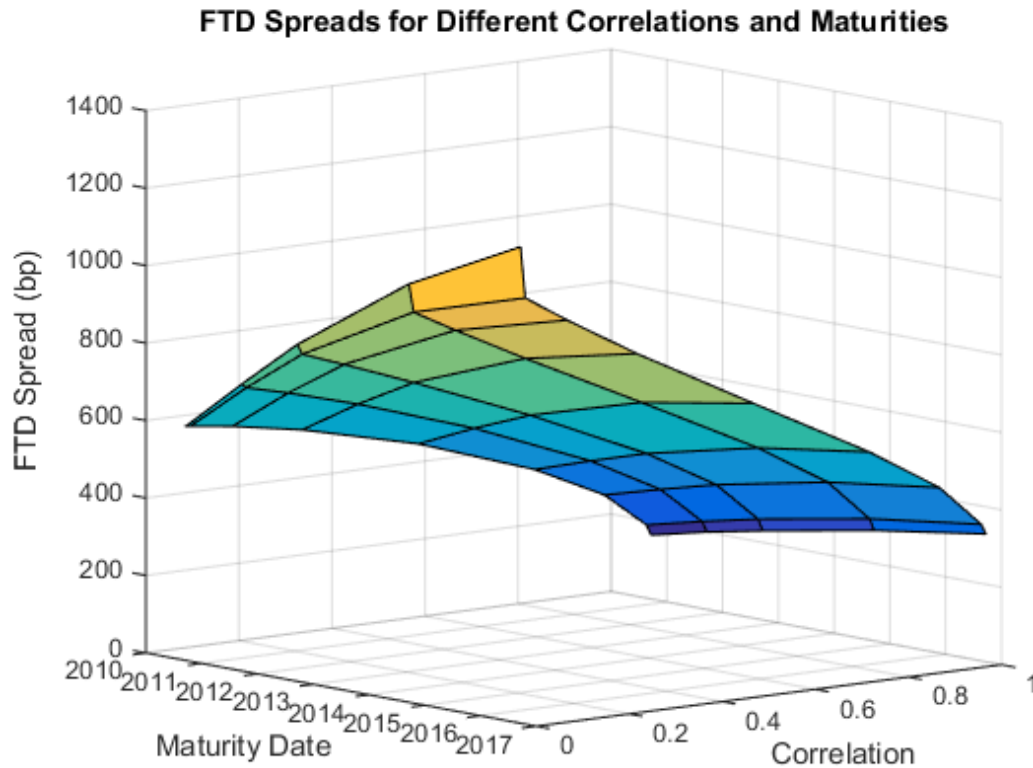
```



For short maturities and small correlations, the basket is effectively independent (the FTD spread is very close to the sum of individual spreads). The correlation effect becomes more significant for longer maturities.

Here is an alternative visualization of the dependency of FTD spreads on correlation.

```
figure
surf(corr,MarketDates,FTDSpreadByCorr)
datetick('y')
ax = gca;
ax.YDir = 'reverse';
view(-40,10)
title('FTD Spreads for Different Correlations and Maturities')
xlabel('Correlation')
ylabel('Maturity Date')
zlabel('FTD Spread (bp)')
```



## References

[1] Loeffler, Gunter and Peter Posch, *Credit risk modeling using Excel and VBA*, Wiley Finance, 2007.

[2] O'Kane, Dominic, *Modelling single-name and multi-name Credit Derivatives*, Wiley Finance, 2008.



## Credit Default Swap Option

### In this section...

“Pricing a Single-Name CDS Option” on page 8-49

“Pricing a CDS Index Option” on page 8-51

“References” on page 8-54

A credit default swap (CDS) option, or credit default swaption, is a contract that provides the holder with the right, but not the obligation, to enter into a credit default swap in the future. CDS options can either be payer swaptions or receiver swaptions. If a payer swaption, the option holder has the right to enter into a CDS where they pay premiums; and, if a receiver swaption, the option holder receives premiums. Financial Instruments Toolbox software provides `cdsoptprice` for pricing payer and receiver credit default swaptions. Also, with some additional steps, `cdsoptprice` can be used for pricing multi-name CDS index options.

### Pricing a Single-Name CDS Option

This example shows how to price a single-name CDS option using `cdsoptprice`. The function `cdsoptprice` is based on the Black's model as described in O'Kane (2008). The optional `knockout` argument for `cdsoptprice` supports two variations of the mechanics of a CDS option. CDS options can be knockout or non-knockout options.

- A knockout option cancels with no payments if there is a credit event before the option expiry date.
- A non-knockout option does not cancel if there is a credit event before the option expiry date. In this case, the option holder of a non-knockout payer swaption can take delivery of the underlying long protection CDS on the option expiry date and exercise the protection, delivering a defaulted obligation in return for par. This portion of protection from option initiation to option expiry is known as the front-end protection (FEP). While this distinction does not affect the receiver swaption, the price of a non-knockout payer swaption is obtained by adding the value of the FEP to the knockout payer swaption price.

Define the CDS instrument.

```
Settle = datenum('12-Jun-2012');
OptionMaturity = datenum('20-Sep-2012');
```

```
CDSMaturity = datenum('20-Sep-2017');
OptionStrike = 200;
SpreadVolatility = .4;
```

Define the zero rate.

```
Zero_Time = [.5 1 2 3 4 5]';
Zero_Rate = [.5 .75 1.5 1.7 1.9 2.2]'/100;
Zero_Dates = daysadd(Settle,360*Zero_Time,1);
ZeroData = [Zero_Dates Zero_Rate]
```

ZeroData =

```
1.0e+05 *
    7.3522    0.0000
    7.3540    0.0000
    7.3576    0.0000
    7.3613    0.0000
    7.3649    0.0000
    7.3686    0.0000
```

Define the market data.

```
Market_Time = [1 2 3 5 7 10]';
Market_Rate = [100 120 145 220 245 270]';
Market_Dates = daysadd(Settle,360*Market_Time,1);
MarketData = [Market_Dates Market_Rate];
```

```
ProbData = cdsbootstrap(ZeroData, MarketData, Settle)
```

ProbData =

```
1.0e+05 *
    7.3540    0.0000
    7.3576    0.0000
    7.3613    0.0000
    7.3686    0.0000
    7.3759    0.0000
    7.3868    0.0000
```

Define the CDS option.

```
[Payer,Receiver] = cdsoptprice(ZeroData, ProbData, Settle, OptionMaturity, ...
    CDSMaturity, OptionStrike, SpreadVolatility, 'Knockout', true);
fprintf('    Payer: %.0f    Receiver: %.0f    (Knockout)\n',Payer,Receiver);
[Payer,Receiver] = cdsoptprice(ZeroData, ProbData, Settle, OptionMaturity, ...
    CDSMaturity, OptionStrike, SpreadVolatility, 'Knockout', false);
fprintf('    Payer: %.0f    Receiver: %.0f    (Non-Knockout)\n',Payer,Receiver);

    Payer: 196    Receiver: 23    (Knockout)
    Payer: 224    Receiver: 23    (Non-Knockout)
```

## Pricing a CDS Index Option

This example shows how to price CDS index options by using `cdsoptprice` with the forward spread adjustment. Unlike a single-name CDS, a CDS portfolio index contains multiple credits. When one or more of the credits default, the corresponding contingent payments are made to the protection buyer but the contract still continues with reduced coupon payments. Considering the fact that the CDS index option does not cancel when some of the underlying credits default before expiry, one might attempt to price CDS index options using the Black's model for non-knockout single-name CDS option. However, Black's model in this form is not appropriate for pricing CDS index options because it does not capture the exercise decision correctly when the strike spread ( $K$ ) is very high, nor does it ensure put-call parity when ( $K$ ) is not equal to the contractual spread (O'Kane, 2008).

However, with the appropriate modifications, Black's model for single-name CDS options used in `cdsoptprice` can provide a good approximation for CDS index options. While there are some variations in the way the Black's model is modified for CDS index options, they usually involve adjusting the forward spread  $F$ , the strike spread  $K$ , or both. Here we describe the approach of adjusting the forward spread only. In the Black's model for single-name CDS options, the forward spread  $F$  is defined as:

$$F = S(t, t_E, T) = \frac{S(t, T)RPV01(t, T) - S(t, t_E)RPV01(t, t_E)}{RPV01(t, t_E, T)}$$

where

$S$  is the spread.

$RPV01$  is the risky present value of a basis point (see `cdsrpv01`).

$t$  is the valuation date.

$t_E$  is the option expiry date.

$T$  is the CDS maturity date.

To capture the exercise decision correctly for CDS index options, we use the knockout form of the Black's model and adjust the forward spread to incorporate the  $FEP$  as follows:

$$F_{Adj} = F + \frac{FEP}{RPV01(t, t_E, T)}$$

where the  $FEP$  can be expressed as

$$FEP = S(t, t_E)RPV01(t, t_E)$$

In `cdsoptprice`, forward spread adjustment can be made with the `AdjustedForwardSpread` parameter. When computing the adjusted forward spread, we can compute the spreads using `cdsspread` and the `RPV01`s using `cdsrpv01`.

Set up the data for the CDS index, its option, and zero curve. The underlying is a 5 year CDS index maturing on 20-Jun-2017 and the option expires on 20-Jun-2012. Note that a flat index spread is assumed when bootstrapping the default probability curve.

```
% CDS index and option data
Recovery = .4;
Basis = 2;
Period = 4;
CDSMaturity = datenum('20-Jun-2017');
ContractSpread = 100;
IndexSpread = 140;
BusDayConvention = 'follow';
Settle = datenum('13-Apr-2012');
OptionMaturity = datenum('20-Jun-2012');
OptionStrike = 140;
SpreadVolatility = .69;

% Zero curve data
MM_Time = [1 2 3 6]';
MM_Rate = [0.004111 0.00563 0.00757 0.01053]';
MM_Dates = daysadd(Settle, 30*MM_Time, 1);
Swap_Time = [1 2 3 4 5 6 7 8 9 10 12 15 20 30]';
Swap_Rate = [0.01387 0.01035 0.01145 0.01318 0.01508 0.01700 0.01868 ...
0.02012 0.02132 0.02237 0.02408 0.02564 0.02612 0.02524]';
Swap_Dates = daysadd(Settle, 360*Swap_Time, 1);
ZeroBasis = 1;
ZeroCompounding = 1;

% Bootstrap the default probability curve assuming a flat index spread.
```

```

ZeroData = [MM_Dates MM_Rate;Swap_Dates Swap_Rate];
MarketDates = (Settle+1:30:CDSMaturity)';
MarketData = [MarketDates repmat(IndexSpread,length(MarketDates),1)];
ProbData = cdsbootstrap(ZeroData, MarketData, Settle);

```

Compute the spot and forward RPV01s, which will be used later in the computation of the FEP and the adjusted forward spread. For this purpose, we can use `cdsrpv01`.

```

% RPV01(t,T)
RPV01_CDSMaturity = cdsrpv01(ZeroData,ProbData,Settle,CDSMaturity,...
    'CleanRPV01',false)

% RPV01(t,t_E,T)
RPV01_OptionExpiryForward = cdsrpv01(ZeroData,ProbData,Settle,CDSMaturity,...
    'StartDate',OptionMaturity,'CleanRPV01',false)

% RPV01(t,t_E) = RPV01(t,T) - RPV01(t,t_E,T)
RPV01_OptionExpiry = RPV01_CDSMaturity - RPV01_OptionExpiryForward

```

```
RPV01_CDSMaturity =
```

```
4.8523
```

```
RPV01_OptionExpiryForward =
```

```
4.5975
```

```
RPV01_OptionExpiry =
```

```
0.2549
```

Compute the spot spreads using `cdsspread`.

```

% S(t,t_E)
Spread_OptionExpiry = cdsspread(ZeroData,ProbData,Settle,OptionMaturity,...
    'Period',Period,'Basis',Basis,'BusDayConvention',BusDayConvention,...
    'PayAccruedPremium',true,'ZeroCompounding',...
    ZeroCompounding,'ZeroBasis',ZeroBasis,'recoveryrate',Recovery)

% S(t,T)
Spread_CDSMaturity = cdsspread(ZeroData,ProbData,Settle,CDSMaturity,...
    'Period',Period,'Basis',Basis,'BusDayConvention',BusDayConvention,...
    'PayAccruedPremium',true,'ZeroCompounding',...
    ZeroCompounding,'ZeroBasis',ZeroBasis,'recoveryrate',Recovery)

```

```
Spread_OptionExpiry =
```

```
140.0005
```

```
Spread_CDSMaturity =
```

```
140.0000
```

The spot spreads and RPV01s are then used to compute the forward spread.

```
% F = S(t,t_E,T)
ForwardSpread = (Spread_CDSMaturity.*RPV01_CDSMaturity - ...
    Spread_OptionExpiry.*RPV01_OptionExpiry)./RPV01_OptionExpiryForward
```

```
ForwardSpread =
```

```
139.9999
```

Compute the front-end protection (FEP).

```
FEP = Spread_OptionExpiry * (cdsrpv01(ZeroData,ProbData,Settle,CDSMaturity)...
    - cdsrpv01(ZeroData,ProbData,Settle,CDSMaturity,'StartDate',OptionMaturity))
```

```
FEP =
```

```
26.3461
```

Compute the adjusted forward spread.

```
AdjustedForwardSpread = ForwardSpread + FEP./RPV01_OptionExpiryForward
```

```
AdjustedForwardSpread =
```

```
145.7305
```

Compute the option prices using `cdsoptprice` with the adjusted forward spread. Note again that the `Knockout` parameter should be set to be `true` because the FEP was already incorporated into the adjusted forward spread.

```
[Payer,Receiver] = cdsoptprice(ZeroData, ProbData, Settle, OptionMaturity, ...
    CDSMaturity, OptionStrike, SpreadVolatility,'Knockout',true,...
    'AdjustedForwardSpread', AdjustedForwardSpread,'PayAccruedPremium',true);
fprintf(' Payer: %.0f Receiver: %.0f \n',Payer,Receiver);
```

```
Payer: 92 Receiver: 66
```

## References

O'Kane, D., *Modelling Single-name and Multi-name Credit Derivatives*, Wiley, 2008.

## See Also

`cdsoptprice` | `cdsrpv01` | `cdsspread`

# Interest-Rate Curve Objects

---

- “Interest-Rate Curve Objects” on page 9-2
- “Creating Interest-Rate Curve Objects” on page 9-4
- “Creating an IRDataCurve Object” on page 9-6
- “Bootstrapping a Swap Curve” on page 9-12
- “Dual Curve Bootstrapping” on page 9-15
- “Creating an IRFunctionCurve Object” on page 9-20
- “Fitting Interest Rate Curve Functions” on page 9-30
- “Analysis of Inflation Indexed Instruments” on page 9-37
- “Converting an IRDataCurve or IRFunctionCurve Object” on page 9-44

## Interest-Rate Curve Objects

### In this section...

“Class Structure” on page 9-2

“Workflow Using Interest-Rate Curve Objects” on page 9-2

### Class Structure

Financial Instruments Toolbox class structure supports interest-rate curve objects. The class structure supports five classes.

Class Name	Description
@IRCurve	Base abstract class for interest-rate curves. <code>IRCurve</code> is an abstract class; you cannot create instances of it directly. You can create <code>IRFunctionCurve</code> and <code>IRDataCurve</code> objects that are derived from this class.
@IRDataCurve	Creates a representation of an interest-rate curve with dates and data. <code>IRDataCurve</code> is constructed directly by specifying dates and corresponding interest rates or discount factors, or you can bootstrap an <code>IRDataCurve</code> object from market data.
@IRFunctionCurve	Creates a representation of an interest-rate curve with a function. <code>IRFunctionCurve</code> is constructed directly by specifying a function handle, or you can fit a function to market data using methods of the <code>IRFunctionCurve</code> object.
@IRBootstrapOptions	The <code>IRBootstrapOptions</code> object lets you specify options relating to the bootstrapping of an <code>IRDataCurve</code> object.
@IRFitOptions	The <code>IRFitOptions</code> object lets you specify options relating to the fitting process for an <code>IRFunctionCurve</code> object.

### Workflow Using Interest-Rate Curve Objects

The supported workflow model for using interest-rate curve objects is:



- 1** Create an interest-rate curve based on an `IRDataCurve` object or an `IRFunctionCurve` object.
  - To create an `IRDataCurve` object:
    - Use vectors of dates and data with interpolation methods.
    - Use bootstrapping based on market instruments.
  - To create an `IRFunctionCurve` object:
    - Specify a function handle.
    - Fit a function using the Nelson-Siegel model, Svensson model, or smoothing spline model.
    - Fit a custom function.
- 2** Use methods of the `IRDataCurve` or `IRFunctionCurve` objects to extract forward, zero, discount factor, or par yield curves for the interest-rate curve object.
- 3** Convert an interest-rate curve from an `IRDataCurve` or `IRFunctionCurve` object to a `RateSpec` structure. This `RateSpec` structure is identical to the `RateSpec` produced by the Financial Instruments Toolbox function `intenvset`. Using the `RateSpec` for an interest-rate curve object, you can then use Financial Instruments Toolbox functions to model an interest-rate structure and price.

## Creating Interest-Rate Curve Objects

Depending on your data and purpose for analysis, you can create an interest-rate curve object by using an `IRDataCurve` or `IRFunctionCurve` object.

To create an `IRDataCurve` object, you can:

- Use the `IRDataCurve` constructor.
- Use the `IRDataCurve` method `bootstrap`.

Using an `IRDataCurve` object, you can use the following methods to determine:

- Forward rate curve — `getForwardRates`
- Zero rate curve — `getZeroRates`
- Discount rate curve — `getDiscountFactors`
- Par yield curve — `getParYields`

Alternatively, to create an `IRFunctionCurve` object, you can:

- Use the `IRFunctionCurve` constructor and directly specify a function handle.
- Use `IRFunctionCurve` methods:
  - `fitNelsonSiegel` fits a “Fitting `IRFunctionCurve` Object Using Nelson-Siegel Method” on page 9-20 to market data for bonds.
  - `fitSvensson` fits a “Fitting `IRFunctionCurve` Object Using Svensson Method” on page 9-22 to market data for bonds.
  - `fitSmoothingSpline` fits a “Fitting `IRFunctionCurve` Object Using Smoothing Spline Method” on page 9-24 function to market data for bonds.
  - `fitFunction` custom fits an interest-rate curve object to market data for bonds.

Using an `IRFunctionCurve` object, you can use the following method to determine:

- Forward rate curve — `getForwardRates`
- Zero rate curve — `getZeroRates`
- Discount rate curve — `getDiscountFactors`
- Par yield curve — `getParYields`

In addition, you can convert an `IRDataCurve` or `IRFunctionCurve` to a `RateSpec` structure. For more information, see “Converting an `IRDataCurve` or `IRFunctionCurve` Object” on page 9-44.

## Creating an IRDataCurve Object

### In this section...

“IRDataCurve Constructor with Dates and Data” on page 9-6

“IRDataCurve Bootstrapping Based on Market Instruments” on page 9-7

### IRDataCurve Constructor with Dates and Data

Use the `IRDataCurve` constructor with vectors of dates and data to create an interest-rate curve object. When constructing the `IRDataCurve` object, you can also use optional inputs to define how the interest-rate curve is constructed from the dates and data.

#### Example

In this example, you create the vectors for `Dates` and `Data` for an interest-rate curve:

```
Data = [2.09 2.47 2.71 3.12 3.43 3.85 4.57 4.58]/100;
Dates = daysadd(today,[360 2*360 3*360 5*360 7*360 10*360 20*360 30*360],1);
```

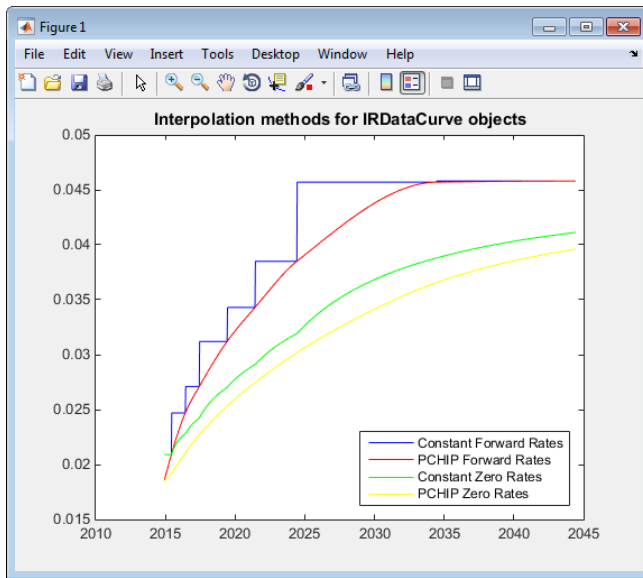
Use the `IRDataCurve` constructor to build interest-rate objects based on the `constant` and `pchip` interpolation methods:

```
irdc_const = IRDataCurve('Forward',today,Dates>Data,'InterpMethod','constant');
irdc_pchip = IRDataCurve('Forward',today,Dates>Data,'InterpMethod','pchip');
```

Plot the forward and zero rate curves for the two `IRDataCurve` objects based on `constant` and `pchip` interpolation methods:

```
PlottingDates = daysadd(today,180:10:360*30,1);
plot(PlottingDates, getForwardRates(irdc_const, PlottingDates),'b')
hold on
plot(PlottingDates, getForwardRates(irdc_pchip, PlottingDates),'r')
plot(PlottingDates, getZeroRates(irdc_const, PlottingDates),'g')
plot(PlottingDates, getZeroRates(irdc_pchip, PlottingDates),'yellow')
legend({'Constant Forward Rates','PCHIP Forward Rates','Constant Zero Rates',...
'PCHIP Zero Rates'},'location','SouthEast')
title('Interpolation methods for IRDataCurve objects')
datetick
```

The plot demonstrates the relationship of the forward and zero rate curves.



## IRDataCurve Bootstrapping Based on Market Instruments

Use the bootstrapping method, based on market instruments, to create an interest-rate curve object. When bootstrapping, you also have the option to define a range of interpolation methods (linear, spline, constant, and pchip).

### Example 1

In this example, you bootstrap a swap curve from deposits, Eurodollar Futures and swaps. The input market data for this example is hard-coded and specified as two cell arrays of data; one cell array indicates the type of instrument and the other contains the `Settle`, `Maturity` values and a market quote for the instrument. For deposits and swaps, the quote is a rate; for the EuroDollar futures, the quote is a price. Although bonds are not used in this example, a bond would also be quoted with a price.

```
InstrumentTypes = {'Deposit'; 'Deposit'; 'Deposit'; 'Deposit'; 'Deposit'; ...
    'Futures'; 'Futures'; ...
    'Futures'; 'Futures'; 'Futures'; ...
    'Futures'; 'Futures'; 'Futures'; ...
    'Futures'; 'Futures'; 'Futures'; ...
    'Futures'; 'Futures'; 'Futures'; ...
    'Swap'; 'Swap'; 'Swap'; 'Swap'; 'Swap'; 'Swap'; 'Swap'};
```

```

Instruments = [datenum('08/10/2007'),datenum('08/17/2007'),.0532063; ...
    datenum('08/10/2007'),datenum('08/24/2007'),.0532000; ...
    datenum('08/10/2007'),datenum('09/17/2007'),.0532000; ...
    datenum('08/10/2007'),datenum('10/17/2007'),.0534000; ...
    datenum('08/10/2007'),datenum('11/17/2007'),.0535866; ...
    datenum('08/08/2007'),datenum('19-Dec-2007'),9485; ...
    datenum('08/08/2007'),datenum('19-Mar-2008'),9502; ...
    datenum('08/08/2007'),datenum('18-Jun-2008'),9509.5; ...
    datenum('08/08/2007'),datenum('17-Sep-2008'),9509; ...
    datenum('08/08/2007'),datenum('17-Dec-2008'),9505.5; ...
    datenum('08/08/2007'),datenum('18-Mar-2009'),9501; ...
    datenum('08/08/2007'),datenum('17-Jun-2009'),9494.5; ...
    datenum('08/08/2007'),datenum('16-Sep-2009'),9489; ...
    datenum('08/08/2007'),datenum('16-Dec-2009'),9481.5; ...
    datenum('08/08/2007'),datenum('17-Mar-2010'),9478; ...
    datenum('08/08/2007'),datenum('16-Jun-2010'),9474; ...
    datenum('08/08/2007'),datenum('15-Sep-2010'),9469.5; ...
    datenum('08/08/2007'),datenum('15-Dec-2010'),9464.5; ...
    datenum('08/08/2007'),datenum('16-Mar-2011'),9462.5; ...
    datenum('08/08/2007'),datenum('15-Jun-2011'),9456.5; ...
    datenum('08/08/2007'),datenum('21-Sep-2011'),9454; ...
    datenum('08/08/2007'),datenum('21-Dec-2011'),9449.5; ...
    datenum('08/08/2007'),datenum('08/08/2014'),.0530; ...
    datenum('08/08/2007'),datenum('08/08/2017'),.0545; ...
    datenum('08/08/2007'),datenum('08/08/2019'),.0551; ...
    datenum('08/08/2007'),datenum('08/08/2022'),.0559; ...
    datenum('08/08/2007'),datenum('08/08/2027'),.0565; ...
    datenum('08/08/2007'),datenum('08/08/2032'),.0566; ...
    datenum('08/08/2007'),datenum('08/08/2037'),.0566];

```

The `bootstrap` method is called as a static method of the “@IRDataCurve” class. Inputs to this method include the curve Type (zero or forward), Settle date, InstrumentTypes, and Instrument data. The `bootstrap` method also supports optional arguments, including an interpolation method, compounding, basis, and an options structure for bootstrapping. For example, you are passing in an “@IRBootstrapOptions” object which includes information for the `ConvexityAdjustment` to forward rates.

```

IRsigma = .01;
CurveSettle = datenum('08/10/2007');
bootModel = IRDataCurve.bootstrap('Forward', CurveSettle, ...
    InstrumentTypes, Instruments, 'InterpMethod', 'pchip', ...
    'Compounding', -1, 'IRBootstrapOptions', ...
    IRBootstrapOptions('ConvexityAdjustment', @(t) .5*IRsigma^2.*t.^2))

```

```
bootModel =
```

```
IRDataCurve
```

```

Type: Forward
Settle: 733264 (10-Aug-2007)

```

```

Compounding: -1
Basis: 0 (actual/actual)
InterpMethod: pchip
Dates: [29x1 double]
Data: [29x1 double]

```

The **bootstrap** method uses an Optimization Toolbox function to solve for any bootstrapped rates.

Plot the forward and zero curves:

```

PlottingDates = (CurveSettle+20:30:CurveSettle+365*25)';
TimeToMaturity = yearfrac(CurveSettle,PlottingDates);
BootstrappedForwardRates = getForwardRates(bootModel, PlottingDates);
BootstrappedZeroRates = getZeroRates(bootModel, PlottingDates);

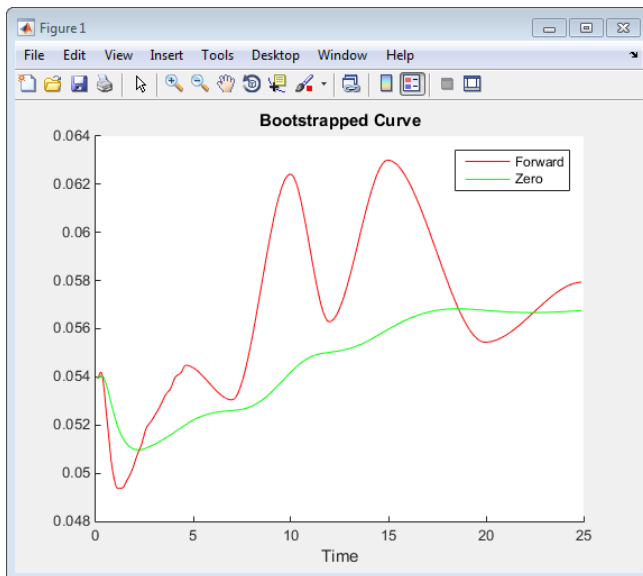
```

```

figure
hold on
plot(TimeToMaturity,BootstrappedForwardRates,'r')
plot(TimeToMaturity,BootstrappedZeroRates,'g')
title('Bootstrapped Curve')
xlabel('Time')
legend({'Forward','Zero'})

```

The plot demonstrates the forward and zero rate curves for the market data.



## Example 2

In this example, you bootstrap a swap curve from deposits, Eurodollar futures and swaps. The input market data for this example is hard-coded and specified as two cell arrays of data; one cell array indicates the type of instrument and the other cell array contains the `Settle`, `Maturity` values and a market quote for the instrument. This example of bootstrapping also demonstrates the use of an `InstrumentBasis` for each `Instrument` type:

```
InstrumentTypes = {'Deposit';'Deposit';...
'Futures';'Futures';'Futures';'Futures';'Futures';'Futures';...
'Swap';'Swap';'Swap';'Swap';};

Instruments = [datenum('08/10/2007'),datenum('09/17/2007'),.0532000; ...
datenum('08/10/2007'),datenum('11/17/2007'),.0535866; ...
datenum('08/08/2007'),datenum('19-Dec-2007'),9485; ...
datenum('08/08/2007'),datenum('19-Mar-2008'),9502; ...
datenum('08/08/2007'),datenum('18-Jun-2008'),9509.5; ...
datenum('08/08/2007'),datenum('17-Sep-2008'),9509; ...
datenum('08/08/2007'),datenum('17-Dec-2008'),9505.5; ...
datenum('08/08/2007'),datenum('18-Mar-2009'),9501; ...
datenum('08/08/2007'),datenum('08/08/2014'),.0530; ...
datenum('08/08/2007'),datenum('08/08/2019'),.0551; ...
datenum('08/08/2007'),datenum('08/08/2027'),.0565; ...
datenum('08/08/2007'),datenum('08/08/2037'),.0566];

CurveSettle = datenum('08/10/2007');
```

The `bootstrap` method is called as a static method of the “@IRDataCurve” class. Inputs to this method include the curve `Type` (zero or forward), `Settle` date, `InstrumentTypes`, and `Instrument` data. The `bootstrap` method also supports optional arguments, including an interpolation method, compounding, basis, and an options structure for bootstrapping. In this example, you are passing an additional `Basis` value for each instrument type:

```
bootModel=IRDataCurve.bootstrap('Forward',CurveSettle,InstrumentTypes, ...
Instruments,'InterpMethod','pchip','InstrumentBasis',[repmat(2,8,1);repmat(0,4,1)])
```

```
bootModel =
```

```
IRDataCurve
```

```
    Type: Forward
    Settle: 733264 (10-Aug-2007)
    Compounding: 2
    Basis: 0 (actual/actual)
    InterpMethod: pchip
    Dates: [12x1 double]
```



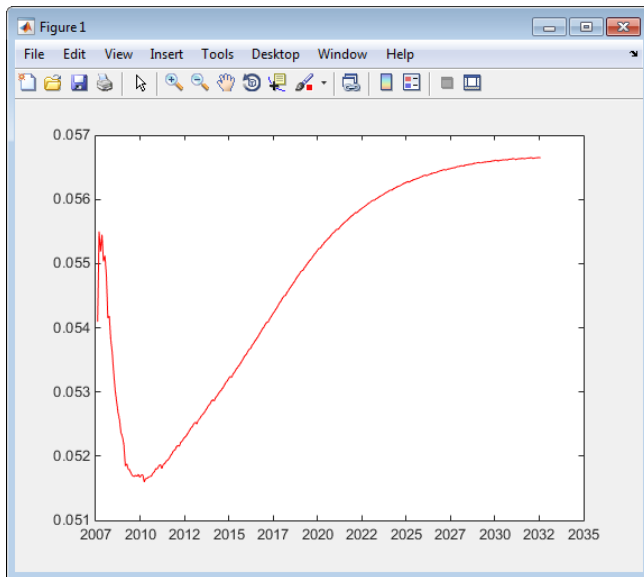
```
Data: [12x1 double]
```

The **bootstrap** method uses an Optimization Toolbox function to solve for any bootstrapped rates.

Plot the par yields curve using the **getParYields** method:

```
PlottingDates = (datenum('08/11/2007'):30:CurveSettle+365*25)';  
plot(PlottingDates, getParYields(bootModel, PlottingDates), 'r')  
datetick
```

The plot demonstrates the par yields curve for the market data.



## Bootstrapping a Swap Curve

This example shows how to bootstrap an interest rate curve, often referred to as a swap curve, using the new `IRDataCurve` object. The static `bootstrap` method takes as inputs a cell array of market instruments (which can be deposits, interest rate futures, swaps, and bonds) and bootstraps an interest rate curve of either the forward or the zero curve. It is also possible to specify multiple interpolation methods, including piecewise constant, linear, and Piecewise Cubic Hermite Interpolating Polynomial (PCHIP)

### Obtain Data

A curve is bootstrapped from market data. In this example, we will bootstrap a swap curve from deposits, Eurodollar Futures and swaps.

For this example, we have hard-coded the input market data, which is simply specified as 2 cell arrays of data, one which indicates the type of instrument and a second cell array containing the `Settle`, `Maturity`, and `Market Quote` for the instrument. For deposits and swaps, the quote is a rate and for the EuroDollar Futures, the quote is a price. Although bonds are not used in this example, a bond would be quoted with a price.

```
InstrumentTypes = {'Deposit'; 'Deposit'; 'Deposit'; 'Deposit'; 'Deposit'; ...
    'Futures'; 'Futures'; ...
    'Futures'; 'Futures'; 'Futures'; ...
    'Futures'; 'Futures'; 'Futures'; ...
    'Futures'; 'Futures'; 'Futures'; ...
    'Futures'; 'Futures'; 'Futures'; ...
    'Swap'; 'Swap'; 'Swap'; 'Swap'; 'Swap'; 'Swap'; 'Swap' };

Instruments = [datenum('08/10/2007'), datenum('08/17/2007'), .0532063; ...
    datenum('08/10/2007'), datenum('08/24/2007'), .0532000; ...
    datenum('08/10/2007'), datenum('09/17/2007'), .0532000; ...
    datenum('08/10/2007'), datenum('10/17/2007'), .0534000; ...
    datenum('08/10/2007'), datenum('11/17/2007'), .0535866; ...
    datenum('08/08/2007'), datenum('19-Dec-2007'), 9485; ...
    datenum('08/08/2007'), datenum('19-Mar-2008'), 9502; ...
    datenum('08/08/2007'), datenum('18-Jun-2008'), 9509.5; ...
    datenum('08/08/2007'), datenum('17-Sep-2008'), 9509; ...
    datenum('08/08/2007'), datenum('17-Dec-2008'), 9505.5; ...
    datenum('08/08/2007'), datenum('18-Mar-2009'), 9501; ...
    datenum('08/08/2007'), datenum('17-Jun-2009'), 9494.5; ...
    datenum('08/08/2007'), datenum('16-Sep-2009'), 9489; ...
    datenum('08/08/2007'), datenum('16-Dec-2009'), 9481.5; ...
```

```

datenum('08/08/2007'),datenum('17-Mar-2010'),9478; ...
datenum('08/08/2007'),datenum('16-Jun-2010'),9474; ...
datenum('08/08/2007'),datenum('15-Sep-2010'),9469.5; ...
datenum('08/08/2007'),datenum('15-Dec-2010'),9464.5; ...
datenum('08/08/2007'),datenum('16-Mar-2011'),9462.5; ...
datenum('08/08/2007'),datenum('15-Jun-2011'),9456.5; ...
datenum('08/08/2007'),datenum('21-Sep-2011'),9454; ...
datenum('08/08/2007'),datenum('21-Dec-2011'),9449.5; ...
datenum('08/08/2007'),datenum('08/08/2014'),.0530; ...
datenum('08/08/2007'),datenum('08/08/2017'),.0545; ...
datenum('08/08/2007'),datenum('08/08/2019'),.0551; ...
datenum('08/08/2007'),datenum('08/08/2022'),.0559; ...
datenum('08/08/2007'),datenum('08/08/2027'),.0565; ...
datenum('08/08/2007'),datenum('08/08/2032'),.0566; ...
datenum('08/08/2007'),datenum('08/08/2037'),.0566];

```

### Construct the Curve via Bootstrapping

The bootstrap method is called as a static method of the `IRDataCurve` class. Inputs to this method include the curve type (Zero or Forward), settle date, instrument types, instrument data and optional arguments including an interpolation method, compounding and an options structure for bootstrapping. Note that in this example, we are passing in an `IRBootstrapOptions` object which includes information for the convexity adjustment to forward rates.

```

IRsigma = .01;
CurveSettle = datenum('08/10/2007');
bootModel = IRDataCurve.bootstrap('Forward', CurveSettle, ...
    InstrumentTypes, Instruments, 'InterpMethod', 'pchip', ...
    'Compounding', -1, 'IRBootstrapOptions', ...
    IRBootstrapOptions('ConvexityAdjustment', @(t) .5*IRsigma^2.*t.^2));

```

### Plot

We can now plot both the forward and zero curves

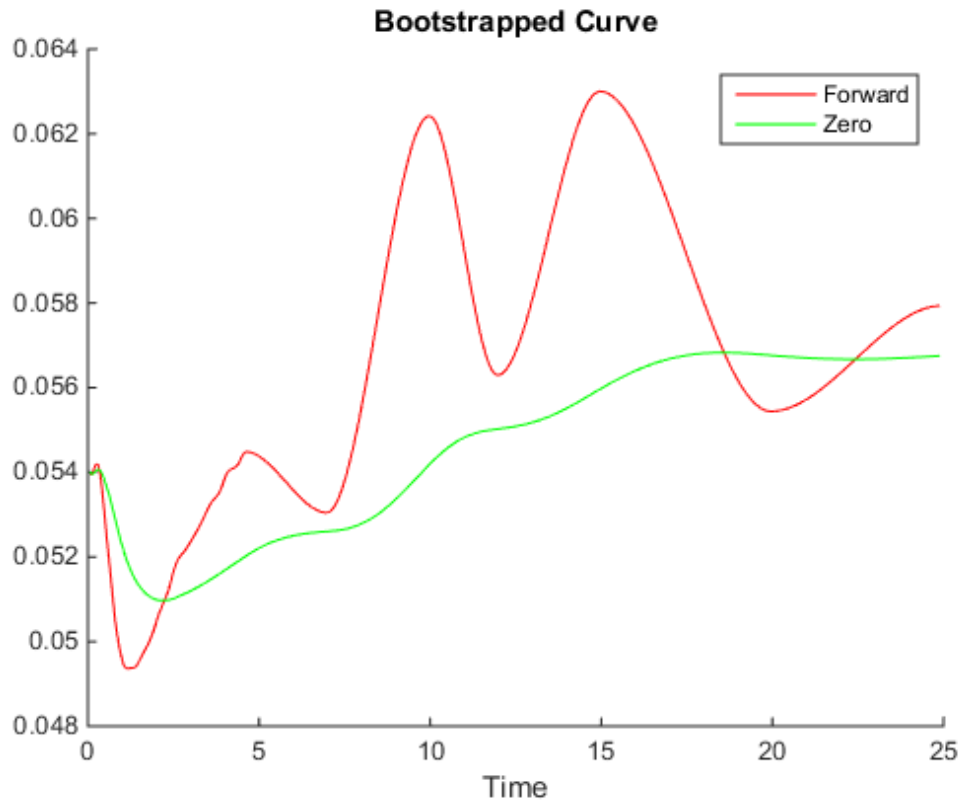
```

PlottingDates = (CurveSettle+20:30:CurveSettle+365*25)';
TimeToMaturity = yearfrac(CurveSettle,PlottingDates);
BootstrappedForwardRates = bootModel.getForwardRates(PlottingDates);
BootstrappedZeroRates = bootModel.getZeroRates(PlottingDates);

figure
hold on
plot(TimeToMaturity,BootstrappedForwardRates,'r')

```

```
plot(TimeToMaturity,BootstrappedZeroRates,'g')
title('Bootstrapped Curve')
xlabel('Time')
legend({'Forward','Zero'})
```



## Bibliography

This example draws from the following papers and journal articles:

- [1] Hagan, P., West, G. (2006), "Interpolation Methods for Curve Construction", Applied Mathematical Finance, Vol 13, No. 2
- [2] Ron, Uri(2000), "A Practical Guide to Swap Curve Construction", Working Papers 00-17, Bank of Canada.

# Dual Curve Bootstrapping

This example shows how to bootstrap a forward curve using a different curve for discounting.

## Define the Data

Data is needed for both the forward and discount curve. For this particular example, it is assumed that the data is provided for EONIA (the discount curve) and EURIBOR (the forward curve). However, this approach can be used in any case where the curve to be built is different than the curve used for discounting cash flows. While the data in this example is hardcoded, it could also be imported into MATLAB with Datafeed Toolbox™ or Database Toolbox™.

```
Settle = datenum('20-Aug-2013');

% Deposit data
EONIADepositRates = [.0007 .00067]';
EONIADepositMat = datenum({'3-Sep-2013', '20-Sep-2013'});
EONIADepositBasis = 2; % act/360
EONIADepositPeriod = 0;

% FRA
EONIAFRARates = [.00025 .0003 .00043 .00054]';
EONIAFRASStartDate = datenum({'11-Sep-2013', '9-Oct-2013', '13-Nov-2013', '11-Dec-2013'});
EONIAFRAEndDate = datenum({'9-Oct-2013', '13-Nov-2013', '11-Dec-2013', '11-Jan-2014'});
EONIAFRABasis = 2; % act/360
EONIAFRAPeriod = 0;

% Swap data
EONIASwapRates = [.0003 .001 .002 .004 .008 .012 .0155 .018 .0193 .02]';
EONIASwapMat = datemnth(Settle, 12*[2:5 7 10 15 20 25 30]');
EONIASwapBasis = 5; % 30/360 ISDA
EONIASwapPeriod = 1;

% EURIBOR Deposit data
EURIBORDepositRates = [.0022 .0021 .002 .0019]';
EURIBORDepositMat = datenum({'3-Sep-2013', '20-Sep-2013', '21-Oct-2013', '20-Nov-2013'});
EURIBORDepositBasis = 2; % act/360
EURIBORDepositPeriod = 0;

% EURIBOR Futures
EURIBORFRARates = [9982 9978 9976 9975]';
EURIBORFRASStartDate = datenum({'18-Dec-2013', '19-Mar-2014', '18-Jun-2014', '17-Sep-2014'});
EURIBORFRAEndDate = datenum({'18-Mar-2014', '19-Jun-2014', '18-Sep-2014', '17-Dec-2014'});
EURIBORFRABasis = 2; % act/360
EURIBORFRAPeriod = 4;

% EURIBOR Swap data
EURIBORSwapRates = [.0026 .0044 .0062 .0082 .012 .015 .018 .02 .021 .0215]';
EURIBORSwapMat = datemnth(Settle, 12*[2:5 7 10 15 20 25 30]');
EURIBORSwapBasis = 5; % 30/360 ISDA
EURIBORSwapPeriod = 1;
```

## Construct a EONIA Discount Curve

Build the EONIA curve. This is essentially the same as the single curve case.

```
CurveType = 'zero';
CurveCompounding = 1;
CurveBasis = 3; % act/365

nEONIADeposits = length(EONIADepositMat);
nEONIAFRA = length(EONIAFRAEndDate);
nEONIASwaps = length(EONIASwapMat);

EONIAInstrumentTypes = [ repmat({'deposit'},nEONIADeposits,1);
    repmat({'fra'},nEONIAFRA,1);repmat({'swap'},nEONIASwaps,1)];

EONIAPeriod = [ repmat(EONIADepositPeriod,nEONIADeposits,1);
    repmat(EONIAFRAPeriod,nEONIAFRA,1);repmat(EONIASwapPeriod,nEONIASwaps,1)];

EONIABasis = [ repmat(EONIADepositBasis,nEONIADeposits,1);
    repmat(EONIAFRABasis,nEONIAFRA,1);repmat(EONIASwapBasis,nEONIASwaps,1)];

EONIAInstrumentData = [[ repmat(Settle,[nEONIADeposits 1]);EONIAFRAStartDate;repmat(Settle,[nEONIASwaps 1])] ...
    [EONIADepositMat;EONIAFRAEndDate;EONIASwapMat] ...
    [EONIADepositRates;EONIAFRARates;EONIASwapRates]];

EONIACurve = IRDataCurve.bootstrap(CurveType,Settle,EONIAInstrumentTypes,...
    EONIAInstrumentData,'Compounding',CurveCompounding,'Basis',CurveBasis,...
    'InstrumentPeriod',EONIAPeriod,'InstrumentBasis',EONIABasis)

EONIACurve =

    Type: zero
    Settle: 735466 (20-Aug-2013)
    Compounding: 1
    Basis: 3 (actual/365)
    InterpMethod: linear
    Dates: [16x1 double]
    Data: [16x1 double]
```

## Construct a EURIBOR Forward Curve

The EURIBOR forward curve is built first using a single curve approach.

```
nEURIBORDeposits = length(EURIBORDepositMat);
nEURIBORFRA = length(EURIBORFRAEndDate);
nEURIBORSwaps = length(EURIBORSwapMat);

EURIBORInstrumentTypes = [ repmat({'deposit'},nEURIBORDeposits,1);
    repmat({'futures'},nEURIBORFRA,1);repmat({'swap'},nEURIBORSwaps,1)];

EURIBORPeriod = [ repmat(EURIBORDepositPeriod,nEURIBORDeposits,1);
    repmat(EURIBORFRAPeriod,nEURIBORFRA,1);repmat(EURIBORSwapPeriod,nEURIBORSwaps,1)];

EURIBORBasis = [ repmat(EURIBORDepositBasis,nEURIBORDeposits,1);
    repmat(EURIBORFRABasis,nEURIBORFRA,1);repmat(EURIBORSwapBasis,nEURIBORSwaps,1)];
```

```

EURIBORInstrumentData = [ repmat(Settle, size(EURIBORInstrumentTypes)) ...
    [EURIBORDepositMat; EURIBORFRAEndDate; EURIBORSwapMat] ...
    [EURIBORDepositRates; EURIBORFRARates; EURIBORSwapRates]];

EURIBORCurve_Single = IRDataCurve.bootstrap(CurveType, Settle, EURIBORInstrumentTypes, ...
    EURIBORInstrumentData, 'Compounding', CurveCompounding, 'Basis', CurveBasis, ...
    'InstrumentPeriod', EURIBORPeriod, 'InstrumentBasis', EURIBORBasis)

EURIBORCurve_Single =

    Type: zero
    Settle: 735466 (20-Aug-2013)
    Compounding: 1
    Basis: 3 (actual/365)
    InterpMethod: linear
    Dates: [18x1 double]
    Data: [18x1 double]

```

### Build the EURIBOR Curve with the EONIA Curve

Next, build a curve using the EONIA curve as a discounting curve. To do this, specify the EONIA curve as an optional input argument.

```

EURIBORCurve = IRDataCurve.bootstrap(CurveType, Settle, EURIBORInstrumentTypes, ...
    EURIBORInstrumentData, 'DiscountCurve', EONIACurve, 'Compounding', ...
    CurveCompounding, 'Basis', CurveBasis, 'InstrumentPeriod', EURIBORPeriod, ...
    'InstrumentBasis', EURIBORBasis)

EURIBORCurve =

    Type: zero
    Settle: 735466 (20-Aug-2013)
    Compounding: 1
    Basis: 3 (actual/365)
    InterpMethod: linear
    Dates: [18x1 double]
    Data: [18x1 double]

```

### Plot the Results

Plot the results to compare the curves.

```

PlottingDates = (Settle+20:30:Settle+365*30)';
TimeToMaturity = yearfrac(Settle, PlottingDates);

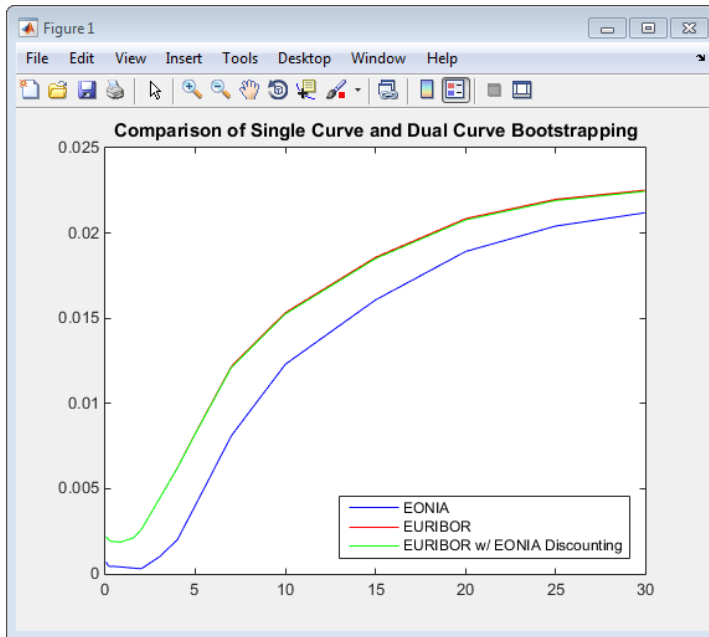
figure
plot(TimeToMaturity, getZeroRates(EONIACurve, PlottingDates), 'b')
hold on
plot(TimeToMaturity, getZeroRates(EURIBORCurve_Single, PlottingDates), 'r')

```

```

plot(TimeToMaturity, getZeroRates(EURIBORCurve, PlottingDates), 'g')
title('Comparison of Single Curve and Dual Curve Bootstrapping')
legend({'EONIA', 'EURIBOR', 'EURIBOR w/ EONIA Discounting'}, 'location', 'southeast')

```



As expected, the difference between the two different EURIBOR curves is small but nontrivial.

## Bibliography

This example draws from the following papers and journal articles:

- [1] Ametrano, F and Bianchetti, M., *Everything You Always Wanted to Know About Multiple Interest Rate Curve Bootstrapping but Were Afraid to Ask*, (April 2, 2013), available at: <http://ssrn.com/abstract=2219548>.
- [2] Bianchetti, M., *Two Curves, One Price*, Risk Magazine, pages 74-80, August 2010.
- [3] Fujii, M, Shimada, Y, Takahashi, A., *A Note on Construction of Multiple Swap Curves with and without Collateral*, (January 2, 2010), CARF Working Paper Series No. CARF-F-154, available at: <http://ssrn.com/abstract=1440633>.



[4] Mercurio, Fabio, *Interest Rates and The Credit Crunch: New Formulas and Market Models*, (February 5, 2009), Bloomberg Portfolio Research Paper No. 2010-01-FRONTIERS.

[5] Nashikkar, A., *Understanding OIS Discounting*, Barclays Capital Interest Rate Strategy, February 24, 2011.

### **See Also**

`bootstrap` | `floatbyzero` | `getZeroRates` | `IRDataCurve` | `swapbyzero`

## Creating an IRFunctionCurve Object

### In this section...

“Fitting IRFunctionCurve Object Using a Function Handle” on page 9-20

“Fitting IRFunctionCurve Object Using Nelson-Siegel Method” on page 9-20

“Fitting IRFunctionCurve Object Using Svensson Method” on page 9-22

“Fitting IRFunctionCurve Object Using Smoothing Spline Method” on page 9-24

“Using fitFunction to Create Custom Fitting Function” on page 9-27

### Fitting IRFunctionCurve Object Using a Function Handle

You can use the constructor `IRFunctionCurve` with a MATLAB function handle to define an interest-rate curve. For more information on defining a function handle, see the MATLAB Programming Fundamentals documentation.

#### Example

This example uses a `FunctionHandle` argument with a value `@(t) t.^2` to construct an interest-rate curve:

```
rr = IRFunctionCurve('Zero',today,@(t) t.^2)
```

```
rr =
```

```
Properties:
  FunctionHandle: @(t)t.^2
             Type: 'Zero'
             Settle: 733600
             Compounding: 2
             Basis: 0
```

### Fitting IRFunctionCurve Object Using Nelson-Siegel Method

Use the method, `fitNelsonSiegel`, for the Nelson-Siegel model that fits the empirical form of the yield curve with a prespecified functional form of the spot rates which is a function of the time to maturity of the bonds.

The Nelson-Siegel model represents a dynamic three-factor model: level, slope, and curvature. However, the Nelson-Siegel factors are unobserved, or latent, which allows

for measurement error, and the associated loadings have economic restrictions (forward rates are always positive, and the discount factor approaches zero as maturity increases). For more information, see “Zero-coupon yield curves: technical documentation,” *BIS Papers*, Bank for International Settlements, Number 25, October, 2005.

### Example

This example uses `IRFunctionCurve` to model the default-free term structure of interest rates in the United Kingdom.

Load the data:

```
load ukdata20080430
```

Convert repo rates to be equivalent zero coupon bonds:

```
RepoCouponRate = repmat(0,size(RepoRates));
RepoPrice = bndprice(RepoRates, RepoCouponRate, RepoSettle, RepoMaturity);
```

Aggregate the data:

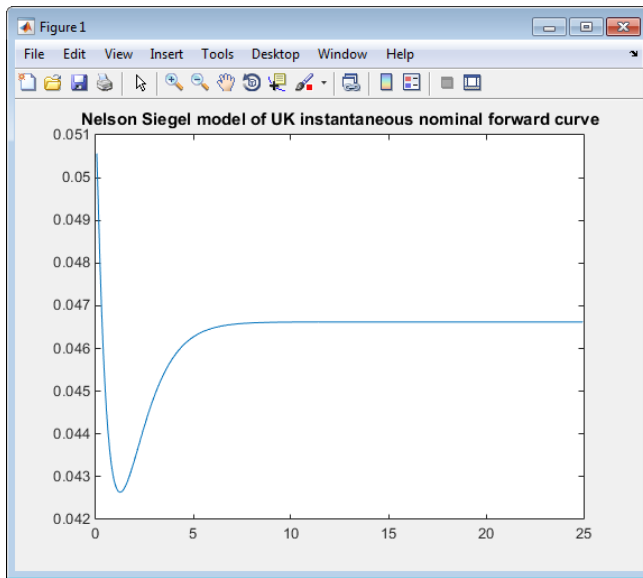
```
Settle = [RepoSettle;BondSettle];
Maturity = [RepoMaturity;BondMaturity];
CleanPrice = [RepoPrice;BondCleanPrice];
CouponRate = [RepoCouponRate;BondCouponRate];
Instruments = [Settle Maturity CleanPrice CouponRate];
InstrumentPeriod = [repmat(0,6,1);repmat(2,31,1)];
CurveSettle = datenum('30-Apr-2008');
```

The `IRFunctionCurve` object provides the capability to fit a Nelson-Siegel curve to observed market data with the `fitNelsonSiegel` method. The fitting is done by calling the Optimization Toolbox function `lsqnonlin`. This method has required inputs of `Type`, `Settle`, and a matrix of instrument data.

```
NSModel = IRFunctionCurve.fitNelsonSiegel('Zero',CurveSettle,...
Instruments,'Compounding',-1,'InstrumentPeriod',InstrumentPeriod);
```

Plot the Nelson-Siegel interest-rate curve for forward rates:

```
PlottingDates = CurveSettle+20:30:CurveSettle+365*25;
TimeToMaturity = yearfrac(CurveSettle,PlottingDates);
NSForwardRates = getForwardRates(NSModel, PlottingDates);
plot(TimeToMaturity,NSForwardRates)
title('Nelson Siegel model of UK instantaneous nominal forward curve')
```



## Fitting IRFunctionCurve Object Using Svensson Method

Use the method, `fitSvensson`, for the Svensson model to improve the flexibility of the curves and the fit for a Nelson-Siegel model. In 1994, Svensson extended Nelson and Siegel's function by adding a further term that allows for a second “hump.” The extra precision is achieved at the cost of adding two more parameters,  $\beta_3$  and  $\tau_2$ , which have to be estimated.

### Example

In this example of using the `fitSvensson` method, an `IRFitOptions` structure, previously defined using the `IRFitOptions` constructor, is used. Thus, you must specify `FitType`, `InitialGuess`, `UpperBound`, `LowerBound`, and the `OptOptions` optimization parameters for `lsqnonlin`.

Load the data:

```
load ukdata20080430
```

Convert repo rates to be equivalent zero coupon bonds:

```
RepoCouponRate = repmat(0,size(RepoRates));
RepoPrice = bndprice(RepoRates, RepoCouponRate, RepoSettle, RepoMaturity);
```

Aggregate the data:

```
Settle = [RepoSettle;BondSettle];
Maturity = [RepoMaturity;BondMaturity];
CleanPrice = [RepoPrice;BondCleanPrice];
CouponRate = [RepoCouponRate;BondCouponRate];
Instruments = [Settle Maturity CleanPrice CouponRate];
InstrumentPeriod = [repmat(0,6,1);repmat(2,31,1)];
CurveSettle = datenum('30-Apr-2008');
```

Define OptOptions for the IRFitOptions constructor:

```
OptOptions = optimoptions('lsqnonlin','MaxFunEvals',1000);
fIRFitOptions = IRFitOptions([5.82 -2.55 -.87 0.45 3.9 0.44],...
'FitType','durationweightedprice','OptOptions',OptOptions,...
'LowerBound',[0 -Inf -Inf -Inf 0 0],'UpperBound',[Inf Inf Inf Inf Inf Inf]);
```

Fit the interest-rate curve using a Svensson model:

```
SvenssonModel = IRFunctionCurve.fitSvensson('Zero',CurveSettle,...
Instruments,'IRFitOptions', fIRFitOptions, 'Compounding',-1,...
'InstrumentPeriod',InstrumentPeriod)
```

Local minimum possible.

lsqnonlin stopped because the final change in the sum of squares relative to its initial value is less than the default value of the function tolerance.

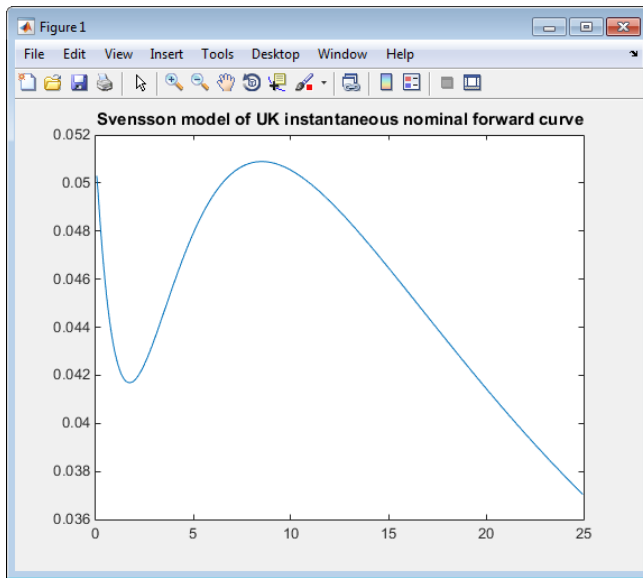
SvenssonModel =

```
    Type: Zero
    Settle: 733528 (30-Apr-2008)
    Compounding: -1
    Basis: 0 (actual/actual)
```

The status message, output from `lsqnonlin`, indicates that the optimization to find parameters for the Svensson equation terminated successfully.

Plot the Svensson interest-rate curve for forward rates:

```
PlottingDates = CurveSettle+20:30:CurveSettle+365*25;
TimeToMaturity = yearfrac(CurveSettle,PlottingDates);
SvenssonForwardRates = getForwardRates(SvenssonModel, PlottingDates);
plot(TimeToMaturity,SvenssonForwardRates)
title('Svensson model of UK instantaneous nominal forward curve')
```



## Fitting IRFunctionCurve Object Using Smoothing Spline Method

Use the method, `fitSmoothingSpline`, to model the term structure with a spline, specifically, the term structure represents the forward curve with a cubic spline.

---

**Note:** You must have a license for Curve Fitting Toolbox software to use the `fitSmoothingSpline` method.

---

### Example

The `IRFunctionCurve` object is used to fit a smoothing spline representation of the forward curve with a penalty function. Required inputs are `Type`, `Settle`, the matrix of `Instruments`, and `LambdaFun`, a function handle containing the penalty function

Load the data:

```
load ukdata20080430
```

Convert repo rates to be equivalent zero coupon bonds:

```
RepoCouponRate = repmat(0,size(RepoRates));  
RepoPrice = bndprice(RepoRates, RepoCouponRate, RepoSettle, RepoMaturity);
```

Aggregate the data:

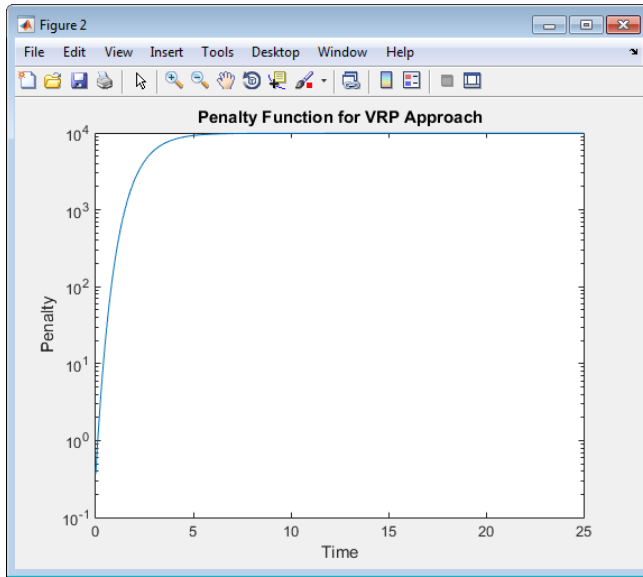
```
Settle = [RepoSettle;BondSettle];  
Maturity = [RepoMaturity;BondMaturity];  
CleanPrice = [RepoPrice;BondCleanPrice];  
CouponRate = [RepoCouponRate;BondCouponRate];  
Instruments = [Settle Maturity CleanPrice CouponRate];  
InstrumentPeriod = [repmat(0,6,1);repmat(2,31,1)];  
CurveSettle = datenum('30-Apr-2008');
```

Choose parameters for Lambdafun:

```
L = 9.2;  
S = -1;  
mu = 1;
```

Define the Lambdafun penalty function:

```
lambdafun = @(t) exp(L - (L-S)*exp(-t/mu));  
t = 0:.1:25;  
y = lambdafun(t);  
figure  
semilogy(t,y);  
title('Penalty Function for VRP Approach')  
ylabel('Penalty')  
xlabel('Time')
```



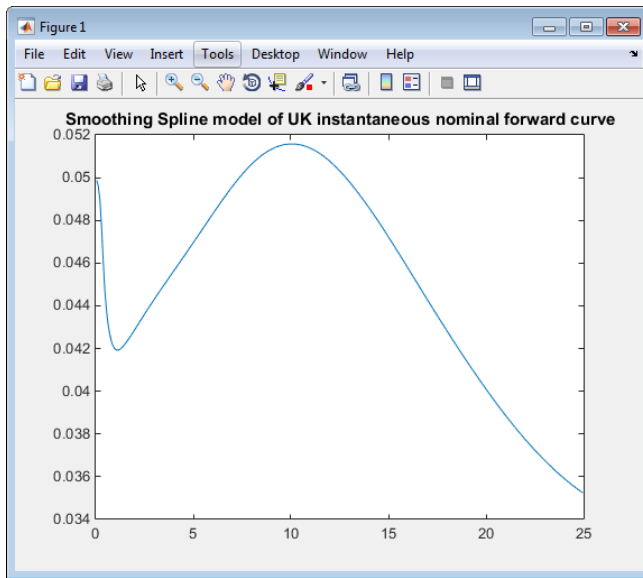
Use the `fitSmoothingSpline` method to fit the interest-rate curve and model the `Lambdafun` penalty function:

```
VRPModel = IRFunctionCurve.fitSmoothingSpline('Forward',CurveSettle,...
Instruments,lambdafun,'Compounding',-1, 'InstrumentPeriod',InstrumentPeriod);
```

Plot the smoothing spline interest-rate curve for forward rates:

```
PlottingDates = CurveSettle+20:30:CurveSettle+365*25;
TimeToMaturity = yearfrac(CurveSettle,PlottingDates);
VRPForwardRates = getForwardRates(VRPModel, PlottingDates);
plot(TimeToMaturity,VRPForwardRates)
title('Smoothing Spline model of UK instantaneous nominal forward curve')
```





## Using fitFunction to Create Custom Fitting Function

When using an `IRFunctionCurve` object, you can create a custom fitting function with the `fitFunction` method. To use `fitFunction`, you must define a `FunctionHandle`. In addition, you must also use the constructor `IRFitOptions` to define `IRFitOptionsObj` to support an `InitialGuess` for the parameters of the curve function.

### Example

The following example demonstrates the use of `fitFunction` with a `FunctionHandle` and an `IRFitOptionsObj`:

```
Settle = repmat(datenum('30-Apr-2008'),[6 1]);
Maturity = [datenum('07-Mar-2009');datenum('07-Mar-2011');...
datenum('07-Mar-2013');datenum('07-Sep-2016');...
datenum('07-Mar-2025');datenum('07-Mar-2036')];

CleanPrice = [100.1;100.1;100.8;96.6;103.3;96.3];
CouponRate = [0.0400;0.0425;0.0450;0.0400;0.0500;0.0425];
Instruments = [Settle Maturity CleanPrice CouponRate];
CurveSettle = datenum('30-Apr-2008');
```

Define the FunctionHandle:

```
functionHandle = @(t,theta) polyval(theta,t);
```

Define the OptOptions for IRFitOptions:

```
OptOptions = optimoptions('lsqnonlin','display','iter');
```

Define fitFunction:

```
CustomModel = IRFunctionCurve.fitFunction('Zero', CurveSettle, ...
functionHandle, Instruments, IRFitOptions([.05 .05 .05], 'FitType','price',...
'OptOptions',OptOptions));
```

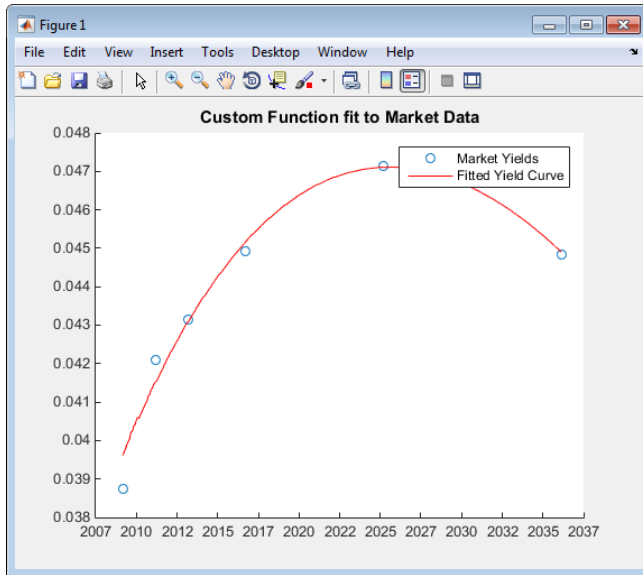
Iteration	Func-count	f(x)	Norm of step	First-order optimality	CG-iterations
0	4	38036.7		4.92e+04	
1	8	38036.7	10	4.92e+04	0
2	12	38036.7	2.5	4.92e+04	0
3	16	38036.7	0.625	4.92e+04	0
4	20	38036.7	0.15625	4.92e+04	0
5	24	30741.5	0.0390625	1.72e+05	0
6	28	30741.5	0.078125	1.72e+05	0
7	32	30741.5	0.0195312	1.72e+05	0
8	36	28713.6	0.00488281	2.33e+05	0
9	40	20323.3	0.00976562	9.47e+05	0
10	44	20323.3	0.0195312	9.47e+05	0
11	48	20323.3	0.00488281	9.47e+05	0
12	52	20323.3	0.0012207	9.47e+05	0
13	56	19698.8	0.000305176	1.08e+06	0
14	60	17493	0.000610352	7e+06	0
15	64	17493	0.0012207	7e+06	0
16	68	17493	0.000305176	7e+06	0
17	72	15455.1	7.62939e-05	2.25e+07	0
18	76	15455.1	0.000177499	2.25e+07	0
19	80	13317.1	3.8147e-05	3.18e+07	0
20	84	12865.3	7.62939e-05	7.83e+07	0
21	88	11779.8	7.62939e-05	7.58e+06	0
22	92	11747.6	0.000152588	1.45e+05	0
23	96	11720.9	0.000305176	2.33e+05	0
24	100	11667.2	0.000610352	1.48e+05	0
25	104	11558.6	0.0012207	3.55e+05	0
26	108	11335.5	0.00244141	1.57e+05	0
27	112	10863.8	0.00488281	6.36e+05	0
28	116	9797.14	0.00976562	2.53e+05	0
29	120	6882.83	0.0195312	9.18e+05	0
30	124	6882.83	0.0373993	9.18e+05	0
31	128	3218.45	0.00934981	1.96e+06	0
32	132	612.703	0.0186996	3.01e+06	0
33	136	13.0998	0.0253882	3.05e+06	0
34	140	0.0762922	0.00154002	5.05e+04	0
35	144	0.0731652	3.61102e-06	29.9	0
36	148	0.0731652	6.32335e-08	0.063	0

Local minimum possible.

lsqnonlin stopped because the final change in the sum of squares relative to its initial value is less than the default value of the function tolerance.

Plot the custom function that is defined using fitFunction:

```
Yields = bndyield(CleanPrice,CouponRate,Settle(1),Maturity);  
scatter(Maturity,Yields);  
PlottingPoints = min(Maturity):30:max(Maturity);  
hold on;  
plot(PlottingPoints, getParYields(CustomModel, PlottingPoints),'r');  
datetick  
legend('Market Yields','Fitted Yield Curve')  
title('Custom Function fit to Market Data')
```



## Fitting Interest Rate Curve Functions

This example shows how to use objects to model the term structure of interest rates (also referred to as the yield curve). This can be contrasted with modeling the term structure with vectors of dates and data and interpolating between the points (which can currently be done with the function `PRBYZERO`).

The term structure can refer to at least three different curves: the discount curve, zero curve, or forward curve.

The new object `IRFunctionCurve` allows the user to model an interest rate curve as a function.

This example will explore using `IRFunctionCurve` to model the default-free term structure of interest rates in the United Kingdom. Three different forms for the term structure will be implemented, which will be discussed in more detail later:

- Nelson-Siegel
- Svensson
- Smoothing Cubic Spline with a so-called Variable Roughness Penalty (VRP)

### Choosing the Data

The first question in modeling the yield curve is what data should be used. To model a default-free yield curve, default-free, option-free market instruments must be used. The most significant component of the data set will be UK Government Bonds (known as Gilts). Historical data was retrieved from the following site:

<http://www.dmo.gov.uk>

Repo data will be used to construct the short end of the curve. Repo data was retrieved from the following site:

<http://www.bba.org.uk>

Note also that the data must be specified as a matrix where the columns are `Settle`, `Maturity`, `CleanPrice` and `CouponRate` -- and that instruments must be bonds or synthetically converted to bonds.

Market data for a close date of April 30, 2008, has been downloaded and saved to the following data file, which can be loaded into MATLAB® with the following command

```

% Load the data
load ukdata20080430

% Convert repo rates to be equivalent zero coupon bonds
RepoCouponRate = repmat(0,size(RepoRates));
RepoPrice = bndprice(RepoRates, RepoCouponRate, RepoSettle, RepoMaturity);

% Aggregate the data
Settle = [RepoSettle;BondSettle];
Maturity = [RepoMaturity;BondMaturity];
CleanPrice = [RepoPrice;BondCleanPrice];
CouponRate = [RepoCouponRate;BondCouponRate];
Instruments = [Settle Maturity CleanPrice CouponRate];
InstrumentPeriod = [repmat(0,6,1);repmat(2,31,1)];

CurveSettle = datenum('30-Apr-2008');

```

### Fit Nelson-Siegel Model to Market Data

The Nelson-Siegel model proposes that the instantaneous forward curve can be modeled with the following:

$$f = \beta_0 + \beta_1 e^{-\frac{m}{\tau}} + \beta_2 e^{-\frac{m}{\tau}} \frac{m}{\tau}$$

This can be integrated to derive an equation for the zero curve (see [6] for more information on the equations and the derivation):

$$s = \beta_0 + (\beta_1 + \beta_2) \frac{\tau}{m} (1 - e^{-\frac{m}{\tau}}) - \beta_2 e^{-\frac{m}{\tau}}$$

See [1] for more information.

The IRFunctionCurve object provides the capability to fit a Nelson Siegel curve to observed market data with the FITNELSONSIEGEL method. The fitting is done by calling the Optimization Toolbox™ function LSQNONLIN.

This method has required inputs: Curve Type, Curve Settle, and a matrix of instrument data.

Optional input arguments, specified in parameter value pairs, are:

- IRFitOptions structure: Provides capability to choose which quantity to be minimized (price, yield, or duration weighted price) and other optimization parameters (e.g.: upper and lower bounds for parameters)
- Curve Compounding and Basis (Day Count Convention)
- Additional instrument parameters, Period, Basis, FirstCouponDate, etc.

```
NSModel = IRFunctionCurve.fitNelsonSiegel('Zero',CurveSettle,...
    Instruments,'InstrumentPeriod',InstrumentPeriod);
```

### Fit Svensson Model

A very similar model to the Nelson-Siegel is the Svensson model, which adds two additional parameters to account for greater flexibility in the term structure. This model proposes that the forward rate can be modeled with the following form:

$$f = \beta_0 + \beta_1 e^{-\frac{m}{\tau_1}} + \beta_2 e^{-\frac{m}{\tau_1}} \frac{m}{\tau_1} + \beta_3 e^{-\frac{m}{\tau_2}} \frac{m}{\tau_2}$$

As above, this can be integrated to derive an equation for the zero curve:

$$s = \beta_0 + \beta_1(1 - e^{-\frac{m}{\tau_1}})(-\frac{\tau_1}{m}) + \beta_2((1 - e^{-\frac{m}{\tau_1}})\frac{\tau_1}{m} - e^{-\frac{m}{\tau_1}}) + \beta_3((1 - e^{-\frac{m}{\tau_2}})\frac{\tau_2}{m} - e^{-\frac{m}{\tau_2}})$$

See [2] for more information.

Fitting the parameters to this model proceeds in a similar fashion to the Nelson-Siegel model.

```
SvenssonModel = IRFunctionCurve.fitSvensson('Zero',CurveSettle,...
    Instruments,'InstrumentPeriod',InstrumentPeriod);
```

### Fit Smoothing Spline

The term structure can also be modeled with a spline -- specifically, one way to model the term structure is by representing the forward curve with a cubic spline. To ensure that the spline is sufficiently smooth, a penalty is imposed relating to the curvature (second derivative) of the spline:

$$\sum_{i=1}^N \left[ \frac{P_i - \hat{P}_i(f)}{D_i} \right]^2 + \int_0^M \lambda_t(m) [f''(m)]^2 dm$$

where the first term is the difference between the observed price  $P$  and the predicted price,  $P_{\text{hat}}$ , (weighted by the bond's duration,  $D$ ) summed over all bonds in our data set and the second term is the penalty term (where  $\lambda$  is a penalty function and  $f$  is the spline)

See [3], [4], [5] below.

There have been different proposals for the specification of the penalty function  $\lambda$ . One approach, advocated by [4], and currently used by the UK Debt Management Office, is a penalty function of the following form:

$$\log(\lambda(m)) = L - (L - S)e^{-\frac{m}{\mu}}$$

The parameters  $L$ ,  $S$ , and  $\mu$  are typically estimated from historical data.

The `IRFunctionCurve` object can be used to fit a smoothing spline representation of the forward curve with a penalty function.

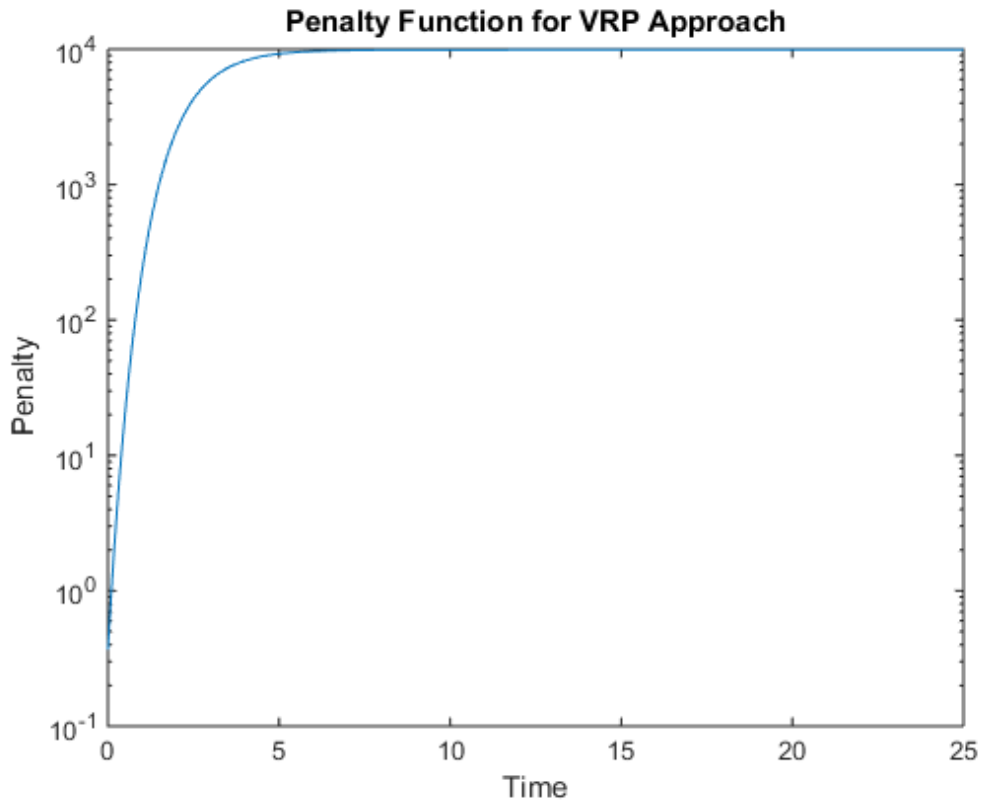
Required inputs, like for methods above, are a Curve Type, Curve Settle, Instrument matrix, and new for this method, a function handle containing the penalty function

Optional parameters are similar to `FITNELSONSIEGEL` and `FITSVENSSON`

```
% Parameters chosen to be roughly similar to [4] below.
L = 9.2;
S = -1;
mu = 1;

lambdafun = @(t) exp(L - (L-S)*exp(-t/mu)); % Construct penalty function
t = 0:.1:25; % Construct data to plot penalty function
y = lambdafun(t);
figure
semilogy(t,y);
title('Penalty Function for VRP Approach')
ylabel('Penalty')
xlabel('Time')

VRPModel = IRFunctionCurve.fitSmoothingSpline('Forward',CurveSettle,...
    Instruments,lambdafun,'Compounding',-1,...
    'InstrumentPeriod',InstrumentPeriod);
```



### Use Fitted Curves and Plot Results

Once a curve has been constructed, methods can be called to extract the Forward and Zero Rates and the Discount Factors. This curve can also be converted into a RateSpec structure, to be used with functions in the Financial Instruments Toolbox™

```
PlottingDates = CurveSettle+20:30:CurveSettle+365*25;
TimeToMaturity = yearfrac(CurveSettle,PlottingDates);

NSForwardRates = NSModel.getForwardRates(PlottingDates);
SvenssonForwardRates = SvenssonModel.getForwardRates(PlottingDates);
VRPForwardRates = VRPModel.getForwardRates(PlottingDates);
```

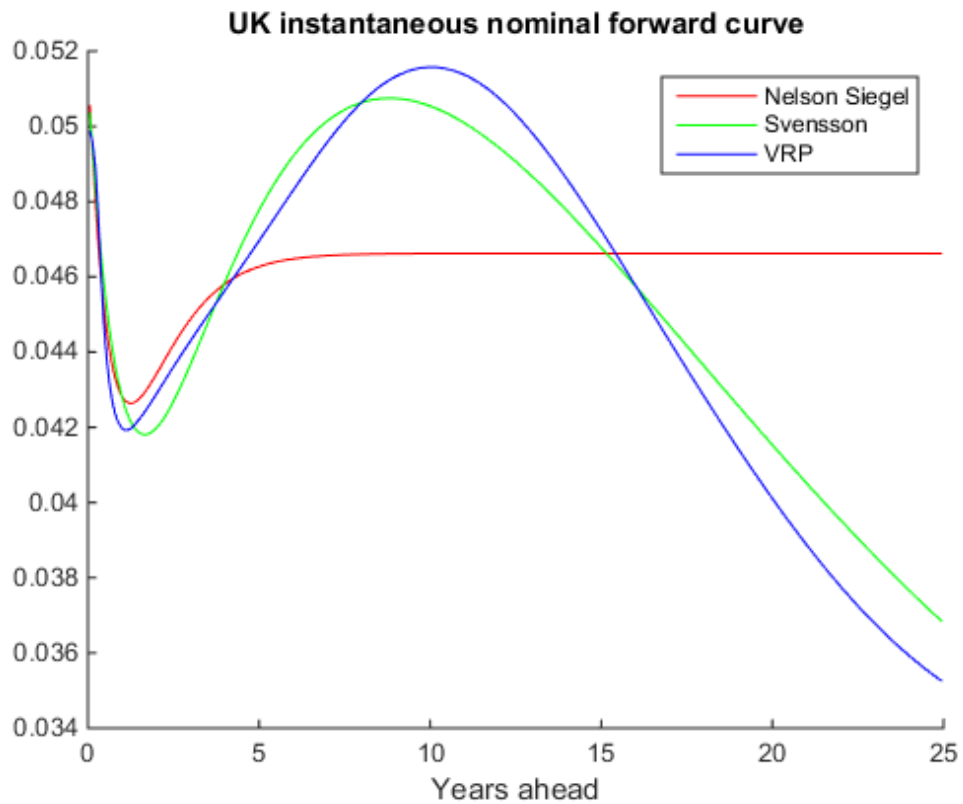
```
figure
```



```

hold on
plot(TimeToMaturity,NSForwardRates,'r')
plot(TimeToMaturity,SvenssonForwardRates,'g')
plot(TimeToMaturity,VRPForwardRates,'b')
title('UK instantaneous nominal forward curve')
xlabel('Years ahead')
legend({'Nelson Siegel', 'Svensson', 'VRP'})

```



### Compare with this Link

This link provides a live look at the derived yield curve published by the UK

<http://www.bankofengland.co.uk>

### Bibliography

This example is based on the following papers and journal articles:

- [1] Nelson, C.R., Siegel, A.F., (1987), "Parsimonious modelling of yield curves", *Journal of Business*, 60, pp 473-89
- [2] Svensson, L.E.O. (1994), "Estimating and interpreting forward interest rates: Sweden 1992-4", *International Monetary Fund, IMF Working Paper*, 1994/114
- [3] Fisher, M., Nychka, D., Zervos, D. (1995), "Fitting the term structure of interest rates with smoothing splines", *Board of Governors of the Federal Reserve System, Federal Reserve Board Working Paper* 95-1
- [4] Anderson, N., Sleath, J. (1999), "New estimates of the UK real and nominal yield curves", *Bank of England Quarterly Bulletin*, November, pp 384-92
- [5] Waggoner, D. (1997), "Spline Methods for Extracting Interest Rate Curves from Coupon Bond Prices", *Federal Reserve Board Working Paper* 97-10
- [6] "Zero-coupon yield curves: technical documentation", *BIS Papers No. 25* October 2005
- [7] Bolder, D.J., Gusba, S (2002), "Exponentials, Polynomials, and Fourier Series: More Yield Curve Modelling at the Bank of Canada," *Working Papers 02-29*, Bank of Canada
- [8] Bolder, D.J., Streliski, D (1999), "Yield Curve Modelling at the Bank of Canada," *Technical Reports 84*, Bank of Canada

## Analysis of Inflation Indexed Instruments

This example shows how to analyze inflation indexed instruments in MATLAB®.

This file does not introduce any new functionality. Instead, existing functions in the Financial Toolbox™ and Financial Instruments Toolbox™ are used.

### Computing Real Prices and Yields for Inflation Indexed Bonds

Inflation indexed bonds have grown in popularity and currently are issued by many countries, including the US, UK, Italy and France. While initially there was a great deal of variation in the design of inflation indexed bonds (for example the length of the indexation lag), the majority of inflation indexed bonds now have a 3 month lag and are capital-indexed, i.e., the principal of the bond is indexed to inflation. Therefore, the coupon rate of the bond is constant, but the actual coupon payments vary as the principal of the bond is indexed to inflation.

Specifically, the indexation is done with the following ratio

$$IndexRatio = \frac{CPI_{Ref}}{CPI_{Base}}$$

where  $CPI_{Base}$  is the level of the Consumer Price Index (or equivalent price measure) at the time of the bond's issue, and the  $CPI_{Ref}$  is the reference CPI.

Further, the  $CPI_{Ref}$  is typically computed by linearly interpolating between the data 2 and 3 months previous, as in the following:

$$CPI_{Ref} = CPI_{Month-3} + \frac{SettleDay - 1}{DaysInMonth} (CPI_{Month-2} - CPI_{Month-3})$$

Computing the cash flows for an inflation indexed bond is simply a case of computing the appropriate Reference CPI and Index Ratio.

Market convention for inflation indexed bonds is to quote the price and yield using the actual (i.e., unadjusted) coupon, which means that this is a real price and yield. Existing Financial Toolbox functions BNDPRICE and BNDYIELD can be used. For example,

```
Price = 124 + 9/32;
Settle = datenum('28-Sep-2009');
Coupon = .03375;
Maturity = datenum('15-Apr-2032');
```

```
RealYield = bndyield(Price,Coupon,Settle,Maturity);  
disp(['Real Yield: ', num2str(RealYield*100) '%'])
```

```
Real Yield: 2.0278%
```

### Constructing Nominal, Real and Inflation Curves

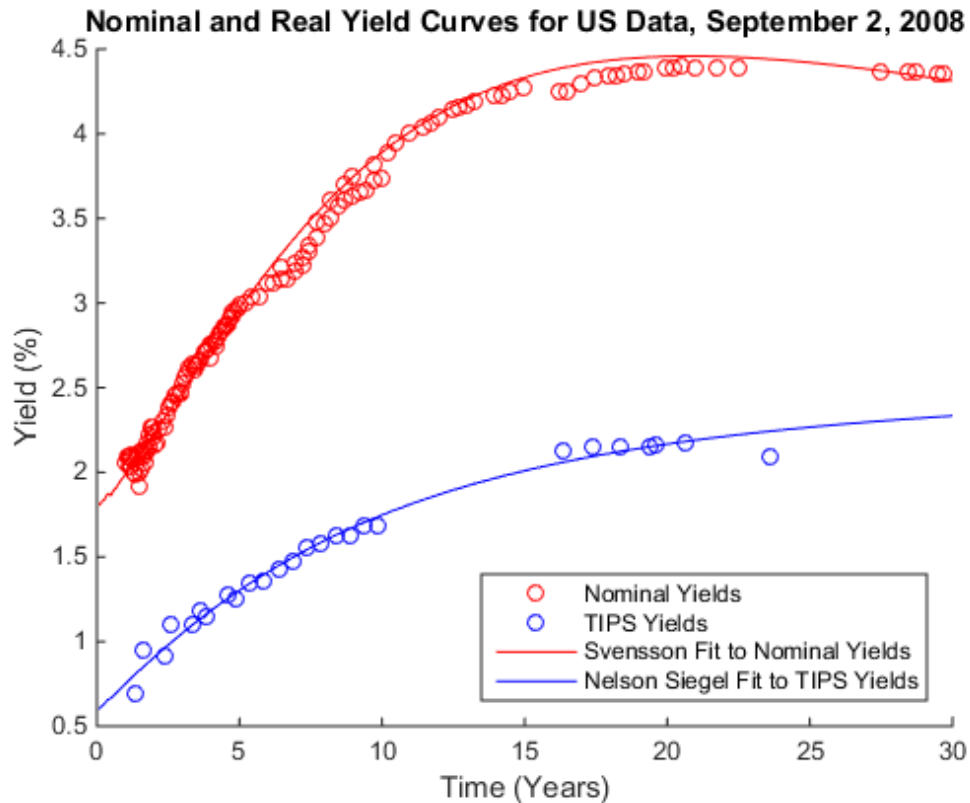
With the advent of the inflation indexed bond market, real curves can be constructed in a similar fashion to nominal curves. Using the available market data, a real curve can be constructed which can be compared to the nominal curve.

Note that one issue relates to the indexation lag of the bonds. As discussed above, typically the indexation lag is 3 months, which means that the inflation compensation is not actually matched up with the maturity -- or the coupon payments -- of the bond. While Anderson and Sleath [1] discuss below an approach to resolving this discrepancy, for this example the lag is simply noted.

In the example below, the `IRFunctionCurve` object in the Financial Instruments Toolbox™ is used to fit Nelson Siegel and Svensson models to real and nominal yield curves in the US. Note that a typical Nelson Siegel model places restrictions on the model parameters to ensure that the interest rates are always positive. However, real interest rates can be negative, which means that the Nelson Siegel restrictions are not used in the case below.

```
% Load the data  
load usbond_02Sep2008  
Settle = datenum('02-Sep-2008');  
NominalTimeToMaturity = yearfrac(Settle,NominalMaturity);  
TIPSTimeToMaturity = yearfrac(Settle,TIPSMaturity);  
  
% Compute the yields  
NominalYield = bndyield(NominalPrice,NominalCoupon,Settle,NominalMaturity);  
TIPSYield = bndyield(TIPSPrice,TIPSCoupon,Settle,TIPSMaturity);  
  
% Plot the yields  
scatter(NominalTimeToMaturity,NominalYield*100,'r')  
hold on  
scatter(TIPSTimeToMaturity,TIPSYield*100,'b')  
  
% Fit yield curves using the IRFunctionCurve object  
TIPSInstruments = [repmat(Settle,size(TIPSPrice,1),1) TIPSMaturity ...  
    TIPSPrice TIPSCoupon];  
TIPSSvensson = IRFunctionCurve.fitNelsonSiegel('Zero',Settle,TIPSInstruments);
```

```
NominalInstruments = [repmat(Settle,size(NominalPrice,1),1) NominalMaturity ...  
    NominalPrice NominalCoupon];  
NominalSvensson = IRFunctionCurve.fitSvensson('Zero',Settle,NominalInstruments);  
  
PlotDates = Settle+30:30:Settle+365*30;  
PlotTimeToMaturity = yearfrac(Settle,PlotDates);  
plot(PlotTimeToMaturity,NominalSvensson.getParYields(PlotDates)*100,'r')  
plot(PlotTimeToMaturity,TIPSSvensson.getParYields(PlotDates)*100,'b')  
  
% Annotate plot  
title('Nominal and Real Yield Curves for US Data, September 2, 2008')  
xlabel('Time (Years)')  
ylabel('Yield (%)')  
legend({'Nominal Yields','TIPS Yields','Svensson Fit to Nominal Yields',...  
    'Nelson Siegel Fit to TIPS Yields'},'location','southeast')  
  
% Create an inflation curve by subtracting the real curve from the nominal  
% curve  
InflationCurve = IRDataCurve('Zero',Settle,PlotDates,...  
    NominalSvensson.getZeroRates(PlotDates) - TIPSSvensson.getZeroRates(PlotDates));
```



### Constructing Inflation Curves from Zero Coupon Inflation Swaps

Inflation linked derivatives have also experienced a great deal of growth in the last few years. Some of the most liquidly traded inflation derivatives are zero coupon inflation swaps and year on year inflation swaps.

In a zero coupon inflation swap, the inflation payer agrees to pay the rate of inflation at maturity (lagged by a certain amount) compounded by the number of years. The inflation receiver typically pays a fixed rate, again compounded by the tenor of the instrument.

Using the notation from Hurd and Relleen [4] below

$$(1 + Rate_{swap})^T = (1 + Inflation_{t-L,t+T-L})^T$$

where  $t$  is the current time,  $T$  is the tenor and  $L$  is the lag

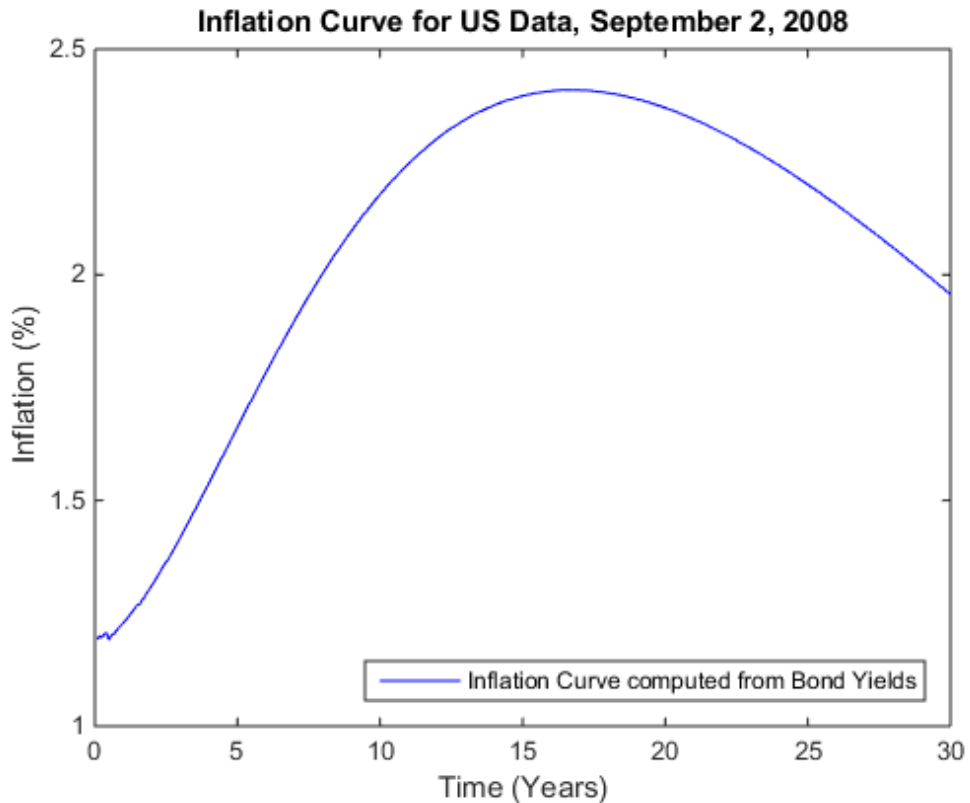
Zero coupon inflation swaps can be used to build an inflation curve, which can then be compared with the inflation curve constructed from government bonds.

One point to note is that in pricing inflation derivatives and building inflation curves, incorporating seasonality can be a critical factor. This issue is not dealt with here.

In the code below, the inflation curve constructed above is plotted. It would be straightforward to add to this plot an inflation curve constructed from zero coupon inflation swaps given market data.

```
figure
plot(PlotTimeToMaturity, InflationCurve.getParYields(PlotDates)*100, 'b')

title('Inflation Curve for US Data, September 2, 2008')
xlabel('Time (Years)')
ylabel('Inflation (%)')
legend({'Inflation Curve computed from Bond Yields'}, 'location', 'southeast')
```



### Bibliography

This example is based on the following papers and journal articles:

- [1] Anderson N. and Sleath J. (2001), "New Estimates of the UK Real and Nominal Yield Curves", Bank of England, working paper 126.
- [2] Brigo, D. and F. Mercurio. Interest Rate Models - Theory and Practice: With Smile, Inflation and Credit. Springer, 2006.
- [3] Deacon, M., A. Derry, and D. Mirfendereski. Inflation-Indexed Securities: Bonds, Swaps, and Other Derivatives. Wiley Finance, 2004.
- [4] Hurd, M. and J. Relleen (2006), "New Information from Inflation Swaps and Index-linked Bonds". Quarterly Bulletin, Spring 2006.



[5] Gurkaynak, R. S., and B.P. Sack, and J.H. Wright, The TIPS Yield Curve and Inflation Compensation (October 2008). FEDS Working Paper No. 2008-05.

[6] Kerkhoef, J. "Inflation Derivatives Explained". Lehman Brothers.

## Converting an IRDataCurve or IRFunctionCurve Object

### In this section...

“Introduction” on page 9-44

“Using the toRateSpec Method” on page 9-44

“Using Vector of Dates and Data Methods” on page 9-46

### Introduction

The IRDataCurve and IRFunctionCurve objects for interest-rate curves support conversion to:

- A RateSpec structure. The RateSpec generated from an IRDataCurve or IRFunctionCurve object, using the toRateSpec method, is identical to the RateSpec structure created with intenvset using Financial Instruments Toolbox software.
- A vector of dates and data from an IRDataCurve object acceptable to prbyzero, bkcall, bkput, tfutbyprice, and tfutbyyield or any function that requires a term structure of interest rates.

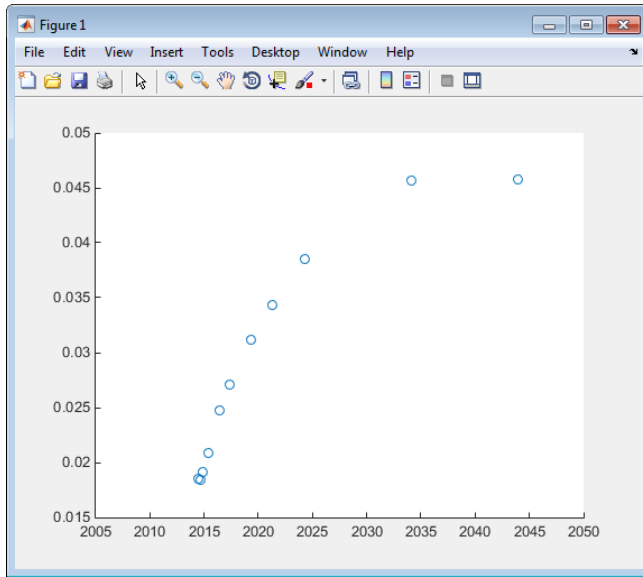
### Using the toRateSpec Method

To convert an IRDataCurve or IRFunctionCurve object to a RateSpec structure, you must first create an interest-rate curve object. Then, use the toRateSpec method for an IRDataCurve object or the toRateSpec method for an IRFunctionCurve object.

### Example

Create a data vector from the following data: <http://www.ustreas.gov/offices/domestic-finance/debt-management/interest-rate/yield.shtml>:

```
Data = [1.85 1.84 1.91 2.09 2.47 2.71 3.12 3.43 3.85 4.57 4.58]/100;  
Dates = daysadd(today,[30 90 180 360 2*360 3*360 5*360 7*360 10*360 20*360 30*360],2);  
scatter(Dates,Data)  
datetick
```



Create an IRDataCurve interest-rate curve object:

```
rr = IRDataCurve('Zero', today, Dates, Data);
```

Convert to a RateSpec:

```
toRateSpec(rr, today+30:30:today+365)
```

```
ans =
```

```

    FinObj: 'RateSpec'
  Compounding: 2
        Disc: [12x1 double]
        Rates: [12x1 double]
    EndTimes: [12x1 double]
    StartTimes: [12x1 double]
        EndDates: [12x1 double]
    StartDates: 733569
  ValuationDate: 733569
        Basis: 0
  EndMonthRule: 1

```

## Using Vector of Dates and Data Methods

You can use the `getZeroRates` method for an `IRDataCurve` object with a `Dates` property to create a vector of dates and data acceptable for `prbyzero` in Financial Toolbox software and `bkcall`, `bkput`, `tfutbyprice`, and `tfutbyyield` in Financial Instruments Toolbox software.

### Example

This is an example of using the `IRDataCurve` method `getZeroRates` with `prbyzero`:

```
Data = [2.09 2.47 2.71 3.12 3.43 3.85 4.57 4.58]/100;
Dates = daysadd(today,[360 2*360 3*360 5*360 7*360 10*360 20*360 30*360],1);
irdc = IRDataCurve('Zero',today,Dates>Data,'InterpMethod','pchip');
Maturity = daysadd(today,8*360,1);
CouponRate = .055;
ZeroDates = daysadd(today,180:180:8*360,1);
ZeroRates = getZeroRates(irdc, ZeroDates);
BondPrice = prbyzero([Maturity CouponRate], today, ZeroRates, ZeroDates)
```

```
BondPrice =
    113.9250
```

# Numerix Workflows

---

- “Working with Simple Numerix Trades” on page 10-2
- “Working with Advanced Numerix Trades” on page 10-5
- “Use Numerix to Price Cash Deposits” on page 10-10
- “Use Numerix for Interest-Rate Risk Assessment” on page 10-12

## Working with Simple Numerix Trades

This example shows how to price a callable reverse floater using Numerix CAIL.

Initialize Numerix environment.

```
import com.numerix.integration.*;
import com.numerix.integration.implementation.*;

n = numerix('i:\NumeriX_java_10_3_0\data')

n =
    Path: 'i:\NumeriX_java_10_3_0\data'
    RepositoryPath: 'i:\NumeriX_java_10_3_0\data\Repository'
    Repository: [1x1 com.numerix.integration.implementation.FileSystemRepository]
    Context: [1x1 com.numerix.integration.implementation.LocalCalculationContext]
    LookupsPath: 'i:\NumeriX_java_10_3_0\data\Data\LookupRules'
    MarketsPath: 'i:\NumeriX_java_10_3_0\data\Data\Markets'
    FixingsPath: 'i:\NumeriX_java_10_3_0\data\Data\Fixings'
    TradesPath: 'i:\NumeriX_java_10_3_0\data\Data\Trades'
    Parameters: [1x1 com.numerix.integration.implementation.CalculationParameters]
```

Create a market.

```
quotes = java.util.HashMap;
quotes.put('IR.USD-LIBOR-3M.SWAP-1Y.MID', 0.0066056);
quotes.put('IR.USD-LIBOR-3M.SWAP-10Y.MID', 0.022465005);
quotes.put('IR.USD-LIBOR-3M.SWAP-20Y.MID', 0.027544995);
market = Market('EOD_14-NOV-2011', DateExtensions.date('14-Nov-2011'), quotes.entrySet());
```

Define a trade instance for a callable reverse floater based on instrument template located in the Repository.

```
tradeDescriptor = 'TRADE.IR.CALLBLEREVERSEFLOATER';
tradeParameters = java.util.HashMap;
tradeParameters.put('Trade ID', '1001');
tradeParameters.put('Quote Type', 'MID');
tradeParameters.put('Currency', 'USD');
tradeParameters.put('Notional', 1000000.0);
tradeParameters.put('Effective Date', DateExtensions.date('1-Dec-2011'));
tradeParameters.put('Termination Date', DateExtensions.date('1-Dec-2021'));
tradeParameters.put('IR Index', 'LIBOR');
tradeParameters.put('IR Index Tenor', '3M');
tradeParameters.put('Structured Freq', '3M');
tradeParameters.put('Structured Side', 'Receive');
tradeParameters.put('Structured Coupon Floor', 0.0);
tradeParameters.put('Structured Coupon UpBd', 0.08);
tradeParameters.put('StructuredCoupon Multiplier', 1.4);
tradeParameters.put('Structured Coupon Cap', 0.05);
tradeParameters.put('Structured Basis', 'ACT/360');
tradeParameters.put('Funding Freq', '3M');
tradeParameters.put('Funding Side', 'Pay');
```

```

tradeParameters.put('Funding Spread', 0.003);
tradeParameters.put('Funding Basis', 'ACT/360');
tradeParameters.put('Call Start Date', DateExtensions.date('1-Dec-2013'));
tradeParameters.put('Call End Date', DateExtensions.date('1-Dec-2020'));
tradeParameters.put('Option Side', 'Short');
tradeParameters.put('Option Type', 'Right to Terminate');
tradeParameters.put('Call Frequency', '3M');
tradeParameters.put('Model', 'IR.USD-LIBOR-3M.MID.DET');
tradeParameters.put('Method', 'BackwardAnalytic');

```

Create the trade instance.

```
trade = RepositoryExtensions.createTradeInstance(n.Repository, tradeDescriptor, tradeParameters)
```

Price the trade.

```
results = CalculationContextExtensions.calculate(n.Context, trade, market, Request.getAll());
```

Parse the results for MATLAB and display.

```

r = n.parseResults(results)
disp([r.Name r.Category r.Currency r.Data])
r =
    Category: {13x1 cell}
    Currency: {13x1 cell}
    Name: {13x1 cell}
    Data: {13x1 cell}

    'Reporting Currency'      'Price'      ''      'USD'
    'Structured Cashflow Log' 'Cashflow'   ''      {41x20 cell}
    'Structured Leg PV Accrued' 'Price'      'USD'   [ 0]
    'PV'                      'Price'      'USD'   [ 6.4133e+04]
    'Structured Leg PV Clean' 'Price'      'USD'   [ 4.2637e+05]
    'Option PV'              'Price'      'USD'   [-1.3220e+05]
    'Funding Cashflow Log'   'Cashflow'   ''      {41x20 cell}
    'Structured Leg PV'      'Price'      'USD'   [ 4.2637e+05]
    'Funding Leg PV'        'Price'      'USD'   [-2.3004e+05]
    'Funding Leg PV Accrued' 'Price'      'USD'   [ 0]
    'Funding Leg PV Clean'  'Price'      'USD'   [-2.3004e+05]
    'Yield Risk Report'     ''           ''      { 4x30 cell}
    'Messages'              ''           ''      { 4x1 cell}

```

## See Also

[numerix | parseResults](#)

## Related Examples

- “Working with Advanced Numerix Trades”
- “Use Numerix to Price Cash Deposits”
- “Use Numerix for Interest-Rate Risk Assessment”

## **External Web Sites**

- <http://www.numerix.com/cail>



## Working with Advanced Numerix Trades

This example shows how to price multiple trades from MATLAB using Numerix CAIL.

Initialize Numerix environment.

```
import com.numerix.integration.*;
import com.numerix.integration.implementation.*;

n = numerix('i:\NumeriX_java_10_3_0\data')

n =
    Path: 'i:\NumeriX_java_10_3_0\data'
    RepositoryPath: 'i:\NumeriX_java_10_3_0\data\Repository'
    Repository: [1x1 com.numerix.integration.implementation.FileSystemRepository]
    Context: [1x1 com.numerix.integration.implementation.LocalCalculationContext]
    LookupsPath: 'i:\NumeriX_java_10_3_0\data\Data\LookupRules'
    MarketsPath: 'i:\NumeriX_java_10_3_0\data\Data\Markets'
    FixingsPath: 'i:\NumeriX_java_10_3_0\data\Data\Fixings'
    TradesPath: 'i:\NumeriX_java_10_3_0\data\Data\Trades'
    Parameters: [1x1 com.numerix.integration.implementation.CalculationParameters]
```

Specify the hybrid model for multiple trades.

```
hySpec = HybridModelSpecification;
hySpec.addHW1F('IR-USD', 'USD', 'LIBOR', '3M', 'MeanReversion(0.5),DiagonalSwaption(ATM, 10Y)');
hySpec.addHW1F('IR-EUR', 'EUR', 'EURIBOR', '6M', 'MeanReversion(0.5),DiagonalSwaption(ATM, 10Y)');
hySpec.addFXBlack('FX-USDEUR', 'USD', 'EUR', 'LIBOR', '3M', 'EURIBOR', '6M', 'StrikeFXEuropean(ATM, 10Y)');
%5 Specify the factor correlations.
hyCorrelations = HybridModelCorrelationMatrix(hySpec);
hyCorrelations.add('IR-USD', 'IR-EUR', 0.5);
hyCorrelations.add('IR-USD', 'FX-USDEUR', 0.25);
hyCorrelations.add('IR-EUR', 'FX-USDEUR', 0.25);

% Specify the model parameters.
hybridModelParameters = java.util.HashMap;
hybridModelParameters.put('Quote Type', 'MID');
hybridModelParameters.put('Payout Currency', 'USD');
hybridModelParameters.put('Specification', hySpec);
hybridModelParameters.put('Correlations', hyCorrelations);
```

Specify exposure calculation parameters.

```
observationDates = CustomObservationSchedule;
observationDates.add(DateExtensions.date(2011, 12, 1));
for y = 2012:2013
    for m = 1:12
        observationDates.add(DateExtensions.date(y, m, 1));
    end
end

exposureParameters = java.util.HashMap;
exposureParameters.put('Model ID', 'HYBRID');
exposureParameters.put('Observation Dates', observationDates);
```

Define the first trade instance.

```

tradeParameters1 = java.util.HashMap;
tradeParameters1.put('Trade ID', 'RVFL1001');
tradeParameters1.put('Quote Type', 'MID');
tradeParameters1.put('Currency', 'USD');
tradeParameters1.put('Notional', 1000000.0);
tradeParameters1.put('Effective Date', DateExtensions.date('1-Dec-2011'));
tradeParameters1.put('Termination Date', DateExtensions.date('1-Dec-2021'));
tradeParameters1.put('IR Index', 'LIBOR');
tradeParameters1.put('IR Index Tenor', '3M');
tradeParameters1.put('Structured Freq', '3M');
tradeParameters1.put('Structured Side', 'Receive');
tradeParameters1.put('Structured Coupon Floor', 0.0);
tradeParameters1.put('Structured Coupon UpBd', 0.08);
tradeParameters1.put('StructuredCoupon Multiplier', 1.4);
tradeParameters1.put('Structured Coupon Cap', 0.05);
tradeParameters1.put('Structured Basis', 'ACT/360');
tradeParameters1.put('Funding Freq', '3M');
tradeParameters1.put('Funding Side', 'Pay');
tradeParameters1.put('Funding Spread', 0.003);
tradeParameters1.put('Funding Basis', 'ACT/360');
tradeParameters1.put('Call Start Date', DateExtensions.date('1-Dec-2013'));
tradeParameters1.put('Call End Date', DateExtensions.date('1-Dec-2020'));
tradeParameters1.put('Option Side', 'Short');
tradeParameters1.put('Option Type', 'Right to Terminate');
tradeParameters1.put('Call Frequency', '3M');
tradeParameters1.put('Model', 'HYBRID');
tradeParameters1.put('Method', 'BackwardMC');
tradeInstance1 = RepositoryExtensions.createTradeInstance(n.Repository, 'TRADE.IR.CALLABLEREVERSEFLOATER', tradeParameters1);

```

Define the second trade instance.

```

tradeParameters2 = java.util.HashMap;
tradeParameters2.put('Trade ID', 'CASHDEP1001');
tradeParameters2.put('Quote Type', 'MID');
tradeParameters2.put('Currency', 'USD');
tradeParameters2.put('Coupon Rate', 0.05);
tradeParameters2.put('Yield', 0.044);
tradeParameters2.put('Notional', 100.0);
tradeParameters2.put('Effective Date', DateExtensions.date('1-Apr-2012'));
tradeParameters2.put('Maturity', DateExtensions.date('1-Apr-2013'));
tradeParameters2.put('IR Index', 'LIBOR');
tradeParameters2.put('IR Index Tenor', '3M');
tradeParameters2.put('Model', 'HYBRID');
tradeParameters2.put('Method', 'BACKWARDMC');
tradeInstance2 = RepositoryExtensions.createTradeInstance(n.Repository, 'IR.CASHDEPOSIT', tradeParameters2);

```

Create the third trade instance.

```

tradeParameters3 = java.util.HashMap;
tradeParameters3.put('Trade ID', 'FXFWD1001');
tradeParameters3.put('Quote Type', 'MID');
tradeParameters3.put('Base Currency', 'USD');
tradeParameters3.put('Term Currency', 'EUR');
tradeParameters3.put('Delivery Date', DateExtensions.date('1-Jun-2012'));
tradeParameters3.put('Contract FX Forward Rate', 80.5);
tradeParameters3.put('Base Notional', 1000000.0);
tradeParameters3.put('Base IR Index', 'LIBOR');
tradeParameters3.put('Term IR Index', 'EURIBOR');
tradeParameters3.put('Base IR Index Tenor', '3m');
tradeParameters3.put('Term IR Index Tenor', '6m');
tradeParameters3.put('Calendar', 'NewYork Target');

```

```
tradeParameters3.put('Spot Lag', '2bd');
tradeParameters3.put('Model', 'HYBRID');
tradeParameters3.put('Method', 'BACKWARDMC');
tradeInstance3 = RepositoryExtensions.createTradeInstance(n.Repository, 'FX.FXFORWARD', tradeParameters3);
```

Set tradeInstances for all three trade instances.

```
tradeInstances = java.util.ArrayList;
tradeInstances.add(tradeInstance1);
tradeInstances.add(tradeInstance2);
tradeInstances.add(tradeInstance3);
n.Parameters.setInstances(tradeInstances);
```

Add a custom lookup so these trade instances reference the hybrid model.

```
n.Parameters.getLookups.add(0, ExactLookupRule('HYBRID', 'MODEL.HYBRID', hybridModelParameters.entrySet));
```

Add another custom lookup so that exposure report has parameters defined.

```
n.Parameters.getLookups.add(1, ExactLookupRule('RISK.REPORT.EXPOSURE', 'REPORT.EXPOSURE', exposureParameters.entrySet));
```

Perform the calculation.

```
results = n.Context.calculate(n.Parameters, Request.getExposure);
```

Parse the results for MATLAB and display.

```
r = n.parseResults(results)
disp([r.Trade(2) r.Market(2)])
disp([r.Results{2}.Name r.Results{2}.Category r.Results{2}.Currency r.Results{2}.Data])
disp([r.Results{2}.Name{1}])
disp([r.Results{2}.Data{1}])
```

r =

```
Trade: {3x1 cell}
Market: {3x1 cell}
Results: {3x1 cell}

'CASHDEP1001' 'EOD'

'Exposure' '' '' {21x501 cell}
'Exposure.Discount Factors' '' '' {21x501 cell}
'Messages' '' '' {12x1 cell}
```

Exposure

Columns 1 through 3

'DATE'	'VALUE 1'	'VALUE 2'
'Tue May 01 13:00:00 EDT 2012'	[104.198166609924]	[103.386222783828]
'Fri Jun 01 13:00:00 EDT 2012'	[ 104.09953599675]	[102.117465067435]
'Sun Jul 01 13:00:00 EDT 2012'	[105.524567506006]	[100.055731577867]
'Wed Aug 01 13:00:00 EDT 2012'	[105.787455961524]	[100.318762976796]
'Sat Sep 01 13:00:00 EDT 2012'	[104.417483614373]	[100.764337265155]
'Mon Oct 01 13:00:00 EDT 2012'	[104.692275556824]	[100.980213613911]
'Thu Nov 01 13:00:00 EDT 2012'	[104.443818312902]	[101.478508725115]
'Sat Dec 01 12:00:00 EST 2012'	[104.736646932343]	[101.679769557039]
'Tue Jan 01 12:00:00 EST 2013'	[104.577562970494]	[102.423339265735]

```
'Fri Feb 01 12:00:00 EST 2013' [ 104.28994278039] [103.117326879887]
'Fri Mar 01 12:00:00 EST 2013' [ 104.70469459715] [104.232180198939]
'Mon Apr 01 13:00:00 EDT 2013' [ 105.07334321718] [ 105.05089338769]
'Wed May 01 13:00:00 EDT 2013' [ 0] [ 0]
'Sat Jun 01 13:00:00 EDT 2013' [ 0] [ 0]
'Mon Jul 01 13:00:00 EDT 2013' [ 0] [ 0]
'Thu Aug 01 13:00:00 EDT 2013' [ 0] [ 0]
'Sun Sep 01 13:00:00 EDT 2013' [ 0] [ 0]
'Tue Oct 01 13:00:00 EDT 2013' [ 0] [ 0]
'Fri Nov 01 13:00:00 EDT 2013' [ 0] [ 0]
'Sun Dec 01 12:00:00 EST 2013' [ 0] [ 0]
```

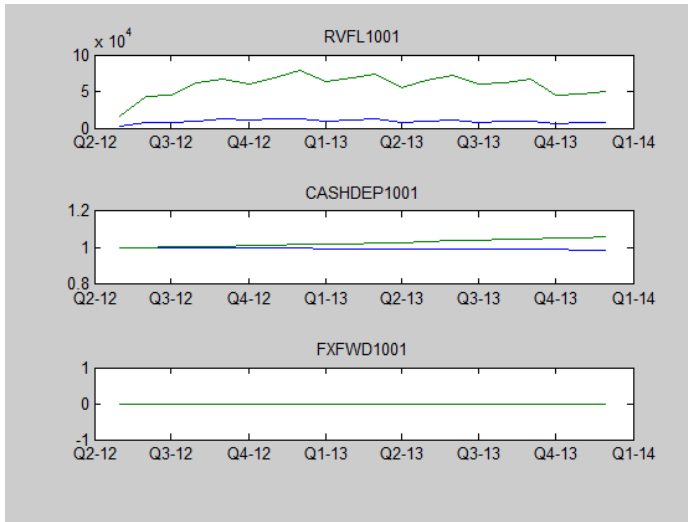
Columns 499 through 501

```
'VALUE 498' 'VALUE 499' 'VALUE 500'
[ 105.36273206453] [104.335982034187] [104.141595030057]
[105.904822463264] [104.238089023172] [104.276676080686]
[103.893060436208] [103.613968079212] [106.188617261199]
[103.183889382889] [105.499763150412] [105.440275818983]
[103.310404527817] [105.233622768447] [105.267337892552]
[103.274239052394] [104.716952177783] [ 104.33099834332]
[103.583983117053] [104.710250522521] [105.501004542869]
[103.379982561438] [105.146939039653] [104.681616459661]
[103.821169954095] [105.567274949306] [104.835971977691]
[104.016530403399] [105.254054161819] [104.842156238753]
[104.481475787501] [105.197179985119] [104.962752610848]
[105.061984636083] [105.077227736476] [105.077766765965]
[ 0] [ 0] [ 0]
[ 0] [ 0] [ 0]
[ 0] [ 0] [ 0]
[ 0] [ 0] [ 0]
[ 0] [ 0] [ 0]
[ 0] [ 0] [ 0]
[ 0] [ 0] [ 0]
[ 0] [ 0] [ 0]
```

Plot the results for the second trade instance, CASHDEP1001, with the corresponding Exposure Discount Factors.

```
figure('Tag', 'NumerixAdvancedRiskExample');
for ii=1:3
    % Get dates
    dates = cell2mat(r.Results{ii}.Data{expIndex}(2:end,1));
    dates = dates(:,4:end);
    dates = floor(datenum(dates));
    % Get exposures
    mtm = cell2mat(r.Results{ii}.Data{expIndex}(2:end,2:end));
    exposures = max(0,mtm); % Exposure at contract level, no netting
    EE = mean(exposures); % Expected Exposure
    PFE = prctile(exposures,95); % Potential Future Exposure
    subplot(3,1,ii)
    plot(dates,EE,dates,PFE)
    title(r.Trade{ii})
    datetick
```

end



## See Also

`numerix` | `parseResults`

## Related Examples

- “Working with Simple Numerix Trades”
- “Use Numerix to Price Cash Deposits”
- “Use Numerix for Interest-Rate Risk Assessment”

## External Web Sites

- <http://www.numerix.com/cail>

## Use Numerix to Price Cash Deposits

This example shows how to use the Numerix CAIL API to price a cash deposit from MATLAB. The trade parameters are read from the `Cashdeposit1.csv` in the Numerix Data Trades directory.

Initialize Numerix environment.

```
import com.numerix.integration.*;
import com.numerix.integration.implementation.*;

n = numerix('i:\NumeriX_java_10_3_0\data')

n =
    Path: 'i:\NumeriX_java_10_3_0\data'
    RepositoryPath: 'i:\NumeriX_java_10_3_0\data\Repository'
    Repository: [1x1 com.numerix.integration.implementation.FileSystemRepository]
    Context: [1x1 com.numerix.integration.implementation.LocalCalculationContext]
    LookupsPath: 'i:\NumeriX_java_10_3_0\data\Data\LookupRules'
    MarketsPath: 'i:\NumeriX_java_10_3_0\data\Data\Markets'
    FixingsPath: 'i:\NumeriX_java_10_3_0\data\Data\Fixings'
    TradesPath: 'i:\NumeriX_java_10_3_0\data\Data\Trades'
    Parameters: [1x1 com.numerix.integration.implementation.CalculationParameters]
```

Create a market.

```
market = Market('EOD_16-APR-2012', DateExtensions.date('16-APR-2012'), []);
```

Read the `Cashdeposit1.csv` file from the Numerix Trades directory.

```
[-,-,tradeInfo] = xlsread([n.TradesPath '\Cashdeposit1.csv'])
```

```
tradeInfo =
    'Template'      'String'      'TRADE_IR_CASHDEPOSIT'
    'Trade ID'     'ID'          'CASHDEP1001'
    'Quote Type'   'String'      'MID'
    'Effective Date' 'Date'        '4/1/2012'
    'Maturity'     'Date'        '4/1/2013'
    'Notional'     'Double'      [          100]
    'Currency'     'Currency'    'USD'
    'Coupon Rate'  'Double'      [          0.0500]
    'Yield'        'Double'      [          0.0440]
    'IR Index'     'String'      'Libor'
    'IR Index Tenor' 'Tenor'      '3m'
```

Define a trade instance from the imported CASHDEP1001 instrument.

```
tradeDescriptor = tradeInfo{1,3};
tradeParameters = java.util.HashMap;
numTradeInfoFields = size(tradeInfo,1);
for i = 2:numTradeInfoFields
    switch tradeInfo{i,2}
        case {'DATE','Date'}
            % ...
```

```

        tradeParameters.put(tradeInfo{i,1},DateExtensions.date(datestr(tradeInfo{i,3}, 'dd-mmm-yyyy')));
    otherwise
        tradeParameters.put(tradeInfo{i,1},tradeInfo{i,3});
    end
end

```

Create the trade instance.

```
trade = RepositoryExtensions.createTradeInstance(n.Repository, tradeDescriptor, tradeParameters);
```

Price the trade.

```
results = CalculationContextExtensions.calculate(n.Context, trade, market, Request.getAll);
```

Parse the results for MATLAB and display.

```
r = n.parseResults(results)
disp([r.Name r.Category r.Currency r.Data])
```

```

r =
    Category: {9x1 cell}
    Currency: {9x1 cell}
    Name: {9x1 cell}
    Data: {9x1 cell}

    'Modified Duration'    'Price'    ''    [ 0.9349]
    'Accrued Interest'    'Price'    'USD' [ 0.2083]
    'Reporting Currency'  'Price'    ''    'USD'
    'PV'                   'Price'    'USD' [ 100.7607]
    'Instrument'           'Price'    ''    [1x85 char]
    'Clean Price'         'Price'    'USD' [ 100.5524]
    'Convexity'           'Price'    ''    [ 1.7481]
    'YTM'                 'Price'    ''    []
    'Messages'            ''         ''    []

```

## See Also

numerix | parseResults

## Related Examples

- “Working with Simple Numerix Trades”
- “Working with Advanced Numerix Trades”
- “Use Numerix for Interest-Rate Risk Assessment”

## External Web Sites

- <http://www.numerix.com/cail>

## Use Numerix for Interest-Rate Risk Assessment

This example shows how to use the Numerix CAIL API for interest-rate curve stripping for risk assessment.

Initialize Numerix environment.

```
import com.numerix.integration.*;
import com.numerix.integration.implementation.*;

n = numerix('i:\NumeriX_java_10_3_0\data')

n =
    Path: 'i:\NumeriX_java_10_3_0\data'
    RepositoryPath: 'i:\NumeriX_java_10_3_0\data\Repository'
    Repository: [1x1 com.numerix.integration.implementation.FileSystemRepository]
    Context: [1x1 com.numerix.integration.implementation.LocalCalculationContext]
    LookupsPath: 'i:\NumeriX_java_10_3_0\data\Data\LookupRules'
    MarketsPath: 'i:\NumeriX_java_10_3_0\data\Data\Markets'
    FixingsPath: 'i:\NumeriX_java_10_3_0\data\Data\Fixings'
    TradesPath: 'i:\NumeriX_java_10_3_0\data\Data\Trades'
    Parameters: [1x1 com.numerix.integration.implementation.CalculationParameters]
```

Specify the current market associated with the Numerix CAIL environment.

```
markets = get(n.Parameters, 'Markets');
currentMarket = markets.get(0);
outInstance = RefObject(currentMarket);
```

Define the interest-rate curve key IR.USD-LIBOR-3M.MID.

```
n.Context.tryResolveId('IR.USD-LIBOR-3M.MID', outInstance);
currentInstance = outInstance.argvalue;
```

Set the instance and market.

```
n.Parameters.setMarkets(java.util.Arrays.asList(currentMarket));
n.Parameters.setInstances(java.util.Arrays.asList(currentInstance));
```

Calculate the interest-rate curve stripping.

```
results = n.Context.calculate(n.Parameters, Request.getAll());
```

The calculation returns the results from stripping the interest-rate curve for IR.USD-LIBOR-3M.MID. Parse the results for MATLAB and display.

```
% IR.USD-LIBOR-3M.MID.
r = n.parseResults(results)

disp([r.Instance r.Market])
```



```

disp([r.Results{1}.Name r.Results{1}.Category r.Results{1}.Currency r.Results{1}.Data])
disp([r.Results{1}.Name{1}])
disp([r.Results{1}.Data{1}])

r =

    Instance: {'IR.USD-LIBOR-3M.MID'}
      Market: {'EOD'}
      Results: {[1x1 struct]}

'IR.USD-LIBOR-3M.MID'   'EOD'

'Curve Info'         ''      ''      {30x3 cell}
'Messages'           ''      ''      { 7x1 cell}

Curve Info

'KEY'                'DATE'                'DISCOUNTFACTOR'
'CASH RATE 16-APR-2012 17-APR-2012' 'Tue Apr 17 13:00:00 EDT 2012' [ 1.0000]
'CASH RATE 16-APR-2012 18-APR-2012' 'Wed Apr 18 13:00:00 EDT 2012' [ 1.0000]
'CASH RATE 16-APR-2012 23-APR-2012' 'Mon Apr 23 13:00:00 EDT 2012' [ 1.0000]
'CASH RATE 16-APR-2012 30-APR-2012' 'Mon Apr 30 13:00:00 EDT 2012' [ 0.9999]
'CASH RATE 16-APR-2012 16-MAY-2012' 'Wed May 16 13:00:00 EDT 2012' [ 0.9998]
'CASH RATE 16-APR-2012 18-JUN-2012' 'Mon Jun 18 13:00:00 EDT 2012' [ 0.9994]
'CASH RATE 16-APR-2012 16-JUL-2012' 'Mon Jul 16 13:00:00 EDT 2012' [ 0.9988]
'CASH RATE 18-MAY-2012 12-AUG-2012' 'Sun Aug 12 13:00:00 EDT 2012' [ 0.9987]
'CASH RATE 20-JUN-2012 20-SEP-2012' 'Thu Sep 20 13:00:00 EDT 2012' [ 0.9981]
'CASH RATE 18-JUL-2012 18-OCT-2012' 'Thu Oct 18 13:00:00 EDT 2012' [ 0.9975]
'CASH RATE 15-AUG-2012 15-NOV-2012' 'Thu Nov 15 12:00:00 EST 2012' [ 0.9973]
'CASH RATE 19-SEP-2012 19-DEC-2012' 'Wed Dec 19 12:00:00 EST 2012' [ 0.9968]
'CASH RATE 17-OCT-2012 17-JAN-2013' 'Thu Jan 17 12:00:00 EST 2013' [ 0.9962]
'CASH RATE 19-DEC-2012 19-MAR-2013' 'Tue Mar 19 13:00:00 EDT 2013' [ 0.9955]
'SWAP RATE 18-APR-2012 19-APR-2016' 'Tue Apr 19 13:00:00 EDT 2016' [ 0.9645]
'SWAP RATE 18-APR-2012 18-APR-2017' 'Tue Apr 18 13:00:00 EDT 2017' [ 0.9445]
'SWAP RATE 18-APR-2012 18-APR-2018' 'Wed Apr 18 13:00:00 EDT 2018' [ 0.9199]
'SWAP RATE 18-APR-2012 18-APR-2019' 'Thu Apr 18 13:00:00 EDT 2019' [ 0.8925]
'SWAP RATE 18-APR-2012 21-APR-2020' 'Tue Apr 21 13:00:00 EDT 2020' [ 0.8639]
'SWAP RATE 18-APR-2012 19-APR-2021' 'Mon Apr 19 13:00:00 EDT 2021' [ 0.8356]
'SWAP RATE 18-APR-2012 19-APR-2022' 'Tue Apr 19 13:00:00 EDT 2022' [ 0.8069]
'SWAP RATE 18-APR-2012 18-APR-2023' 'Tue Apr 18 13:00:00 EDT 2023' [ 0.7784]
'SWAP RATE 18-APR-2012 18-APR-2024' 'Thu Apr 18 13:00:00 EDT 2024' [ 0.7506]
'SWAP RATE 18-APR-2012 19-APR-2027' 'Mon Apr 19 13:00:00 EDT 2027' [ 0.6733]
'SWAP RATE 18-APR-2012 20-APR-2032' 'Tue Apr 20 13:00:00 EDT 2032' [ 0.5682]
'SWAP RATE 18-APR-2012 20-APR-2037' 'Mon Apr 20 13:00:00 EDT 2037' [ 0.4828]
'SWAP RATE 18-APR-2012 21-APR-2042' 'Mon Apr 21 13:00:00 EDT 2042' [ 0.4112]
'SWAP RATE 18-APR-2012 18-APR-2052' 'Thu Apr 18 13:00:00 EDT 2052' [ 0.3087]
'SWAP RATE 18-APR-2012 18-APR-2062' 'Tue Apr 18 13:00:00 EDT 2062' [ 0.2414]

```

## See Also

numerix | parseResults

## Related Examples

- “Working with Simple Numerix Trades”
- “Working with Advanced Numerix Trades”
- “Use Numerix to Price Cash Deposits”

## **External Web Sites**

- <http://www.numerix.com/cail>

# Class Reference

---

## @IRBootstrapOptions

Create specific options for bootstrapping an interest-rate curve object

In this section...
“Hierarchy” on page A-2
“Constructor” on page A-2
“Public Read-Only Properties” on page A-2
“Methods” on page A-3

### Hierarchy

**Superclasses:** None

**Subclasses:** None

### Constructor

IRBootstrapOptions

### Public Read-Only Properties

Name	Description
ConvexityAdjustment	Controls the convexity adjustment to interest rate futures. This can be specified as a function handle that takes time to maturity as an input and returns a value which is <code>ConvexityAdjustment</code> . Alternatively, you can define <code>ConvexityAdjustment</code> as an N-by-1 vector of values, where N is the number of interest rate futures. In either case, the <code>ConvexityAdjustment</code> is subtracted from the futures rate.  For more information on defining a function handle, see the MATLAB Programming Fundamentals documentation.

## **Methods**

There are no methods.

## @IRCurve

Base abstract class for interest-rate curve objects

In this section...
“Hierarchy” on page A-4
“Description” on page A-4
“Constructor” on page A-4
“Public Read-Only Properties” on page A-4
“Methods” on page A-5

### Hierarchy

**Superclasses:** None

**Subclasses:** @IRDataCurve, @IRFunctionCurve

### Description

IRCurve is an abstract class; you cannot create instances of it directly. You can create IRDataCurve and IRFunctionCurve objects that are derived from this class.

### Constructor

@IRCurve is an abstract class. To construct an IRCurve object, use one of the subclass constructors, IRDataCurve or IRFunctionCurve.

### Public Read-Only Properties

Name	Description
Type	Type of interest-rate curve: zero, forward, or discount.
Settle	Scalar for the Settle date of the curve.
Compounding	Scalar that sets the compounding frequency per year for the IRCurve object:

Name	Description
	<ul style="list-style-type: none"> <li>• -1 = Continuous compounding</li> <li>• 1 = Annual compounding</li> <li>• 2 = Semiannual compounding (default)</li> <li>• 3 = Compounding three times per year</li> <li>• 4 = Quarterly compounding</li> <li>• 6 = Bimonthly compounding</li> <li>• 12 = Monthly compounding</li> </ul>
Basis	<p>Day-count basis of the interest-rate curve. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul>

## Methods

Classes that inherit from the `IRCurve` abstract class must implement the following methods.

Method	Description
getForwardRates	Returns forward rates for input dates.

<b>Method</b>	<b>Description</b>
<code>getZeroRates</code>	Returns zero rates for input dates.
<code>getDiscountFactors</code>	Returns discount factors for input dates.
<code>getParYields</code>	Returns par yields for input dates.
<code>toRateSpec</code>	Converts to be a <code>RateSpec</code> object. This is identical to the <code>RateSpec</code> structure produced by the Financial Instruments Toolbox function <code>intenvset</code> .



## @IRDataCurve

Represent interest-rate curve object based on vector of dates and data

### In this section...

“Hierarchy” on page A-7

“Description” on page A-7

“Constructor” on page A-7

“Public Read-Only Properties” on page A-7

“Methods” on page A-9

## Hierarchy

**Superclasses:** @IRCurve

**Subclasses:** None

## Description

IRDataCurve is a representation of an interest-rate curve object with dates and data. You can construct this object directly by specifying dates and corresponding interest rates or discount factors; alternatively, you can bootstrap the object from market data. After an interest-rate curve object is constructed, you can:

- Calculate forward and zero rates and determine par yields.
- Extract the discount factors.
- Convert to a `RateSpec` structure that is identical to the `RateSpec` structure produced by the Financial Instruments Toolbox function `intenvset`.

## Constructor

IRDataCurve

## Public Read-Only Properties

Name	Description
Type	Type of interest-rate curve: zero, forward, or discount.

Name	Description
Settle	Scalar for the <b>Settle</b> date of the curve.
Compounding	Scalar that sets the compounding frequency per year for the <b>IRCurve</b> object: <ul style="list-style-type: none"> <li>• -1 = Continuous compounding</li> <li>• 1 = Annual compounding</li> <li>• 2 = Semiannual compounding (default)</li> <li>• 3 = Compounding three times per year</li> <li>• 4 = Quarterly compounding</li> <li>• 6 = Bimonthly compounding</li> <li>• 12 = Monthly compounding</li> </ul>
Basis	Day-count basis of the financial curve. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul>
Dates	Dates corresponding to rate data.
Data	Interest-rate data or discount factors for the curve object.

Name	Description
InterpMethod	<p>Values are:</p> <ul style="list-style-type: none"> <li>• 'linear' — Linear interpolation (default).</li> <li>• 'constant' — Piecewise constant interpolation.</li> <li>• 'pchip' — Piecewise cubic Hermite interpolation.</li> <li>• 'spline' — Cubic spline interpolation.</li> </ul>

## Methods

The following table contains links to methods with supporting reference pages, including examples.

Method	Description
getForwardRates	Returns forward rates for input dates.
getZeroRates	Returns zero rates for input dates.
getDiscountFactors	Returns discount factors for input dates.
getParYields	Returns par yields for input dates.
toRateSpec	Converts to be a RateSpec object. This structure is identical to the RateSpec produced by the Financial Instruments Toolbox function <code>intenvset</code> .
bootstrap	Bootstraps an interest rate curve from market data.

## @IRFitOptions

Object to specify fitting options for an `IRFunctionCurve` interest-rate curve object

In this section...
“Hierarchy” on page A-10
“Description” on page A-10
“Constructor” on page A-10
“Public Read-Only Properties” on page A-10
“Methods” on page A-11

### Hierarchy

**Superclasses:** None

**Subclasses:** None

### Description

The `IRFitOptions` object allows you to specify options relating to the fitting process for an `IRFunctionCurve` object. Input arguments are specified in parameter/value pairs. The `IRFitOptions` structure provides the capability to choose which quantity to be minimized and other optimization parameters.

### Constructor

`IRFitOptions`

### Public Read-Only Properties

Name	Description
<code>FitType</code>	<code>Price</code> , <code>Yield</code> , or <code>DurationWeightedPrice</code> determines which is minimized in the curve fitting process. <code>DurationWeightedPrice</code> is the default.

Name	Description
InitialGuess	Initial guess for the parameters of the curve function.
UpperBound	Upper bound for the parameters of the curve function.
LowerBound	Lower bound for the parameters of the curve function.
OptOptions	Optimization structure based on the output from the Optimization Toolbox function <code>optimset</code> or <code>optimoptions</code> . This optimization structure is evaluated by <code>lsqnonlin</code> .
A	Inequality constraint for parameters, ignored if <code>OptimFunction</code> is set to <code>lsqnonlin</code> .
b	Inequality constraint for parameters, ignored if <code>OptimFunction</code> is set to <code>lsqnonlin</code> .
OptimFunction	Optimization function used to fit function, either <code>lsqnonlin</code> or <code>fmincon</code> .

## Methods

There are no methods.

## @IRFunctionCurve

Represent an interest-rate curve object using a function

### In this section...

“Hierarchy” on page A-12

“Description” on page A-12

“Constructor” on page A-12

“Public Read-Only Properties” on page A-12

“Methods” on page A-14

### Hierarchy

**Superclasses:** @IRCurve

**Subclasses:** None

### Description

`IRFunctionCurve` is a representation of an interest-rate curve object. You can construct this object directly by specifying a function handle or a function can be fit to market data using methods of the object. After an interest-rate curve object is constructed; you can:

- Calculate forward and zero rates and determine par yields.
- Extract the discount factors.
- Convert to a `RateSpec` structure; this is identical to the `RateSpec` structure produced by the Financial Instruments Toolbox function `intenvset`.

### Constructor

`IRFunctionCurve`

### Public Read-Only Properties

Name	Description
Type	Type of interest-rate curve: zero, forward, or discount.
Settle	Scalar for the <code>Settle</code> date of the curve.

Name	Description
Compounding	Scalar that sets the compounding frequency per year for the <code>IRCurve</code> object: <ul style="list-style-type: none"> <li>• -1 = Continuous compounding</li> <li>• 1 = Annual compounding</li> <li>• 2 = Semiannual compounding (default)</li> <li>• 3 = Compounding three times per year</li> <li>• 4 = Quarterly compounding</li> <li>• 6 = Bimonthly compounding</li> <li>• 12 = Monthly compounding</li> </ul>
Basis	Day-count basis of the interest-rate curve. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul>
FunctionHandle	Function handle that defines the interest-rate curve. For more information on defining a function handle, see the MATLAB Programming Fundamentals documentation.
Parameters	Fitted parameters for function.

## Methods

The following table contains links to methods with supporting reference pages, including examples.

Method	Description
<code>getForwardRates</code>	Returns forward rates for input dates.
<code>getZeroRates</code>	Returns zero rates for input dates.
<code>getDiscountFactors</code>	Returns discount factors for input dates.
<code>getParYields</code>	Returns par yields for input dates.
<code>toRateSpec</code>	Converts to be a <code>RateSpec</code> object. This is identical to the <code>RateSpec</code> structure produced by the Financial Instruments Toolbox function <code>intenvset</code> .
<code>fitSvensson</code>	Fits a Svensson function to market data.
<code>fitNelsonSiegel</code>	Fits a Nelson-Siegel function to market data.
<code>fitSmoothingSpline</code>	Fits a smoothing spline function to market data.
<code>fitFunction</code>	Fits a custom function to market data.



# Functions — Alphabetical List

---

## asianbycrr

Price Asian option from Cox-Ross-Rubinstein binomial tree

### Syntax

```
Price = asianbycrr(CRRTree, OptSpec, Strike, Settle,
ExerciseDates, AmericanOpt, AvgType, AvgPrice, AvgDate)
```

### Arguments

CRRTree	Stock tree structure created by <code>crrtree</code> .
OptSpec	NINST-by-1 list of string values 'Call' or 'Put'.
Strike	NINST-by-1 vector of strike price values. Each row is the schedule for one option.
Settle	NINST-by-1 vector of <code>Settle</code> dates. The settle date for every Asian option is set to the valuation date of the stock tree. The Asian argument <code>Settle</code> is ignored.
ExerciseDates	<p>For a European option (<code>AmericanOpt = 0</code>):</p> <p>NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option (<code>AmericanOpt = 1</code>):</p> <p>NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-<code>NaN</code> date is listed, or if <code>ExerciseDates</code> is NINST-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.</p>
AmericanOpt	(Optional) If <code>AmericanOpt = 0</code> , <code>NaN</code> , or is unspecified, the option is a European option. If <code>AmericanOpt = 1</code> , the option is an American option.

AvgType	(Optional) String = 'arithmetic' for arithmetic average (default) or 'geometric' for geometric average.
AvgPrice	(Optional) Scalar representing the average price of the underlying asset at <b>Settle</b> . This argument is used when <b>AvgDate</b> < <b>Settle</b> . Default is the current stock price.
AvgDate	(Optional) Scalar representing the date on which the averaging period begins. Default = <b>Settle</b> .

## Description

`Price = asianbycrr(CRRTree, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt, AvgType, AvgPrice, AvgDate)` calculates the value of fixed- and floating-strike Asian options. To compute the value of a floating-strike Asian option, specify **Strike** as NaN. Fixed-strike Asian options are also known as average price options. Floating-strike Asian options are also known as average strike options.

**Price** is a NINST-by-1 vector of expected prices at time 0.

Asian options are priced using Hull-White (1993). Consequently, for these options only the root node contains a unique price.

## Examples

### Price a Floating-Strike Asian Option Using a CRR Binomial Tree

This example shows how to price a floating-strike Asian option using a CRR binomial tree using the file `deriv.mat`, which provides `CRRTree`. The `CRRTree` structure contains the stock specification and time information needed to price the option.

```
load deriv.mat;

OptSpec = 'put';
Strike = NaN;
Settle = '01-Jan-2003';
ExerciseDates = '01-Jan-2004';

Price = asianbycrr(CRRTree, OptSpec, Strike, Settle, ...
```

ExerciseDates)

Price =

1.2177

- “Pricing Asian Options”

## More About

- “Asian Option”

## References

Hull, J., and A. White, “Efficient Procedures for Valuing European and American Path-Dependent Options,” *Journal of Derivatives*, Volume 1, pp. 21-31.

## See Also

crmtree | instasian

# asianbyeqp

Price Asian option from Equal Probabilities binomial tree

## Syntax

```
Price = asianbyeqp(EQPTree, OptSpec, Strike, Settle,
ExerciseDates, AmericanOpt, AvgType, AvgPrice, AvgDate)
```

## Arguments

EQPTree	Stock tree structure created by <code>eqptree</code> .
OptSpec	NINST-by-1 list of string values 'Call' or 'Put'.
Strike	NINST-by-1 vector of strike price values. Each row is the schedule for one option.
Settle	NINST-by-1 vector of <code>Settle</code> dates. The settle date for every Asian option is set to the valuation date of the stock tree. The Asian argument <code>Settle</code> is ignored.
ExerciseDates	<p>For a European option (<code>AmericanOpt = 0</code>):</p> <p>NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option (<code>AmericanOpt = 1</code>):</p> <p>NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <code>ExerciseDates</code> is NINST-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.</p>
AmericanOpt	(Optional) If <code>AmericanOpt = 0</code> , NaN, or is unspecified, the option is a European option. If <code>AmericanOpt = 1</code> , the option is an American option.

AvgType	(Optional) String = 'arithmetic' for arithmetic average (default) or 'geometric' for geometric average.
AvgPrice	(Optional) Scalar representing the average price of the underlying asset at <b>Settle</b> . This argument is used when <b>AvgDate</b> < <b>Settle</b> . Default is the current stock price.
AvgDate	(Optional) Scalar representing the date on which the averaging period begins.

## Description

`Price = asianbyeqp(EQPTree, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt, AvgType, AvgPrice, AvgDate)` calculates the value of fixed- and floating-strike Asian options. To compute the value of a floating-strike Asian option, specify **Strike** as NaN. Fixed-strike Asian options are also known as average price options. Floating-strike Asian options are also known as average strike options.

`Price` is a NINST-by-1 vector of expected prices at time 0.

## Examples

### Price a Floating-Strike Asian Option Using an EQP Equity Tree

This example shows how to price a floating-strike Asian option using an EQP equity tree by loading the file `deriv.mat`, which provides `EQPTree`. The `EQPTree` structure contains the stock specification and time information needed to price the option.

```
load deriv.mat;

OptSpec = 'put';
Strike = NaN;
Settle = '01-Jan-2003';
ExerciseDates = '01-Jan-2004';

Price = asianbyeqp(EQPTree, OptSpec, Strike, Settle, ...
ExerciseDates)
```

Price =

1.2724

## More About

- “Asian Option”

## References

Hull, J., and A. White, “Efficient Procedures for Valuing European and American Path-Dependent Options,” *Journal of Derivatives*, Volume 1, pp. 21-31.

## See Also

eqptree | instasian

## asianbyitt

Price Asian options using implied trinomial tree (ITT)

### Syntax

```
Price = asianbyitt(ITTTree, OptSpec, Strike, Settle,
ExerciseDates, AmericanOpt, AvgType, AvgPrice, AvgDate)
```

### Arguments

ITTTree	Stock tree structure created by <code>itttree</code> .
OptSpec	NINST-by-1 list of string values 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values. Each row represents the schedule for one option.
Settle	NINST-by-1 vector of <code>Settle</code> dates. The settle date for every Asian option is set to the valuation date of the stock tree. The Asian argument <code>Settle</code> is ignored.
ExerciseDates	For a European option ( <code>AmericanOpt = 0</code> ):  NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date which is the option expiry date.  For an American option ( <code>AmericanOpt = 1</code> ):  NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <code>ExerciseDates</code> is NINST-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.
AmericanOpt	(Optional) If <code>AmericanOpt = 0</code> , NaN, or is unspecified, the option is a European option. If <code>AmericanOpt = 1</code> , the option is an American option.



AvgType	(Optional) String = 'arithmetic' for arithmetic average (default) or 'geometric' for geometric average.
AvgPrice	(Optional) Scalar representing the average price of the underlying asset at <b>Settle</b> . This argument is used when <b>AvgDate</b> < <b>Settle</b> . Default is the current stock price.
AvgDate	(Optional) Scalar representing the date on which the averaging period begins.

## Description

`Price = asianbyitt(ITTree, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt, AvgType, AvgPrice, AvgDate)` calculates the value of fixed- and floating-strike Asian options. To compute the value of a floating-strike Asian option, specify **Strike** as NaN. Fixed-strike Asian options are also known as average price options. Floating-strike Asian options are also known as average strike options.

**Price** is a NINST-by-1 vector of expected prices at time 0.

---

**Note:** The **Settle** date for every Asian option is set to the **ValuationDate** of the stock tree. The Asian argument, **Settle**, is ignored.

---

## Examples

### Price a Floating-Strike Asian Option Using an ITT Equity Tree

This example shows how to price a floating-strike Asian option using an ITT equity tree by loading the file `deriv.mat`, which provides `ITTree`. The `ITTree` structure contains the stock specification and time information needed to price the option.

```
load deriv.mat;

OptSpec = 'put';
Strike = NaN;
Settle = '01-Jan-2006';
ExerciseDates = '01-Jan-2007';
```

```
Price = asianbyitt(ITTree, OptSpec, Strike, Settle, ExerciseDates)
```

```
Price =  
    1.0778
```

### More About

- “Asian Option”

### References

Hull, J., and A. White, “Efficient Procedures for Valuing European and American Path-Dependent Options,” *Journal of Derivatives*, Volume 1, 1993, pp. 21-31.

### See Also

instasian | itttree

# asianbyls

Price European or American Asian option using Longstaff-Schwartz model

## Syntax

```
Price = asianbyls(RateSpec,StockSpec,OptSpec,Strike,Settle,
ExerciseDates)
Price = asianbyls( ____,Name,Value)
```

```
[Price,Paths,Times,Z] = asianbyls(RateSpec,StockSpec,OptSpec,Strike,
Settle,
ExerciseDates)
[Price,Paths,Times,Z] = asianbyls( ____,Name,Value)
```

## Description

`Price = asianbyls(RateSpec,StockSpec,OptSpec,Strike,Settle, ExerciseDates)` returns fixed- and floating-strike Asian option prices using the Longstaff-Schwartz model. `asianbyls` computes prices of European and American Asian options. For American options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium. To compute the value of a floating-strike Asian option, `Strike` should be specified as `NaN`. Fixed-strike Asian options are also known as average price options and floating-strike Asian options are also known as average strike options.

`Price = asianbyls( ____,Name,Value)` returns fixed- and floating-strike Asian option prices using optional name-value pair arguments and the Longstaff-Schwartz model. `asianbyls` computes prices of European and American Asian options. For American options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium. To compute the value of a floating-strike Asian option, `Strike` should be specified as `NaN`. Fixed-strike Asian options are also known as average price options and floating-strike Asian options are also known as average strike options.

```
[Price,Paths,Times,Z] = asianbyls(RateSpec,StockSpec,OptSpec,Strike,
Settle,
```

`ExerciseDates`) returns fixed- and floating-strike Asian option `Price`, `Paths`, `Times`, and `Z` values using the Longstaff-Schwartz model. `asianbyls` computes prices of European and American Asian options. For American options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium. To compute the value of a floating-strike Asian option, `Strike` should be specified as `NaN`. Fixed-strike Asian options are also known as average price options and floating-strike Asian options are also known as average strike options.

`[Price,Paths,Times,Z] = asianbyls( ____,Name,Value)` returns fixed and floating strike Asian option `Price`, `Paths`, `Times`, and `Z` values using optional name-value pair arguments and the Longstaff-Schwartz model. `asianbyls` computes prices of European and American Asian options. For American options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium. To compute the value of a floating-strike Asian option, `Strike` should be specified as `NaN`. Fixed-strike Asian options are also known as average price options and floating-strike Asian options are also known as average strike options.

## Examples

### Compute the Price of an Asian Option Using the Longstaff-Schwartz Model

Define the `RateSpec`.

```
Rates = 0.05;  
StartDate = 'Jan-1-2013';  
EndDate = 'Jan-1-2014';  
RateSpec = intenvset('ValuationDate', StartDate, 'StartDates', StartDate, ...  
    'EndDates', EndDate, 'Compounding', -1, 'Rates', Rates)
```

```
RateSpec =  
  
    FinObj: 'RateSpec'  
    Compounding: -1  
    Disc: 0.9512  
    Rates: 0.0500  
    EndTimes: 1  
    StartTimes: 0  
    EndDates: 735600  
    StartDates: 735235  
    ValuationDate: 735235
```

```
Basis: 0
EndMonthRule: 1
```

Define the `StockSpec` for the asset.

```
AssetPrice = 100;
Sigma = 0.2;
StockSpec = stockspec(Sigma, AssetPrice)
```

```
StockSpec =
```

```
      FinObj: 'StockSpec'
      Sigma: 0.2000
      AssetPrice: 100
      DividendType: []
      DividendAmounts: 0
      ExDividendDates: []
```

Define the Asian 'call' option.

```
Settle = 'Jan-1-2013';
ExerciseDates = 'Jan-1-2014';
Strike = 110;
OptSpec = 'call';
```

Compute the price for the European arithmetic average price for the Asian option using the Longstaff-Schwartz model.

```
NumTrials = 10000;
NumPeriods = 100;
AvgType = 'arithmetic';
Antithetic = true;
Price = asianbyls(RateSpec, StockSpec, OptSpec, Strike, Settle, ExerciseDates, ...
'NumTrials', NumTrials, 'NumPeriods', NumPeriods, 'Antithetic', Antithetic, 'AvgType', A
```

```
Price =
```

```
1.9693
```

- “Pricing Asian Options”

## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

Interest-rate term structure (annualized and continuously compounded), specified by the `RateSpec` obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: `struct`

### **StockSpec** — Stock specification for underlying asset

structure

Stock specification for underlying asset, specified using `StockSpec` obtained from `stockspec`. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, stocks, stock indices, and commodities. If dividends are not specified in `StockSpec`, dividends are assumed to be 0.

Data Types: `struct`

### **OptSpec** — Definition of option

string with a value of 'call' or 'put'

Definition of option, specified as 'call' or 'put' using a string.

Data Types: `char`

### **Strike** — Option strike price value

nonnegative scalar integer

Option strike price value, specified with a nonnegative scalar integer. To compute the value of a floating-strike Asian option, `Strike` should be specified as `NaN`. Floating-strike Asian options are also known as average strike options.

Data Types: `double`

### **Settle** — Settlement or trade date

date string | nonnegative scalar integer

Settlement or trade date for the Asian option, specified as a nonnegative scalar integer or date string.

Data Types: char

### **ExerciseDates** — Option exercise dates

date string | nonnegative scalar integer

Option exercise dates, specified as a nonnegative scalar integer or date string:

- For a European option, use a 1-by-1 vector of dates. For a European option, there is only one **ExerciseDates** on the option expiry date.
- For an American option, use a 1-by-2 vector of exercise date boundaries. The option can be exercised on any date between or including the pair of dates on that row. If only one non-NaN date is listed, or if **ExerciseDates** is a 1-by-1 vector of serial date numbers or cell array of strings, the option can be exercised between **Settle** and the single listed **ExerciseDates**.

Data Types: char

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of **Name**,**Value** arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes ( ' '). You can specify several name and value pair arguments in any order as **Name1**,**Value1**, . . . ,**NameN**,**ValueN**.

Example: `Price =`

```
asianbyls(RateSpec,StockSpec,OptSpec,Strike,Settle,ExerciseDates,'NumTrials',N
```

### **'AmericanOpt'** — Option type

0 European (default) | scalar with value [0,1]

Option type, specified as NINST-by-1 positive integer scalar flags with values:

- 0 — European
- 1 — American

Data Types: single | double

### **'AvgType'** — Average types

arithmetic (default) | string with values of arithmetic or geometric

Average types, specified as **arithmetic** for arithmetic average, or **geometric** for geometric average.

Data Types: double

**'AvgPrice' — Average price of underlying asset at Settle**

scalar

Average price of underlying asset at `Settle`, specified as a scalar.

---

**Note:** Use this argument when `AvgDate < Settle`.

---

Data Types: double

**'AvgDate' — Date averaging period begins**

scalar

Date averaging period begins, specified as a scalar.

Data Types: double

**'NumTrials' — Simulation trials**

1000 (default) | scalar

Simulation trials, specified as a scalar number of independent sample paths.

Data Types: double

**'NumPeriods' — Simulation periods per trial**

100 (default) | scalar

Simulation periods per trial, specified as a scalar number. `NumPeriods` is considered only when pricing European Asian options. For American Asian options `NumPeriod` is equal to the number of exercise days during the life of the option.

Data Types: double

**'Z' — Dependent random variates**

scalar | nonnegative integer

Dependent random variates used to generate the Brownian motion vector (i.e., Wiener processes) that drive the simulation, specified as a `NumPeriods-by-2-by-NumTrials` 3-D time series array.

Data Types: single | double



**'Antithetic' — Indicator for antithetic sampling**

false (default) | logical flag with value of true or false

Logical flag to indicate antithetic sampling, specified with a value of true or false.

Data Types: logical

## Output Arguments

**Price — Expected price of Asian option**

scalar

Expected price of the Asian option, returned as a 1-by-1 scalar.

**Paths — Simulated paths of correlated state variables**

vector

Simulated paths of correlated state variables, returned as a  $(\text{NumPeriods} + 1)$ -by-1-by- $\text{NumTrials}$  3-D time series array. Each row of **Paths** is the transpose of the state vector  $X(t)$  at time  $t$  for a given trial.**Times — Observation times associated with simulated paths**

vector

Observation times associated with the simulated paths, returned as a  $(\text{NumPeriods} + 1)$ -by-1 column vector of observation times associated with the simulated paths. Each element of **Times** is associated with the corresponding row of **Paths**.**Z — Dependent random variates**

vector

Dependent random variates, returned, if **Z** is specified as an optional input argument, the same value is returned. Otherwise, **Z** contains the random variates generated internally.

## More About

- “Asian Option”

## See Also

asianbycrr | asianbykv | asianbylevy | asiainsensbyls | intenvset | stockspect

## asiansensbyls

Calculate European or American Asian option prices and sensitivities using Longstaff-Schwartz model

### Syntax

```
PriceSens = asiansensbyls(RateSpec,StockSpec,OptSpec,StrikeSettle,  
Exercisedates)
```

```
PriceSens = asiansensbyls( ____,Name,Value)
```

```
[PriceSens,Path,Times,Z] = asiansensbyls(RateSpec,StockSpec,OptSpec,  
StrikeSettle,  
Exercisedates)
```

```
[PriceSens,Path,Times,Z] = asiansensbyls( ____,Name,Value)
```

### Description

`PriceSens = asiansensbyls(RateSpec,StockSpec,OptSpec,StrikeSettle, Exercisedates)` returns Asian option prices and sensitivities for fixed- and floating-strike Asian options using the Longstaff-Schwartz model. `asiansensbyls` supports European and American Asian options. For American options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium. To compute the value of a floating-strike Asian option, `Strike` should be specified as `NaN`. Fixed-strike Asian options are also known as average price options and floating-strike Asian options are also known as average strike options.

`PriceSens = asiansensbyls( ____,Name,Value)` returns Asian option prices and sensitivities for fixed- and floating-strike Asian options using optional name-value pair arguments and the Longstaff-Schwartz model. `asiansensbyls` supports European and American Asian options. For American options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium. To compute the value of a floating-strike Asian option, `Strike` should be specified as `NaN`. Fixed-strike Asian options are also known as average price options and floating-strike Asian options are also known as average strike options.

```
[PriceSens,Path,Times,Z] = asiansensbyls(RateSpec,StockSpec,OptSpec,  
StrikeSettle,
```

`ExerciseDates`) returns Asian option prices and sensitivities (`PriceSens`, `Path`, `Times`, and `Z`) for fixed- and floating-strike Asian options using the Longstaff-Schwartz model. `asiansensbyls` supports European and American Asian options. For American options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium. To compute the value of a floating-strike Asian option, `Strike` should be specified as `NaN`. Fixed-strike Asian options are also known as average price options and floating-strike Asian options are also known as average strike options.

`[PriceSens,Path,Times,Z] = asiansensbyls( ____,Name,Value)` returns Asian option prices and sensitivities (`PriceSens`, `Path`, `Times`, and `Z`) for fixed- and floating-strike Asian options using optional name-value pair arguments and the Longstaff-Schwartz model. `asiansensbyls` supports European and American Asian options. For American options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium. To compute the value of a floating-strike Asian option, `Strike` should be specified as `NaN`. Fixed-strike Asian options are also known as average price options and floating-strike Asian options are also known as average strike options.

## Examples

### Compute the Price and Sensitivities of an Asian Option Using the Longstaff-Schwartz Model

Define the `RateSpec`.

```
Rates = 0.05;
StartDate = 'Jan-1-2013';
EndDate = 'Jan-1-2014';
RateSpec = intenvset('ValuationDate', StartDate, 'StartDates', StartDate, ...
'EndDates', EndDate, 'Compounding', -1, 'Rates', Rates)
```

```
RateSpec =
    FinObj: 'RateSpec'
    Compounding: -1
    Disc: 0.9512
    Rates: 0.0500
    EndTimes: 1
    StartTimes: 0
    EndDates: 735600
    StartDates: 735235
    ValuationDate: 735235
    Basis: 0
```

```
EndMonthRule: 1
```

Define the `StockSpec` for the asset.

```
AssetPrice = 100;  
Sigma = 0.2;  
StockSpec = stockspec(Sigma, AssetPrice)
```

```
StockSpec =
```

```
      FinObj: 'StockSpec'  
      Sigma: 0.2000  
      AssetPrice: 100  
      DividendType: []  
      DividendAmounts: 0  
      ExDividendDates: []
```

Define the Asian 'call' option.

```
Settle = 'Jan-1-2013';  
ExerciseDates = 'Jan-1-2014';  
Strike = 110;  
OptSpec = 'call';
```

Compute the price for the European arithmetic average price and sensitivities for the Asian option using the Longstaff-Schwartz model.

```
NumTrials = 10000;  
NumPeriods = 100;  
AvgType = 'arithmetic';  
Antithetic = true;  
OutSpec = {'Price', 'Delta', 'Gamma'};  
PriceSens = asiandsensbyls(RateSpec, StockSpec, OptSpec, Strike, Settle, ExerciseDates,  
    'NumTrials', NumTrials, 'NumPeriods', NumPeriods, 'Antithetic', Antithetic, 'AvgType',  
    AvgType, 'OutSpec', OutSpec)
```

```
PriceSens =
```

```
    1.9693
```

- “Pricing Asian Options”

## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

Interest-rate term structure (annualized and continuously compounded), specified by the **RateSpec** obtained from **intenvset**. For information on the interest-rate specification, see **intenvset**.

Data Types: `struct`

### **StockSpec** — Stock specification for underlying asset

structure

Stock specification for underlying asset, specified using **StockSpec** obtained from **stockspec**. For information on the stock specification, see **stockspec**.

**stockspec** can handle other types of underlying assets. For example, stocks, stock indices, and commodities. If dividends are not specified in **StockSpec**, dividends are assumed to be 0.

Data Types: `struct`

### **OptSpec** — Definition of option

string with value 'call' or 'put'

Definition of option, specified as 'call' or 'put' using a string.

Data Types: `char`

### **Strike** — Option strike price value

nonnegative scalar integer

Option strike price value, specified with a nonnegative scalar integer. To compute the value of a floating-strike Asian option, **Strike** should be specified as NaN. Floating-strike Asian options are also known as average strike options.

Data Types: `double`

### **Settle** — Settlement date or trade date

nonnegative scalar integer | date string

Settlement date or trade date for the Asian option, specified as a nonnegative scalar integer or date string.

Data Types: char

### **ExerciseDates** — Option exercise dates

nonnegative integer | data string

Option exercise dates, specified as a nonnegative scalar integer or date string:

- For a European option, use a 1-by-1 vector of dates. For a European option, there is only one **ExerciseDates** on the option expiry date.
- For an American option, use a 1-by-2 vector of exercise date boundaries. The option can be exercised on any date between or including the pair of dates on that row. If only one non-NaN date is listed, or if **ExerciseDates** is a 1-by-1 vector of serial date numbers or cell array of strings, the option can be exercised between **Settle** and the single listed **ExerciseDates**.

Data Types: char

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of **Name**,**Value** arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes ( ' '). You can specify several name and value pair arguments in any order as **Name1**,**Value1**, . . . ,**NameN**,**ValueN**.

```
Example: PriceSens =  
asiansensbyls(RateSpec,StockSpec,OptSpec,Strike,Settle,ExerciseDates,'NumTrials',  
NumPeriods,'Antithetic',Antithetic,'AvgType',AvgType,'OutSpec',  
{'All'})
```

### **'AmericanOpt'** — Option type

0 European (default) | scalar with values [0,1]

Option type, specified as NINST-by-1 positive integer scalar flags with values:

- 0 — European
- 1 — American

Data Types: single | double

### **'AvgType'** — Average types

arithmetic (default) | string with values of arithmetic or geometric

Average types, specified as `arithmetic` for arithmetic average, or `geometric` for geometric average.

Data Types: `double`

**'AvgPrice' — Average price of underlying asset at Settle**

scalar

Average price of underlying asset at `Settle`, specified as a scalar.

---

**Note:** Use this argument when `AvgDate < Settle`.

---

Data Types: `double`

**'AvgDate' — Date averaging period begins**

scalar

Date averaging period begins, specified as a scalar.

Data Types: `double`

**'NumTrials' — Simulation trials**

1000 (default) | scalar

Simulation trials, specified as a scalar number of independent sample paths.

Data Types: `double`

**'NumPeriods' — Simulation periods per trial**

100 (default) | scalar

Simulation periods per trial, specified as a scalar number. `NumPeriods` is considered only when pricing European Asian options. For American Asian options `NumPeriod` is equal to the number of exercise days during the life of the option.

Data Types: `double`

**'Z' — Dependent random variates**

scalar | nonnegative integer

Dependent random variates used to generate the Brownian motion vector (i.e., Wiener processes) that drive the simulation, specified as a `NumPeriods-by-2-by-NumTrials` 3-D time series array.

Data Types: `single` | `double`

**'Antithetic'** — Indicates antithetic sampling

`false` (default) | logical flag with value of `true` or `false`

Indicates antithetic sampling, specified with a value of `true` or `false`.

Data Types: `logical`

**'OutSpec'** — Define outputs

`{'Price'}` (default) | string with values `'Price'`, `'Delta'`, `'Gamma'`, `'Vega'`, `'Lambda'`, `'Rho'`, `'Theta'`, and `'All'` | cell array of strings with values `'Price'`, `'Delta'`, `'Gamma'`, `'Vega'`, `'Lambda'`, `'Rho'`, `'Theta'`, and `'All'`

Define outputs specifying NOUT-by-1 or 1-by-NOUT cell array of strings with possible values of `'Price'`, `'Delta'`, `'Gamma'`, `'Vega'`, `'Lambda'`, `'Rho'`, `'Theta'` and `'All'`.

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec` to include each sensitivity:

Example: `OutSpec =`  
`{'delta', 'gamma', 'vega', 'lambda', 'rho', 'theta', 'price'}`

Data Types: `char` | `cell`

## Output Arguments

**PriceSens** — Expected price and sensitivities of Asian option

vector

Expected price and sensitivities of the Asian option, returned as an NINST-by-1 vector.

**Paths** — Simulated paths of correlated state variables

vector

Simulated paths of correlated state variables, returned as a  $(\text{NumPeriods} + 1)$ -by-2-by-NumTrials 3-D time series array. Each row of `Paths` is the transpose of the state vector  $X(t)$  at time  $t$  for a given trial.

**Times** — Observation times associated with simulated paths

vector



Observation times associated with simulated paths, returned as a  $(\text{NumPeriods} + 1)$ -by-1 column vector of observation times associated with the simulated paths. Each element of `Times` is associated with the corresponding row of `Paths`.

### **Z — Dependent random variates**

vector

Dependent random variates, returned, if `Z` is specified as an optional input argument, the same value is returned. Otherwise, `Z` contains the random variates generated internally.

## **More About**

- “Asian Option”

### **See Also**

`asianbycrr` | `asianbykv` | `asianbylevy` | `asianbyls` | `intenvset` | `stockspec`

## asianbykv

Prices European geometric Asian options using Kemna-Vorst model

### Syntax

```
Price = asianbykv(RateSpec, StockSpec, OptSpec, Strike, Settle,  
ExerciseDates)
```

### Description

Price = asianbykv(RateSpec, StockSpec, OptSpec, Strike, Settle, ExerciseDates) returns prices of European geometric Asian options using the Kemna-Vorst model.

### Examples

#### Compute the Price of an Asian Option Using the Kemna-Vorst Model

Define the RateSpec.

```
StartDates = 'Jan-1-2013';  
EndDates = 'Jan-1-2014';  
Rates = 0.035;  
Basis = 1;  
RateSpec = intenvset('ValuationDate', StartDates, 'StartDates', StartDates, ...  
'EndDates', EndDates, 'Rates', Rates, 'Compounding', -1, 'Basis', Basis)
```

RateSpec =

```
    FinObj: 'RateSpec'  
  Compounding: -1  
        Disc: 0.9656  
        Rates: 0.0350  
   EndTimes: 1  
  StartTimes: 0  
   EndDates: 735600
```

```

    StartDates: 735235
    ValuationDate: 735235
        Basis: 1
    EndMonthRule: 1

```

Define the `StockSpec` for the asset.

```

AssetPrice = 100;
Sigma = 0.15;
DivType = 'continuous';
DivAmounts = 0.03;
StockSpec = stockspec(Sigma, AssetPrice, DivType, DivAmounts)

```

`StockSpec =`

```

        FinObj: 'StockSpec'
        Sigma: 0.1500
        AssetPrice: 100
        DividendType: {'continuous'}
        DividendAmounts: 0.0300
        ExDividendDates: []

```

Define the Asian 'call' and 'put' options.

```

Strike = 102;
OptSpec = {'put'; 'call'};
Settle = 'Jan-1-2013';
Maturity = 'Apr-1-2013';

```

Compute the European geometric Average Price for the Asian option using the Kemna-Vorst model.

```

Price = asiansensbykv(RateSpec, StockSpec, OptSpec, Strike, Settle, Maturity)

```

`Price =`

```

    2.8881
    0.9210

```

- “Pricing Asian Options”

## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

The annualized continuously compounded interest-rate term structure specified by the `RateSpec` obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: `struct`

### **StockSpec** — Stock specification for underlying asset

structure

Stock specification for underlying asset, specified using `StockSpec` obtained from `stockspec`. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, stocks, stock indices and commodities. If dividends are not specified in `StockSpec`, dividends are assumed to be 0.

Data Types: `struct`

### **OptSpec** — Definition of option

string with value 'call' or 'put' | cell array of strings

Definition of option, specified as 'call' or 'put' using a NINST-by-1 cell array of strings.

Data Types: `cell` | `char`

### **Strike** — Option strike price values

nonnegative integer | vector of nonnegative integers

Option strike price values, specified with nonnegative integers using a NINST-by-1 vector.

Data Types: `single` | `double`

### **Settle** — Settlement dates or trade dates

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Settlement dates or trade dates for the Asian option, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: char | cell

### **ExerciseDates — European option exercise dates**

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

European option exercise dates, specified as nonnegative integers or date strings using a NINST-by-1 vector or cell array of exercise dates. For an European option, there is only one ExerciseDates on the option expiry date.

Data Types: char | cell

## **Output Arguments**

### **Price — Expected prices of an Asian option**

vector

Expected prices of the Asian option, returned as an NINST-by-1 vector.

## **More About**

- “Asian Option”

### **See Also**

asianbycrr | asianbylevy | asianbyls | asiansensbykv | intenvset | stockspect

## asiansensbykv

Calculate prices and sensitivities of European geometric Asian options using Kemna-Vorst model

### Syntax

```
PriceSens = asiansensbykv(RateSpec,StockSpec,OptSpec,Strike,Settle,
ExerciseDates)
PriceSens = asiansensbykv( ____,Name,Value)
```

### Description

`PriceSens = asiansensbykv(RateSpec,StockSpec,OptSpec,Strike,Settle,ExerciseDates)` returns prices and sensitivities of European geometric Asian options using Kemna-Vorst model.

`PriceSens = asiansensbykv( ____,Name,Value)` returns prices and sensitivities of European geometric Asian options using optional Name-Value pairs for the Kemna-Vorst model.

### Examples

#### Compute the Price and Sensitivities of an Asian Option Using the Kemna-Vorst Model

Define the RateSpec.

```
StartDates = 'Jan-1-2013';
EndDates = 'Jan-1-2014';
Rates = 0.035;
Basis = 1;
RateSpec = intenvset('ValuationDate', StartDates, 'StartDates', StartDates, ...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', -1, 'Basis', Basis)
```

```
RateSpec =
```

```

        FinObj: 'RateSpec'
    Compounding: -1
        Disc: 0.9656
        Rates: 0.0350
    EndTimes: 1
    StartTimes: 0
        EndDates: 735600
    StartDates: 735235
    ValuationDate: 735235
        Basis: 1
    EndMonthRule: 1

```

Define the `StockSpec` for the asset.

```

AssetPrice = 100;
Sigma = 0.15;
DivType = 'continuous';
DivAmounts = 0.03;
StockSpec = stockspec(Sigma, AssetPrice, DivType, DivAmounts)

```

`StockSpec =`

```

        FinObj: 'StockSpec'
        Sigma: 0.1500
    AssetPrice: 100
    DividendType: {'continuous'}
    DividendAmounts: 0.0300
    ExDividendDates: []

```

Define the Asian 'call' and 'put' options.

```

Strike = 102;
OptSpec = {'put'; 'call'};
Settle = 'Jan-1-2013';
ExerciseDates = 'Jan-1-2014';

```

Compute the European geometric Average Price and sensitivities for the Asian option using the Kemna-Vorst model.

```

OutSpec = {'Price', 'Delta', 'Gamma'};
PriceSens = asiansensbykv(RateSpec, StockSpec, OptSpec, Strike,...
Settle, ExerciseDates, 'OutSpec', OutSpec)

```

PriceSens =

4.3871  
2.5163

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## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

The annualized continuously compounded interest-rate term structure specified by the **RateSpec** obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: `struct`

### **StockSpec** — Stock specification for underlying asset

structure

Stock specification for underlying asset, specified using **StockSpec** obtained from `stockspec`. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, stocks, stock indices and commodities. If dividends are not specified in **StockSpec**, dividends are assumed to be 0.

Data Types: `struct`

### **OptSpec** — Definition of option

string with values 'call' or 'put' | cell array of strings

Definition of option, specified as 'call' or 'put' using a NINST-by-1 cell array of strings.

Data Types: `cell` | `char`

### **Strike** — Option strike price values

nonnegative integer | vector of nonnegative integers



Option strike price values, specified with nonnegative integers using a NINST- by-1 vector.

Data Types: `single` | `double`

### **Settle** — Settlement dates or trade dates

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Settlement dates or trade dates for the Asian option, specified as nonnegative integers or date strings using a NINST-by-1 vector or cell array of dates.

Data Types: `char` | `cell`

### **ExerciseDates** — Option exercise dates

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

European option exercise dates, specified as nonnegative integers or date strings using a NINST-by-1 vector or cell array of exercise dates. For an European option, there is only one **ExerciseDates** on the option expiry date.

Data Types: `char` | `cell`

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of **Name**,**Value** arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as **Name1**,**Value1**, . . . ,**NameN**,**ValueN**.

Example: `PriceSens = asiansensbykv(RateSpec,StockSpec,OptSpec,Strike,Settle,ExerciseDates,'OutSpec',{'All'})`

### **'OutSpec'** — Define outputs

`{'Price'}` (default) | string with values: 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta' and 'All'. | cell array of strings with values: 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta' and 'All'.

Define outputs specifying NOUT- by-1 or 1-by-NOUT cell array of strings with possible values of 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta' and 'All'.

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec` as:

```
Example: OutSpec =  
{'delta', 'gamma', 'vega', 'lambda', 'rho', 'theta', 'price'}
```

Data Types: char | cell

## Output Arguments

### **PriceSens** — Expected prices and sensitivities of the Asian option

vector

Expected prices and sensitivities of the Asian option, returned as an 1-by-1 vector. If the `OutSpec` is not specified only price is returned.

## More About

- “Asian Option”

## See Also

`asianbycrr` | `asianbykv` | `asianbylevy` | `asianbyls` | `intenvset` | `stockspec`

# asianbylevy

Price of European arithmetic Asian options using Levy model

## Syntax

```
Price = asianbylevy(RateSpec, StockSpec, OptSpec, Strike, Settle,
  ExerciseDates)
```

## Description

Price = asianbylevy(RateSpec, StockSpec, OptSpec, Strike, Settle, ExerciseDates) returns European arithmetic average pricing for Asian options using the Levy model.

## Examples

### Compute the Price of an Asian Option Using the Levy Model

Define the RateSpec.

```
Rates = 0.07;
StartDates = 'Jan-1-2013';
EndDates = 'Jan-1-2014';
RateSpec = intenvset('ValuationDate', StartDates, 'StartDates', StartDates, 'EndDates',
  EndDates, 'Rates', Rates, 'Compounding', -1)
```

RateSpec =

```
      FinObj: 'RateSpec'
  Compounding: -1
         Disc: 0.9324
         Rates: 0.0700
    EndTimes: 1
  StartTimes: 0
    EndDates: 735600
```

```
StartDates: 735235
ValuationDate: 735235
Basis: 0
EndMonthRule: 1
```

Define the `StockSpec` for the asset.

```
AssetPrice = 6.8;
Sigma = 0.14;
DivType = 'continuous';
DivAmounts = 0.09;
StockSpec = stockspeg(Sigma, AssetPrice, DivType, DivAmounts)
```

```
StockSpec =
```

```
FinObj: 'StockSpec'
Sigma: 0.1400
AssetPrice: 6.8000
DividendType: {'continuous'}
DividendAmounts: 0.0900
ExDividendDates: []
```

Define two options for 'call' and 'put'.

```
Settle = 'Jan-1-2013';
Maturity = 'July-1-2013';
Strike = 6.9;
OptSpec = {'call'; 'put'};
```

Compute the European arithmetic average price for the Asian option using the Levy model.

```
Price= asianbylevy(RateSpec, StockSpec, OptSpec, Strike, Settle, Maturity)
```

```
Price =
```

```
0.0944
0.2237
```

- “Pricing Asian Options”

## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

Interest-rate term structure (annualized and continuously compounded), specified by the `RateSpec` obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: `struct`

### **StockSpec** — Stock specification for underlying asset

structure

Stock specification for underlying asset, specified using `StockSpec` obtained from `stockspec`. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, stocks, stock indices, and commodities. If dividends are not specified in `StockSpec`, dividends are assumed to be 0.

Data Types: `struct`

### **OptSpec** — Definition of option

string with values 'call' or 'put' | cell array of strings

Definition of option, specified as 'call' or 'put' using a NINST-by-1 cell array of strings.

Data Types: `char` | `cell`

### **Strike** — Option strike price values

nonnegative integer | vector of nonnegative integers

Option strike price values, specified with nonnegative integers as a NINST-by-1 vector.

Data Types: `single` | `double`

### **Settle** — Settlement dates or trade dates

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Settlement dates or trade dates for the Asian option, specified as nonnegative integers or date strings using a NINST-by-1 vector or cell array of dates.

Data Types: char | cell

**ExerciseDates** — Option exercise dates

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Option exercise dates, specified as nonnegative integers or date strings using a NINST-by-1 vector or cell array of exercise dates. For a European option, there is only one **ExerciseDates** on the option expiry date.

Data Types: char | cell

## Output Arguments

**Price** — Expected prices of Asian option

vector

Expected prices of the Asian option, returned as a NINST-by-1 vector.

## More About

- “Asian Option”

**See Also**

asianbycrr | asianbykv | asianbyls | asiansensbylevy | intenvset | stockspect

# asiansensbylevy

Calculate prices and sensitivities of European arithmetic Asian options using Levy model

## Syntax

```
PriceSens = asiansensbylevy(RateSpec,StockSpec,OptSpec,StrikeSettle,
ExerciseDates)
```

```
PriceSens = asiansensbylevy( ____,Name,Value)
```

## Description

PriceSens = asiansensbylevy(RateSpec,StockSpec,OptSpec,StrikeSettle, ExerciseDates) returns European average pricing and sensitivities for arithmetic Asian options using the Levy model.

PriceSens = asiansensbylevy( \_\_\_\_,Name,Value) returns European average pricing and sensitivities for arithmetic Asian options using the Levy model with optional name-value pair arguments.

## Examples

### Compute the Price and Sensitivities of an Asian Option Using the Levy Model

Define the RateSpec.

```
Rates = 0.07;
StartDates = 'Jan-1-2013';
EndDates = 'Jan-1-2014';
RateSpec = intenvset('ValuationDate', StartDates, 'StartDates', StartDates, 'EndDates',
EndDates, 'Rates', Rates, 'Compounding', -1)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
  Compounding: -1
        Disc: 0.9324
        Rates: 0.0700
```

```
EndTimes: 1
StartTimes: 0
EndDates: 735600
StartDates: 735235
ValuationDate: 735235
Basis: 0
EndMonthRule: 1
```

Define the `StockSpec` for the asset.

```
AssetPrice = 6.8;
Sigma = 0.14;
DivType = 'continuous';
DivAmounts = 0.09;
StockSpec = stockspec(Sigma, AssetPrice, DivType, DivAmounts)
```

```
StockSpec =
```

```
FinObj: 'StockSpec'
Sigma: 0.1400
AssetPrice: 6.8000
DividendType: {'continuous'}
DividendAmounts: 0.0900
ExDividendDates: []
```

Define two options for a 'call' and 'put'.

```
Settle = 'Jan-1-2013';
ExerciseDates = 'Jan-1-2014';
Strike = 6.9;
OptSpec = {'call'; 'put'};
```

Compute the European arithmetic average price and sensitivities for the Asian option using the Levy model.

```
OutSpec = {'Price', 'Delta', 'Gamma'};
PriceSens = asiandelta(PriceSpec, StockSpec, OptSpec, Strike, ...
Settle, ExerciseDates, 'OutSpec', OutSpec)
```

```
PriceSens =
```

```
0.1358
```



0.2921

- “Pricing Asian Options”

## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

Interest-rate term structure (annualized and continuously compounded), specified by the `RateSpec` obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: `struct`

### **StockSpec** — Stock specification for underlying asset

structure

Stock specification for underlying asset, specified using `StockSpec` obtained from `stockspec`. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, stocks, stock indices, and commodities. If dividends are not specified in `StockSpec`, dividends are assumed to be 0.

Data Types: `struct`

### **OptSpec** — Definition of option

string with values 'call' or 'put' | cell array of strings

Definition of option, specified as 'call' or 'put' using a NINST-by-1 cell array of strings.

Data Types: `char` | `cell`

### **Strike** — Option strike price values

nonnegative integer | vector of nonnegative integers

Option strike price values, specified with nonnegative integers using a NINST-by-1 vector.

Data Types: `single` | `double`

**Settle** — Settlement dates or trade dates

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Settlement dates or trade dates for the Asian option, specified as nonnegative integers or date strings using a NINST-by-1 vector or cell array of dates.

Data Types: char | cell

**ExerciseDates** — Option exercise dates

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Option exercise dates, specified as nonnegative integers or date strings using a NINST-by-1 vector or cell array of exercise dates. For a European option, there is only one **ExerciseDates** on the option expiry date.

Data Types: char | cell

## Name-Value Pair Arguments

Specify optional comma-separated pairs of **Name**,**Value** arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as **Name1**,**Value1**, . . . ,**NameN**,**ValueN**.

Example: `PriceSens = asiansensbylevy(RateSpec,StockSpec,OptSpec,Strike,Settle,ExerciseDates,'OutSpec',{'All'})`

**'OutSpec'** — Define outputs

{'Price'} (default) | string with values 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'. | cell array of strings with values 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'

Define outputs specifying NOUT- by-1 or 1-by-NOUT cell array of strings with possible values of 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta' and 'All'.

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying **OutSpec** to include each sensitivity:

```
Example: OutSpec =  
{'delta','gamma','vega','lambda','rho','theta','price'}
```

Data Types: char | cell

## Output Arguments

### **PriceSens** — Expected prices and sensitivities of Asian option

vector

Expected prices and sensitivities of the Asian option, returned as an 1-by-1 vector. If the `OutSpec` is not specified only the price is returned.

## More About

- “Asian Option”

## See Also

asianbycrr | asianbykv | asianbykv | asianbyls | intenvset | stockspec

## assetbybls

Determine price of asset-or-nothing digital options using Black-Scholes model

### Syntax

```
Price = assetbybls(RateSpec, StockSpec, Settle, Maturity,  
OptSpec, Strike)
```

### Arguments

RateSpec	The annualized continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of payoff strike price values.

### Description

`Price = assetbybls(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike)` computes asset-or-nothing option prices using the Black-Scholes option pricing model.

Price is a NINST-by-1 vector of expected option prices.

### Examples

#### Compute Asset-Or-Nothing Digital Option Prices Using the Black-Scholes Option Pricing Model

Consider two asset-or-nothing put options on a nondividend paying stock with a strike of 95 and 93 and expiring on January 30, 2009. On November 3, 2008 the stock is trading at

97.50. Using this data, calculate the price of the asset-or-nothing put options if the risk-free rate is 4.5% and the volatility is 22%. First, create the RateSpec.

```
Settle = 'Nov-3-2008';
Maturity = 'Jan-30-2009';
Rates = 0.045;
Compounding = -1;
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
    'EndDates', Maturity, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
    Compounding: -1
        Disc: 0.9893
        Rates: 0.0450
    EndTimes: 0.2391
    StartTimes: 0
    EndDates: 733803
    StartDates: 733715
    ValuationDate: 733715
        Basis: 0
    EndMonthRule: 1
```

Define the StockSpec.

```
AssetPrice = 97.50;
Sigma = .22;
StockSpec = stockspec(Sigma, AssetPrice)
```

```
StockSpec =
```

```
    FinObj: 'StockSpec'
        Sigma: 0.2200
    AssetPrice: 97.5000
    DividendType: []
    DividendAmounts: 0
    ExDividendDates: []
```

Define the put options.

```
OptSpec = {'put'};
```

```
Strike = [95;93];
```

Calculate the price.

```
Paon = assetbybls(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike)
```

```
Paon =
```

```
    33.7666
```

```
    26.9662
```

### **See Also**

assetsensbybls | cashbybls | gapbybls | supersharebybls

# assetsensbybls

Determine price and sensitivities of asset-or-nothing digital options using Black-Scholes model

## Syntax

```
PriceSens = assetsensbybls(RateSpec, StockSpec, Settle,
Maturity, OptSpec, Strike)
```

```
PriceSens = assetsensbybls(RateSpec, StockSpec, Settle,
Maturity, OptSpec, Strike, OutSpec)
```

## Arguments

RateSpec	The annualized, continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.
OutSpec	(Optional) All optional inputs are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. You can specify parameter name/value pairs in any order. Names are case-insensitive and partial string matches are allowed provided no ambiguities exist. Valid parameter names are: <ul style="list-style-type: none"> <li>NOUT-by-1 or 1-by-NOUT cell array of strings indicating the nature and order of the outputs for the function. Possible values are 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', or 'All'.</li> </ul>

For example, `OutSpec = {'Price'; 'Lambda'; 'Rho'}` specifies that the output should be Price, Lambda, and Rho, in that order.

To invoke from a function: `[Price, Lambda, Rho] = assetsensbybls(..., 'OutSpec', {'Price', 'Lambda', 'Rho'})`

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec = {'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', 'Price'}`;

- Default is `OutSpec = {'Price'}`.

## Description

`PriceSens = assetsensbybls(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike)` computes asset-or-nothing option prices using the Black-Scholes option pricing model.

`PriceSens = assetsensbybls(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike, OutSpec)` includes the parameter/value pairs defined for `OutSpec`, and computes asset-or-nothing option prices and sensitivities using the Black-Scholes option pricing model.

`PriceSens` is a NINST-by-1 vector of expected option prices and sensitivities.

## Examples

### Compute Asset-Or-Nothing Digital Option Prices and Sensitivities Using the Black-Scholes Option Pricing Model

Consider two asset-or-nothing put options on a nondividend paying stock with a strike of 95 and 93 and expiring on January 30, 2009. On November 3, 2008 the stock is trading at 97.50. Using this data, calculate the price and sensitivity of the asset-or-nothing put options if the risk-free rate is 4.5% and the volatility is 22%. First, create the `RateSpec`.



```

Settle = 'Nov-3-2008';
Maturity = 'Jan-30-2009';
Rates = 0.045;
Compounding = -1;
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
'EndDates', Maturity, 'Rates', Rates, 'Compounding', Compounding)

```

```
RateSpec =
```

```

    FinObj: 'RateSpec'
  Compounding: -1
        Disc: 0.9893
        Rates: 0.0450
    EndTimes: 0.2391
    StartTimes: 0
        EndDates: 733803
        StartDates: 733715
  ValuationDate: 733715
        Basis: 0
    EndMonthRule: 1

```

Define the StockSpec.

```

AssetPrice = 97.50;
Sigma = .22;
StockSpec = stockspec(Sigma, AssetPrice)

```

```
StockSpec =
```

```

    FinObj: 'StockSpec'
    Sigma: 0.2200
  AssetPrice: 97.5000
  DividendType: []
  DividendAmounts: 0
  ExDividendDates: []

```

Define the put options.

```

OptSpec = {'put'};
Strike = [95;93];

```

Calculate the delta, price, and gamma.

```
OutSpec = { 'delta'; 'price'; 'gamma'};  
[Delta, Price, Gamma] = assetsensbybls(RateSpec, StockSpec, Settle,...  
Maturity, OptSpec, Strike, 'OutSpec', OutSpec)
```

```
Delta =
```

```
-3.0833  
-2.8337
```

```
Price =
```

```
33.7666  
26.9662
```

```
Gamma =
```

```
0.0941  
0.1439
```

**See Also**  
assetbybls

# barrierbycrr

Price barrier option from Cox-Ross-Rubinstein binomial tree

## Syntax

```
[Price, PriceTree] = barrierbycrr(CRRTree, OptSpec, Strike,
Settle, ExerciseDates, AmericanOpt, BarrierSpec, Barrier,
Rebate, Options)
```

## Arguments

CRRTree	Stock tree structure created by <code>crrtree</code> .
OptSpec	NINST-by-1 list of string values 'Call' or 'Put'.
Strike	NINST-by-1 vector of strike price values. Each row is the schedule for one option.
Settle	NINST-by-1 vector of <code>Settle</code> dates. The settle date for every barrier option is set to the valuation date of the stock tree. The barrier argument <code>Settle</code> is ignored.
ExerciseDates	<p>For a European option (<code>AmericanOpt = 0</code>):</p> <p>NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option (<code>AmericanOpt = 1</code>):</p> <p>NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <code>ExerciseDates</code> is NINST-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.</p>
AmericanOpt	If <code>AmericanOpt = 0</code> , NaN, or is unspecified, the option is a European option. If <code>AmericanOpt = 1</code> , the option is an American option.

BarrierSpec	List of string values:  'UI': Up Knock In  'UO': Up Knock Out  'DI': Down Knock In  'DO': Down Knock Out
Barrier	Vector of barrier values.
Rebate	(Optional) NINST-by-1 matrix of rebate values. Default = 0. For Knock-in options, the rebate is paid at expiry. For Knock-out options, the rebate is paid when the barrier is reached.
Options	(Optional) Derivatives pricing options structure created with <code>derivset</code> .

See `instbarrier` for a description of barrier contract arguments.

## Description

`[Price, PriceTree] = barrierbycrr(CRRTree, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt, BarrierSpec, Barrier, Rebate, Options)` computes the price of barrier options using a CRR binomial tree.

`Price` is a NINST-by-1 vector of expected prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

## Examples

### Price a Barrier Option Using a CRR Binomial Tree

This example shows how to price a barrier option using a CRR binomial tree by loading the file `deriv.mat`, which provides `CRRTree`. The `CRRTree` structure contains the stock specification and time information needed to price the option.

```
load deriv.mat;
```

```
OptSpec = 'Call';  
Strike = 105;  
Settle = '01-Jan-2003';  
ExerciseDates = '01-Jan-2006';  
AmericanOpt = 1;  
BarrierSpec = 'UI';  
Barrier = 102;  
  
Price = barrierbycrr(CRRTree, OptSpec, Strike, Settle, ...  
ExerciseDates, AmericanOpt, BarrierSpec, Barrier)
```

```
Price =  
  
    12.1272
```

## More About

- “Pricing Options Structure”

## References

Derman, E., I. Kani, D. Ergener and I. Bardhan, “Enhanced Numerical Methods for Options with Barriers,” *Financial Analysts Journal*, (Nov. - Dec. 1995), pp. 65-74.

## See Also

crrtree | instbarrier

## barrierbyeqp

Price barrier option from Equal Probabilities binomial tree

### Syntax

```
[Price, PriceTree] = barrierbyeqp(EQPTree, OptSpec, Strike,
ExerciseDates, AmericanOpt, BarrierSpec, Barrier, Rebate,
Options)
```

### Arguments

EQPTree	Stock tree structure created by eqptree.
OptSpec	NINST-by-1 list of string values 'Call' or 'Put'.
Strike	NINST-by-1 vector of strike price values. Each row is the schedule for one option.
Settle	NINST-by-1 vector of Settle dates. The settle date for every barrier option is set to the valuation date of the stock tree. The barrier argument Settle is ignored.
ExerciseDates	For a European option (AmericanOpt = 0):  NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.  For an American option (AmericanOpt = 1):  NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if ExerciseDates is NINST-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.
AmericanOpt	If AmericanOpt = 0, NaN, or is unspecified, the option is a European option. If AmericanOpt = 1, the option is an American option.

BarrierSpec	List of string values:  'UI': Up Knock In  'UO': Up Knock Out  'DI': Down Knock In  'DO': Down Knock Out
Barrier	Vector of barrier values.
Rebate	(Optional) NINST-by-1 matrix of rebate values. Default = 0. For Knock-in options, the rebate is paid at expiry. For Knock-out options, the rebate is paid when the barrier is reached.
Options	(Optional) Derivatives pricing options structure created with derivset.

See `instbarrier` for a description of barrier contract arguments.

## Description

`[Price, PriceTree] = barrierbyeqp(EQPTree, OptSpec, Strike, ExerciseDates, AmericanOpt, BarrierSpec, Barrier, Rebate, Options)` computes the price of barrier options using an equal probabilities binomial tree.

`Price` is a NINST-by-1 vector of expected prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

## Examples

### Price a Barrier Option Using an EQP Equity Tree

This example shows how to price a barrier option using an EQP equity tree by loading the file `deriv.mat`, which provides `EQPTree`. The `EQPTree` structure contains the stock specification and time information needed to price the option.

```
load deriv.mat;
```

```
OptSpec = 'Call';
Strike = 105;
Settle = '01-Jan-2003';
ExerciseDates = '01-Jan-2006';
AmericanOpt = 1;
BarrierSpec = 'UI';
Barrier = 102;

Price = barrierbyeqp(EQPTree, OptSpec, Strike, Settle, ...
ExerciseDates, AmericanOpt, BarrierSpec, Barrier)

Price =

    12.2632
```

## More About

- “Pricing Options Structure”

## References

Derman, E., I. Kani, D. Ergener and I. Bardhan, “Enhanced Numerical Methods for Options with Barriers,” *Financial Analysts Journal*, (Nov. - Dec. 1995), pp. 65-74.

## See Also

eqptree | instbarrier



# barrierbyitt

Price barrier options using implied trinomial tree (ITT)

## Syntax

```
[Price, PriceTree] = barrierbyitt(ITTree, OptSpec, Strike,
ExerciseDates, AmericanOpt, BarrierSpec, Barrier, Rebate,
Options)
```

## Arguments

ITTree	Stock tree structure created by <code>itttree</code> .
OptSpec	NINST-by-1 list of string values 'Call' or 'Put'.
Strike	European and American option, NINST-by-1 vector of strike price values. Each row is the schedule for one option.
Settle	NINST-by-1 vector of <code>Settle</code> dates. The settle date for every barrier option is set to the valuation date of the stock tree. The barrier argument <code>Settle</code> is ignored.
ExerciseDates	For a European option ( <code>AmericanOpt = 0</code> ):  NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.  For an American option ( <code>AmericanOpt = 1</code> ):  NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <code>ExerciseDates</code> is NINST-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.
AmericanOpt	If <code>AmericanOpt = 0</code> , NaN, or is unspecified, the option is a European option. If <code>AmericanOpt = 1</code> , the option is an American option.

BarrierSpec	List of string values:  'UI': Up Knock In  'UO': Up Knock Out  'DI': Down Knock In  'DO': Down Knock Out
Barrier	Vector of barrier values.
Rebate	(Optional) NINST-by-1 matrix of rebate values. Default = 0. For Knock In options, the rebate is paid at expiry. For Knock Out options, the rebate is paid when the barrier is reached.
Options	(Optional) Derivatives pricing options structure created with derivset.

See `instbarrier` for a description of barrier contract arguments.

## Description

`[Price, PriceTree] = barrierbyitt(ITTree, OptSpec, Strike, ExerciseDates, AmericanOpt, BarrierSpec, Barrier, Rebate, Options)` computes the price of barrier options using an implied trinomial tree.

`Price` is a NINST-by-1 vector of expected prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

---

**Note:** The `Settle` date for every barrier option is set to the `ValuationDate` of the stock tree. The barrier argument, `Settle`, is ignored.

---

## Examples

### Price a Barrier Option Using an ITT Tree

This example shows how to price a barrier option using an ITT tree by loading the file `deriv.mat`, which provides `ITTTree`. The `ITTTree` structure contains the stock specification and time information needed to price the option.

```
load deriv.mat;

OptSpec = 'Call';
Strike = 85;
Settle = '01-Jan-2006';
ExerciseDates = '31-Dec-2008';
AmericanOpt = 1;
BarrierSpec = 'UI';
Barrier = 115;

Price = barrierbyitt(ITTTree,OptSpec,Strike,Settle,ExerciseDates,AmericanOpt,...
BarrierSpec,Barrier)

Price =

    2.4074
```

## More About

- “Pricing Options Structure”

## References

Derman, E., I. Kani, D. Ergener, and I. Bardhan, “Enhanced Numerical Methods for Options with Barriers,” *Financial Analysts Journal*, Nov.-Dec.,1995.

## See Also

`instbarrier` | `itttree`

## basketbyju

Price European basket options using Nengjiu Ju approximation model

### Syntax

```
Price = basketbyju(RateSpec, BasketStockSpec, OptSpec, Strike,  
Settle, Maturity)
```

### Description

Price = basketbyju(RateSpec, BasketStockSpec, OptSpec, Strike, Settle, Maturity) prices European basket options using the Nengjiu Ju approximation model.

### Input Arguments

#### RateSpec

Annualized, continuously compounded rate term structure. For more information on the interest rate specification, see `intenvset`.

#### BasketStockSpec

BasketStock specification. For information on the basket of stocks specification, see `basketstocks`.

#### OptSpec

String or 2-by-1 cell array of the strings 'call' or 'put'.

#### Strike

Scalar for the option strike price.

#### Settle

Scalar of the settlement or trade date specified as a string or serial date number.

## Maturity

Maturity date specified as a string or serial date number.

## Output Arguments

### Price

Price of the basket option.

## Examples

Find a European call basket option of two stocks. Assume that the stocks are currently trading at \$10 and \$11.50 with annual volatilities of 20% and 25%, respectively. The basket contains one unit of the first stock and one unit of the second stock. The correlation between the assets is 30%. On January 1, 2009, an investor wants to buy a 1-year call option with a strike price of \$21.50. The current annualized, continuously compounded interest rate is 5%. Use this data to compute the price of the call basket option with the Ju approximation model.

```

Settle = 'Jan-1-2009';
Maturity = 'Jan-1-2010';

% Define RateSpec
Rate = 0.05;
Compounding = -1;
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', ...
Settle, 'EndDates', Maturity, 'Rates', Rate, 'Compounding', Compounding);

% Define the Correlation matrix. Correlation matrices are symmetric, and
% have ones along the main diagonal.
Corr = [1 0.30; 0.30 1];

% Define BasketStockSpec
AssetPrice = [10;11.50];
Volatility = [0.2;0.25];
Quantity = [1;1];
BasketStockSpec = basketstockspec(Volatility, AssetPrice, Quantity, Corr);

%Compute the price of the call basket option
OptSpec = {'call'};
Strike = 21.5;
PriceCorr30 = basketbyju(RateSpec, BasketStockSpec, OptSpec, Strike, Settle, Maturity)

```

This returns:

```
PriceCorr30 =
```

2.12214

Compute the price of the basket instrument for these two stocks with a correlation of 60%. Then compare this cost to the total cost of buying two individual call options:

```
Corr = [1 0.60; 0.60 1];

% Define the new BasketStockSpec
BasketStockSpec = basketstockspec(Volatility, AssetPrice, Quantity, Corr);

%Compute the price of the call basket option with Correlation = -0.60
PriceCorr60 = basketbyju(RateSpec, BasketStockSpec, OptSpec, Strike, Settle, Maturity)
```

This returns:

```
PriceCorr60 =

    2.27566
```

The following table summarizes the sensitivity of the option to correlation changes. In general, the premium of the basket option decreases with lower correlation and increases with higher correlation.

Correlation	-0.60	-0.30	0	0.30	0.60
Premium	1.52830	1.76006	1.9527	2.1221	2.2756

Compute the cost of two vanilla 1-year call options using the Black-Scholes (BLS) model on the individual assets:

```
StockSpec = stockspec(Volatility, AssetPrice);
StrikeVanilla= [10;11.5];

PriceVanillaOption = optstockbybls(RateSpec, StockSpec, Settle, Maturity,...
OptSpec, StrikeVanilla)
```

This returns:

```
PriceVanillaOption =

    1.0451
    1.4186
```

Find the total cost of buying two individual call options:

```
sum(PriceVanillaOption)
```

This returns:

ans=2.4637

The total cost of purchasing two individual call options is \$2.4637, compared to the maximum cost of the basket option of \$2.27 with a correlation of 60%.

## More About

- “Basket Option” on page 3-21

## References

Nengjiu Ju, “Pricing Asian and Basket Options Via Taylor Expansion”, *Journal of Computational Finance*, Vol. 5, 2002.

## See Also

[basketstockspec](#) | [basketsensbyju](#)

## basketbyls

Price basket options using Longstaff-Schwartz model

### Syntax

```
Price = basketbyls(RateSpec, BasketStockSpec, OptSpec, Strike,
Settle, ExerciseDates)
Price = basketbyls(RateSpec, BasketStockSpec, OptSpec, Strike,
Settle, ExerciseDates, 'ParameterName', ParameterValue ...)
```

### Description

`Price = basketbyls(RateSpec, BasketStockSpec, OptSpec, Strike, Settle, ExerciseDates)` prices basket options using the Longstaff-Schwartz model.

`Price = basketbyls(RateSpec, BasketStockSpec, OptSpec, Strike, Settle, ExerciseDates, 'ParameterName', ParameterValue ...)` accepts optional inputs as one or more comma-separated parameter/value pairs. *'ParameterName'* is the name of the parameter inside single quotes. *'ParameterValue'* is the value corresponding to *'ParameterName'*. Specify parameter-value pairs in any order. Names are case-insensitive and partial string matches are allowable, if no ambiguities exist.

### Input Arguments

#### RateSpec

Annualized, continuously compounded rate term structure. For more information on the interest rate specification, see `intenvset`.

#### BasketStockSpec

BasketStock specification. For information on the basket of stocks specification, see `basketstockspec`.



**OptSpec**

String or 2-by-1 cell array of the strings 'call' or 'put'.

**Strike**

The option strike price:

- For a European or Bermuda option, **Strike** is a scalar (European) or 1-by-NSTRIKES (Bermuda) vector of strike price.
- For an American option, **Strike** is a scalar vector of the strike price.

**Settle**

Scalar of the settlement or trade date specified as a string or serial date number.

**ExerciseDates**

The exercise date for the option:

- For a European or Bermuda option, **ExerciseDates** is a 1-by-1 (European) or 1-by-NSTRIKES (Bermuda) vector of exercise dates. For a European option, there is only one **ExerciseDate** on the option expiry date.
- For an American option, **ExerciseDates** is a 1-by-2 vector of exercise date boundaries. The option exercises on any date between, or including, the pair of dates on that row. If there is only one non-NaN date, or if **ExerciseDates** is 1-by-1, the option exercises between the **Settle** date and the single listed **ExerciseDate**.

**Parameter–Value Pairs****AmericanOpt**

Parameter values are a scalar flag.

- 0 — European/Bermuda
- 1 — American

**Default:** 0

**NumPeriods**

Parameter value is a scalar number of simulation periods per trial. **NumPeriods** is considered only when pricing European basket options. For American and Bermuda

basket options, NumPeriod equals the number of exercise days during the life of the option.

**Default:** 100

### **NumTrials**

Parameter value is a scalar number of independent sample paths (simulation trials).

**Default:** 1000

## **Output Arguments**

### **Price**

Price of the basket option.

## **Examples**

### **Prices Basket Options Using the Longstaff-Schwartz Model**

Find an American call basket option of three stocks. The stocks are currently trading at \$35, \$40 and \$45 with annual volatilities of 12%, 15% and 18%, respectively. The basket contains 33.33% of each stock. Assume the correlation between all pair of assets is 50%. On May 1, 2009, an investor wants to buy a three-year call option with a strike price of \$42. The current annualized continuously compounded interest rate is 5%. Use this data to compute the price of the call basket option using the Longstaff-Schwartz model.

```
Settle = 'May-1-2009';  
Maturity = 'May-1-2012';  
  
% Define RateSpec  
Rate = 0.05;  
Compounding = -1;  
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', ...  
Settle, 'EndDates', Maturity, 'Rates', Rate, 'Compounding', Compounding);  
  
% Define the Correlation matrix. Correlation matrices are symmetric,  
% and have ones along the main diagonal.  
Corr = [1 0.50 0.50; 0.50 1 0.50; 0.50 0.50 1];
```

```

% Define BasketStockSpec
AssetPrice = [35;40;45];
Volatility = [0.12;0.15;0.18];
Quantity = [0.333;0.333;0.333];
BasketStockSpec = basketstockspec(Volatility, AssetPrice, Quantity, Corr);

% Compute the price of the call basket option
OptSpec = {'call'};
Strike = 42;
AmericanOpt = 1; % American option
Price = basketbyls(RateSpec, BasketStockSpec, OptSpec, Strike, Settle, Maturity,...
'AmericanOpt',AmericanOpt)

Price =

    5.4687

```

Increase the number of simulation trials to 2000 to give the following results:

```

NumTrial = 2000;
Price = basketbyls(RateSpec, BasketStockSpec, OptSpec, Strike, Settle, Maturity,...
'AmericanOpt',AmericanOpt,'NumTrials',NumTrial)

Price =

    5.5501

```

## More About

- “Basket Option” on page 3-21

## References

Longstaff, F.A., and E.S. Schwartz, “Valuing American Options by Simulation: A Simple Least-Squares Approach”, *The Review of Financial Studies*, Vol. 14, No. 1, Spring 2001, pp. 113–147.

**See Also**

`basketstockspec` | `basketsensbyls`

# basketsensbyju

Determine European basket options price and sensitivities using Nengjiu Ju approximation model

## Syntax

```
PriceSens = basketsensbyju(RateSpec, BasketStockSpec, OptSpec,
Strike,
Settle, Maturity)
PriceSens = basketsensbyju(RateSpec, BasketStockSpec, OptSpec,
Strike,
Settle, Maturity, 'ParameterName', ParameterValue ...)
```

## Description

`PriceSens = basketsensbyju(RateSpec, BasketStockSpec, OptSpec, Strike, Settle, Maturity)` calculates prices and sensitivities for basket options using the Nengjiu Ju approximation model.

`PriceSens = basketsensbyju(RateSpec, BasketStockSpec, OptSpec, Strike, Settle, Maturity, 'ParameterName', ParameterValue ...)` accepts optional inputs as one or more comma-separated parameter/value pairs. *'ParameterName'* is the name of the parameter inside single quotes. *'ParameterValue'* is the value corresponding to *'ParameterName'*. Specify parameter-value pairs in any order. Names are case-insensitive and partial string matches are allowable, if no ambiguities exist.

## Input Arguments

### RateSpec

Annualized, continuously compounded rate term structure. For more information on the interest rate specification, see `intenvset`.

**BasketStockSpec**

BasketStock specification. For information on the basket of stocks specification, see `basketstockspec`.

**OptSpec**

String or 2-by-1 cell array of the strings 'call' or 'put'.

**Strike**

Scalar of the option strike price.

**Settle**

Scalar of the settlement or trade date specified as a string or serial date number.

**Maturity**

Maturity date, specified as a string or serial date number.

**Parameter-Value Pairs****OutSpec**

Parameter value is an NOUT-by-1 or 1-by-NOUT cell array of strings indicating the nature and order of the outputs for the function. Possible values are 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'. For example, `OutSpec = {'Price', 'Lambda', 'Rho'}` specifies that the output is Price, Lambda, and Rho, in that order.

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec` as `OutSpec = {'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', 'Price'};`

**Default:** `OutSpec = {'Price'}`

**UndIdx**

Scalar of the indice of the underlying instrument to compute the sensitivity.

Default: UndIdx = [ ]

## Output Arguments

### PriceSens

Expected prices or sensitivities values for the basket option.

## Examples

### Calculate Prices and Sensitivities for Basket Options Using the Nengjiu Ju Approximation Model

Find a European call basket option of five stocks. Assume that the basket contains:

- 5% of the first stock trading at \$110
- 15% of the second stock trading at \$75
- 20% of the third stock trading at \$40
- 25% of the fourth stock trading at \$125
- 35% of the fifth stock trading at \$92

These stocks have annual volatilities of 20% and the correlation between the assets is zero. On May 1, 2009, an investor wants to buy a 1-year call option with a strike price of \$90. The current annualized, continuously compounded interest is 5%. Use this data to compute price and delta of the call basket option with the Ju approximation model.

```
Settle = 'May-1-2009';
Maturity = 'May-1-2010';

% Define RateSpec
Rate = 0.05;
Compounding = -1;
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', ...
Settle, 'EndDates', Maturity, 'Rates', Rate, 'Compounding', Compounding);

% Define the Correlation matrix. Correlation matrices are symmetric, and
% have ones along the main diagonal.
NumInst = 5;
InstIdx = ones(NumInst,1);
```

```
Corr = diag(ones(5,1), 0);

% Define BasketStockSpec
AssetPrice = [110; 75; 40; 125; 92];
Volatility = 0.2;
Quantity = [0.05; 0.15; 0.2; 0.25; 0.35];
BasketStockSpec = basketstockspec(Volatility, AssetPrice, Quantity, Corr);

% Compute the price of the call basket option. Calculate also the delta
% of the first stock.
OptSpec = {'call'};
Strike = 90;
OutSpec = {'Price', 'Delta'};
UndIdx = 1; % First element in the basket
[Price, Delta] = basketsensbyju(RateSpec, BasketStockSpec, OptSpec, Strike, Settle, ..
Maturity, 'OutSpec', OutSpec, 'UndIdx', UndIdx)
```

```
Price =
    5.1610
```

```
Delta =
    0.0297
```

Compute Delta with respect to the second asset:

```
UndIdx = 2; % Second element in the basket
OutSpec = {'Delta'};
Delta = basketsensbyju(RateSpec, BasketStockSpec, OptSpec, Strike, Settle, Maturity, ..
'OutSpec', OutSpec, 'UndIdx', UndIdx)
```

```
Delta =
    0.0906
```

## More About

- “Basket Option” on page 3-21



## References

Nengjiu Ju, “Pricing Asian and Basket Options Via Taylor Expansion”, *Journal of Computational Finance*, Vol. 5, 2002.

## See Also

[basketstockspec](#) | [basketbyju](#)

## basketsensbyls

Determine price and sensitivities for basket options using Longstaff-Schwartz model

### Syntax

```
PriceSens = basketsensbyls(RateSpec, BasketStockSpec, OptSpec,  
Strike,  
Settle, ExerciseDates)  
PriceSens = basketsensbyls(RateSpec, BasketStockSpec, OptSpec,  
Strike,  
Settle, ExerciseDates, 'ParameterName', ParameterValue ...)
```

### Description

`PriceSens = basketsensbyls(RateSpec, BasketStockSpec, OptSpec, Strike, Settle, ExerciseDates)` prices basket options using the Longstaff-Schwartz model.

`PriceSens = basketsensbyls(RateSpec, BasketStockSpec, OptSpec, Strike, Settle, ExerciseDates, 'ParameterName', ParameterValue ...)` accepts optional inputs as one or more comma-separated parameter/value pairs. `'ParameterName'` is the name of the parameter inside single quotes. `'ParameterValue'` is the value corresponding to `'ParameterName'`. Specify parameter-value pairs in any order. Names are case-insensitive and partial string matches are allowable, if no ambiguities exist.

### Input Arguments

#### RateSpec

Annualized, continuously compounded rate term structure. For more information on the interest rate specification, see `intenvset`.

## **BasketStockSpec**

BasketStock specification. For information on the basket of stocks specification, see `basketstockspec`.

## **OptSpec**

String or 2-by-1 cell array of the strings 'call' or 'put'.

## **Strike**

The option strike price:

- For a European or Bermuda option, **Strike** is a scalar (European) or 1-by-NSTRIKES (Bermuda) vector of strike price.
- For an American option, **Strike** is a scalar vector of strike price.

## **Settle**

Scalar of settlement or trade date.

## **ExerciseDates**

The exercise date for the option:

- For a European or Bermuda option, **ExerciseDates** is a 1-by-1 (European) or 1-by-NSTRIKES (Bermuda) vector of exercise dates. For a European option, there is only one **ExerciseDate** on the option expiry date.
- For an American option, **ExerciseDates** is a 1-by-2 vector of exercise date boundaries. The option exercises on any date between or including the pair of dates on that row. If there is only one non-NaN date, or if **ExerciseDates** is 1-by-1, the option exercises between the **Settle** date and the single listed **ExerciseDate**.

## **Parameter–Value Pairs**

### **AmericanOpt**

Parameter values are a scalar flag.

- 0 — European/Bermuda
- 1 — American

**Default:** 0

### **NumPeriods**

Parameter value is a scalar number of simulation periods. `NumPeriods` is considered only when pricing European basket options. For American and Bermuda basket options, `NumPeriod` equals the number of exercise days during the life of the option.

**Default:** 100

### **NumTrials**

Parameter value is a scalar number of independent sample paths (simulation trials).

**Default:** 1000

### **OutSpec**

Parameter value is an NOUT-by-1 or 1-by-NOUT cell array of strings indicating the nature and order of the outputs for the function. Possible values are 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'. For example, `OutSpec = {'Price', 'Lambda', 'Rho'}` specifies that the output is Price, Lambda, and Rho, in that order.

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec` as `OutSpec = {'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', 'Price'};`

**Default:** `OutSpec = {'Price'}`

### **UndIdx**

Scalar of the indice of the underlying instrument to compute the sensitivity.

**Default:** `UndIdx = []`

## **Output Arguments**

### **PriceSens**

Expected prices or sensitivities values.

## Examples

### Calculate Price and Sensitivities for Basket Options Using the Longstaff-Schwartz Model

Find a European put basket option of two stocks. The basket contains 50% of each stock. The stocks are currently trading at \$90 and \$75, with annual volatilities of 15%. Assume that the correlation between the assets is zero. On May 1, 2009, an investor wants to buy a one-year put option with a strike price of \$80. The current annualized, continuously compounded interest is 5%. Use this data to compute price and delta of the put basket option with the Longstaff-Schwartz approximation model.

```

Settle = 'May-1-2009';
Maturity = 'May-1-2010';

% Define RateSpec
Rate = 0.05;
Compounding = -1;
RateSpec = intenvset('ValuationDate', Settle, 'StartDates',...
Settle, 'EndDates', Maturity, 'Rates', Rate, 'Compounding', Compounding);

% Define the Correlation matrix. Correlation matrices are symmetric,
% and have ones along the main diagonal.
NumInst = 2;
InstIdx = ones(NumInst,1);
Corr = diag(ones(NumInst,1), 0);

% Define BasketStockSpec
AssetPrice = [90; 75];
Volatility = 0.15;
Quantity = [0.50; 0.50];
BasketStockSpec = basketstockspec(Volatility, AssetPrice, Quantity, Corr);

% Compute the price of the put basket option. Calculate also the delta
% of the first stock.
OptSpec = {'put'};
Strike = 80;
OutSpec = {'Price', 'Delta'};
UndIdx = 1; % First element in the basket

[PriceSens, Delta] = basketsensbyls(RateSpec, BasketStockSpec, OptSpec,...
Strike, Settle, Maturity, 'OutSpec', OutSpec, 'UndIdx', UndIdx)

```

```
PriceSens =  
    0.9822
```

```
Delta =  
    -0.0995
```

Compute the Price and Delta of the basket with a correlation of -20%:

```
NewCorr = [1 -0.20; -0.20 1];
```

```
% Define the new BasketStockSpec.
```

```
BasketStockSpec = basketstockspec(Volatility, AssetPrice, Quantity, NewCorr);
```

```
% Compute the price and delta of the put basket option.
```

```
[PriceSens, Delta] = basketsensbyls(RateSpec, BasketStockSpec, OptSpec,...  
Strike, Settle, Maturity, 'OutSpec', OutSpec, 'UndIdx', UndIdx)
```

```
PriceSens =  
    0.7814
```

```
Delta =  
    -0.0961
```

## More About

- “Basket Option” on page 3-21

## References

Longstaff, F.A., and E.S. Schwartz, “Valuing American Options by Simulation: A Simple Least-Squares Approach”, *The Review of Financial Studies*, Vol. 14, No. 1, Spring 2001, pp. 113–147.

**See Also**

[basketstockspec](#) | [basketbyls](#)

## basketstockspec

Specify basket stock structure using Longstaff-Schwartz model

### Syntax

```
BasketStockSpec = basketstockspec(Sigma, AssetPrice, Quantity,  
Correlation)  
BasketStockSpec = basketstockspec(Sigma, AssetPrice, Quantity,  
Correlation, 'ParameterName', ParameterValue ...)
```

### Description

`BasketStockSpec = basketstockspec(Sigma, AssetPrice, Quantity, Correlation)` creates a basket stock structure.

`BasketStockSpec = basketstockspec(Sigma, AssetPrice, Quantity, Correlation, 'ParameterName', ParameterValue ...)` accepts optional inputs as one or more comma-separated parameter/value pairs. `'ParameterName'` is the name of the parameter inside single quotes. `'ParameterValue'` is the value corresponding to `'ParameterName'`. Specify parameter-value pairs in any order. Names are case-insensitive and partial string matches are allowable, if no ambiguities exist.

### Input Arguments

#### **Sigma**

NINST-by-1 vector of decimal annual price volatility of the underlying security.

#### **AssetPrice**

NINST-by-1 vector of underlying asset price values at time 0.

#### **Quantity**

NINST-by-1 vector of quantities of the instruments contained in the basket.



## Correlation

NINST-by-NINST matrix of correlation values.

## Parameter–Value Pairs

### DividendAmounts

NINST-by-1 cell array specifying the dividend amounts for basket instruments. Each element of the cell array is a 1-by-NDIV row vector of cash dividends or a scalar representing a continuous annualized dividend yield for the corresponding instrument.

### DividendType

NINST-by-1 cell array of strings specifying each stock's dividend type. Dividend type must be either **cash** for actual dollar dividends or **continuous** for continuous dividend yield. .

### ExDividendDates

NINST-by-1 cell array specifying the ex-dividend dates for the basket instruments. Each row is a 1-by-NDIV matrix of ex-dividend dates for **cash** type. For rows that correspond to basket instruments with **continuous** dividend type, the cell is empty. If none of the basket instruments pay **continuous** dividends, do not specify **ExDividendDates**.

## Output Arguments

### BasketStockSpec

Structure encapsulating the properties of a basket stock structure.

## Examples

### Create a Basket Stock Structure for Three Stocks

Find a basket option of three stocks. The stocks are currently trading at \$56, \$92 and \$125 with annual volatilities of 20%, 12% and 15%, respectively. The basket option contains 25% of the first stock, 40% of the second stock, and 35% of the third. The first stock provides a continuous dividend of 1%, while the other two provide no dividends.

The correlation between the first and second asset is 30%, between the second and third asset 11%, and between the first and third asset 16%. Use this data to create the `BasketStockSpec` structure:

```
AssetPrice = [56;92;125];
Sigma = [0.20;0.12;0.15];

% Create the Correlation matrix. Correlation matrices are symmetric and
% have ones along the main diagonal.
NumInst = 3;
Corr = zeros(NumInst,1);
Corr(1,2) = .30;
Corr(2,3) = .11;
Corr(1,3) = .16;
Corr = triu(Corr,1) + tril(Corr',-1) + diag(ones(NumInst,1), 0);

% Define dividends
DivType = cell(NumInst,1);
DivType{1}='continuous';
DivAmounts = cell(NumInst,1);
DivAmounts{1} = 0.01;

Quantity = [0.25; 0.40; 0.35];

BasketStockSpec = basketstockspec(Sigma, AssetPrice, Quantity, Corr, ...
'DividendType', DivType, 'DividendAmounts', DivAmounts)

BasketStockSpec =

    FinObj: 'BasketStockSpec'
    Sigma: [3x1 double]
    AssetPrice: [3x1 double]
    Quantity: [3x1 double]
    Correlation: [3x3 double]
    DividendType: {3x1 cell}
    DividendAmounts: {3x1 cell}
    ExDividendDates: {3x1 cell}
```

Examine the `BasketStockSpec` structure.

```
BasketStockSpec.Correlation
```

```
ans =
```

```
    1.0000    0.3000    0.1600
    0.3000    1.0000    0.1100
    0.1600    0.1100    1.0000
```

### Create a Basket Stock Structure for Two Stocks

Find a basket option of two stocks. The stocks are currently trading at \$60 and \$55 with volatilities of 30% per annum. The basket option contains 50% of each stock. The first stock provides a cash dividend of \$0.25 on May 1, 2009 and September 1, 2009. The second stock provides a continuous dividend of 3%. The correlation between the assets is 40%. Use this data to create the structure `BasketStockSpec`:

```
AssetPrice = [60;55];
Sigma = [0.30;0.30];

% Create the Correlation matrix. Correlation matrices are symmetric and
% have ones along the main diagonal.
Correlation = [1 0.40;0.40 1];

% Define dividends
NumInst = 2;
DivType = cell(NumInst,1);
DivType{1}='cash';
DivType{2}='continuous';

DivAmounts = cell(NumInst,1);
DivAmounts{1} = [0.25 0.25];
DivAmounts{2} = 0.03;

ExDates = cell(NumInst,1);
ExDates{1} = {'May-1-2009' 'Sept-1-2009'};

Quantity = [0.5; 0.50];

BasketStockSpec = basketstockspec(Sigma, AssetPrice, Quantity, Correlation, ...
'DividendType', DivType, 'DividendAmounts', DivAmounts, 'ExDividendDates',ExDates)

BasketStockSpec =

    FinObj: 'BasketStockSpec'
```

```
        Sigma: [2x1 double]
    AssetPrice: [2x1 double]
        Quantity: [2x1 double]
    Correlation: [2x2 double]
    DividendType: {2x1 cell}
    DividendAmounts: {2x1 cell}
    ExDividendDates: {2x1 cell}
```

Examine the `BasketStockSpec` structure.

`BasketStockSpec.DividendType`

```
ans =
```

```
    'cash'
    'continuous'
```

## More About

- “Basket Option” on page 3-21

## See Also

`basketbyls` | `basketbyju` | `basketsensbyju` | `basketsensbyls` | `stockspec` | `intenvset`

# bdtpprice

Instrument prices from Black-Derman-Toy interest-rate tree

## Syntax

```
[Price, PriceTree] = bdtpprice(BDTree, InstSet, Options)
```

## Arguments

BDTree	Interest-rate tree structure created by <code>bdttree</code> .
InstSet	Variable containing a collection of NINST instruments. Instruments are categorized by type. Each type can have different data fields. The stored data field is a row vector or string for each instrument.
Options	(Optional) Derivatives pricing options structure created with <code>derivset</code> .

## Description

`[Price, PriceTree] = bdtpprice(BDTree, InstSet, Options)` computes arbitrage-free prices for instruments using an interest-rate tree created with `bdttree`. All instruments contained in a financial instrument variable, `InstSet`, are priced.

`Price` is a number of instruments (NINST)-by-1 vector of prices for each instrument at time 0. The prices are computed by backward dynamic programming on the interest-rate tree. If an instrument cannot be priced, NaN is returned.

`PriceTree` is a MATLAB structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node.

`PriceTree.PTree` contains the clean prices.

`PriceTree.AITree` contains the accrued interest.

`PriceTree.tObs` contains the observation times.

`bdtprice` handles instrument types: 'Bond', 'CashFlow', 'OptBond', 'OptEmBond', 'OptFloat', 'OptEmFloat', 'Fixed', 'Float', 'Cap', 'Floor', 'RangeFloat', 'Swap'. See `instadd` to construct defined types.

Related single-type pricing functions are:

- `bondbybdt`: Price a bond from a BDT tree.
- `capbybdt`: Price a cap from a BDT tree.
- `cfbybdt`: Price an arbitrary set of cash flows from a BDT tree.
- `fixedbybdt`: Price a fixed-rate note from a BDT tree.
- `floatbybdt`: Price a floating-rate note from a BDT tree.
- `floorbybdt`: Price a floor from a BDT tree.
- `optbndbybdt`: Price a bond option from a BDT tree.
- `optfloatbybdt`: Price a floating-rate note with an option from a BDT tree.
- `optemfloatbybdt`: Price a floating-rate note with an embedded option from a BDT tree.
- `optembndbybdt`: Price a bond with embedded option by a BDT tree.
- `rangefloatbybdt`: Price range floating note using a BDT tree.
- `swapbybdt`: Price a swap from a BDT tree.
- `swaptionbybdt`: Price a swaption from a BDT tree.

## Examples

### Price a Cap and Bond Instruments Contained in an Instrument Set

Load the BDT tree and instruments from the data file `deriv.mat` to price the cap and bond instruments contained in the instrument set.

```
load deriv.mat;
BDTSubSet = instselect(BDTInstSet, 'Type', {'Bond', 'Cap'});

instdisp(BDTSubSet)
```

```

instdisp(BDTSubSet)
Index Type CouponRate Settle Maturity Period Basis EndMonthRule IssueDate FirstCouponDate LastCouponDate Sta
1 Bond 0.1 01-Jan-2000 01-Jan-2003 1 NaN NaN NaN NaN NaN NaN
2 Bond 0.1 01-Jan-2000 01-Jan-2004 2 NaN NaN NaN NaN NaN NaN

Index Type Strike Settle Maturity CapReset Basis Principal Name Quantity
3 Cap 0.15 01-Jan-2000 01-Jan-2004 1 NaN NaN 15% Cap 30

```

Price the bond and cap.

```
[Price, PriceTree] = bdtprice(BDTTree, BDTSubSet)
```

```
Warning: Not all cash flows are aligned with the tree. Result will be approximated.
> In checktree at 289
   In bdtprice at 85
```

```
Price =
```

```

95.5030
93.9079
 1.4375

```

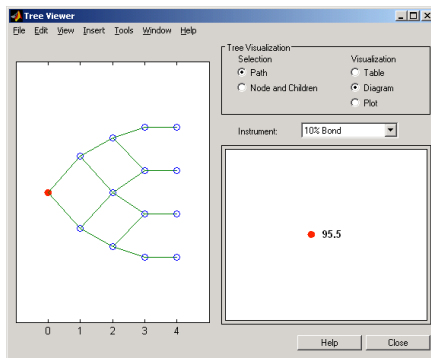
```
PriceTree =
```

```

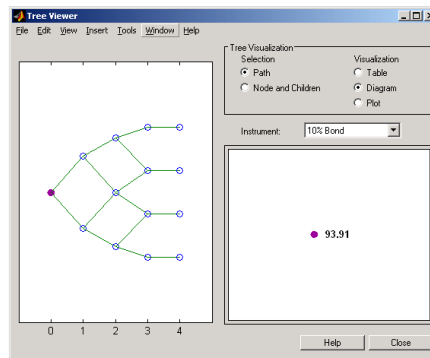
FinObj: 'BDTPriceTree'
PTree: {[3x1 double] [3x2 double] [3x3 double] [3x4 double] [3x4 double]}
AITree: {[3x1 double] [3x2 double] [3x3 double] [3x4 double] [3x4 double]}
tObs: [0 1 2 3 4]

```

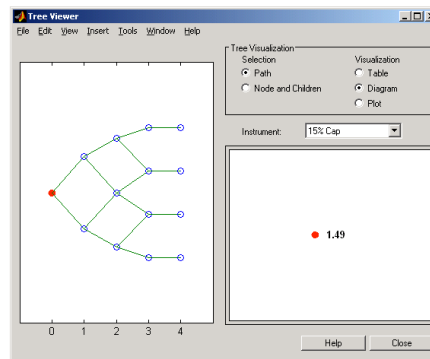
You can use the `treeviewer` function to see the prices of these three instruments along the price tree.



First 10% Bond (Maturity 2003)



Second 10% Bond (Maturity 2004)



15% Cap

## Price Multi-Stepped Coupon Bonds

Price the following multi-stepped coupon bonds using the following data:

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2010';
StartDates = ValuationDate;
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};
Compounding = 1;

% Create RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);
```



```
% Create a portfolio of stepped coupon bonds with different maturities
Settle = '01-Jan-2010';
Maturity = {'01-Jan-2011'; '01-Jan-2012'; '01-Jan-2013'; '01-Jan-2014'};
CouponRate = {{'01-Jan-2011' .042; '01-Jan-2012' .05; '01-Jan-2013' .06; '01-Jan-2014' .07}}
```

```
% Display the instrument portfolio
ISet = instbond(CouponRate, Settle, Maturity, 1);
instdisp(ISet)
```

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate
1	Bond	[Cell]	01-Jan-2010	01-Jan-2011	1	0	1	NaN
2	Bond	[Cell]	01-Jan-2010	01-Jan-2012	1	0	1	NaN
3	Bond	[Cell]	01-Jan-2010	01-Jan-2013	1	0	1	NaN
4	Bond	[Cell]	01-Jan-2010	01-Jan-2014	1	0	1	NaN

Build a BDTTree to price the stepped coupon bonds. Assume the volatility to be 10%

```
Sigma = 0.1;
BDTTimeSpec = bdttimespec(ValuationDate, EndDates, Compounding);
BDTVolSpec = bdtvolspec(ValuationDate, EndDates, Sigma*ones(1, length(EndDates)));
BDTT = bdttree(BDTVolSpec, RS, BDTTimeSpec);
```

```
% Compute the price of the stepped coupon bonds
PBDT = bdtprice(BDTT, ISet)
```

```
PBDT =
```

```
100.6763
100.7368
100.9266
101.0115
```

## Price a Portfolio of Stepped Callable Bonds and Stepped Vanilla Bonds

Price a portfolio of stepped callable bonds and stepped vanilla bonds using the following data: The data for the interest rate term structure is as follows:

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2010';
StartDates = ValuationDate;
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};
```

```

Compounding = 1;

%Create RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% Create an instrument portfolio of 3 stepped callable bonds and three
% stepped vanilla bonds
Settle = '01-Jan-2010';
Maturity = {'01-Jan-2012'; '01-Jan-2013'; '01-Jan-2014'};
CouponRate = {'01-Jan-2011' .042; '01-Jan-2012' .05; '01-Jan-2013' .06; '01-Jan-2014' .07};
OptSpec='call';
Strike=100;
ExerciseDates='01-Jan-2011'; %Callable in one year

% Bonds with embedded option
ISet = instoptembnd(CouponRate, Settle, Maturity, OptSpec, Strike,...
ExerciseDates, 'Period', 1);

% Vanilla bonds
ISet = instbond(ISet, CouponRate, Settle, Maturity, 1);

% Display the instrument portfolio
instdisp(ISet)

```

Index	Type	CouponRate	Settle	Maturity	OptSpec	Strike	ExerciseDates
1	OptEmBond	[Cell]	01-Jan-2010	01-Jan-2012	call	100	01-Jan-2011
2	OptEmBond	[Cell]	01-Jan-2010	01-Jan-2013	call	100	01-Jan-2011
3	OptEmBond	[Cell]	01-Jan-2010	01-Jan-2014	call	100	01-Jan-2011

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate
4	Bond	[Cell]	01-Jan-2010	01-Jan-2012	1	0	1	NaN
5	Bond	[Cell]	01-Jan-2010	01-Jan-2013	1	0	1	NaN
6	Bond	[Cell]	01-Jan-2010	01-Jan-2014	1	0	1	NaN

Build a BDTTree and price the instruments. Build the tree Assume the volatility to be 10%

```

Sigma = 0.1;
BDTTimeSpec = bdttimespec(ValuationDate, EndDates, Compounding);
BDTVolSpec = bdtvolspec(ValuationDate, EndDates, Sigma*ones(1, length(EndDates)));
BDTT = bdttree(BDTVolSpec, RS, BDTTimeSpec);

%The first three rows corresponds to the price of the stepped callable bonds and the

```

```
%last three rows corresponds to the price of the stepped vanilla bonds.
PBDT = bdtprice(BDTT, ISet)
```

```
PBDT =
```

```
100.4799
100.3228
100.0840
100.7368
100.9266
101.0115
```

### Price a Portfolio with Range Notes and a Floating Rate Note

Compute the price of a portfolio with range notes and a floating rate note using the following data: The data for the interest rate term structure is as follows:

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2011';
StartDates = ValuationDate;
EndDates = {'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'};
Compounding = 1;

% Create RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% Create an instrument portfolio with two range notes and a floating rate
% note with the following data:
Spread = 200;
Settle = 'Jan-1-2011';
Maturity = 'Jan-1-2014';

% First Range Note:
RateSched(1).Dates = {'Jan-1-2012'; 'Jan-1-2013' ; 'Jan-1-2014'};
RateSched(1).Rates = [0.045 0.055; 0.0525 0.0675; 0.06 0.08];

% Second Range Note:
RateSched(2).Dates = {'Jan-1-2012'; 'Jan-1-2013' ; 'Jan-1-2014'};
RateSched(2).Rates = [0.048 0.059; 0.055 0.068 ; 0.07 0.09];

% Create InstSet
InstSet = instadd('RangeFloat', Spread, Settle, Maturity, RateSched);
```

```
% Add a floating-rate note
InstSet = instadd(InstSet, 'Float', Spread, Settle, Maturity);
```

```
% Display the portfolio instrument
instdisp(InstSet)
```

Index	Type	Spread	Settle	Maturity	RateSched	FloatReset	Basis	Princ
1	RangeFloat	200	01-Jan-2011	01-Jan-2014	[Struct]	1	0	100
2	RangeFloat	200	01-Jan-2011	01-Jan-2014	[Struct]	1	0	100

Index	Type	Spread	Settle	Maturity	FloatReset	Basis	Principal	EndMonthRU
3	Float	200	01-Jan-2011	01-Jan-2014	1	0	100	1

Build a BDTTree and price the instruments. Build the tree Assume the volatility to be 10%.

```
Sigma = 0.1;
BDTTS = bdttimespec(ValuationDate, EndDates, Compounding);
BDTVS = bdtvolspec(ValuationDate, EndDates, Sigma*ones(1, length(EndDates)));
BDTT = bdttree(BDTV, RS, BDTTS);
```

```
% Price the portfolio
Price = bdtprice(BDTT, InstSet)
```

```
Price =

    100.2841
     98.0757
    105.5147
```

## More About

- “Pricing Options Structure”

## See Also

bdtrens | bdttree | instadd | intenvprice | intenvsens

# bdtSENS

Instrument prices and sensitivities from Black-Derman-Toy interest-rate tree

## Syntax

```
[Delta, Gamma, Vega, Price] = bdtSENS(BDTTree, InstSet,
Options)
```

## Arguments

<b>BDTTree</b>	Interest-rate tree structure created by <code>bdttree</code> .
<b>InstSet</b>	Variable containing a collection of NINST instruments. Instruments are categorized by type. Each type can have different data fields. The stored data field is a row vector or string for each instrument.
<b>Options</b>	(Optional) Derivatives pricing options structure created with <code>derivset</code> .

## Description

`[Delta, Gamma, Vega, Price] = bdtSENS(BDTTree, InstSet, Options)` computes instrument sensitivities and prices for instruments using an interest-rate tree created with the `bdttree` function. NINST instruments from a financial instrument variable, `InstSet`, are priced. `bdtSENS` handles instrument types: 'Bond', 'CashFlow', 'OptBond', 'OptEmBond', 'OptEmBond', 'OptFloat', 'OptEmFloat', 'Fixed', 'Float', 'Cap', 'Floor', 'RangeFloat', 'Swap'. See `instadd` for information on instrument types.

**Delta** is an NINST-by-1 vector of deltas, representing the rate of change of instrument prices with respect to changes in the interest rate. **Delta** is computed by finite differences in calls to `bdttree`. See `bdttree` for information on the observed yield curve.

**Gamma** is an NINST-by-1 vector of gammas, representing the rate of change of instrument deltas with respect to the changes in the interest rate. **Gamma** is computed by finite differences in calls to `bdttree`.

Vega is an NINST-by-1 vector of vegas, representing the rate of change of instrument prices with respect to the changes in the volatility  $\sigma(t, T)$ . Vega is computed by finite differences in calls to `bdttree`. See `bdtvolspec` for information on the volatility process.

---

**Note** All sensitivities are returned as dollar sensitivities. To find the per-dollar sensitivities, divide by the respective instrument price.

---

Price is an NINST-by-1 vector of prices of each instrument. The prices are computed by backward dynamic programming on the interest-rate tree. If an instrument cannot be priced, NaN is returned.

Delta and Gamma are calculated based on yield shifts of 100 basis points. Vega is calculated based on a 1% shift in the volatility process.

## Examples

### Compute Instrument Sensitivities and Prices for Cap and Bond instruments

Load the tree and instruments from the `deriv.mat` data file.

```
load deriv.mat;
BDTSubSet = instselect(BDTInstSet, 'Type', {'Bond', 'Cap'});
```

```
instdisp(BDTSubSet)
```

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate
1	Bond	0.1	01-Jan-2000	01-Jan-2003	1	NaN	NaN	NaN
2	Bond	0.1	01-Jan-2000	01-Jan-2004	2	NaN	NaN	NaN

Index	Type	Strike	Settle	Maturity	CapReset	Basis	Principal	Name	Quantity
3	Cap	0.15	01-Jan-2000	01-Jan-2004	1	NaN	NaN	15% Cap	30

Compute Delta and Gamma for the cap and bond instruments contained in the instrument set.

```
[Delta, Gamma] = bdtrens(BDTTree, BDTSubSet)
```

Warning: Not all cash flows are aligned with the tree. Result will be

approximated.

Delta =

-232.6681

-281.0517

63.8102

Gamma =

1.0e+03 \*

0.8037

1.1819

1.8535

## More About

- “Pricing Options Structure”

## See Also

bdtprice | bdttree | bdtvolspec | instadd

## bdttimespec

Specify time structure for Black-Derman-Toy interest-rate tree

### Syntax

TimeSpec = bdttimespec(ValuationDate, Maturity, Compounding)

### Arguments

ValuationDate	Scalar date marking the pricing date and first observation in the tree. Specify as serial date number or date string.
Maturity	Number of levels (depth) of the tree. A number of levels (NLEVELS)-by-1 vector of dates marking the cash flow dates of the tree. Cash flows with these maturities fall on tree nodes. Maturity should be in increasing order.
Compounding	<p>(Optional) Scalar value representing the rate at which the input zero rates were compounded when annualized. Default = 1. This argument determines the formula for the discount factors:</p> <p>Compounding = 1, 2, 3, 4, 6, 12</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the compounding frequency, Z is the zero rate, and T is the time in periodic units; for example, T = F is 1 year.</p> <p>Compounding = 365</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the number of days in the basis year and T is a number of days elapsed computed by basis.</p> <p>Compounding = -1</p> <p>Disc = <math>\exp(-T*Z)</math>, where T is time in years.</p>



## Description

`TimeSpec = bdttimespec(ValuationDate, Maturity, Compounding)` sets the number of levels and node times for a BDT tree and determines the mapping between dates and time for rate quoting.

`TimeSpec` is a structure specifying the time layout for `bdttree`. The state observation dates are `[ValuationDate; Maturity(1:end-1)]`. Because a forward rate is stored at the last observation, the tree can value cash flows out to `Maturity`.

## Examples

### Specify a Five-Period Tree with Annual Nodes

This example shows how to specify a five-period tree with annual nodes and use annual compounding to report rates.

```
Compounding = 1;
ValuationDate = '01-01-2000';
Maturity = ['01-01-2001'; '01-01-2002'; '01-01-2003';
'01-01-2004'; '01-01-2005'];
```

```
TimeSpec = bdttimespec(ValuationDate, Maturity, Compounding)
```

```
TimeSpec =
    FinObj: 'BDTTimeSpec'
  ValuationDate: 730486
    Maturity: [5x1 double]
  Compounding: 1
    Basis: 0
  EndMonthRule: 1
```

### See Also

`bdttree` | `bdtvolspec`

## bdttree

Construct Black-Derman-Toy interest-rate tree

### Syntax

```
BDTTree = bdttree(VolSpec, RateSpec, TimeSpec)
```

### Arguments

VolSpec	Volatility process specification. See <code>bdtvolspec</code> for information on the volatility process.
RateSpec	Interest-rate specification for the initial rate curve. See <code>intenvset</code> for information on declaring an interest-rate variable.
TimeSpec	Tree time layout specification. Defines the observation dates of the BDT tree and the <b>Compounding</b> rule for date to time mapping and price-yield formulas. See <code>bdttimespec</code> for information on the tree structure.

### Description

`BDTTree = bdttree(VolSpec, RateSpec, TimeSpec)` creates a structure containing time and interest-rate information on a recombining tree.

### Examples

Using the data provided, create a BDT volatility specification (`VolSpec`), rate specification (`RateSpec`), and tree time layout specification (`TimeSpec`). Then use these specifications to create a BDT tree with `bdttree`.

```
Compounding = 1;  
ValuationDate = '01-01-2000';  
StartDate = ValuationDate;  
EndDates = ['01-01-2001'; '01-01-2002'; '01-01-2003'];
```

```

'01-01-2004'; '01-01-2005'];
Rates = [.1; .11; .12; .125; .13];
Volatility = [.2; .19; .18; .17; .16];

RateSpec = intenvset('Compounding', Compounding,...
    'ValuationDate', ValuationDate,...
    'StartDates', StartDate,...
    'EndDates', EndDates,...
    'Rates', Rates);

BDTTimeSpec = bdttimespec(ValuationDate, EndDates, Compounding);
BDTVolSpec = bdtvolspec(ValuationDate, EndDates, Volatility);
BDTTree = bdttree(BDTVolSpec, RateSpec, BDTTimeSpec)

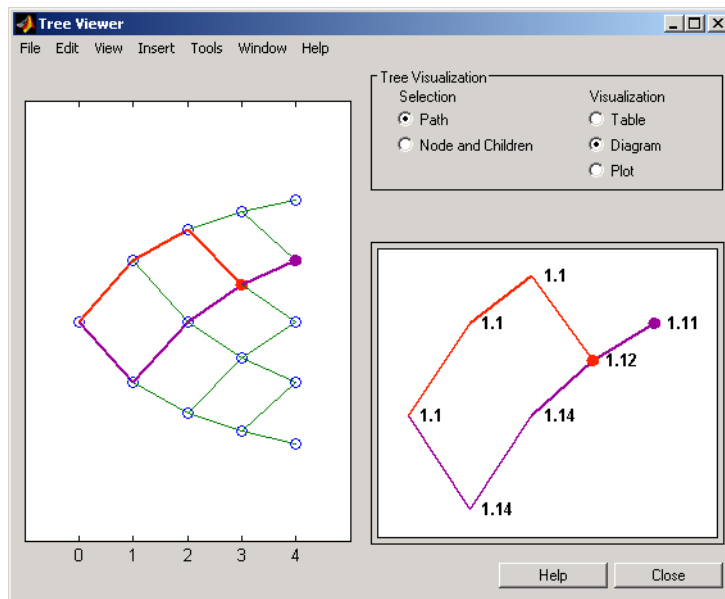
BDTTree =

    FinObj: 'BDTFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
    tObs: [0 1 2 3 4]
    dObs: [730486 730852 731217 731582 731947]
    TFwd: {[5x1 double] [4x1 double] [3x1 double] [2x1 double] [4]}
    CFlowT: {[5x1 double] [4x1 double] [3x1 double] [2x1 double] [5]}
    FwdTree: {[1.1000] [1.0979 1.1432] [1.0976 1.1377 1.1942] [1.0872 1.1183 1.1606 1.2179] [1x5 double]}

```

Use `treeviewer` to observe the tree you have created.

```
treeviewer(BDTTree)
```



**See Also**

`bdtprice` | `bdttimespec` | `bdtvolspec` | `intenvset`

# bdtvolspec

Specify Black-Derman-Toy interest-rate volatility process

## Syntax

```
Volspec = bdtvolspec(ValuationDate, VolDates, VolCurve,
InterpMethod)
```

## Arguments

ValuationDate	Scalar value representing the observation date of the investment horizon.
VolDates	Number of points (NPOINTS)-by-1 vector of yield volatility end dates.
VolCurve	NPOINTS-by-1 vector of yield volatility values in decimal form. The term structure of VolCurve is the yield volatility represented by the value of the volatility of the yield from time $t = 0$ to time $t + i$ , where $i$ is any point within the volatility curve.
InterpMethod	(Optional) Interpolation method. Default is 'linear'. See <code>interp1</code> for more information.

## Description

Volspec = bdtvolspec(ValuationDate, VolDates, VolCurve, InterpMethod) creates a structure specifying the volatility for `bdttree`.

## Examples

### Create a BDT Volatility Specification

This example shows how to create a BDT volatility specification (VolSpec) using the following data.

```
ValuationDate = '01-01-2000';
EndDates = ['01-01-2001'; '01-01-2002'; '01-01-2003';
'01-01-2004'; '01-01-2005'];
Volatility = [.2; .19; .18; .17; .16];

BDTVolSpec = bdtvolspec(ValuationDate, EndDates, Volatility)
```

```
BDTVolSpec =

    FinObj: 'BDTVolSpec'
  ValuationDate: 730486
    VolDates: [5x1 double]
    VolCurve: [5x1 double]
VolInterpMethod: 'linear'
```

## See Also

[bdttree](#) | [interp1](#)

# bkprice

Instrument prices from Black-Karasinski interest-rate tree

## Syntax

```
[Price, PriceTree] = bkprice(BKTree, InstSet, Options)
```

## Arguments

<b>BKTree</b>	Interest-rate tree structure created by <code>bktree</code> .
<b>InstSet</b>	Variable containing a collection of NINST instruments. Instruments are categorized by type. Each type can have different data fields. The stored data field is a row vector or string for each instrument.
<b>Options</b>	(Optional) Derivatives pricing options structure created with <code>derivset</code> .

## Description

`[Price, PriceTree] = bkprice(BKTree, InstSet, Options)` computes arbitrage-free prices for instruments using an interest-rate tree created with `bktree`. All instruments contained in a financial instrument variable, `InstSet`, are priced.

`Price` is a number of instruments (NINST)-by-1 vector of prices for each instrument. The prices are computed by backward dynamic programming on the interest-rate tree. If an instrument cannot be priced, NaN is returned.

`PriceTree` is a MATLAB structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node.

`PriceTree.PTree` contains the clean prices.

`PriceTree.AITree` contains the accrued interest.

`PriceTree.tObs` contains the observation times.

bkprice handles instrument types: 'Bond', 'CashFlow', 'OptBond', 'OptEmBond', 'OptEmBond', 'OptFloat', 'OptEmFloat', 'Fixed', 'Float', 'Cap', 'Floor', 'RangeFloat', 'Swap'. See `instadd` to construct defined types.

Related single-type pricing functions are:

- `bondbybk`: Price a bond from a Black-Karasinski tree.
- `capbybk`: Price a cap from a Black-Karasinski tree.
- `cfbybk`: Price an arbitrary set of cash flows from a Black-Karasinski tree.
- `fixedbybk`: Price a fixed-rate note from a Black-Karasinski tree.
- `floatbybk`: Price a floating-rate note from a Black-Karasinski tree.
- `floorbybk`: Price a floor from a Black-Karasinski tree.
- `optbndbybk`: Price a bond option from a Black-Karasinski tree.
- `optembndbybk`: Price a bond with embedded option by a Black-Karasinski tree.
- `optfloatbybdt`: Price a floating-rate note with an option from a Black-Karasinski tree.
- `optemfloatbybdt`: Price a floating-rate note with an embedded option from a Black-Karasinski tree.
- `rangefloatbybk`: Price range floating note from a Black-Karasinski tree.
- `swapbybk`: Price a swap from a Black-Karasinski tree.
- `swaptionbybk`: Price a swaption from a Black-Karasinski tree.

## Examples

Load the BK tree and instruments from the data file `deriv.mat`. Price the cap and bond instruments contained in the instrument set.

```
load deriv.mat;
BKSubSet = instselect(BKInstSet, 'Type', {'Bond', 'Cap'});

instdisp(BKSubSet)

%Table of instrument portfolio partially displayed:
Index Type   CouponRate Settle      Maturity   Period ... Name ...
1      Bond    0.03         01-Jan-2004 01-Jan-2007 1      ... 3% bond
2      Bond    0.03         01-Jan-2004 01-Jan-2008 2      ... 3% bond

Index Type Strike Settle      Maturity   CapReset ... Name ...
3      Cap    0.04         01-Jan-2004 01-Jan-2008 1      ... 4% Cap

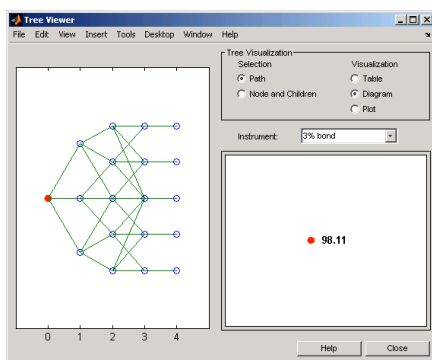
[Price, PriceTree] = bkprice(BKTree, BKSubSet);
```



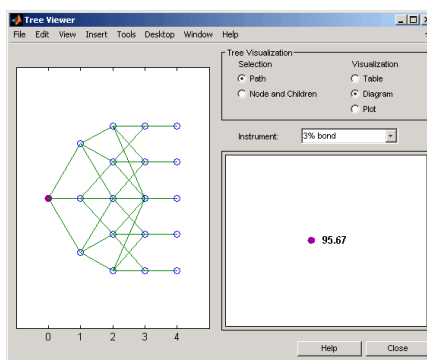
Price =  
 98.1096  
 95.6734  
 2.2706

You can use `treeviewer` to see the prices of these three instruments along the price tree.

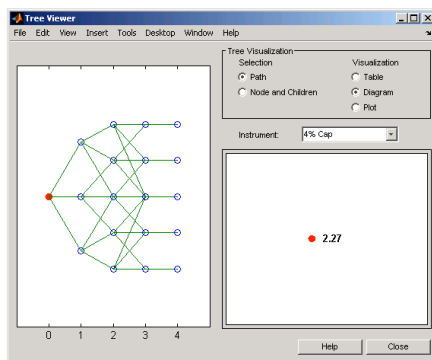
`treeviewer(PriceTree, BKSubSet)`



First 3% Bond (Maturity 2007)



Second 3% Bond (Maturity 2008)



4% Cap

Price the following multi-stepped coupon bonds using the following data:

`% The data for the interest rate term structure is as follows:`

```

Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2010';
StartDates = ValuationDate;
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};
Compounding = 1;

% Create RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% Create a portfolio of stepped coupon bonds with different maturities
Settle = '01-Jan-2010';
Maturity = {'01-Jan-2011'; '01-Jan-2012'; '01-Jan-2013'; '01-Jan-2014'};
CouponRate = {{'01-Jan-2011' .042; '01-Jan-2012' .05; '01-Jan-2013' .06; '01-Jan-2014' .07}};

ISet = instbond(CouponRate, Settle, Maturity, 1);
instdisp(ISet)

%Table of instrument portfolio partially displayed:
Index Type CouponRate Settle Maturity Period Basis EndMonthRule ... Face
1 Bond [Cell] 01-Jan-2010 01-Jan-2011 1 0 1 ... 100
2 Bond [Cell] 01-Jan-2010 01-Jan-2012 1 0 1 ... 100
3 Bond [Cell] 01-Jan-2010 01-Jan-2013 1 0 1 ... 100
4 Bond [Cell] 01-Jan-2010 01-Jan-2014 1 0 1 ... 100

% Build the tree with the following data
VolDates = ['1-Jan-2011'; '1-Jan-2012'; '1-Jan-2013'; '1-Jan-2014'];
VolCurve = 0.01;
AlphaDates = '01-01-2014';
AlphaCurve = 0.1;

BKVolSpec = bkvolspec(RS.ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);
BKTimeSpec = bktimespec(RS.ValuationDate, VolDates, Compounding);
BKT = bktree(BKVolSpec, RS, BKTimeSpec);

% Compute the price of the stepped coupon bonds
PBK = bkprice(BKT, ISet)

PBK =

100.6763
100.7368
100.9266
101.0115

```

Price a portfolio of stepped callable bonds and stepped vanilla bonds using the following data:

```

% The data for the interest rate term structure is as follows:
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2010';
StartDates = ValuationDate;
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};
Compounding = 1;

%Create RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

```

```

% Create an instrument portfolio of 3 stepped callable bonds and three
% stepped vanilla bonds
Settle = '01-Jan-2010';
Maturity = {'01-Jan-2012'; '01-Jan-2013'; '01-Jan-2014'};
CouponRate = {'01-Jan-2011' .042; '01-Jan-2012' .05; '01-Jan-2013' .06; '01-Jan-2014' .07};
OptSpec='call';
Strike=100;
ExerciseDates='01-Jan-2011'; %Callable in one year

% Bonds with embedded option
ISet = instoptembnd(CouponRate, Settle, Maturity, OptSpec, Strike,...
ExerciseDates, 'Period', 1);

% Vanilla bonds
ISet = instbond(ISet, CouponRate, Settle, Maturity, 1);

% Display the instrument portfolio
instdisp(ISet)

%Table of instrument portfolio partially displayed:
Index Type CouponRate      Settle      Maturity      OptSpec Strike ExerciseDates ... AmericanOpt
1      OptEmBond [Cell]  01-Jan-2010  01-Jan-2012   call      100  01-Jan-2011  ...  0
2      OptEmBond [Cell]  01-Jan-2010  01-Jan-2013   call      100  01-Jan-2011  ...  0
3      OptEmBond [Cell]  01-Jan-2010  01-Jan-2014   call      100  01-Jan-2011  ...  0

Index Type CouponRate Settle      Maturity      Period Basis EndMonthRule ... Face
4      Bond [Cell]  01-Jan-2010  01-Jan-2012   1          0      1          ... 100
5      Bond [Cell]  01-Jan-2010  01-Jan-2013   1          0      1          ... 100
6      Bond [Cell]  01-Jan-2010  01-Jan-2014   1          0      1          ... 100

% Build the tree with the following data
VolDates = ['1-Jan-2011'; '1-Jan-2012'; '1-Jan-2013'; '1-Jan-2014'];
VolCurve = 0.01;
AlphaDates = '01-01-2014';
AlphaCurve = 0.1;

BKVolSpec = bkvolspec(RS.ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);
BKTimeSpec = bktimespec(RS.ValuationDate, VolDates, Compounding);
BKT = bktree(BKVolSpec, RS, BKTimeSpec);

% The first three rows corresponds to the price of the stepped callable bonds
% and the last three rows corresponds to the price of the stepped vanilla bonds.

PBK = bkprice(BKT, ISet)

PBK =

100.6735
100.6763
100.6763
100.7368
100.9266
101.0115

```

Compute the price of a portfolio using the following data:

```

% The data for the interest rate term structure is as follows:
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2011';
StartDates = ValuationDate;
EndDates = {'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'};
Compounding = 1;

% Create RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates',...
StartDates, 'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% Create an instrument portfolio with two range notes and a floating rate
% note with the following data:
Spread = 200;
Settle = 'Jan-1-2011';
Maturity = 'Jan-1-2014';

% First Range Note:
RateSched(1).Dates = {'Jan-1-2012'; 'Jan-1-2013' ; 'Jan-1-2014'};
RateSched(1).Rates = [0.045 0.055; 0.0525 0.0675; 0.06 0.08];

% Second Range Note:
RateSched(2).Dates = {'Jan-1-2012'; 'Jan-1-2013' ; 'Jan-1-2014'};
RateSched(2).Rates = [0.048 0.059; 0.055 0.068 ; 0.07 0.09];

% Create InstSet
InstSet = instadd('RangeFloat', Spread, Settle, Maturity, RateSched);

% Add a floating-rate note
InstSet = instadd(InstSet, 'Float', Spread, Settle, Maturity);

% Display the portfolio instrument
instdisp(InstSet)

Index Type      Spread Settle      Maturity  RateSched FloatReset Basis Principal EndMonthRule
1   RangeFloat  200    01-Jan-2011  01-Jan-2014 [Struct]  1      0    100      1
2   RangeFloat  200    01-Jan-2011  01-Jan-2014 [Struct]  1      0    100      1

Index Type      Spread Settle      Maturity  FloatReset Basis Principal EndMonthRule
3   Float       200    01-Jan-2011  01-Jan-2014  1      0    100      1

% The data to build the tree is as follows:
VolDates = ['1-Jan-2012'; '1-Jan-2013'; '1-Jan-2014'; '1-Jan-2015'];
VolCurve = 0.01;
AlphaDates = '01-01-2015';
AlphaCurve = 0.1;

BKVS = bkvolspec(RS.ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);
BKTS = bktimespec(RS.ValuationDate, VolDates, Compounding);
BKT = bktree(BKVS, RS, BKTS);

% Price the portfolio
Price = bkprice(BKT, InstSet)

```

Price =

105.5147

101.4740

105.5147

### **See Also**

bksens | bktree | instadd | intenvprice | intenvsens

## bksens

Instrument prices and sensitivities from Black-Karasinski interest-rate tree

### Syntax

```
[Delta, Gamma, Vega, Price] = bksens(BKTree, InstSet,
Options)
```

### Arguments

BKTree	Interest-rate tree structure created by <code>bktree</code> .
InstSet	Variable containing a collection of NINST instruments. Instruments are categorized by type. Each type can have different data fields. The stored data field is a row vector or string for each instrument.
Options	(Optional) Derivatives pricing options structure created with <code>derivset</code> .

### Description

`[Delta, Gamma, Vega, Price] = bksens(BKTree, InstSet, Options)` computes instrument sensitivities and prices for instruments using an interest-rate tree created with the `bktree` function. NINST instruments from a financial instrument variable, `InstSet`, are priced. `bksens` handles instrument types: 'Bond', 'CashFlow', 'OptBond', 'OptEmBond', 'OptEmBond', 'OptFloat', 'OptEmFloat', 'Fixed', 'Float', 'Cap', 'Floor', 'RangeFloat', 'Swap'. See `instadd` for information on instrument types.

`Delta` is an NINST-by-1 vector of deltas, representing the rate of change of instrument prices with respect to changes in the interest rate. `Delta` is computed by finite differences in calls to `bktree`. See `bktree` for information on the observed yield curve.

`Gamma` is an NINST-by-1 vector of gammas, representing the rate of change of instrument deltas with respect to the changes in the interest rate. `Gamma` is computed by finite differences in calls to `bktree`.

Vega is an NINST-by-1 vector of vegas, representing the rate of change of instrument prices with respect to the changes in the volatility  $\sigma(t, T)$ . Vega is computed by finite differences in calls to `bktree`. See `bkvolspec` for information on the volatility process.

---

**Note** All sensitivities are returned as dollar sensitivities. To find the per-dollar sensitivities, divide by the respective instrument price.

---

Price is an NINST-by-1 vector of prices of each instrument. The prices are computed by backward dynamic programming on the interest-rate tree. If an instrument cannot be priced, NaN is returned.

Delta and Gamma are calculated based on yield shifts of 100 basis points. Vega is calculated based on a 1% shift in the volatility process.

## Examples

### Compute Instrument Sensitivities and Prices for Cap and Bond Instruments

Load the tree and instruments from the `deriv.mat` data file.

```
load deriv.mat;
BKSubSet = instselect(BKInstSet, 'Type', {'Bond', 'Cap'});
```

```
instdisp(BKSubSet)
```

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate
1	Bond	0.03	01-Jan-2004	01-Jan-2007	1	0	1	NaN
2	Bond	0.03	01-Jan-2004	01-Jan-2008	1	0	1	NaN

Index	Type	Strike	Settle	Maturity	CapReset	Basis	Principal	Name	Quantity
3	Cap	0.04	01-Jan-2004	01-Jan-2008	1	0	100	4% Cap	10

Compute Delta and Gamma for the cap and bond instruments contained in the instrument set.

```
[Delta, Gamma] = bksens(BKTree, BKSubSet)
```

Delta =

-285.7151  
-365.7048  
189.5319

Gamma =

1.0e+03 \*  
  
0.8456  
1.4345  
6.9999

### More About

- “Pricing Options Structure”

### See Also

`bkprice` | `bktree` | `bkvolspec` | `instadd`



# bktimespec

Specify time structure for Black-Karasinski tree

## Syntax

TimeSpec = bktimespec(ValuationDate, Maturity, Compounding)

## Arguments

ValuationDate	Scalar date marking the pricing date and first observation in the tree. Specify as a serial date number or date string.
Maturity	Number of levels (depth) of the tree. A number of levels (NLEVELS)-by-1 vector of dates marking the cash flow dates of the tree. Cash flows with these maturities fall on tree nodes. Maturity should be in increasing order.
Compounding	<p>(Optional) Scalar value representing the rate at which the input zero rates were compounded when annualized. Default = -1 (continuous compounding). This argument determines the formula for the discount factors:</p> <p>Compounding = 1, 2, 3, 4, 6, 12 = F</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the compounding frequency, Z is the zero rate, and T is the time in periodic units; for example, T = F is 1 year.</p> <p>Compounding = 365</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the number of days in the basis year and T is a number of days elapsed computed by basis.</p> <p>Compounding = -1</p> <p>Disc = <math>\exp(-T*Z)</math>, where T is time in years.</p>

## Description

`TimeSpec = bktimespec(ValuationDate, Maturity, Compounding)` sets the number of levels and node times for an BK tree and determines the mapping between dates and time for rate quoting.

`TimeSpec` is a structure specifying the time layout for `bktree`. The state observation dates are `[Settle; Maturity(1:end-1)]`. Because a forward rate is stored at the last observation, the tree can value cash flows out to `Maturity`.

## Examples

### Specify a Four-Period Tree with Annual Nodes

This example shows how to specify a four-period tree with annual nodes using annual compounding to report rates.

```
ValuationDate = 'Jan-1-2004';
Maturity = ['12-31-2004'; '12-31-2005'; '12-31-2006';
'12-31-2007'];
Compounding = 1;
TimeSpec = bktimespec(ValuationDate, Maturity, Compounding)
```

```
TimeSpec =
    FinObj: 'BKTimeSpec'
  ValuationDate: 731947
    Maturity: [4x1 double]
  Compounding: 1
    Basis: 0
  EndMonthRule: 1
```

### See Also

`bktree` | `bkvolspec` | `hwtree`

# bktree

Construct Black-Karasinski interest-rate tree

## Syntax

```
BKTree = bktree(VolSpec, RateSpec, TimeSpec)  
BKTree = bktree(VolSpec, RateSpec, TimeSpec, Name, Value)
```

## Description

`BKTree = bktree(VolSpec, RateSpec, TimeSpec)` creates a structure containing time and interest-rate information on a recombining tree.

`BKTree = bktree(VolSpec, RateSpec, TimeSpec, Name, Value)` creates a structure containing time and interest-rate information on a recombining tree with additional options specified by one or more `Name, Value` pair arguments.

## Input Arguments

### VolSpec

Volatility process specification. See `bkvolspec` for information on the volatility process.

### RateSpec

Interest-rate specification for the initial rate curve. See `intenvset` for information on declaring an interest-rate variable.

### TimeSpec

Tree time layout specification. Defines the observation dates of the BK tree and the compounding rule for date to time mapping and price-yield formulas. See `bktimespec` for information on the tree structure.

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes ( ' '). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

### 'Method'

String specifying the Hull-White method upon which the tree-node connectivity algorithm is based. Possible values are `HW1996` and `HW2000`.

---

**Note:** `bktree` supports two tree-node connectivity algorithms. `HW1996` is based on the original paper published in the *Journal of Derivatives*, and `HW2000` is the general version of the algorithm, as specified in the paper published in August 2000.

---

**Default:** `HW1996`

## Output Arguments

### BKTree

Structure containing time and interest rate information of a trinomial recombining tree.

## Examples

Using the data provided, create a BK volatility specification (`VolSpec`), rate specification (`RateSpec`), and tree time layout specification (`TimeSpec`). Then use these specifications to create a BK tree using `bktree`.

```
Compounding = -1;  
ValuationDate = '01-01-2004';  
StartDate = ValuationDate;  
VolDates = [ '12-31-2004'; '12-31-2005'; '12-31-2006';  
             '12-31-2007' ];  
VolCurve = 0.01;  
AlphaDates = '01-01-2008';
```

```

AlphaCurve = 0.1;
Rates = [0.0275; 0.0312; 0.0363; 0.0415];

BKVolspec = bkvolspec(ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);

RateSpec = intenvset('Compounding', Compounding,...
'ValuationDate', ValuationDate,...
'StartDates', ValuationDate,...
'EndDates', VolDates,...
'Rates', Rates);

BKTimeSpec = bktimespec(ValuationDate, VolDates, Compounding);

BKTree = bktree(BKVolspec, RateSpec, BKTimeSpec)

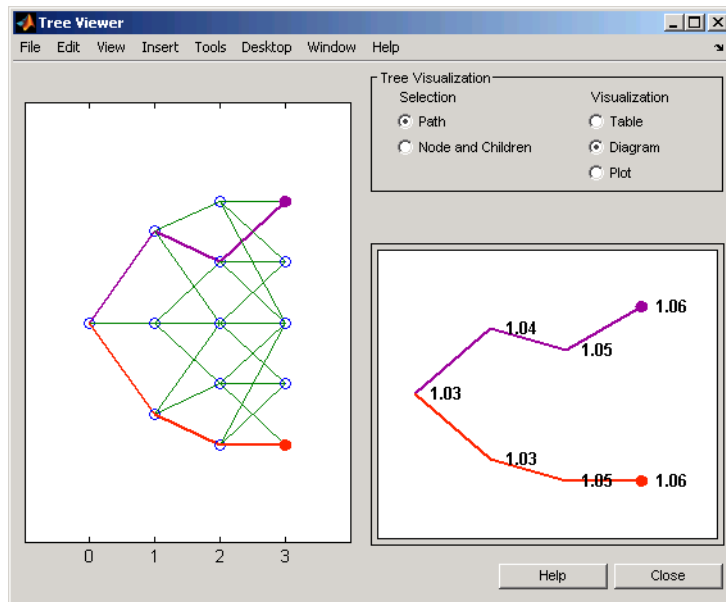
BKTree =

    FinObj: 'BKFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
    tObs: [0 0.9973 1.9973 2.9973]
    dObs: [731947 732312 732677 733042]
    CFlowT: {[4x1 double] [3x1 double] [2x1 double] [3.9973]}
    Probs: {[3x1 double] [3x3 double] [3x5 double]}
    Connect: {[2] [2 3 4] [2 2 3 4 4]}
    FwdTree: {1x4 cell}

```

Use `treeview` to observe the tree you have created.

```
treeview(BKTree)
```



Using the data provided, create a Hull-White volatility specification (`VolSpec`), rate specification (`RateSpec`), and tree time layout specification (`TimeSpec`). Then use these specifications to create a Hull-White tree using `hwtree`.

```
Compounding = -1;
ValuationDate = '01-01-2004';
StartDate = ValuationDate;
VolDates = ['12-31-2004'; '12-31-2005'; '12-31-2006';
'12-31-2007'];
VolCurve = 0.01;
AlphaDates = '01-01-2008';
AlphaCurve = 0.1;
Rates = [0.0275; 0.0312; 0.0363; 0.0415];

HWWolSpec = hwwolspec(ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);

RateSpec = intenvset('Compounding', Compounding,...
'ValuationDate', ValuationDate,...
'StartDates', ValuationDate,...
'EndDates', VolDates,...
'Rates', Rates);

HWTTimeSpec = hwtimespec(ValuationDate, VolDates, Compounding);
HWTTree = hwtree(HWWolSpec, RateSpec, HWTTimeSpec)

HWTTree =
```

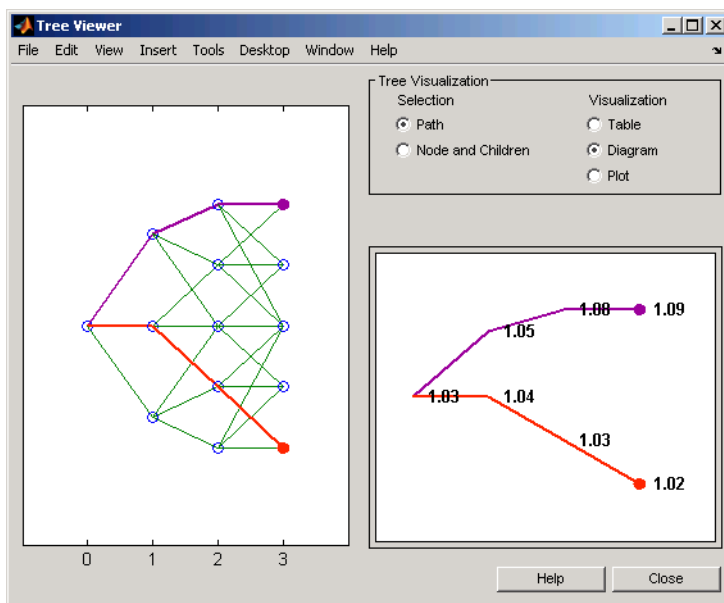
```

FinObj: 'HWFwdTree'
VolSpec: [1x1 struct]
TimeSpec: [1x1 struct]
RateSpec: [1x1 struct]
  tObs: [0 0.9973 1.9973 2.9973]
  dObs: [731947 732312 732677 733042]
CFlowT: {[4x1 double] [3x1 double] [2x1 double] [3.9973]}
  Probs: {[3x1 double] [3x3 double] [3x5 double]}
Connect: {[2] [2 3 4] [2 2 3 4 4]}
FwdTree: {1x4 cell}

```

Use `treeviewer` to observe the tree you have created.

```
treeviewer(HWTree)
```



## References

Hull, J., and A. White, "Using Hull-White Interest Rate Trees", *Journal of Derivatives*, 1996.

Hull, J., and A. White, "The General Hull-White Model and Super Calibration", August 2000.

### **See Also**

| `bkprice` | `bktimespec` | `bkvolspec` | `intenvset`

### **Tutorials**

- “Calibrating Hull-White Model Using Market Data”



# bkvolspec

Specify Black-Karasinski interest-rate volatility process

## Syntax

```
Volspec = bkvolspec(ValuationDate, VolDates, VolCurve,
AlphaDates, AlphaCurve, InterpMethod)
```

## Arguments

ValuationDate	Scalar value representing the observation date of the investment horizon.
VolDates	Number of points (NPOINTS)-by-1 vector of yield volatility end dates.
VolCurve	NPOINTS-by-1 vector of annualized yield volatility values in decimal form. The term structure of VolCurve is the yield volatility represented by the value of the volatility of the yield from time $t = 0$ to time $t + i$ , where $i$ is any point within the volatility curve.
AlphaDates	NPOINTS-by-1 vector of mean reversion end dates.
AlphaCurve	NPOINTS-by-1 vector of positive mean reversion values in decimal form.
InterpMethod	(Optional) Interpolation method. Default is 'linear'. See <code>interp1</code> for more information.

## Description

Volspec = bkvolspec(ValuationDate, VolDates, VolCurve, AlphaDates, AlphaCurve, InterpMethod) creates a structure specifying the volatility for bktree.

## Examples

### Create a Black-Karasinski Volatility Specification

This example shows how to create a Black-Karasinski volatility specification (VolSpec) using the following data.

```
ValuationDate = '01-01-2004';
StartDate = ValuationDate;
VolDates = ['12-31-2004'; '12-31-2005'; '12-31-2006';
'12-31-2007'];
VolCurve = 0.01;
AlphaDates = '01-01-2008';
AlphaCurve = 0.1;
BKVolSpec = bkvolspec(ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve)
```

```
BKVolSpec =
```

```
    FinObj: 'BKVolSpec'
  ValuationDate: 731947
    VolDates: [4x1 double]
    VolCurve: [4x1 double]
    AlphaCurve: 0.1000
    AlphaDates: 733408
  VolInterpMethod: 'linear'
```

### See Also

bktree | interp1

# bondbybdt

Price bond from Black-Derman-Toy interest-rate tree

## Syntax

```
[Price, PriceTree] = bondbybdt(BDTree, CouponRate, Settle,
Maturity)
```

```
[Price, PriceTree] = bondbybdt(BDTree, CouponRate, Settle,
Maturity, Period, Basis, EndMonthRule, IssueDate,
FirstCouponDate, LastCouponDate, StartDate, Face,
Options)
```

```
[Price, PriceTree] = bondbybdt(BDTree, CouponRate, Settle,
Maturity, Name, Value)
```

## Input Arguments

<b>BDTree</b>	Interest-rate tree structure created by <code>bdttree</code> .
<b>CouponRate</b>	Decimal annual rate. <b>CouponRate</b> is a NINST-by-1 vector or NINST-by-1 cell array of decimal annual rates, or decimal annual rate schedules. For the latter case of a variable coupon schedule, each element of the cell array is a NumDates-by-2 cell array, where the first column is dates and the second column is its associated rate. The date indicates the last day that the coupon rate is valid.
<b>Settle</b>	Settlement date. A vector of serial date numbers or date strings. <b>Settle</b> must be earlier than <b>Maturity</b> .
<b>Maturity</b>	Maturity date. A vector of serial date numbers or date strings.

The **Settle** date for every bond is set to the **ValuationDate** of the BDT tree. The bond argument **Settle** is ignored.

## Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

### Period

Coupons per year of the bond. A vector of integers. Values are 1, 2, 3, 4, 6, and 12.

**Default:** 2

### Basis

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### EndMonthRule

End-of-month rule. A NINST-by-1 vector. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

### **IssueDate**

Date when a bond was issued.

**Default:**

### **FirstCouponDateDate**

Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When **FirstCouponDate** and **LastCouponDate** are both specified, **FirstCouponDate** takes precedence in determining the coupon payment structure. If you do not specify a **FirstCouponDate**, the cash flow payment dates are determined from other inputs.

**Default:**

### **LastCouponDateDate**

Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified **FirstCouponDate**, a specified **LastCouponDate** determines the coupon structure of the bond. The coupon structure of a bond is truncated at the **LastCouponDate**, regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a **LastCouponDate**, the cash flow payment dates are determined from other inputs.

**Default:**

### **StartDate**

Date when a bond actually starts (the date from which a bond cash flow is considered). To make an instrument forward-starting, specify this date as a future date. If you do not specify **StartDate**, the effective start date is the **Settle** date.

**Default:**

**Face**

Face or par value. **Face** is a NINST-by-1 vector or NINST-by-1 cell array of face values, or face value schedules. For the latter case, each element of the cell array is a NumDates-by-2 cell array, where the first column is dates and the second column is its associated face value. The date indicates the last day that the face value is valid.

**Default:** 100

**Options**

Derivatives pricing options structure created with `derivset`.

**Default:**

**Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name,Value arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

**AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** false

**BusinessDayConvention**

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

## Holidays

Holidays used for business day convention. `NHOLIDAYS`-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, `holidays.m` is used.

## Description

`[Price, PriceTree] = bondbybdt(BDTree, CouponRate, Settle, Maturity)` computes the price of a bond from a BDT interest-rate tree.

`[Price, PriceTree] = bondbybdt(BDTree, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face, Options)` computes the price of a bond from a BDT interest-rate tree using optional input arguments.

`[Price, PriceTree] = bondbybdt(BDTree, CouponRate, Settle, Maturity, Name, Value)` computes the price of a bond from a BDT interest-rate tree with additional options specified by one or more `Name, Value` pair arguments.

`Price` is a number of instruments (`NINST`)-by-1 matrix of expected prices at time 0.

`PriceTree` is a MATLAB structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node. Within `PriceTree`:

- `PriceTree.PTree` contains the clean prices.
- `PriceTree.AITree` contains the accrued interest.
- `PriceTree.tObs` contains the observation times.

`bondbybdt` computes prices of vanilla bonds, stepped coupon bonds, and amortizing bonds with no market purchase option and no call provisions.

## Examples

### Price a Bond Using a BDT Tree

Price a 10% bond using a BDT interest-rate tree.

Load `deriv.mat`, which provides `BDTTree`. The `BDTTree` structure contains the time and interest-rate information needed to price the bond.

```
load deriv.mat;
```

Define the bond using the required arguments. Other arguments use defaults.

```
CouponRate = 0.10;  
Settle = '01-Jan-2000';  
Maturity = '01-Jan-2003';  
Period = 1;
```

Use `bondbybdt` to compute the price of the bond.

```
Price = bondbybdt(BDTTree, CouponRate, Settle, Maturity, Period)
```

```
Price =  
  
    95.5030
```

### Price a Stepped Coupon Bond

Price single stepped coupon bonds using market data.

Define the interest-rate term structure.

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];  
ValuationDate = 'Jan-1-2010';  
StartDates = ValuationDate;  
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};  
Compounding = 1;
```

Create the `RateSpec`.

```
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, 'EndDates', ..  
EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RS =  
  
    FinObj: 'RateSpec'  
    Compounding: 1  
           Disc: [4x1 double]  
           Rates: [4x1 double]
```



```

    EndTimes: [4x1 double]
    StartTimes: [4x1 double]
    EndDates: [4x1 double]
    StartDates: 734139
    ValuationDate: 734139
    Basis: 0
    EndMonthRule: 1

```

Create the stepped bond instrument.

```

Settle = '01-Jan-2010';
Maturity = {'01-Jan-2011'; '01-Jan-2012'; '01-Jan-2013'; '01-Jan-2014'};
CouponRate = {'01-Jan-2012' .0425; '01-Jan-2014' .0750};
Period = 1;

```

Build the BDT tree and assume the volatility to be 10% using the following market data:

```

Sigma = 0.1;
BDTTimeSpec = bdttimespec(ValuationDate, EndDates);
BDTVolSpec = bdtvolspec(ValuationDate, EndDates, Sigma*ones(1, length(EndDates)));
BDTT = bdttree(BDTVolSpec, RS, BDTTimeSpec)

```

BDTT =

```

    FinObj: 'BDTFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
    tObs: [0 1 2 3]
    dObs: [734139 734504 734869 735235]
    TFwd: {[4x1 double] [3x1 double] [2x1 double] [3]}
    CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4]}
    FwdTree: {1x4 cell}

```

Compute the price of the stepped coupon bonds.

```

PBDT= bondbybdt(BDTT, CouponRate, Settle, Maturity, Period)

```

PBDT =

```

100.7246

```

```
100.0945
101.5900
102.0820
```

### Price Two Bonds with Amortization Schedules

Price two bonds with amortization schedules using the `Face` input argument to define the schedule.

Define the interest-rate term structure.

```
Rates = 0.035;
ValuationDate = '1-Nov-2011';
StartDates = ValuationDate;
EndDates = '1-Nov-2017';
Compounding = 1;
```

Create the `RateSpec`.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);
```

Create the bond instrument. The bonds have a coupon rate of 4% and 3.85%, a period of one year, and mature on 1-Nov-2017.

```
CouponRate = [0.04; 0.0385];
Settle = '1-Nov-2011';
Maturity = '1-Nov-2017';
Period = 1;
```

Define the amortizing schedule.

```
Face = {{'1-Nov-2015' 100; '1-Nov-2016' 85; '1-Nov-2017' 70};
{'1-Nov-2015' 100; '1-Nov-2016' 90; '1-Nov-2017' 80}};
```

Build the BDT tree and assume the volatility to be 10%.

```
MatDates = {'1-Nov-2012'; '1-Nov-2013'; '1-Nov-2014'; '1-Nov-2015'; '1-Nov-2016'; '1-Nov-2017'};
BDTTimeSpec = bdttimespec(ValuationDate, MatDates);
Volatility = 0.1;
BDTVolSpec = bdtvolspec(ValuationDate, MatDates, Volatility*ones(1, length(MatDates)));
BDTT = bdttree(BDTVolSpec, RateSpec, BDTTimeSpec);
```

Compute the price of the amortizing bonds.

```
Price = bondbybdt(BDTT, CouponRate, Settle, Maturity, 'Period', Period, ...  
'Face', Face)
```

```
Price =
```

```
102.4791
```

```
101.7786
```

## More About

### Vanilla Bond

A vanilla coupon bond is a security representing an obligation to repay a borrowed amount at a designated time and to make periodic interest payments until that time. The issuer of a bond makes the periodic interest payments until the bond matures. At maturity, the issuer pays to the holder of the bond the principal amount owed (face value) and the last interest payment.

### Stepped Coupon Bond

A step-up and step-down bond is a debt security with a predetermined coupon structure over time. With these instruments, coupons increase (step up) or decrease (step down) at specific times during the life of the bond.

### Bond with an Amortization Schedule

An amortized bond is treated as an asset, with the discount amount being amortized to interest expense over the life of the bond.

- “Pricing Options Structure”

### See Also

bdtprice | bdttree | cfamounts | instbond

## blackvolbyrebonato

Compute Black volatility for LIBOR Market Model using Rebonato formula

### Syntax

```
outVol = blackvolbyrebonato(ZeroCurve,VolFunc,CorrMat,  
ExerciseDate,Maturity)  
outVol = blackvolbyrebonato( ____,Name,Value)
```

### Description

`outVol = blackvolbyrebonato(ZeroCurve,VolFunc,CorrMat,ExerciseDate,Maturity)` computes the Black volatility for a swaption using a LIBOR Market Model.

`outVol = blackvolbyrebonato( ____,Name,Value)` computes the Black volatility for a swaption using a LIBOR Market Model with optional name-value pair arguments.

### Examples

#### Price Swaption for LIBOR Market Model Using the Rebonato Formula

Define the input maturity and tenor for a LIBOR Market Model (LMM) specified by the cell array of volatility function handles, and a correlation matrix for the LMM.

```
Settle = datenum('11-Aug-2004');  
  
% Zero Curve  
CurveTimes = (1:10)';  
CurveDates = daysadd(Settle,360*CurveTimes,1);  
  
ZeroRates = [0.03 0.033 0.036 0.038 0.04 0.042 0.043 0.044 0.045 0.046]';  
  
% Construct an IRCurve  
irdc = IRDataCurve('Zero',Settle,CurveDates,ZeroRates);  
  
LMMVolFunc = @(a,t) (a(1)*t + a(2)).*exp(-a(3)*t) + a(4);
```

```

LMMVolParams = [.3 -.02 .7 .14];

numRates = length(ZeroRates);
VolFunc(1:numRates-1) = {@(t) LMMVolFunc(LMMVolParams,t)};

Beta = .08;
CorrFunc = @(i,j,Beta) exp(-Beta*abs(i-j));
CorrMat = CorrFunc(meshgrid(1:numRates-1)',meshgrid(1:numRates-1),Beta);

ExerciseDate = datenum('11-Aug-2009');
Maturity = daysadd(ExerciseDate,360*[3;4],1);

Vol = blackvolbyrebonato(irdc,VolFunc,CorrMat,ExerciseDate,Maturity,'Period',1)

Vol =

    0.2113
    0.1990

```

- “Price Swaptions With Interest-Rate Models Using Simulation”

## Input Arguments

### **ZeroCurve** — Zero-curve for `LiborMarketModel` model

structure

Zero-curve for the `LiborMarketModel`, specified using `IRDataCurve` or `RateSpec`.

Data Types: `struct`

### **VolFunc** — Function handle for volatility

cell array of function handles

Function handle for volatility, specified by a `NumRates`-by-1 cell array of function handles. Each function handle must take time as an input and return a scalar volatility

Data Types: `cell` | `function_handle`

### **CorrMat** — Correlation matrix

vector

Correlation matrix, specified by `NumRates`-by-`NumRates`.

Data Types: `single` | `double`

### **ExerciseDate** — Swaption exercise date

`nonnegative integer` | `vector of nonnegative integers` | `string of dates`

Swaption exercise dates, specified by a `NumSwaptions-by-1` vector of serial date numbers or date strings.

Data Types: `single` | `double` | `cell`

### **Maturity** — Swap maturity date

`nonnegative integer` | `vector of nonnegative integers` | `string of dates`

Swap maturity dates, specified using a `NumSwaptions-by-1` vector of dates or date strings.

Data Types: `single` | `double` | `cell`

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (`' '`). You can specify several name and value pair arguments in any order as `Name1, Value1, ..., NameN, ValueN`.

Example: `Vol =`

```
blackvolbyrebonato(irdc, VolFunc, CorrMat, ExerciseDate, Maturity, 'Period', 1)
```

### **'Period'** — Compounding frequency of curve and reset of swaptions

2 (default) | `positive integer from the set [1, 2, 3, 4, 6, 12]` | `vector of positive integers from the set [1, 2, 3, 4, 6, 12]`

Compounding frequency of curve and reset of swaptions, specified as a positive integers for the values 1, 2, 4, 6, 12 in a `NumSwaptions-by-1` vector.

Data Types: `single` | `double`

## **Output Arguments**

### **outVol** — Black volatility for specified swaption

`scalar` | `vector`

Black volatility, returned as a vector for the specified swaptions.

## More About

### Algorithms

The Rebonato approximation formula relates the Black volatility for a European swaption, given a set of volatility functions and a correlation matrix

$$(\nu_{\alpha,\beta}^{LFM})^2 = \sum_{i,j=\alpha+1}^{\beta} \frac{w_i(0)w_j(0)F_i(0)F_j(0)\rho_{i,j}}{S_{\alpha,\beta}(0)^2} \int_0^{T_\alpha} \sigma_i(t)\sigma_j(t)dt$$

where:

$$w_i(t) = \frac{\tau_i P(t, T_i)}{\sum_{k=\alpha+1}^{\beta} \tau_k P(t, t_k)}$$

### References

- [1] Brigo, D. and F. Mercurio, *Interest Rate Models - Theory and Practice*, Springer Finance, 2006.

### See Also

LiborMarketModel

## blackvolbysabr

Calculate implied Black volatility using SABR model

### Syntax

```
outVol = blackvolbysabr(Alpha,Beta,Rho,Nu,Settle,  
ExerciseDate,ForwardValue,Strike)  
outVol = blackvolbysabr( ____,Name,Value)
```

### Description

`outVol = blackvolbysabr(Alpha,Beta,Rho,Nu,Settle,ExerciseDate,ForwardValue,Strike)` calculates the implied Black volatility using the SABR stochastic volatility model.

`outVol = blackvolbysabr( ____,Name,Value)` calculates the implied Black volatility using the SABR stochastic volatility model with optional name-value pair arguments.

### Examples

#### Compute the Implied Black Volatility Using the SABR Model

Define the model parameters and option data.

```
ForwardRate = 0.0357;  
Strike = 0.03;  
Alpha = 0.036;  
Beta = 0.5;  
Rho = -0.25;  
Nu = 0.35;  
  
Settle = datenum('15-Sep-2013');  
ExerciseDate = datenum('15-Sep-2015');
```

Compute the Black volatility using the SABR model.



```
ComputedVols = blackvolbysabr(Alpha, Beta, Rho, Nu, Settle, ...  
ExerciseDate, ForwardRate, Strike)
```

```
ComputedVols =
```

```
0.2122
```

- “Calibrate the SABR Model ”
- “Price a Swaption Using the SABR Model ”

## Input Arguments

### **Alpha — Current SABR volatility**

scalar

Current SABR volatility, specified as a scalar.

Data Types: double

### **Beta — SABR constant elasticity of variance (CEV) exponent**

scalar

SABR CEV exponent, specified as a scalar.

Data Types: double

### **Rho — Correlation between forward value and volatility**

scalar

Correlation between forward value and volatility, specified as a scalar.

Data Types: double

### **Nu — Volatility of volatility**

scalar

Volatility of volatility, specified as a scalar.

Data Types: double

**Settle — Settlement date**

scalar for serial nonnegative date number | scalar for date string

Settlement date, specified as a scalar using a serial nonnegative date number or date string.

Data Types: double | char

**ExerciseDate — Option exercise date**

scalar for serial nonnegative date number | scalar for date string

Option exercise date, specified as a scalar using a serial nonnegative date number or date string.

Data Types: double | char

**ForwardValue — Current forward value of underlying asset**

scalar | vector

Current forward value of the underlying asset, specified as a scalar or vector of size NumVols-by-1.

Data Types: double

**Strike — Option strike price values**

scalar | vector

Option strike price values, specified as a scalar value or a vector of size NumVols-by-1.

Data Types: double

**Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

Example: outVol =

blackvolbysabr(Alpha,Beta,Rho,Nu,Settle,ExerciseDate,ForwardValue,Strike,'Basis')

**'Basis' — Day-count basis of instrument**

0 (actual/actual) (default) | positive integers of the set [1...13]

Day-count basis of the instrument specified as a positive integer of the set [1 . . . 13]. The **Basis** value represents the basis used when annualizing the input forward-rate tree:

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: double

**'Model' — Version of SABR model**

'Hagan2002' (default) | value 'Obloj2008'

Version of SABR model, specified with either value:

- 'Hagan2002' — Original version by Hagan et al. (2002)
- 'Obloj2008' — Version by Obloj (2008)

Data Types: char

## Output Arguments

**outVo1 — Implied Black volatility computed by SABR model**

scalar | vector

Implied Black volatility computed by SABR model, returned as a scalar or vector of size NumVols-by-1.

## More About

### Algorithms

The SABR stochastic volatility model treats the underlying forward  $\hat{F}$  and volatility  $\hat{\alpha}$  as separate random processes, which are related with correlation  $\rho$  :

$$\begin{aligned}d\hat{F} &= \hat{\alpha}\hat{F}^\beta dW_1 \\d\hat{\alpha} &= v\hat{\alpha}dW_2 \\dW_1dW_2 &= \rho dt \\ \hat{F}(0) &= F \\ \hat{\alpha}(0) &= \alpha\end{aligned}$$

where

- $\hat{F}$  is the underlying forward (a variable).
- $F$  is the current underlying forward (a constant).
- $\hat{\alpha}$  is the SABR volatility (a variable).
- $\alpha$  is the current SABR volatility (a constant).
- $\beta$  is the SABR constant elasticity of variance (CEV) exponent.
- $v$  is the volatility of volatility.
- $dW_1$  is Brownian motion.
- $dW_2$  is Brownian motion.
- $\rho$  is the correlation between forward value and volatility.

In contrast, Black's lognormal model assumes a constant volatility,  $\sigma_B$ .

$$d\hat{F} = \sigma_B \hat{F} dW$$

Hagan et al. (2002) derived the following closed-form approximation of implied Black lognormal volatility ( $\sigma_B$ ) for the SABR model

$$\sigma_B(F, K) = \frac{\alpha \left\{ 1 + \left[ \frac{(1-\beta)^2}{24} \frac{\alpha^2}{(FK)^{1-\beta}} + \frac{1}{4} \frac{\rho\beta v\alpha}{(FK)^{(1-\beta)/2}} + \frac{2-3\rho^2}{24} v^2 \right] T + \dots \right\}}{(FK)^{(1-\beta)/2} \left\{ 1 + \frac{(1-\beta)^2}{24} \log^2(F/K) + \frac{(1-\beta)^4}{1920} \log^4(F/K) + \dots \right\}} \left( \frac{z}{x(z)} \right)$$

$$z = \frac{v}{\alpha} (FK)^{(1-\beta)/2} \log(F/K)$$

$$x(z) = \log \left\{ \frac{\sqrt{1-2\rho z + z^2} + z - \rho}{1-\rho} \right\}$$

where

- $F$  is the current forward value of the underlying.
- $\alpha$  is the current SABR volatility.
- $K$  is the strike value.
- $T$  is the time to option maturity.

Obloj (2008) advocated the following closed-form approximation of implied Black lognormal volatility for the SABR model (for  $\beta < 1$ )

$$\sigma_B(F, K) = \frac{v \log(F/K)}{x(z)} \left\{ 1 + \left[ \frac{(1-\beta)^2}{24} \frac{\alpha^2}{(FK)^{1-\beta}} + \frac{1}{4} \frac{\rho\beta v\alpha}{(FK)^{(1-\beta)/2}} + \frac{2-3\rho^2}{24} v^2 \right] T + \dots \right\}$$

$$z = \frac{v}{\alpha} \frac{F^{(1-\beta)} - K^{(1-\beta)}}{1-\beta}$$

$$x(z) = \log \left\{ \frac{\sqrt{1-2\rho z + z^2} + z - \rho}{1-\rho} \right\}$$

These expressions can be simplified in special situations, such as the at-the-money ( $F = K$ ) and stochastic lognormal ( $\beta = 1$ ) cases [1,2].

## References

[1] Hagan, P. S., D. Kumar, A.S. Lesniewski, and D.E. Woodward *Managing Smile Risk*, Wilmott Magazine, September, pp. 84–108, 2002.

[2] Obloj, J. *Fine-tune your smile: Correction to Hagan et. al.* Wilmott Magazine, 2008.

## See Also

swaptionbyblk

# bondbybk

Price bond from Black-Karasinski interest-rate tree

## Syntax

```
[Price, PriceTree] = bondbybk(BKTree, CouponRate,
Settle, Maturity)
[Price, PriceTree] = bondbybk(BKTree, CouponRate,
Settle, Maturity, Period, Basis, EndMonthRule, IssueDate,
FirstCouponDate, LastCouponDate, StartDate, Face,
Options)
[Price, PriceTree] = bondbybk(BKTree, CouponRate,
Settle, Maturity, Name, Value)
```

## Input Arguments

BKTree	Forward rate tree structure created by <code>bktree</code> .
CouponRate	Decimal annual rate. <code>CouponRate</code> is a NINST-by-1 vector or NINST-by-1 cell array of decimal annual rates, or decimal annual rate schedules. For the latter case of a variable coupon schedule, each element of the cell array is a NumDates-by-2 cell array, where the first column is dates and the second column is its associated rate. The date indicates the last day that the coupon rate is valid.
Settle	Settlement date. A vector of serial date numbers or date strings. <code>Settle</code> must be earlier than <code>Maturity</code> . The <code>Settle</code> date for every bond is set to the <code>ValuationDate</code> of the BK Tree. The bond argument, <code>Settle</code> , is ignored.
Maturity	Maturity date. A vector of serial date numbers or date strings.

## Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

**Period**

Coupons per year of the bond. A vector of integers. Values are 1, 2, 3, 4, 6, and 12.

**Default:** 2

**Basis**

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

**EndMonthRule**

End-of-month rule. A NINST-by-1 vector. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.



**Default:** 1

### **IssueDate**

Date when a bond was issued.

**Default:**

### **FirstCouponDateDate**

Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When **FirstCouponDate** and **LastCouponDate** are both specified, **FirstCouponDate** takes precedence in determining the coupon payment structure. If you do not specify a **FirstCouponDate**, the cash flow payment dates are determined from other inputs.

**Default:**

### **LastCouponDateDate**

Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified **FirstCouponDate**, a specified **LastCouponDate** determines the coupon structure of the bond. The coupon structure of a bond is truncated at the **LastCouponDate**, regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a **LastCouponDate**, the cash flow payment dates are determined from other inputs.

**Default:**

### **StartDate**

Date when a bond actually starts (the date from which a bond cash flow is considered). To make an instrument forward-starting, specify this date as a future date. If you do not specify **StartDate**, the effective start date is the **Settle** date.

**Default:**

### **Face**

Face or par value. **Face** is a NINST-by-1 vector or NINST-by-1 cell array of face values, or face value schedules. For the latter case, each element of the cell array is a NumDates-

by-2 cell array, where the first column is dates and the second column is its associated face value. The date indicates the last day that the face value is valid.

**Default:** 100

### **Options**

Derivatives pricing options structure created with `derivset`.

**Default:**

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, ..., NameN, ValueN`.

### **AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. `NINST-by-1` of logicals.

**Default:** false

### **BusinessDayConvention**

Require payment dates to be business dates. `NINST-by-1` cell array with possible choices of business day convention:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

### **Holidays**

Holidays used for business day convention. `NHOLIDAYS-by-1` of MATLAB date numbers.

**Default:** If no dates are specified, `holidays.m` is used.

## Description

`[Price, PriceTree] = bondbybk(BKTree, CouponRate, Settle, Maturity)` computes the price of a bond from a Black-Karasinski interest-rate tree.

`[Price, PriceTree] = bondbybk(BKTree, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face, Options)` computes the price of a bond from a Black-Karasinski interest-rate tree using optional input arguments.

`[Price, PriceTree] = bondbybk(BKTree, CouponRate, Settle, Maturity, Name, Value)` computes the price of a bond from a Black-Karasinski interest-rate tree with additional options specified by one or more `Name, Value` pair arguments.

`Price` is a number of instruments (NINST)-by-1 matrix of expected prices at time 0.

`PriceTree` is a structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node. Within `PriceTree`:

- `PriceTree.PTree` contains the clean prices.
- `PriceTree.AITree` contains the accrued interest.
- `PriceTree.tObs` contains the observation times.

`bondbybk` computes prices of vanilla bonds, stepped coupon bonds, and amortizing bonds with no market purchase option and no call provisions.

## Examples

### Price a Bond Using a BK Tree

Price a 4% bond using a Black-Karasinski interest-rate tree.

Load `deriv.mat`, which provides `BKTree`. The `BKTree` structure contains the time and interest-rate information needed to price the bond.

```
load deriv.mat;
```

Define the bond using the required arguments. Other arguments use defaults.

```
CouponRate = 0.04;  
Settle = '01-Jan-2004';  
Maturity = '31-Dec-2008';
```

Use `bondbybk` to compute the price of the bond.

```
Price = bondbybk(BKTree, CouponRate, Settle, Maturity)
```

Warning: Not all cash flows are aligned with the tree. Result will be approximated.

```
Price =  
  
    98.0300
```

### Price a Stepped Coupon Bond

Price single stepped coupon bonds using market data.

Define the interest-rate term structure.

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];  
ValuationDate = 'Jan-1-2010';  
StartDates = ValuationDate;  
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; ...  
            'Jan-1-2013'; 'Jan-1-2014'};  
Compounding = 1;
```

Create the `RateSpec`.

```
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...  
              'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RS =  
  
    FinObj: 'RateSpec'  
    Compounding: 1  
           Disc: [4x1 double]  
           Rates: [4x1 double]
```

```

        EndTimes: [4x1 double]
        StartTimes: [4x1 double]
        EndDates: [4x1 double]
        StartDates: 734139
        ValuationDate: 734139
        Basis: 0
        EndMonthRule: 1

```

Create the stepped bond instrument.

```

Settle = '01-Jan-2010';
Maturity = {'01-Jan-2011'; '01-Jan-2012'; '01-Jan-2013'; '01-Jan-2014'};
CouponRate = {'01-Jan-2012' .0425; '01-Jan-2014' .0750};
Period = 1;

```

Build the BK tree using the following market data:

```

VolDates = ['1-Jan-2011'; '1-Jan-2012'; '1-Jan-2013'; '1-Jan-2014'];
VolCurve = 0.01;
AlphaDates = '01-01-2014';
AlphaCurve = 0.1;

```

```

BKVolSpec = bkvolspec(RS.ValuationDate, VolDates, VolCurve, ...
AlphaDates, AlphaCurve);
BKTimeSpec = bktimespec(RS.ValuationDate, VolDates, Compounding);
BKT = bktree(BKVolSpec, RS, BKTimeSpec);

```

Compute the price of the stepped coupon bonds.

```

PBK= bondbybk(BKT, CouponRate, Settle,Maturity , Period)

```

```

PBK =

    100.7246
    100.0945
    101.5900
    102.0820

```

### Price a Bond with an Amortization Schedule

Price a bond with an amortization schedule using the **Face** input argument to define the schedule.

Define the interest-rate term structure.

```
Rates = 0.065;  
ValuationDate = '1-Jan-2011';  
StartDates = ValuationDate;  
EndDates = '1-Jan-2017';  
Compounding = 1;
```

Create the RateSpec.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...  
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'  
    Compounding: 1  
        Disc: 0.6853  
        Rates: 0.0650  
    EndTimes: 6  
    StartTimes: 0  
        EndDates: 736696  
        StartDates: 734504  
    ValuationDate: 734504  
        Basis: 0  
    EndMonthRule: 1
```

Create the bond instrument. The bond has a coupon rate of 7%, a period of one year, and matures on 1-Jan-2017.

```
CouponRate = 0.07;  
Settle = '1-Jan-2011';  
Maturity = '1-Jan-2017';  
Period = 1;  
Face = {{ '1-Jan-2015' 100; '1-Jan-2016' 90; '1-Jan-2017' 80 }};
```

Build the BK tree with the following market data:

```
VolDates = [ '1-Jan-2012'; '1-Jan-2013'; ...  
    '1-Jan-2014'; '1-Jan-2015'; '1-Jan-2016'; '1-Jan-2017' ];  
VolCurve = 0.01;  
AlphaDates = '01-01-2017';  
AlphaCurve = 0.1;
```

```
BKVolSpec = bkvolspec(RateSpec.ValuationDate, VolDates, VolCurve,...  
AlphaDates, AlphaCurve);  
BKTimeSpec = bktimespec(RateSpec.ValuationDate, VolDates, Compounding);  
BKT = bktree(BKVolSpec, RateSpec, BKTimeSpec);
```

Compute the price of the amortizing bond.

```
Price = bondbybk(BKT, CouponRate, Settle, Maturity, 'Period', Period,...  
'Face', Face)
```

```
Price =  
102.3155
```

Compare the results with price of a vanilla bond.

```
PriceVanilla = bondbybk(BKT, CouponRate, Settle, Maturity, Period)
```

```
PriceVanilla =  
102.4205
```

## More About

### Vanilla Bond

A vanilla coupon bond is a security representing an obligation to repay a borrowed amount at a designated time and to make periodic interest payments until that time. The issuer of a bond makes the periodic interest payments until the bond matures. At maturity, the issuer pays to the holder of the bond the principal amount owed (face value) and the last interest payment.

### Stepped Coupon Bond

A step-up and step-down bond is a debt security with a predetermined coupon structure over time. With these instruments, coupons increase (step up) or decrease (step down) at specific times during the life of the bond.

### **Bond with an Amortization Schedule**

An amortized bond is treated as an asset, with the discount amount being amortized to interest expense over the life of the bond.

- “Pricing Options Structure”

### **See Also**

`bkprice` | `bktree` | `cfamounts` | `hwprice` | `hwtree` | `instbond`



# bondbyhjm

Price bond from Heath-Jarrow-Morton interest-rate tree

## Syntax

```
[Price, PriceTree] = bondbyhjm(HJMTree, CouponRate, Settle,
Maturity)
```

```
[Price, PriceTree] = bondbyhjm(HJMTree, CouponRate, Settle,
Maturity, Period, Basis, EndMonthRule, IssueDate,
FirstCouponDate, LastCouponDate, StartDate, Face,
Options)
```

```
[Price, PriceTree] = bondbyhjm(HJMTree, CouponRate,
Settle, Maturity, Name, Value)
```

## Input Arguments

HJMTree	Forward rate tree structure created by <code>hjmtree</code> .
CouponRate	Decimal annual rate. <b>CouponRate</b> is a NINST-by-1 vector or NINST-by-1 cell array of decimal annual rates, or decimal annual rate schedules. For the latter case of a variable coupon schedule, each element of the cell array is a NumDates-by-2 cell array, where the first column is dates and the second column is its associated rate. The date indicates the last day that the coupon rate is valid.
Settle	Settlement date. A vector of serial date numbers or date strings. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. A vector of serial date numbers or date strings.

The **Settle** date for every bond is set to the **ValuationDate** of the HJM tree. The bond argument **Settle** is ignored.

## Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

### Period

Coupons per year of the bond. A vector of integers. Values are 1, 2, 3, 4, 6, and 12.

**Default:** 2

### Basis

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### EndMonthRule

End-of-month rule. A NINST-by-1 vector. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

### **IssueDate**

Date when a bond was issued.

**Default:**

### **FirstCouponDateDate**

Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When **FirstCouponDate** and **LastCouponDate** are both specified, **FirstCouponDate** takes precedence in determining the coupon payment structure. If you do not specify a **FirstCouponDate**, the cash flow payment dates are determined from other inputs.

**Default:**

### **LastCouponDateDate**

Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified **FirstCouponDate**, a specified **LastCouponDate** determines the coupon structure of the bond. The coupon structure of a bond is truncated at the **LastCouponDate**, regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a **LastCouponDate**, the cash flow payment dates are determined from other inputs.

**Default:**

### **StartDate**

Date when a bond actually starts (the date from which a bond cash flow is considered). To make an instrument forward-starting, specify this date as a future date. If you do not specify **StartDate**, the effective start date is the **Settle** date.

**Default:**

**Face**

Face or par value. **Face** is a NINST-by-1 vector or NINST-by-1 cell array of face values, or face value schedules. For the latter case, each element of the cell array is a NumDates-by-2 cell array, where the first column is dates and the second column is its associated face value. The date indicates the last day that the face value is valid.

**Default:** 100

**Options**

Derivatives pricing options structure created with `derivset`.

**Default:**

**Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name,Value arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1, . . . ,NameN,ValueN.

**AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** false

**BusinessDayConvention**

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

## Holidays

Holidays used for business day convention. NHOLIDAYS-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, `holidays.m` is used.

## Description

`[Price, PriceTree] = bondbyhjm(HJMTree, CouponRate, Settle, Maturity)` computes the price of a bond from an HJM forward-rate tree.

`[Price, PriceTree] = bondbyhjm(HJMTree, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face, Options)` computes the price of a bond from an HJM forward-rate tree with optional input arguments.

`[Price, PriceTree] = bondbyhjm(HJMTree, CouponRate, Settle, Maturity, Name, Value)` computes the price of a bond from an HJM forward-rate tree with additional options specified by one or more Name, Value pair arguments.

`Price` is a number of instruments (NINST)-by-1 matrix of expected prices at time 0.

`PriceTree` is a structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node. Within `PriceTree`:

- `PriceTree.PBush` contains the clean prices.
- `PriceTree.AIBush` contains the accrued interest.
- `PriceTree.tObs` contains the observation times.

`bondbyhjm` computes prices of vanilla bonds, stepped coupon bonds, and amortizing bonds with no market purchase option and no call provisions.

## Examples

### Price a Bond Using an HJM Tree

Price a 4% bond using an HJM interest-rate tree.

Load `deriv.mat`, which provides `HJMTree`. The `HJMTree` structure contains the time and interest-rate information needed to price the bond.

```
load deriv.mat;
```

Define the bond using the required arguments. Other arguments use defaults.

```
CouponRate = 0.04;  
Settle = '01-Jan-2000';  
Maturity = '01-Jan-2004';
```

Use `bondbyhjm` to compute the price of the bond.

```
Price = bondbyhjm(HJMTree, CouponRate, Settle, Maturity)
```

```
Warning: Not all cash flows are aligned with the tree. Result will be  
approximated.
```

```
Price =  
  
    97.5280
```

### Price a Stepped Coupon Bond

Price single stepped coupon bonds using market data.

Define the interest-rate term structure.

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];  
ValuationDate = 'Jan-1-2010';  
StartDates = ValuationDate;  
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};  
Compounding = 1;
```

Create the `RateSpec`.

```
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...  
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);
```

Create the stepped bond instrument.

```
Settle = '01-Jan-2010';  
Maturity = {'01-Jan-2011'; '01-Jan-2012'; '01-Jan-2013'; '01-Jan-2014'};  
CouponRate = {'01-Jan-2012' .0425; '01-Jan-2014' .0750};
```

```
Period = 1;
```

Build the HJM tree using the following market data:

```
Volatility = [.2; .19; .18; .17];
CurveTerm = [ 1; 2; 3; 4];
HJMTimeSpec = hjmtimespec(ValuationDate, EndDates);
HJMVolSpec = hjmvolspec('Proportional', Volatility, CurveTerm, 1e6);
HJMT = hjmtree(HJMVolSpec,RS,HJMTimeSpec);
```

Compute the price of the stepped coupon bonds.

```
PHJM= bondbyhjm(HJMT, CouponRate, Settle,Maturity , Period)
```

```
PHJM =
```

```
100.7246
100.0945
101.5900
102.0820
```

### Price a Bond with an Amortization Schedule

Price a bond with an amortization schedule using the **Face** input argument to define the schedule.

Define the interest-rate term structure.

```
Rates = 0.065;
ValuationDate = '1-Jan-2011';
StartDates = ValuationDate;
EndDates= '1-Jan-2017';
Compounding = 1;
```

Create the RateSpec.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```
FinObj: 'RateSpec'
```

```
Compounding: 1
  Disc: 0.6853
  Rates: 0.0650
  EndTimes: 6
  StartTimes: 0
  EndDates: 736696
  StartDates: 734504
ValuationDate: 734504
  Basis: 0
EndMonthRule: 1
```

Create the bond instrument. The bond has a coupon rate of 7%, a period of one year, and matures on 1-Jan-2017.

```
CouponRate = 0.07;
Settle = '1-Jan-2011';
Maturity = '1-Jan-2017';
Period = 1;
Face = {{ '1-Jan-2015' 100; '1-Jan-2016' 90; '1-Jan-2017' 80}};
```

Build the HJM tree using the following market data:

```
Volatility = [.2; .19; .18; .17];
CurveTerm = [ 1; 2; 3; 4];
MaTree = {'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015';...
'Jan-1-2016'; 'Jan-1-2017'};
HJMTimeSpec = hjmtimespec(ValuationDate, MaTree);
HJMVolSpec = hjmvolspec('Proportional', Volatility, CurveTerm, 1e6);
HJMT = hjmtree(HJMVolSpec, RateSpec, HJMTimeSpec);
```

Compute the price of the amortizing bond.

```
Price = bondbyhjm(HJMT, CouponRate, Settle, Maturity, 'Period',...
Period, 'Face' , Face)
```

```
Price =
    102.3155
```

Compare the results with price of a vanilla bond.

```
PriceVanilla = bondbyhjm(HJMT, CouponRate, Settle, Maturity, Period)
```



PriceVanilla =

102.4205

## More About

### Vanilla Bond

A vanilla coupon bond is a security representing an obligation to repay a borrowed amount at a designated time and to make periodic interest payments until that time. The issuer of a bond makes the periodic interest payments until the bond matures. At maturity, the issuer pays to the holder of the bond the principal amount owed (face value) and the last interest payment.

### Stepped Coupon Bond

A step-up and step-down bond is a debt security with a predetermined coupon structure over time. With these instruments, coupons increase (step up) or decrease (step down) at specific times during the life of the bond.

### Bond with an Amortization Schedule

An amortized bond is treated as an asset, with the discount amount being amortized to interest expense over the life of the bond.

- “Pricing Options Structure”

### See Also

[cfamounts](#) | [hjmprice](#) | [hjmtree](#) | [instbond](#)

## bondbyhw

Price bond from Hull-White interest-rate tree

### Syntax

```
[Price, PriceTree] = bondbyhw(HWTree, CouponRate,
Settle, Maturity)
[Price, PriceTree] = bondbyhw(HWTree, CouponRate,
Settle, Maturity, Period, Basis, EndMonthRule, IssueDate,
FirstCouponDate, LastCouponDate, StartDate, Face,
Options)
[Price, PriceTree] = bondbyhw(HWTree, CouponRate,
Settle, Maturity, Name, Value)
```

### Input Arguments

HWTree	Forward-rate tree structure created by <code>hwtree</code> .
CouponRate	Decimal annual rate. <code>CouponRate</code> is a NINST-by-1 vector or NINST-by-1 cell array of decimal annual rates, or decimal annual rate schedules. For the latter case of a variable coupon schedule, each element of the cell array is a NumDates-by-2 cell array, where the first column is dates and the second column is its associated rate. The date indicates the last day that the coupon rate is valid.
Settle	Settlement date. A vector of serial date numbers or date strings. <code>Settle</code> must be earlier than <code>Maturity</code> .
Maturity	Maturity date. A vector of serial date numbers or date strings.

The `Settle` date for every bond is set to the `ValuationDate` of the HW tree. The bond argument `Settle` is ignored.

## Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

### Period

Coupons per year of the bond. A vector of integers. Values are 1, 2, 3, 4, 6, and 12.

**Default:** 2

### Basis

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### EndMonthRule

End-of-month rule. NINST-by-1 vector. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

### **IssueDate**

Date when a bond was issued.

**Default:**

### **FirstCouponDateDate**

Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When **FirstCouponDate** and **LastCouponDate** are both specified, **FirstCouponDate** takes precedence in determining the coupon payment structure. If you do not specify a **FirstCouponDate**, the cash flow payment dates are determined from other inputs.

**Default:**

### **LastCouponDateDate**

Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified **FirstCouponDate**, a specified **LastCouponDate** determines the coupon structure of the bond. The coupon structure of a bond is truncated at the **LastCouponDate**, regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a **LastCouponDate**, the cash flow payment dates are determined from other inputs.

**Default:**

### **StartDate**

Date when a bond actually starts (the date from which a bond cash flow is considered). To make an instrument forward-starting, specify this date as a future date. If you do not specify **StartDate**, the effective start date is the **Settle** date.

**Default:**

## Face

Face or par value. **Face** is a NINST-by-1 vector or NINST-by-1 cell array of face values, or face value schedules. For the latter case, each element of the cell array is a NumDates-by-2 cell array, where the first column is dates and the second column is its associated face value. The date indicates the last day that the face value is valid.

**Default:** 100

## Options

Derivatives pricing options structure created with `derivset`.

**Default:**

## Name-Value Pair Arguments

Specify optional comma-separated pairs of Name,Value arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

## AdjustCashFlowsBasis

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** false

## BusinessDayConvention

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

## Holidays

Holidays used for business day convention. NHOLIDAYS-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, `holidays.m` is used.

## Description

`[Price, PriceTree] = bondbyhw(HWTree, CouponRate, Settle, Maturity)` computes the price of a bond from a Hull-White interest-rate tree.

`[Price, PriceTree] = bondbyhw(HWTree, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face, Options)` computes the price of a bond from a Hull-White interest-rate tree with optional input arguments.

`[Price, PriceTree] = bondbyhw(HWTree, CouponRate, Settle, Maturity, Name, Value)` computes the price of a bond from a Hull-White interest-rate tree with additional options specified by one or more Name, Value pair arguments.

`Price` is a number of instruments (NINST)-by-1 matrix of expected prices at time 0.

`PriceTree` is a structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node. Within `PriceTree`:

- `PriceTree.PTree` contains the clean prices.
- `PriceTree.AITree` contains the accrued interest.
- `PriceTree.tObs` contains the observation times.

`bondbyhw` computes prices of vanilla bonds, stepped coupon bonds, and amortizing bonds with no market purchase option and no call provisions.

## Examples

### Price a Bond Using the HW Tree

Price a 4% bond using a Hull-White interest-rate tree.

Load `deriv.mat`, which provides `HWTtree`. The `HWTtree` structure contains the time and interest-rate information needed to price the bond.

```
load deriv.mat;
```

Define the bond using the required arguments. Other arguments use defaults.

```
CouponRate = 0.04;
Settle = '01-Jan-2004';
Maturity = '31-Dec-2008';
```

Use `bondbyhw` to compute the price of the bond.

```
Price = bondbyhw(HWTtree, CouponRate, Settle, Maturity)
```

Warning: Not all cash flows are aligned with the tree. Result will be approximated.

```
Price =
    98.0483
```

### Price a Stepped Coupon Bond

Price single stepped coupon bonds using market data.

Define the interest-rate term structure.

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2010';
StartDates = ValuationDate;
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};
Compounding = 1;
```

Create the `RateSpec`.

```
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RS =
    FinObj: 'RateSpec'
    Compounding: 1
    Disc: [4x1 double]
```

```

        Rates: [4x1 double]
        EndTimes: [4x1 double]
        StartTimes: [4x1 double]
        EndDates: [4x1 double]
        StartDates: 734139
ValuationDate: 734139
        Basis: 0
        EndMonthRule: 1

```

Create the stepped bond instrument.

```

Settle = '01-Jan-2010';
Maturity = {'01-Jan-2011'; '01-Jan-2012'; '01-Jan-2013'; '01-Jan-2014'};
CouponRate = {'01-Jan-2012' .0425; '01-Jan-2014' .0750};
Period = 1;

```

Build the HW tree using the following market data:

```

VolDates = ['1-Jan-2011'; '1-Jan-2012'; '1-Jan-2013'; '1-Jan-2014'];
VolCurve = 0.01;
AlphaDates = '01-01-2014';
AlphaCurve = 0.1;

```

```

HWVolSpec = hwwolspec(RS.ValuationDate, VolDates, VolCurve, ...
AlphaDates, AlphaCurve);
HWTTimeSpec = hwtimespec(RS.ValuationDate, VolDates, Compounding);
HWT = hwtree(HWVolSpec, RS, HWTTimeSpec);

```

Compute the price of the stepped coupon bonds.

```

PHW= bondbyhw(HWT, CouponRate, Settle,Maturity , Period)

```

```

PHW =
    100.7246
    100.0945
    101.5900
    102.0820

```

## Price Two Bonds with Amortization Schedules

Price two bonds with amortization schedules using the `Face` input argument to define the schedules.



Define the interest rate term structure.

```
Rates = 0.035;
ValuationDate = '1-Nov-2011';
StartDates = ValuationDate;
EndDates = '1-Nov-2017';
Compounding = 1;
```

Create the RateSpec.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);
```

Create the bond instrument. The bonds have a coupon rate of 4% and 3.85%, a period of one year, and mature on 1-Nov-2017.

```
CouponRate = [0.04; 0.0385];
Settle = '1-Nov-2011';
Maturity = '1-Nov-2017';
Period = 1;
```

Define the amortizing schedule.

```
Face = {'1-Nov-2015' 100; '1-Nov-2016' 85; '1-Nov-2017' 70};
{'1-Nov-2015' 100; '1-Nov-2016' 90; '1-Nov-2017' 80};
```

Build the HW tree and assume the volatility to be 10%.

```
VolDates = ['1-Nov-2012'; '1-Nov-2013'; '1-Nov-2014'; '1-Nov-2015'; '1-Nov-2016'; '1-Nov-2017'];
VolCurve = 0.1;
AlphaDates = '01-01-2017';
AlphaCurve = 0.1;
```

```
HWVolSpec = hwvolspec(RateSpec.ValuationDate, VolDates, VolCurve, ...
AlphaDates, AlphaCurve);
HWTTimeSpec = hwtimespec(RateSpec.ValuationDate, VolDates, Compounding);
HWT = hwtree(HWVolSpec, RateSpec, HWTTimeSpec);
```

Compute the price of the amortizing bonds.

```
Price = bondbyhw(HWT, CouponRate, Settle, Maturity, 'Period', Period, ...
'Face', Face)
```

```
Price =
```

102.4791

101.7786

## More About

### Vanilla Bond

A vanilla coupon bond is a security representing an obligation to repay a borrowed amount at a designated time and to make periodic interest payments until that time. The issuer of a bond makes the periodic interest payments until the bond matures. At maturity, the issuer pays to the holder of the bond the principal amount owed (face value) and the last interest payment.

### Stepped Coupon Bond

A step-up and step-down bond is a debt security with a predetermined coupon structure over time. With these instruments, coupons increase (step up) or decrease (step down) at specific times during the life of the bond.

### Bond with an Amortization Schedule

An amortized bond is treated as an asset, with the discount amount being amortized to interest expense over the life of the bond.

- “Pricing Options Structure”

## See Also

`bkprice` | `bktree` | `cfamounts` | `hwprice` | `hwtree` | `instbond`

# bondbyzero

Price bond from set of zero curves

## Syntax

```
[Price, DirtyPrice, CFlowAmounts, CFlowDates] =
bondbyzero(RateSpec, CouponRate, Settle, Maturity)
[Price, DirtyPrice, CFlowAmounts, CFlowDates] =
bondbyzero(RateSpec, CouponRate, Settle, Maturity,
Period, Basis, EndMonthRule, IssueDate,
FirstCouponDate, LastCouponDate, StartDate, Face)
[Price, DirtyPrice, CFlowAmounts, CFlowDates] =
bondbyzero(RateSpec, CouponRate, Settle,
Maturity, Name, Value)
```

## Description

[Price, DirtyPrice, CFlowAmounts, CFlowDates] = bondbyzero(RateSpec, CouponRate, Settle, Maturity) returns a NINST-by-NUMCURVES matrix of clean bond prices. Each column arises from one of the zero curves.

[Price, DirtyPrice, CFlowAmounts, CFlowDates] = bondbyzero(RateSpec, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face) returns a NINST-by-NUMCURVES matrix of clean bond prices. Each column arises from one of the zero curves.

[Price, DirtyPrice, CFlowAmounts, CFlowDates] = bondbyzero(RateSpec, CouponRate, Settle, Maturity, Name, Value) returns a NINST-by-NUMCURVES matrix of clean bond prices (each column arises from one of the zero curves) with additional options specified by one or more Name, Value pair arguments.

**bondbyzero** computes prices of vanilla bonds, stepped coupon bonds, and amortizing bonds with no market purchase option and no call provisions.

## Input Arguments

### RateSpec

Structure containing the properties of an interest-rate structure. See `intenvset` for information on creating `RateSpec`.

### CouponRate

Decimal annual rate. `CouponRate` is a NINST-by-1 vector or NINST-by-1 cell array of decimal annual rates, or decimal annual rate schedules. For the latter case of a variable coupon schedule, each element of the cell array is a `NumDates`-by-2 cell array, where the first column is dates and the second column is its associated rate. The date indicates the last day that the coupon rate is valid.

### Settle

Settlement date. `Settle` must be either a scalar or NINST-by-1 vector of serial date numbers or date strings of the same value which represent the settlement date for each bond. `Settle` must be earlier than `Maturity`.

### Maturity

Maturity date. NINST-by-1 vector of dates representing the maturity date for each swap.

## Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

### Period

Coupons per year of the bond. A vector of integers. Values are 1, 2, 3, 4, 6, and 12.

### Default: 2

### Basis

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)

- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### **EndMonthRule**

End-of-month rule. A NINST-by-1 vector. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

### **IssueDate**

Date when a bond was issued.

**Default:**

### **FirstCouponDateDate**

Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When **FirstCouponDate** and **LastCouponDate** are both specified,

**FirstCouponDate** takes precedence in determining the coupon payment structure. If you do not specify a **FirstCouponDate**, the cash flow payment dates are determined from other inputs.

**Default:**

### **LastCouponDateDate**

Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified **FirstCouponDate**, a specified **LastCouponDate** determines the coupon structure of the bond. The coupon structure of a bond is truncated at the **LastCouponDate**, regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a **LastCouponDate**, the cash flow payment dates are determined from other inputs.

**Default:**

### **StartDate**

Date when a bond actually starts (the date from which a bond cash flow is considered). To make an instrument forward-starting, specify this date as a future date. If you do not specify **StartDate**, the effective start date is the **Settle** date.

**Default:**

### **Face**

Face or par value. **Face** is a NINST-by-1 vector or NINST-by-1 cell array of face values, or face value schedules. For the latter case, each element of the cell array is a NumDates-by-2 cell array, where the first column is dates and the second column is its associated face value. The date indicates the last day that the face value is valid.

**Default:** 100

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name,Value arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

**AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** false

**BusinessDayConvention**

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

**Holidays**

Holidays used for business day convention. NHOLIDAYS-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, `holidays.m` is used.

## Output Arguments

**Price**

NINST-by-NUMCURVES matrix of clean bond prices. Each column arises from one of the zero curves.

**DirtyPrice**

NINST-by-NUMCURVES matrix of dirty bond price (clean + accrued interest). Each column arises from one of the zero curves.

**CFlowAmounts**

NINST-by-NUMCFS matrix of cash flows for each bond

## CFlowDates

NUMCFS-by-1 matrix of payment dates for each bond

## Examples

### Price a Vanilla Bond

Price a 4% bond using a zero curve.

Load `deriv.mat`, which provides `ZeroRateSpec`, the interest-rate term structure, needed to price the bond.

```
load deriv.mat;
CouponRate = 0.04;
Settle = '01-Jan-2000';
Maturity = '01-Jan-2004';
Price = bondbyzero(ZeroRateSpec, CouponRate, Settle, Maturity)
```

```
Price =
    97.5334
```

### Price a Stepped Coupon Bond

Price single stepped coupon bonds using market data.

Define data for the interest-rate term structure.

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2010';
StartDates = ValuationDate;
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};
Compounding = 1;
```

Create the `RateSpec`.

```
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RS =
```



```

    FinObj: 'RateSpec'
  Compounding: 1
    Disc: [4x1 double]
    Rates: [4x1 double]
    EndTimes: [4x1 double]
    StartTimes: [4x1 double]
    EndDates: [4x1 double]
    StartDates: 734139
  ValuationDate: 734139
    Basis: 0
  EndMonthRule: 1

```

Create the stepped bond instrument.

```

Settle = '01-Jan-2010';
Maturity = {'01-Jan-2011'; '01-Jan-2012'; '01-Jan-2013'; '01-Jan-2014'};
CouponRate = {'01-Jan-2012' .0425; '01-Jan-2014' .0750};
Period = 1;

```

Compute the price of the stepped coupon bonds.

```
PZero= bondbyzero(RS, CouponRate, Settle, Maturity ,Period)
```

```

PZero =

    100.7246
    100.0945
    101.5900
    102.0820

```

### Price a Bond with an Amortizing Schedule

Price a bond with an amortizing schedule using the `Face` input argument to define the schedule.

Define data for the interest-rate term structure.

```

Rates = 0.065;
ValuationDate = '1-Jan-2011';
StartDates = ValuationDate;
EndDates= '1-Jan-2017';

```

```
Compounding = 1;
```

Create the RateSpec.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...  
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'  
  Compounding: 1  
        Disc: 0.6853  
        Rates: 0.0650  
    EndTimes: 6  
  StartTimes: 0  
    EndDates: 736696  
  StartDates: 734504  
ValuationDate: 734504  
        Basis: 0  
  EndMonthRule: 1
```

Create and price the amortizing bond instrument. The bond has a coupon rate of 7%, a period of one year, and matures on 1-Jan-2017.

```
CouponRate = 0.07;  
Settle = '1-Jan-2011';  
Maturity = '1-Jan-2017';  
Period = 1;  
Face = {'1-Jan-2015' 100; '1-Jan-2016' 90; '1-Jan-2017' 80};  
Price = bondbyzero(RateSpec, CouponRate, Settle, Maturity, 'Period', ...  
Period, 'Face', Face)
```

```
Price =
```

```
    102.3155
```

Compare the results with price of a vanilla bond.

```
PriceVanilla = bondbyzero(RateSpec, CouponRate, Settle, Maturity, Period)
```

```
PriceVanilla =
```

```
102.4205
```

Price both the amortizing and vanilla bonds.

```
Face = {{'1-Jan-2015' 100; '1-Jan-2016' 90; '1-Jan-2017' 80};
        100};
PriceBonds = bondbyzero(RateSpec, CouponRate, Settle, Maturity, 'Period',...
                        Period, 'Face', Face)
```

```
PriceBonds =
```

```
102.3155
102.4205
```

## More About

### Vanilla Bond

A vanilla coupon bond is a security representing an obligation to repay a borrowed amount at a designated time and to make periodic interest payments until that time. The issuer of a bond makes the periodic interest payments until the bond matures. At maturity, the issuer pays to the holder of the bond the principal amount owed (face value) and the last interest payment.

### Stepped Coupon Bond

A step-up and step-down bond is a debt security with a predetermined coupon structure over time. With these instruments, coupons increase (step up) or decrease (step down) at specific times during the life of the bond.

### Bond with an Amortization Schedule

An amortized bond is treated as an asset, with the discount amount being amortized to interest expense over the life of the bond.

## See Also

| [swapbyzero](#) | [cfamounts](#) | [cfbyzero](#) | [fixedbyzero](#) | [floatbyzero](#)

## bushpath

Extract entries from node of bushy tree

### Syntax

Values = bushpath(Tree, BranchList)

### Arguments

Tree	Bushy tree.
BranchList	Number of paths (NUMPATHS) by path length (PATHLENGTH) matrix containing the sequence of branchings.

### Description

Values = bushpath(Tree, BranchList) extracts entries of a node of a bushy tree. The node path is described by the sequence of branchings taken, starting at the root. The top branch is number 1, the second-to-top is 2, and so on. Set the branch sequence to zero to obtain the entries at the root node.

Values is a number of values (NUMVALS)-by-NUMPATHS matrix containing the retrieved entries of a bushy tree.

### Examples

Create an HJM tree by loading the example file.

```
load deriv.mat;
```

Then

```
FwdRates = bushpath(HJMTree.FwdTree, [1 2 1])
```

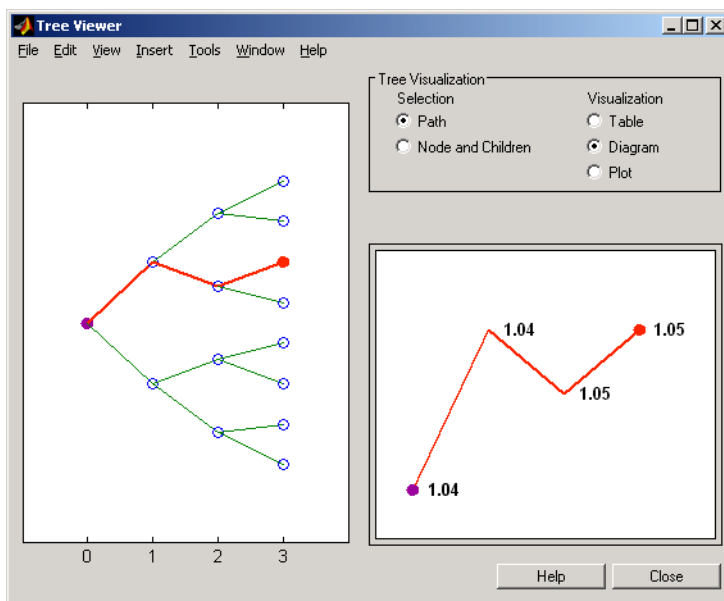
returns the rates at the tree nodes located by taking the up branch, then the down branch, and finally the up branch again.

```
FwdRates =
```

```
1.0356  
1.0364  
1.0526  
1.0463
```

You can visualize this with the `treeviewer` function.

```
treeviewer(HJMTree)
```



## See Also

`bushshape` | `mkbush`

## bushshape

Retrieve shape of bushy tree

### Syntax

```
[NumLevels, NumChild, NumPos, NumStates,  
Trim] = bushshape(Tree)
```

### Arguments

Tree	Bushy tree.
------	-------------

### Description

```
[NumLevels, NumChild, NumPos, NumStates,  
Trim] = bushshape(Tree) returns information on a bushy tree's shape.
```

`NumLevels` is the number of time levels of the tree.

`NumChild` is a 1-by-number of levels (`NUMLEVELS`) vector with the number of branches (children) of the nodes in each level.

`NumPos` is a 1-by-`NUMLEVELS` vector containing the length of the state vectors in each level.

`NumStates` is a 1-by-`NUMLEVELS` vector containing the number of state vectors in each level.

`Trim` is 1 if `NumPos` decreases by 1 when moving from one time level to the next. Otherwise, it is 0.

### Examples

Create an HJM tree by loading the example file.



```
      1      2      4      8
Trim =
  1
```

You can recreate this tree using the `mkbush` function.

```
Tree = mkbush(NumLevels, NumChild(1), NumPos(1), Trim);
Tree = mkbush(NumLevels, NumChild, NumPos);
```

### See Also

`bushpath` | `mkbush`



# capbybdt

Price cap instrument from Black-Derman-Toy interest-rate tree

## Syntax

```
[Price, PriceTree] = capbybdt(BDTree, Strike, Settle,
Maturity, Reset, Basis, Principal, Options)
```

## Arguments

<b>BDTree</b>	Interest-rate tree structure created by <code>bdttree</code> .
<b>Strike</b>	Number of instruments (NINST)-by-1 vector of rates at which the cap is exercised.
<b>Settle</b>	Settlement dates. NINST-by-1 vector of dates representing the settlement dates of the cap.
<b>Maturity</b>	NINST-by-1 vector of dates representing the maturity dates of the cap.
<b>Reset</b>	(Optional) NINST-by-1 vector representing the frequency of payments per year. Default = 1.
<b>Basis</b>	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> </ul>

	<ul style="list-style-type: none"> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Principal	(Optional) NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid. Default is 100.
Options	(Optional) Derivatives pricing options structure created with derivset.

## Description

[Price, PriceTree] = capbybdt(BDTree, Strike, Settle, Maturity, Reset, Basis, Principal, Options) computes the price of a cap instrument from a BDT interest-rate tree.

Price is the expected price of the cap at time 0.

PriceTree is the tree structure with values of the cap at each node.

The Settle date for every cap is set to the ValuationDate of the BDT tree. The cap argument Settle is ignored.

---

**Note:** Use the optional name-value pair argument, Principal, to pass a schedule to compute price for an amortizing cap.

---

## Examples

### Price a 3% Cap Instrument Using a BDT Interest-Rate Tree

Load the file deriv.mat, which provides BDTree. The BDTree structure contains the time and interest-rate information needed to price the cap instrument.

```
load deriv.mat;
```

Set the required values. Other arguments will use defaults.

```
Strike = 0.03;
Settle = '01-Jan-2000';
Maturity = '01-Jan-2004';
```

Use `capbybdt` to compute the price of the cap instrument.

```
Price = capbybdt(BDTree, Strike, Settle, Maturity)
```

```
Price =
    28.4001
```

### Price a 10% Cap Instrument Using a BDT Interest-Rate Tree

Set the required arguments for the three specifications required to create a BDT tree.

```
Compounding = 1;
ValuationDate = '01-01-2000';
StartDate = ValuationDate;
EndDates = ['01-01-2001'; '01-01-2002'; '01-01-2003';
'01-01-2004'; '01-01-2005'];
Rates = [.1; .11; .12; .125; .13];
Volatility = [.2; .19; .18; .17; .16];
```

Create the specifications.

```
RateSpec = intenvset('Compounding', Compounding, ...
'ValuationDate', ValuationDate, ...
'StartDates', StartDate, ...
'EndDates', EndDates, ...
'Rates', Rates);
BDTTimeSpec = bdttimespec(ValuationDate, EndDates, Compounding);
BDTVolSpec = bdtvolspec(ValuationDate, EndDates, Volatility);
```

Create the BDT tree from the specifications.

```
BDTree = bdttree(BDTVolSpec, RateSpec, BDTTimeSpec)
```

```
BDTree =
```

```
    FinObj: 'BDTFwdTree'  
    VolSpec: [1x1 struct]  
    TimeSpec: [1x1 struct]  
    RateSpec: [1x1 struct]  
        tObs: [0 1 2 3 4]  
        dObs: [730486 730852 731217 731582 731947]  
        TFwd: {[5x1 double] [4x1 double] [3x1 double] [2x1 double] [4]}  
        CFlowT: {[5x1 double] [4x1 double] [3x1 double] [2x1 double] [5]}  
        FwdTree: {1x5 cell}
```

Set the cap arguments. Remaining arguments will use defaults.

```
CapStrike = 0.10;  
Settlement = ValuationDate;  
Maturity = '01-01-2002';  
CapReset = 1;
```

Use `capbybdt` to find the price of the cap instrument.

```
Price= capbybdt(BDTree, CapStrike, Settlement, Maturity,...  
CapReset)
```

```
Price =  
  
    1.7169
```

### Compute the Price of an Amortizing Cap Using the BDT Model

Define the `RateSpec`.

```
Rates = [0.03583; 0.042147; 0.047345; 0.052707; 0.054302];  
ValuationDate = '15-Nov-2011';  
StartDates = ValuationDate;  
EndDates = {'15-Nov-2012'; '15-Nov-2013'; '15-Nov-2014' ; '15-Nov-2015'; '15-Nov-2016'};  
Compounding = 1;  
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...  
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```

    FinObj: 'RateSpec'
  Compounding: 1
    Disc: [5x1 double]
    Rates: [5x1 double]
    EndTimes: [5x1 double]
    StartTimes: [5x1 double]
    EndDates: [5x1 double]
    StartDates: 734822
  ValuationDate: 734822
    Basis: 0
  EndMonthRule: 1

```

Define the cap instrument.

```

Settle = '15-Nov-2011';
Maturity = '15-Nov-2015';
Strike = 0.04;
Reset = 1;
Principal = {'15-Nov-2012' 100; '15-Nov-2013' 70; '15-Nov-2014' 40; '15-Nov-2015' 10};

```

Build the BDT Tree.

```

BDTTimeSpec = bdttimespec(ValuationDate, EndDates);
Volatility = 0.10;
BDTVolSpec = bdtvolspec(ValuationDate, EndDates, Volatility*ones(1,length(EndDates)))
BDTTree = bdttree(BDTVolSpec, RateSpec, BDTTimeSpec)

```

BDTTree =

```

    FinObj: 'BDTFwdTree'
  VolSpec: [1x1 struct]
  TimeSpec: [1x1 struct]
  RateSpec: [1x1 struct]
    tObs: [0 1 2 3 4]
    dObs: [734822 735188 735553 735918 736283]
    TFwd: {[5x1 double] [4x1 double] [3x1 double] [2x1 double] [4]}
    CFlowT: {[5x1 double] [4x1 double] [3x1 double] [2x1 double] [5]}
  FwdTree: {1x5 cell}

```

Price the amortizing cap.

```

Basis = 0;

```

```
Price = capbybdt(BDTree, Strike, Settle, Maturity, Reset, Basis, Principal)
```

```
Price =
```

```
1.4042
```

### More About

- “Pricing Options Structure”

### See Also

`bdttree` | `cfbybdt` | `floorbybdt` | `swapbybdt`

# capbybk

Price cap instrument from Black-Karasinski interest-rate tree

## Syntax

```
[Price, PriceTree] = capbybk(BKTree, Strike, Settle, Maturity,
Reset, Basis, Principal, Options)
```

## Arguments

<b>BKTree</b>	Interest-rate tree structure created by <code>bktree</code> .
<b>Strike</b>	Number of instruments (NINST)-by-1 vector of rates at which the cap is exercised.
<b>Settle</b>	Settlement dates. NINST-by-1 vector of dates representing the settlement dates of the cap.
<b>Maturity</b>	NINST-by-1 vector of dates representing the maturity dates of the cap.
<b>Reset</b>	(Optional) NINST-by-1 vector representing the frequency of payments per year. Default = 1.
<b>Basis</b>	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> </ul>

	<ul style="list-style-type: none"> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Principal	(Optional) NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid. Default is 100.
Options	(Optional) Derivatives pricing options structure created with derivset.

## Description

[Price, PriceTree] = capbybk(BKTree, Strike, Settle, Maturity, Reset, Basis, Principal, Options) computes the price of a cap instrument from a Black-Karasinski interest-rate tree.

Price is the expected price of the cap at time 0.

PriceTree is the tree structure with values of the cap at each node.

The Settle date for every cap is set to the ValuationDate of the BK tree. The cap argument Settle is ignored.

---

**Note:** Use the optional name-value pair argument, Principal, to pass a schedule to compute price for an amortizing cap.

---

## Examples

### Price a 3% Cap Instrument Using a Black-Karasinski Interest-Rate Tree

Load the file deriv.mat, which provides BKTree. The BKTree structure contains the time and interest-rate information needed to price the cap instrument.



```
load deriv.mat;
```

Set the required values. Other arguments will use defaults.

```
Strike = 0.03;
Settle = '01-Jan-2004';
Maturity = '01-Jan-2007';
```

Use `capbybk` to compute the price of the cap instrument.

```
Price = capbybk(BKTree, Strike, Settle, Maturity)
```

```
Price =
    2.0965
```

### Compute the Price of an Amortizing and Vanilla Caps Using the BK Model

Load `deriv.mat` to specify the `BKTree` and then define the cap instrument.

```
load deriv.mat;
Settle = '01-Jan-2004';
Maturity = '01-Jan-2008';
Strike = 0.05;
Reset = 1;
Principal ={{'01-Jan-2005' 100; '01-Jan-2006' 60; '01-Jan-2007' 30; '01-Jan-2008' 30};...
            100};
```

Price the amortizing and vanilla caps.

```
Basis = 1;
Price = capbybk(BKTree, Strike, Settle, Maturity, Reset, Basis, Principal)
```

```
Price =
    0.2226
    0.7422
```

## More About

- “Pricing Options Structure”

**See Also**

bktree | cfbybk | floorbybk | swapbybk

# capbyblk

Price caps using Black option pricing model

## Syntax

```
[CapPrice, Caplets] = capbyblk(RateSpec, Strike, Settle,
Maturity, Volatility)
[CapPrice, Caplets] = capbyblk(RateSpec, Strike, Settle,
Maturity, Volatility, 'Name1', Value1...)
```

## Arguments

RateSpec	The annualized, continuously compounded rate term structure. For more information, see <code>intenvset</code> .
Strike	NINST-by-1 vector of rates at which the cap is exercised, as a decimal number.
Settle	Scalar representing the settle date of the cap.
Maturity	Scalar representing the maturity date of the cap.
Volatility	NINST-by-1 vector of volatilities.
Reset	(Optional) NINST-by-1 vector representing the frequency of payments per year. Default is 1.
Principal	(Optional) NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid. Default is 100.
Basis	(Optional) NINST-by-1 vector representing the basis used when annualizing the input forward rate. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> </ul>

	<ul style="list-style-type: none"> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<b>ValuationDate</b>	(Optional) Scalar representing the observation date of the investment horizons. The default is the <b>Settle</b> date.
<b>ProjectionCurve</b>	(Optional) The rate curve to be used in generating the future forward rates. This structure must be created using <b>intenvset</b> . Use this optional input if the forward curve is different from the discount curve. If <b>ProjectionCurve</b> is not specified, then <b>RateSpec</b> is used both for discounting cash flows and projecting future forward rates.

---

**Note:** All optional inputs are specified as matching parameter name-value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. You can specify parameter name-value pairs in any order. Names are case-insensitive and partial string matches are allowed provided no ambiguities exist.

---

## Description

[CapPrice, Caplets] = `capbyblk(RateSpec, Strike, Settle, Maturity, Volatility)` to price caps using the Black option pricing model.

[CapPrice, Caplets] = `capbyblk(RateSpec, Strike, Settle, Maturity, Volatility, 'Name1', Value1...)` to price caps using the Black option pricing model with optional name-value pair arguments.

The outputs for capbyblk are:

- CapPrice — NINST-by-1 expected prices of the cap.
- Caplets — NINST-by-NCF array of caplets, padded with NaNs.

---

**Note:** Use the optional name-value pair argument, `Principal`, to pass a schedule to compute the price for an amortizing cap.

---

## Examples

### Price a Cap Using the Black Option Pricing Model

Consider an investor who gets into a contract that caps the interest rate on a \$100,000 loan at 8% quarterly compounded for 3 months, starting on January 1, 2009. Assuming that on January 1, 2008 the zero rate is 6.9394% continuously compounded and the volatility is 20%, use this data to compute the cap price. First, calculate the `RateSpec`:

```
ValuationDate = 'Jan-01-2008';
EndDates = 'April-01-2010';
Rates = 0.069394;
Compounding = -1;
Basis = 1;

RateSpec = intenvset('ValuationDate', ValuationDate, ...
    'StartDates', ValuationDate, 'EndDates', EndDates, ...
    'Rates', Rates, 'Compounding', Compounding, 'Basis', Basis)
```

```
RateSpec =

    FinObj: 'RateSpec'
    Compounding: -1
        Disc: 0.8554
        Rates: 0.0694
    EndTimes: 2.2500
    StartTimes: 0
        EndDates: 734229
    StartDates: 733408
    ValuationDate: 733408
        Basis: 1
    EndMonthRule: 1
```

Compute the price of the cap.

```
Settle = 'Jan-01-2009'; % cap starts in a year
Maturity = 'April-01-2009';
Volatility = 0.20;
CapRate = 0.08;
CapReset = 4;
Principal=100000;

CapPrice = capbyblk(RateSpec, CapRate, Settle, Maturity, Volatility,...
'Reset',CapReset,'ValuationDate',ValuationDate,'Principal', Principal,...
'Basis', Basis)

CapPrice =

    51.6125
```

### Price a Cap Using a Different Curve to Generate the Future Forward Rates

Define the OIS and Libor rates.

```
Settle = datenum('15-Mar-2013');
CurveDates = daysadd(Settle,360*[1/12 2/12 3/12 6/12 1 2 3 4 5 7 10],1);
OISRates = [.0018 .0019 .0021 .0023 .0031 .006 .011 .017 .021 .026 .03]';
LiborRates = [.0045 .0047 .005 .0055 .0075 .0109 .0162 .0216 .0262 .0309 .0348]';
```

Create an associated `RateSpec` for the OIS and Libor curves.

```
OISCurve = intenvset('Rates',OISRates,'StartDate',Settle,'EndDates',CurveDates,'Compound',0);
LiborCurve = intenvset('Rates',LiborRates,'StartDate',Settle,'EndDates',CurveDates,'Compound',0);
```

Define the Cap instruments.

```
Maturity = {'15-Mar-2018';'15-Mar-2020'};
Strike = [0.04;0.05];
BlackVol = 0.2;
```

Price the cap instruments using the term structure `OISCurve` both for discounting the cash flows and generating future forward rates.

```
[Price, Caplets] = capbyblk(OISCurve, Strike, Settle, Maturity, BlackVol)
```

Price =

```
0.7472
0.9890
```

Caplets =

```
0 0.0000 0.0033 0.2996 0.4443 NaN NaN
0 0.0000 0.0003 0.1134 0.2112 0.2292 0.4349
```

Price the cap instruments using the term structure `LiborCurve` to generate future forward rates. The term structure `OISCurve` is used for discounting the cash flows.

```
[PriceLC, CapletsLC] = capbyblk(OISCurve, Strike, Settle, Maturity, BlackVol, 'Projection');
```

PriceLC =

```
1.3293
1.6329
```

CapletsLC =

```
0 0.0000 0.0337 0.4250 0.8706 NaN NaN
0 0.0000 0.0052 0.1767 0.4849 0.3663 0.5998
```

### Compute the Price of Two Amortizing Caps Using the Black Model

Define the `RateSpec`.

```
Rates = [0.0358; 0.0421; 0.0473; 0.0527; 0.0543];
ValuationDate = '15-Nov-2011';
StartDates = ValuationDate;
EndDates = {'15-Nov-2012'; '15-Nov-2013'; '15-Nov-2014'; '15-Nov-2015'; '15-Nov-2016'};
Compounding = 1;
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

RateSpec =

```
    FinObj: 'RateSpec'  
    Compounding: 1  
        Disc: [5x1 double]  
        Rates: [5x1 double]  
        EndTimes: [5x1 double]  
        StartTimes: [5x1 double]  
        EndDates: [5x1 double]  
        StartDates: 734822  
    ValuationDate: 734822  
        Basis: 0  
    EndMonthRule: 1
```

Define the cap instruments.

```
Settle = '15-Nov-2011';  
Maturity = '15-Nov-2015';  
Strike = [0.03;0.035];  
Reset = 1;  
Principal ={{'15-Nov-2012' 100;'15-Nov-2013' 70;'15-Nov-2014' 40;'15-Nov-2015' 10}};
```

Price the amortizing caps.

```
Volatility = 0.10;  
Price = capbyblk (RateSpec, Strike, Settle, Maturity, Volatility,...  
'Reset', Reset, 'Principal', Principal)
```

```
Price =  
  
    3.0339  
    2.0141
```

## See Also

`floorbyblk` | `intenvset`



# capbyhjm

Price cap instrument from Heath-Jarrow-Morton interest-rate tree

## Syntax

```
[Price, PriceTree] = capbyhjm(HJMTTree, Strike,
Settle, Maturity, Reset, Basis, Principal, Options)
```

## Arguments

HJMTTree	Forward-rate tree structure created by <code>hjmTree</code> .
Strike	Number of instruments (NINST)-by-1 vector of rates at which the cap is exercised.
Settle	Settlement dates. NINST-by-1 vector of dates representing the settlement dates of the cap.
Maturity	NINST-by-1 vector of dates representing the maturity dates of the cap.
Reset	(Optional) NINST-by-1 vector representing the frequency of payments per year. Default = 1.
Basis	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> </ul>

	<ul style="list-style-type: none"> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Principal	(Optional) NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid. Default is 100.
Options	(Optional) Derivatives pricing options structure created with derivset.

## Description

[Price, PriceTree] = capbyhjm(HJMTree, Strike, Settle, Maturity, Reset, Basis, Principal, Options) computes the price of a cap instrument from an HJM tree.

Price is the expected price of the cap at time 0.

PriceTree is the tree structure with values of the cap at each node.

The Settle date for every cap is set to the ValuationDate of the HJM tree. The cap argument Settle is ignored.

---

**Note:** Use the optional name-value pair argument, Principal, to pass a schedule to compute price for an amortizing cap.

---

## Examples

### Price a 3% Cap Instrument Using an HJM Forward-Rate Tree

Load the file deriv.mat, which provides HJMTree. The HJMTree structure contains the time and forward-rate information needed to price the cap instrument.

```
load deriv.mat;
```

Set the required values. Other arguments will use defaults.

```
Strike = 0.03;
Settle = '01-Jan-2000';
Maturity = '01-Jan-2004';
```

Use `capbyhjm` to compute the price of the cap instrument.

```
Price = capbyhjm(HJMTree, Strike, Settle, Maturity)
```

```
Price =
    6.2831
```

### Compute the Price of an Amortizing Cap Using the HJM Model

Load `deriv.mat` to specify the `HJMTree` and then define the cap instrument.

```
load deriv.mat;
Settle = '01-Jan-2000';
Maturity = '01-Jan-2004';
Strike = 0.045;
Reset = 1;
Principal = {'01-Jan-2001' 100; '01-Jan-2002' 80; '01-Jan-2003' 70; '01-Jan-2004' 30};
```

Price the amortizing cap.

```
Basis = 1;
Price = capbyhjm(HJMTree, Strike, Settle, Maturity, Reset, Basis, Principal)
```

```
Price =
    1.4588
```

## More About

- “Pricing Options Structure”

**See Also**

cfbyhjm | floorbyhjm | hjmtree | swapbyhjm

# capbyhw

Price cap instrument from Hull-White interest-rate tree

## Syntax

```
[Price, PriceTree] = capbyhw(HWTree, Strike, Settle, Maturity,
Reset, Basis, Principal, Options)
```

## Arguments

<b>HWTree</b>	Interest-rate tree structure created by <code>hwtree</code> .
<b>Strike</b>	Number of instruments (NINST)-by-1 vector of rates at which the cap is exercised.
<b>Settle</b>	Settlement dates. NINST-by-1 vector of dates representing the settlement dates of the cap.
<b>Maturity</b>	NINST-by-1 vector of dates representing the maturity dates of the cap.
<b>Reset</b>	(Optional) NINST-by-1 vector representing the frequency of payments per year. Default = 1.
<b>Basis</b>	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> </ul>

	<ul style="list-style-type: none"> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Principal	(Optional) NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid. Default is 100.
Options	(Optional) Derivatives pricing options structure created with derivset.

## Description

[Price, PriceTree] = capbyhw(HWTree, Strike, Settle, Maturity, Reset, Basis, Principal, Options) computes the price of a cap instrument from a Hull-White interest-rate tree.

Price is the expected price of the cap at time 0.

PriceTree is the tree structure with values of the cap at each node.

The Settle date for every cap is set to the ValuationDate of the HW tree. The cap argument Settle is ignored.

---

**Note:** Use the optional name-value pair argument, Principal, to pass a schedule to compute price for an amortizing cap.

---

## Examples

### Price a 3% Cap Instrument Using a Hull-White Interest-Rate Tree

Load the file deriv.mat, which provides HWTree. The HWTree structure contains the time and interest-rate information needed to price the cap instrument.

```
load deriv.mat;
```

Set the required values. Other arguments will use defaults.

```
Strike = 0.03;
Settle = '01-Jan-2004';
Maturity = '01-Jan-2007';
```

Use capbyhw to compute the price of the cap instrument.

```
Price = capbyhw(HWTree, Strike, Settle, Maturity)
```

```
Price =
    2.3090
```

### Compute the Price of an Amortizing and Vanilla Caps Using the HW Model

Define the RateSpec.

```
Rates = [0.035; 0.042; 0.047; 0.052; 0.054];
ValuationDate = '01-April-2014';
StartDates = ValuationDate;
EndDates = {'01-April-2019'};
Compounding = 1;
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
    FinObj: 'RateSpec'
    Compounding: 1
    Disc: [5x1 double]
    Rates: [5x1 double]
    EndTimes: [5x1 double]
    StartTimes: [5x1 double]
    EndDates: 737516
    StartDates: 735690
    ValuationDate: 735690
    Basis: 0
    EndMonthRule: 1
```

Define the cap instruments.

```
Settle = '01-April-2014';
Maturity = '01-April-2018';
Strike = 0.055;
Reset = 1;
Principal = {{ '01-April-2015' 100; '01-April-2016' 60; '01-April-2017' 40; '01-April-2018'
              100};
```

Build the HW Tree.

```
VolDates = [ '01-April-2015'; '01-April-2016'; '01-April-2017'; '01-April-2018' ];
VolCurve = 0.05;
AlphaDates = '01-April-2018';
AlphaCurve = 0.10;
```

```
HWVolSpec = hwwolspec(RateSpec.ValuationDate, VolDates, VolCurve, ...
                     AlphaDates, AlphaCurve);
HWTTimeSpec = hwtimespec(RateSpec.ValuationDate, VolDates, Compounding);
HWTTree = hwtree(HWVolSpec, RateSpec, HWTTimeSpec)
```

```
HWTTree =
```

```
    FinObj: 'HWFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
      tObs: [0 1 2 3]
      dObs: [735690 736055 736421 736786]
    CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4]}
    Probs: {[3x1 double] [3x3 double] [3x5 double]}
    Connect: {[2] [2 3 4] [2 2 3 4 4]}
    FwdTree: {[1.0350] [1.1252 1.0362 0.9542] [1x5 double] [1x5 double]}
```

Price the amortizing and vanilla caps.

```
Basis = 0;
Price = capbyhw(HWTTree, Strike, Settle, Maturity, Reset, Basis, Principal)
```

```
Price =
```

```
    1.5828
```



4.3690

## More About

- “Pricing Options Structure”

## See Also

cfbyhw | floorbyhw | hwtree | swapbyhw

## capbylg2f

Price cap using Linear Gaussian two-factor model

### Syntax

```
CapPrice = capbylg2f(ZeroCurve,a,b,sigma,eta,rho,Strike,  
Maturity)  
CapPrice = capbylg2f( ____, Name,Value)
```

### Description

CapPrice = capbylg2f(ZeroCurve,a,b,sigma,eta,rho,Strike,  
Maturity) returns cap price for a two-factor additive Gaussian interest-rate model.

CapPrice = capbylg2f( \_\_\_\_, Name,Value) returns cap price for a two-factor additive Gaussian interest-rate model using optional name-value pairs.

---

**Note:** Use the optional name-value pair argument, Notional, to pass a schedule to compute the price for an amortizing cap.

---

### Examples

#### Price a Cap Using a Linear Gaussian Two-Factor Model

Define the ZeroCurve, a, b, sigma, eta, and rho parameters to price the cap.

```
Settle = datenum('15-Dec-2007');  
  
ZeroTimes = [3/12 6/12 1 5 7 10 20 30]';  
ZeroRates = [0.033 0.034 0.035 0.040 0.042 0.044 0.048 0.0475]';  
CurveDates = daysadd(Settle,360*ZeroTimes);  
  
irdc = IRDataCurve('Zero',Settle,CurveDates,ZeroRates);  
  
a = .07;  
b = .5;  
sigma = .01;
```

```

eta = .006;
rho = -.7;

CapMaturity = daysadd(Settle,360*[1:5 7 10 15 20 25 30],1);

Strike = [0.035 0.037 0.038 0.039 0.040 0.042 0.044 0.046 0.047 0.047 0.047]';

Price = capbylg2f(irdc,a,b,sigma,eta,rho,Strike,CapMaturity)

Price =

    0.0316
    0.3225
    0.7761
    1.3240
    1.9394
    3.1247
    4.8451
    7.3752
    9.8582
   11.4673
   12.7850

```

### Price an Amortizing Cap Using a Linear Gaussian Two-Factor Model

Define the ZeroCurve, a, b, sigma, eta, rho, and Notional parameters for the amortizing cap.

```

Settle = datenum('15-Dec-2007');
% Define ZeroCurve
ZeroTimes = [3/12 6/12 1 5 7 10 20 30]';
ZeroRates = [0.033 0.034 0.035 0.040 0.042 0.044 0.048 0.0475]';
CurveDates = daysadd(Settle,360*ZeroTimes);

irdc = IRDataCurve('Zero',Settle,CurveDates,ZeroRates);

% Define a, b, sigma, eta, and rho
a = .07;
b = .5;
sigma = .01;
eta = .006;
rho = -.7;

```

```
% Define the amortizing caps
CapMaturity = daysadd(Settle,360*[1:5 7 10 15 20 25 30],1);
Strike = [0.035 0.037 0.038 0.039 0.040 0.042 0.044 0.046 0.047 0.047 0.047]';
Notional = {'15-Dec-2010' 100;'15-Dec-2014' 70;'15-Dec-2022' 40;'15-Dec-2037' 10};;

% Price the amortizing caps
Price = capbylg2f(irdc,a,b,sigma,eta,rho,Strike,CapMaturity, 'Notional', Notional)

Price =

    0.0316
    0.3225
    0.7761
    1.1313
    1.5362
    2.3213
    2.8297
    3.6878
    3.7297
    3.8906
    4.0223
```

## Input Arguments

### **ZeroCurve** — Zero-curve for Linear Gaussian two-factor model

structure

Zero-curve for the Linear Gaussian two-factor model, specified using `IRDataCurve` or `RateSpec`.

Data Types: `struct`

### **a** — Mean reversion for first factor for Linear Gaussian two-factor model

scalar

Mean reversion for first factor for the Linear Gaussian two-factor model, specified as a scalar.

Data Types: `single` | `double`

### **b** — Mean reversion for second factor for Linear Gaussian two-factor model

scalar

Mean reversion for second factor for the Linear Gaussian two-factor model, specified as a scalar.

Data Types: `single` | `double`

**sigma — Volatility for first factor for Linear Gaussian two-factor model**

scalar

Volatility for first factor for the Linear Gaussian two-factor model, specified as a scalar.

Data Types: `single` | `double`

**eta — Volatility for second factor for Linear Gaussian two-factor model**

scalar

Volatility for second factor for the Linear Gaussian two-factor model, specified as a scalar.

Data Types: `single` | `double`

**rho — Scalar correlation of the factors**

scalar

Scalar correlation of the factors, specified as a scalar.

Data Types: `single` | `double`

**Strike — Cap strike price**

nonnegative integer | vector of nonnegative integers

Cap strike price, specified as a nonnegative integer using a `NumCaps`-by-1 vector.

Data Types: `single` | `double`

**Maturity — Cap maturity date**

nonnegative integer | vector of nonnegative integers | string of dates

Cap maturity date, specified using a `NumCaps`-by-1 vector of serial date numbers or date strings.

Data Types: `single` | `double` | `cell`

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single

quotes (' '). You can specify several name and value pair arguments in any order as Name1, Value1, . . . , NameN, ValueN.

Example: `Price = capbylg2f(irdc,a,b,sigma,eta,rho,Strike,CapMaturity,'Reset',1,'Notional',100)`

**'Reset' — Frequency of cap payments per year**

2 (default) | positive integer from the set [1,2,3,4,6,12] | vector of positive integers from the set [1,2,3,4,6,12]

Frequency of cap payments per year, specified as positive integers for the values 1,2,4,6,12] in a NumCaps-by-1 vector.

Data Types: single | double

**'Notional' — Notional value of cap**

100 (default) | nonnegative integer | vector of nonnegative integers

NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is the associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: single | double

## Output Arguments

**CapPrice — Cap price**

scalar | vector

Expected prices of cap, returned as a scalar or an NumCaps-by-1 vector.

## More About

### Algorithms

The following defines the two-factor additive Gaussian interest rate model, given the ZeroCurve, a, b, sigma, eta, and rho parameters:

$$r(t) = x(t) + y(t) + \phi(t)$$

$$dx(t) = -a(x)(t)dt + \sigma(dW_1(t)), x(0) = 0$$

$$dy(t) = -b(y)(t)dt + \eta(dW_2(t)), y(0) = 0$$

where  $dW_1(t)dW_2(t) = \rho dt$  is a two-dimensional Brownian motion with correlation  $\rho$  and  $\#$  is a function chosen to match the initial zero curve.

## References

- [1] Brigo, D. and F. Mercurio, *Interest Rate Models - Theory and Practice*, Springer Finance, 2006.

## See Also

LinearGaussian2F | floorbylg2f | swaptionbylg2f

## cashbybls

Determine price of cash-or-nothing digital options using Black-Scholes model

### Syntax

```
Price = cashbybls(RateSpec, StockSpec, Settle, Maturity,  
OptSpec, Strike, Payoff)
```

### Arguments

RateSpec	The annualized, continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.
Payoff	NINST-by-1 vector of payoff values or the amount to be paid at expiration.

### Description

`Price = cashbybls(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike, Payoff)` computes cash-or-nothing option prices using the Black-Scholes option pricing model.

Price is a NINST-by-1 vector of expected option prices.



## Examples

### Compute Cash-or-Nothing Option Prices Using the Black-Scholes Option Pricing Model

Consider a European call and put cash-or-nothing options on a futures contract with and exercise strike price of \$90, a fixed payoff of \$10 that expires on October 1, 2008. Assume that on January 1, 2008, the contract trades at \$110, and has a volatility of 25% per annum and the risk-free rate is 4.5% per annum. Using this data, calculate the price of the call and put cash-or-nothing options on the futures contract. First, create the RateSpec:

```
Settle = 'Jan-1-2008';
Maturity = 'Oct-1-2008';
Rates = 0.045;
Compounding = -1;
Basis = 1;
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
    'EndDates', Maturity, 'Rates', Rates, 'Compounding', Compounding, 'Basis', Basis)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
    Compounding: -1
        Disc: 0.9668
        Rates: 0.0450
    EndTimes: 0.7500
    StartTimes: 0
    EndDates: 733682
    StartDates: 733408
    ValuationDate: 733408
        Basis: 1
    EndMonthRule: 1
```

Define the StockSpec.

```
AssetPrice = 110;
Sigma = .25;
DivType = 'Continuous';
DivAmount = Rates;
StockSpec = stockspec(Sigma, AssetPrice, DivType, DivAmount)
```

```
StockSpec =  
    FinObj: 'StockSpec'  
    Sigma: 0.2500  
    AssetPrice: 110  
    DividendType: {'continuous'}  
    DividendAmounts: 0.0450  
    ExDividendDates: []
```

Define the call and put options.

```
OptSpec = {'call'; 'put'};  
Strike = 90;  
Payoff = 10;
```

Calculate the prices.

```
Pcon = cashbybls(RateSpec, StockSpec, Settle,...  
Maturity, OptSpec, Strike, Payoff)
```

```
Pcon =  
    7.6716  
    1.9965
```

## See Also

assetbybls | cashsensbybls | gapbybls | supersharebybls

# cashsensbybls

Determine price and sensitivities of cash-or-nothing digital options using Black-Scholes model

## Syntax

```
PriceSens = cashsensbybls(RateSpec, StockSpec, Settle,
Maturity, OptSpec, Strike, Payoff)
PriceSens = cashsensbybls(RateSpec, StockSpec, Settle,
Maturity, OptSpec, Strike, Payoff, OutSpec)
```

## Arguments

RateSpec	The annualized, continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.
Payoff	NINST-by-1 vector of payoff values or the amount to be paid at expiration.
OutSpec	(Optional) All optional inputs are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. You can specify parameter name/value pairs in any order. Names are case-insensitive and partial string matches are allowed provided no ambiguities exist. Valid parameter names are: <ul style="list-style-type: none"> <li>• NOUT-by-1 or 1-by-NOUT cell array of strings indicating the nature and order of the outputs for the function.</li> </ul>

	<p>Possible values are 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', or 'All'.</p> <p>For example, <code>OutSpec = {'Price'; 'Lambda'; 'Rho'}</code> specifies that the output should be Price, Lambda, and Rho, in that order.</p> <p>To invoke from a function: <code>[Price, Lambda, Rho] = cashsensbybls(..., 'OutSpec', {'Price', 'Lambda', 'Rho'})</code></p> <p><code>OutSpec = {'All'}</code> specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying <code>OutSpec</code> as <code>OutSpec = {'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', 'Price'}</code>;</p> <ul style="list-style-type: none"> <li>• Default is <code>OutSpec = {'Price'}</code>.</li> </ul>
--	--

## Description

`PriceSens = cashsensbybls(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike, Payoff)` computes cash-or-nothing option prices using the Black-Scholes option pricing model.

`PriceSens = cashsensbybls(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike, Payoff, OutSpec)` includes an `OutSpec` argument defined as parameter/value pairs, and computes cash-or-nothing option prices and sensitivities using the Black-Scholes option pricing model.

`PriceSens` is a NINST-by-1 vector of expected option prices and sensitivities.

## Examples

### Compute Cash-or-Nothing Option Prices and Sensitivities Using the Black-Scholes Option Pricing Model

Consider a European call and put cash-or-nothing options on a futures contract with an exercise price of \$90, and a fixed payoff of \$10 that expires on January 1, 2009. Assume

that on October 1, 2008 the contract trades at \$110, and has a volatility of 25% per annum and the risk-free rate is 4.5% per annum. Using this data, calculate the price and sensitivity of the call and put cash-or-nothing options on the futures contract. First, create the RateSpec:

```
Settle = 'Jan-1-2008';
Maturity = 'Oct-1-2008';
Rates = 0.045;
Compounding = -1;
Basis = 1;
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
'EndDates', Maturity, 'Rates', Rates, 'Compounding', Compounding, 'Basis', Basis)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
  Compounding: -1
        Disc: 0.9668
        Rates: 0.0450
    EndTimes: 0.7500
    StartTimes: 0
    EndDates: 733682
    StartDates: 733408
  ValuationDate: 733408
        Basis: 1
  EndMonthRule: 1
```

Define the StockSpec.

```
AssetPrice = 110;
Sigma = .25;
DivType = 'Continuous';
DivAmount = Rates;
StockSpec = stockspec(Sigma, AssetPrice, DivType, DivAmount)
```

```
StockSpec =
```

```
    FinObj: 'StockSpec'
    Sigma: 0.2500
  AssetPrice: 110
  DividendType: {'continuous'}
  DividendAmounts: 0.0450
```

```
ExDividendDates: []
```

Define the call and put options.

```
OptSpec = {'call'; 'put'};  
Strike = 90;  
Payoff = 10;
```

Compute the gamma, theta, and price.

```
OutSpec = { 'gamma'; 'theta'; 'price'};  
[Gamma, Theta, Price] = cashsensbybls(RateSpec, StockSpec, ...  
Settle, Maturity, OptSpec, Strike, Payoff, 'OutSpec', OutSpec)
```

```
Gamma =
```

```
-0.0050  
0.0050
```

```
Theta =
```

```
-2.2489  
1.8139
```

```
Price =
```

```
7.6716  
1.9965
```

## See Also

cashbybls

## cfbybdt

Price cash flows from Black-Derman-Toy interest-rate tree

### Syntax

```
[Price, PriceTree] = cfbybdt(BDTree,
CFlowAmounts, CFlowDates, Settle, Basis, Options)
```

### Arguments

<b>BDTree</b>	Forward-rate tree structure created by <code>bdtree</code> .
<b>CFlowAmounts</b>	Number of instruments ( <b>NINST</b> ) by maximum number of cash flows ( <b>MOSTCFS</b> ) matrix of cash flow amounts. Each row is a list of cash flow values for one instrument. If an instrument has fewer than <b>MOSTCFS</b> cash flows, the end of the row is padded with NaNs.
<b>CFlowDates</b>	<b>NINST</b> -by- <b>MOSTCFS</b> matrix of cash flow dates. Each entry contains the serial date number of the corresponding cash flow in <b>CFlowAmounts</b> .
<b>Settle</b>	Settlement date. A vector of serial date numbers or date strings. The <b>Settle</b> date for every cash flow is set to the <b>ValuationDate</b> of the BDT tree. The cash flow argument, <b>Settle</b> , is ignored.
<b>Basis</b>	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> </ul>

	<ul style="list-style-type: none"> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Options	(Optional) Derivatives pricing options structure created with <code>derivset</code> .

## Description

`[Price, PriceTree] = cfbybdt(BDTree, CFflowAmounts, CFflowDates, Settle, Basis, Options)` prices cash flows from a BDT interest-rate tree.

`Price` is an NINST-by-1 vector of expected prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

## Examples

Price a portfolio containing two cash flow instruments paying interest annually over the four-year period from January 1, 2000 to January 1, 2004.

Load the file `deriv.mat`, which provides `BDTree`. The `BDTree` structure contains the time and interest-rate information needed to price the instruments.

```
load deriv.mat;
```

The valuation date (settle date) specified in `BDTree` is January 1, 2000 (date number 730486).

```
BDTree.RateSpec.ValuationDate
```



```
ans =
```

```
730486
```

Provide values for the other required arguments.

```
CFlowAmounts =[5 NaN 5.5 105; 5 0 6 105];
CFlowDates = [730852, NaN, 731582, 731947;
              730852, 731217, 731582, 731947];
```

Use this information to compute the prices of the two cash flow instruments.

```
[Price, PriceTree] = cfbybdt(BDTTree, CFlowAmounts, ...
                             CFlowDates, BDTTree.RateSpec.ValuationDate)
```

```
Price =
```

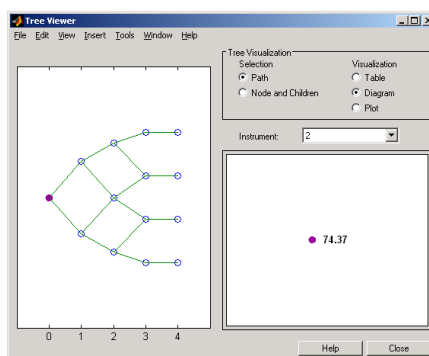
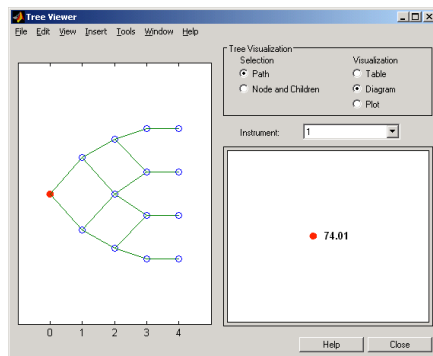
```
74.0112
74.3671
```

```
PriceTree =
```

```
FinObj: 'BDTPriceTree'
tObs: [0 1.00 2.00 3.00 4.00]
PTree: {1x5 cell}
```

You can visualize the prices of the two cash flow instruments with the `treeviewer` function.

```
treeviewer(PriceTree)
```



## **More About**

- “Pricing Options Structure”

## **See Also**

`bdtprice` | `bdttree` | `cfamounts` | `instcf`

# cfbybk

Price cash flows from Black-Karasinski interest-rate tree

## Syntax

[Price, PriceTree] = cfbybk(BKTree, CFlowAmounts, CFlowDates, Settle, Basis, Options)

## Arguments

<b>BKTree</b>	Forward-rate tree structure created by <code>bktree</code> .
<b>CFlowAmounts</b>	Number of instruments ( <b>NINST</b> ) by maximum number of cash flows ( <b>MOSTCFS</b> ) matrix of cash flow amounts. Each row is a list of cash flow values for one instrument. If an instrument has fewer than <b>MOSTCFS</b> cash flows, the end of the row is padded with NaNs.
<b>CFlowDates</b>	<b>NINST</b> -by- <b>MOSTCFS</b> matrix of cash flow dates. Each entry contains the serial date number of the corresponding cash flow in <b>CFlowAmounts</b> .
<b>Settle</b>	Settlement date. A vector of serial date numbers or date strings. The <b>Settle</b> date for every cash flow is set to the <b>ValuationDate</b> of the BK tree. The cash flow argument, <b>Settle</b> , is ignored.
<b>Basis</b>	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> </ul>

	<ul style="list-style-type: none"> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Options	(Optional) Derivatives pricing options structure created with <code>derivset</code> .

## Description

`[Price, PriceTree] = cfbybk(BKTree, CFlowAmounts, CFlowDates, Settle, Basis, Options)` prices cash flows from a Black-Karasinski interest-rate tree.

`Price` is an NINST-by-1 vector of expected prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

## Examples

Price a portfolio containing two cash flow instruments paying interest annually over the four-year period from January 1, 2005 to January 1, 2009.

Load the file `deriv.mat`, which provides `BKTree`. The `BKTree` structure contains the time and interest-rate information needed to price the instruments.

```
load deriv.mat;
```

The valuation date (settle date) specified in `BKTree` is January 1, 2004 (date number 731947).

```
BKTree.RateSpec.ValuationDate
```

```
ans =
```

731947

Provide values for the other required arguments.

```
CFlowAmounts =[5 NaN 5.5 105; 5 0 6 105];
CFlowDates = [732678, NaN, 733408,733774;
              732678, 733034, 733408, 734774];
```

Use this information to compute the prices of the two cash flow instruments.

```
[Price, PriceTree] = cfbybk(BKTree, CFlowAmounts, CFlowDates,...
BKTree.RateSpec.ValuationDate)
```

```
Price =
```

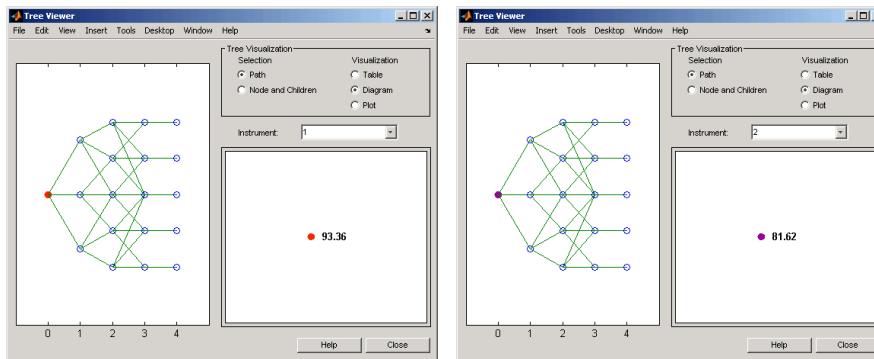
```
93.3600
81.6218
```

```
PriceTree =
```

```
FinObj: 'BKPriceTree'
tObs: [0 1 2 3 4]
PTree: {[2x1 double] [2x3 double] [2x5 double] [2x5
double] [2x5 double]}
Connect: {[2] [2 3 4] [2 2 3 4 4]}
Probs: {[3x1 double] [3x3 double] [3x5 double]}
```

You can visualize the prices of the two cash flow instruments with the `treeviewer` function.

```
treeviewer(PriceTree)
```



## **More About**

- “Pricing Options Structure”

## **See Also**

`bkprice` | `bktree` | `cfamounts` | `instcf`

# cfbyhjm

Price cash flows from Heath-Jarrow-Morton interest-rate tree

## Syntax

```
[Price, PriceTree] = cfbyhjm(HJMTTree, CFlowAmounts,
CFlowDates, Settle, Basis, Options)
```

## Arguments

HJMTTree	Forward-rate tree structure created by <code>hjmtree</code> .
CFlowAmounts	Number of instruments (NINST) by maximum number of cash flows (MOSTCFS) matrix of cash flow amounts. Each row is a list of cash flow values for one instrument. If an instrument has fewer than MOSTCFS cash flows, the end of the row is padded with NaNs.
CFlowDates	NINST-by-MOSTCFS matrix of cash flow dates. Each entry contains the serial date number of the corresponding cash flow in CFlowAmounts.
Settle	Settlement date. A vector of serial date numbers or date strings. The <b>Settle</b> date for every cash flow is set to the <b>ValuationDate</b> of the HJM tree. The cash flow argument, <b>Settle</b> , is ignored.
Basis	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> </ul>

	<ul style="list-style-type: none"> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Options	(Optional) Derivatives pricing options structure created with <code>derivset</code> .

## Description

`[Price, PriceTree] = cfbyhjm(HJMTree, CFlowAmounts, CFlowDates, Settle, Basis, Options)` prices cash flows from an HJM interest-rate tree.

`Price` is an NINST-by-1 vector of expected prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

## Examples

Price a portfolio containing two cash flow instruments paying interest annually over the four-year period from January 1, 2000 to January 1, 2004.

Load the file `deriv.mat`, which provides `HJMTree`. The `HJMTree` structure contains the time and forward-rate information needed to price the instruments.

```
load deriv.mat;
```

The valuation date (settle date) specified in `HJMTree` is January 1, 2000 (date number 730486).

```
HJMTree.RateSpec.ValuationDate
```



```
ans =
```

```
730486
```

Provide values for the other required arguments.

```
CFlowAmounts =[5 NaN 5.5 105; 5 0 6 105];
CFlowDates = [730852, NaN, 731582, 731947;
              730852, 731217, 731582, 731947];
```

Use this information to compute the prices of the two cash flow instruments.

```
[Price, PriceTree] = cfbyhjm(HJMTree, CFlowAmounts, ...
                             CFlowDates, HJMTree.RateSpec.ValuationDate)
```

```
Price =
```

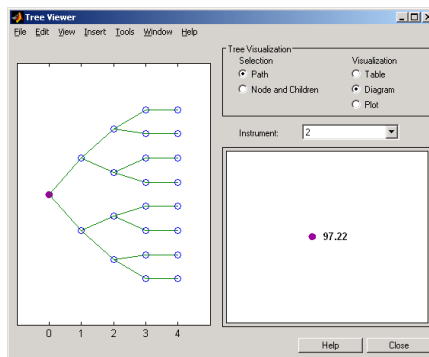
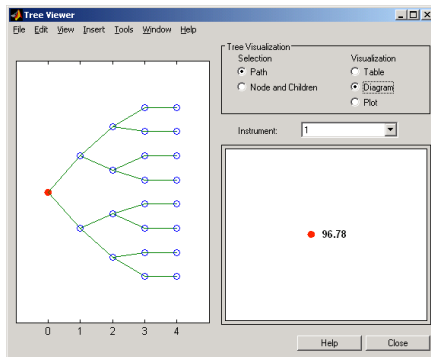
```
96.7805
97.2188
```

```
PriceTree =
```

```
FinObj: 'HJMPriceTree'
tObs: [0 1.00 2.00 3.00 4.00]
PBush: {1x5 cell}
```

You can visualize the prices of the two cash flow instruments with the `treeviewer` function.

```
treeviewer(PriceTree)
```



## **More About**

- “Pricing Options Structure”

## **See Also**

`cfamounts` | `hjmprice` | `hjmtree` | `instcf`

## cfbyhw

Price cash flows from Hull-White interest-rate tree

### Syntax

[Price, PriceTree] = cfbyhw(HWTree, CFlowAmounts, CFlowDates, Settle, Basis, Options)

### Arguments

<b>HWTree</b>	Forward-rate tree structure created by <code>hwtree</code> .
<b>CFlowAmounts</b>	Number of instruments ( <b>NINST</b> ) by maximum number of cash flows ( <b>MOSTCFS</b> ) matrix of cash flow amounts. Each row is a list of cash flow values for one instrument. If an instrument has fewer than <b>MOSTCFS</b> cash flows, the end of the row is padded with NaNs.
<b>CFlowDates</b>	<b>NINST</b> -by- <b>MOSTCFS</b> matrix of cash flow dates. Each entry contains the serial date number of the corresponding cash flow in <b>CFlowAmounts</b> .
<b>Settle</b>	Settlement date. A vector of serial date numbers or date strings. The <b>Settle</b> date for every cash flow is set to the <b>ValuationDate</b> of the HW tree. The cash flow argument, <b>Settle</b> , is ignored.
<b>Basis</b>	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> </ul>

	<ul style="list-style-type: none"> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Options	(Optional) Derivatives pricing options structure created with <code>derivset</code> .

## Description

`[Price, PriceTree] = cfbyhw(HWTree, CFlowAmounts, CFlowDates, Settle, Basis, Options)` prices cash flows from a Hull-White interest-rate tree.

`Price` is an NINST-by-1 vector of expected prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

## Examples

Price a portfolio containing two cash flow instruments paying interest annually over the four-year period from January 1, 2005 to January 1, 2009.

Load the file `deriv.mat`, which provides `HWTree`. The `HWTree` structure contains the time and interest-rate information needed to price the instruments.

```
load deriv.mat;
```

The valuation date (settle date) specified in `HWTree` is January 1, 2004 (date number 731947).

```
HWTree.RateSpec.ValuationDate
```

```
ans =
```

731947

Provide values for the other required arguments.

```
CFlowAmounts =[5 NaN 5.5 105; 5 0 6 105];
CFlowDates = [732678, NaN, 733408, 733774;
              732678, 733034, 733408, 734774];
```

Use this information to compute the prices of the two cash flow instruments.

```
[Price, PriceTree] = cfbyhw(HWTree, CFlowAmounts, CFlowDates,...
HWTree.RateSpec.ValuationDate)
```

```
Price =
```

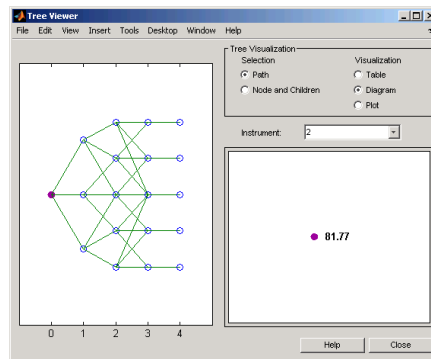
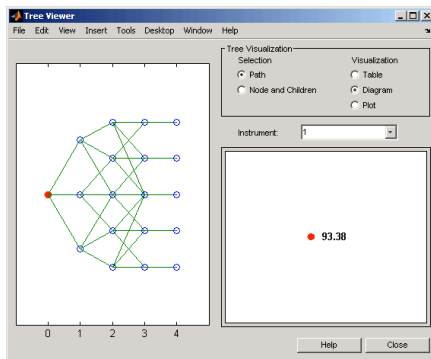
```
93.3789
81.7651
```

```
PriceTree =
```

```
FinObj: 'HWPriceTree'
tObs: [0 1 2 3 4]
PTree: {[2x1 double] [2x3 double] [2x5 double] [2x5
double] [2x5 double]}
Connect: {[2] [2 3 4] [2 2 3 4 4]}
Probs: {[3x1 double] [3x3 double] [3x5 double]}
```

You can visualize the prices of the two cash flow instruments with the `treeviewer` function.

```
treeviewer(PriceTree)
```



## **More About**

- “Pricing Options Structure”

## **See Also**

cfamounts | hwprice | hwtree | instcf

# cfbyzero

Price cash flows from set of zero curves

## Syntax

Price = cfbyzero(RateSpec, CFlowAmounts, CFlowDates, Settle, Basis)

## Arguments

RateSpec	Structure containing the properties of an interest-rate structure. See <code>intenvset</code> for information on creating <code>RateSpec</code> .
CFlowAmounts	Number of instruments ( <code>NINST</code> ) by maximum number of cash flows ( <code>MOSTCFS</code> ) matrix with entries listing cash flow amounts corresponding to each date in <code>CFlowDates</code> . Each row is a list of cash flow values for one instrument. If an instrument has fewer than <code>MOSTCFS</code> cash flows, the end of the row is padded with <code>NaNs</code> .
CFlowDates	<code>NINST</code> -by- <code>MOSTCFS</code> matrix of cash flow dates. Each entry contains the serial date of the corresponding cash flow in <code>CFlowAmounts</code> .
Settle	Settlement date on which the cash flows are priced. <code>Settle</code> must be either a scalar or <code>NINST</code> -by-1 vector of serial date numbers or date strings of the same value which represent the settlement date for each cash flow. <code>Settle</code> must be earlier than <code>Maturity</code> .
Basis	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> </ul>

- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

## Description

`Price = cfbyzero(RateSpec, CFlowAmounts, CFlowDates, Settle, Basis)` computes `Price`, an NINST-by-NUMCURVES matrix of cash flows prices. Each column arises from one of the zero curves.

## Examples

### Compute the Price and Sensitivity From the Interest-Rate Term Structure

This example shows how to price a portfolio containing two cash flow instruments paying interest annually over the four-year period from January 1, 2000 to January 1, 2004. Load the file `deriv.mat`, which provides `ZeroRateSpec`. The `ZeroRateSpec` structure contains the interest-rate information needed to price the instruments.

```
load deriv.mat
CFlowAmounts = [5 NaN 5.5 105; 5 0 6 105];
CFlowDates = [730852, NaN, 731582, 731947;
              730852, 731217, 731582, 731947];
Settle = 730486;
Price = cfbyzero(ZeroRateSpec, CFlowAmounts, CFlowDates, Settle)
```



Price =

96.7804

97.2187

### **See Also**

[bondbyzero](#) | [fixedbyzero](#) | [floatbyzero](#) | [swapbyzero](#)

## chooserbybls

Price European simple chooser options using Black-Scholes model

### Syntax

```
Price = chooserbybls(RateSpec, StockSpec, Settle,  
Maturity, Strike)
```

### Arguments

RateSpec	The annualized continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
Strike	NINST-by-1 vector of strike price values.
ChooseDate	NINST-by-1 vector of chooser dates.

### Description

`Price = chooserbybls(RateSpec, StockSpec, Settle, Maturity, Strike)` computes the price for European simple chooser options using the Black-Scholes model.

Price is a NINST-by-1 vector of expected prices.

---

**Note:** Only dividends of type `continuous` can be considered for choosers.

---

## Examples

### Price European Simple Chooser Options Using the Black-Scholes Model

Consider a European chooser option with an exercise price of \$60 on June 1, 2007. The option expires on December 2, 2007. Assume the underlying stock provides a continuous dividend yield of 5% per annum, is trading at \$50, and has a volatility of 20% per annum. The annualized continuously compounded risk-free rate is 10% per annum. Assume that the choice must be made on August 31, 2007. Using this data:

```
AssetPrice = 50;
Strike = 60;
Settlement = 'Jun-1-2007';
Maturity = 'Dec-2-2007';
ChooseDate = 'Aug-31-2007';
RiskFreeRate = 0.1;
Sigma = 0.20;
Yield = 0.05
```

```
Yield =
    0.0500
```

Define the RateSpec and StockSpec.

```
RateSpec = intenvset('Compounding', -1, 'Rates', RiskFreeRate, 'StartDates',...
Settlement, 'EndDates', Maturity);
StockSpec = stockspe(Sigma, AssetPrice, 'continuous', Yield);
```

Price the chooser option.

```
Price = chooserbybls(RateSpec, StockSpec, Settlement, Maturity,...
Strike, ChooseDate)
```

```
Price =
    8.9308
```

## References

Rubinstein, Mark, “Options for the Undecided,” *Risk* 4, 1991.

## See Also

`blsprice` | `intenvset`

# classfin

Create financial structure or return financial structure class name

## Syntax

```
Obj = classfin(ClassName)
Obj = classfin(Struct, ClassName)
ClassName = classfin(Obj)
```

## Arguments

ClassName	String containing the name of a financial structure class.
Struct	MATLAB structure to be converted into a financial structure.
Obj	Name of a financial structure.

## Description

`Obj = classfin(ClassName)` and `Obj = classfin(Struct, ClassName)` create a financial structure of class `ClassName`.

`ClassName = classfin(Obj)` returns a string containing a financial structure's class name.

## Examples

### Create a Financial Structure

This example shows how to create a financial structure `HJMTimeSpec` and complete its fields. (Typically, the function `hjmtimespec` is used to create `HJMTimeSpec` structures).

```
TimeSpec = classfin('HJMTimeSpec');
TimeSpec.ValuationDate = datenum('Dec-10-1999');
TimeSpec.Maturity = datenum('Dec-10-2002');
```

```
TimeSpec.Compounding = 2;  
TimeSpec.Basis = 0;  
TimeSpec.EndMonthRule = 1;  
TimeSpec
```

```
TimeSpec =  
  
    FinObj: 'HJMTimeSpec'  
ValuationDate: 730464  
    Maturity: 731560  
    Compounding: 2  
        Basis: 0  
    EndMonthRule: 1
```

### Convert an Existing MATLAB Structure into a Financial Structure

This example shows how to convert an existing MATLAB structure into a financial structure.

```
TSpec.ValuationDate = datenum('Dec-10-1999');  
TSpec.Maturity = datenum('Dec-10-2002');  
TSpec.Compounding = 2;  
TSpec.Basis = 0;  
TSpec.EndMonthRule = 0;  
TimeSpec = classfin(TSpec, 'HJMTimeSpec')
```

```
TimeSpec =  
  
    ValuationDate: 730464  
        Maturity: 731560  
    Compounding: 2  
        Basis: 0  
    EndMonthRule: 0  
        FinObj: 'HJMTimeSpec'
```

### Return a String Containing a Financial Structure's Class Name

This example shows how to obtain a string containing a financial structure's class name.

```
load deriv.mat  
ClassName = classfin(HJMTree)
```

ClassName =

HJMFwdTree

**See Also**

isafin

## compoundbycrr

Price compound option from Cox-Ross-Rubinstein binomial tree

### Syntax

```
[Price, PriceTree] = compoundbycrr(CRRTree, UOptSpec, UStrike,
    USettle, UExerciseDates, UAmericanOpt, COptSpec,
    CStrike, CSettle, CExerciseDates, CAmericanOpt)
```

### Arguments

CRRTree	Stock tree structure created by <code>crrtree</code> .
UOptSpec	String = 'Call' or 'Put'.
UStrike	1-by-1 vector of strike price values.
USettle	1-by-1 vector of <code>Settle</code> dates.
UExerciseDates	For a European option ( <code>UAmericanOpt = 0</code> ):  1-by-1 vector of exercise dates. For a European option, there is only one exercise date, the option expiry date.  For an American option ( <code>UAmericanOpt = 1</code> ):  1-by-2 vector of exercise date boundaries. The option can be exercised on any tree date. If only one non-NaN date is listed, or if <code>ExerciseDates</code> is 1-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.
UAmericanOpt	If <code>UAmericanOpt = 0</code> , NaN, or is unspecified, the option is a European option. If <code>UAmericanOpt = 1</code> , the option is an American option.
COptSpec	NINST-by-1 list of string values 'Call' or 'Put' of the compound option.
CStrike	NINST-by-1 vector of strike price values. Each row is the schedule for one option.



<b>CSettle</b>	1-by-1 vector containing the settlement or trade date.
<b>CExerciseDates</b>	For a European option ( <b>CAmericanOpt</b> = 0):  NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.  For an American option ( <b>CAmericanOpt</b> = 1):  NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <b>ExerciseDates</b> is NINST-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.
<b>CAmericanOpt</b>	(Optional) If <b>CAmericanOpt</b> = 0, NaN, or is unspecified, the option is a European option. If <b>CAmericanOpt</b> = 1, the option is an American option.

## Description

[Price, PriceTree] = compoundbycrr(CRRTree, UOptSpec, UStrike, USettle, UExerciseDates, UAmericanOpt, COptSpec, CStrike, CSettle, CExerciseDates, CAmericanOpt) calculates the value of a compound option.

Price is a NINST-by-1 vector of expected prices at time 0.

PriceTree is a tree structure with a vector of instrument prices at each node.

## Examples

### Price a Compound Option Using a CRR Binomial Tree

This example shows how to price a compound option using a CRR binomial tree by loading the file `deriv.mat`, which provides `CRRTree`. The `CRRTree` structure contains the stock specification and time information needed to price the option.

```
load deriv.mat

UOptSpec = 'Call';
UStrike = 130;
USettle = '01-Jan-2003';
UExerciseDates = '01-Jan-2006';
UAmericanOpt = 1;
COptSpec = 'Put';
CStrike = 5;
CSettle = '01-Jan-2003';
CExerciseDates = '01-Jan-2005';

Price = compoundbycrr(CRRTree, UOptSpec, UStrike, USettle, ...
    UExerciseDates, UAmericanOpt, COptSpec, CStrike, CSettle, ...
    CExerciseDates)

Price =

    2.8482
```

## References

Rubinstein, Mark, “Double Trouble,” *Risk* 5, 1991, p. 73.

## See Also

crrtree | instcompound

# compoundbyeqp

Price compound option from Equal Probabilities binomial tree

## Syntax

```
[Price, PriceTree] = compoundbyeqp(EQPTree, UOptSpec, UStrike,
    USettle, UExerciseDates, UAmericanOpt, COptSpec,
    CStrike, CSettle, CExerciseDates, CAmericanOpt)
```

## Arguments

EQPTree	Stock tree structure created by eqptree.
UOptSpec	String = 'Call' or 'Put'.
UStrike	1-by-1 vector of strike price values.
USettle	1-by-1 vector of Settle dates.
UExerciseDates	For a European option (UAmericanOpt = 0):  1-by-1 vector of exercise dates. For a European option, there is only one exercise date, the option expiry date.  For an American option (UAmericanOpt = 1):  1-by-2 vector of exercise date boundaries. The option can be exercised on any tree date. If only one non-NaN date is listed, or if ExerciseDates is 1-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.
UAmericanOpt	If UAmericanOpt = 0, NaN, or is unspecified, the option is a European option. If UAmericanOpt = 1, the option is an American option.
COptSpec	NINST-by-1 list of string values 'Call' or 'Put' of the compound option.
CStrike	NINST-by-1 vector of strike price values. Each row is the schedule for one option.

<code>CSettle</code>	1-by-1 vector containing the settlement or trade date.
<code>CExerciseDates</code>	For a European option ( <code>CAmericanOpt = 0</code> ):  NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.  For an American option ( <code>CAmericanOpt = 1</code> ):  NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <code>ExerciseDates</code> is NINST-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.
<code>CAmericanOpt</code>	If <code>CAmericanOpt = 0</code> , NaN, or is unspecified, the option is a European option. If <code>CAmericanOpt = 1</code> , the option is an American option.

## Description

`[Price, PriceTree] = compoundbyeqp(EQPTree, UOptSpec, UStrike, USettle, UExerciseDates, UAmericanOpt, COptSpec, CStrike, CSettle, CExerciseDates, CAmericanOpt)` calculates the value of a compound option.

`Price` is a NINST-by-1 vector of expected prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

## Examples

### Price a Compound Option Using an EQP Equity Tree

This example shows how to price a compound option using a EQP equity tree by loading the file `deriv.mat`, which provides `EQPTree`. The `EQPTree` structure contains the stock specification and time information needed to price the option.

```
load deriv.mat
UOptSpec = 'Call';
UStrike = 130;
USettle = '01-Jan-2003';
UExerciseDates = '01-Jan-2006';
UAmericanOpt = 1;
COptSpec = 'Put';
CStrike = 5;
CSettle = '01-Jan-2003';
CExerciseDates = '01-Jan-2005';

Price = compoundbyeqp(EQPTree, UOptSpec, UStrike, USettle, ...
    UExerciseDates, UAmericanOpt, COptSpec, CStrike, CSettle, ...
    CExerciseDates)

Price =

    3.3931
```

## References

Rubinstein, Mark, "Double Trouble," *Risk* 5, 1991, p. 73

## See Also

eqptree | instcompound

## compoundbyitt

Price compound options using implied trinomial tree (ITT)

### Syntax

```
[Price, PriceTree] = compoundbyitt(ITTTree, UOptSpec, UStrike,
    USettle, UExerciseDates, UAmericanOpt, COptSpec,
    CStrike, CSettle, CExerciseDates, CAmericanOpt)
```

### Arguments

ITTTree	Stock tree structure created by <code>itttree</code> .
UOptSpec	String = 'call' or 'put'.
UStrike	1-by-1 vector of strike price values.
USettle	1-by-1 vector of <code>Settle</code> dates.
UExerciseDates	For a European option ( <code>UAmericanOpt = 0</code> ):  1-by-1 vector of exercise dates. For a European option, there is only one exercise date, the option expiry date.  For an American option ( <code>UAmericanOpt = 1</code> ):  1-by-2 vector of exercise date boundaries. The option can be exercised on any tree date. If only one non-NaN date is listed, or if <code>ExerciseDates</code> is 1-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.
UAmericanOpt	If <code>UAmericanOpt = 0</code> , NaN, or is unspecified, the option is a European option. If <code>UAmericanOpt = 1</code> , the option is an American option.
COptSpec	NINST-by-1 list of string values 'Call' or 'Put' of the compound option.
CStrike	NINST-by-1 vector of strike price values. Each row is the schedule for one option.

<b>CSettle</b>	1-by-1 vector containing the settlement or trade date.
<b>CExerciseDates</b>	<p>For a European option (<b>CAmericanOpt</b> = 0):</p> <p>NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option (<b>CAmericanOpt</b> = 1):</p> <p>NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <b>CExerciseDates</b> is NINST-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.</p>
<b>CAmericanOpt</b>	(Optional) If <b>CAmericanOpt</b> = 0, NaN, or is unspecified, the option is a European option. If <b>CAmericanOpt</b> = 1, the option is an American option.

## Description

[Price, PriceTree] = compoundbyitt(ITTree, UOptSpec, UStrike, USettle, UExerciseDates, UAmericanOpt, COptSpec, CStrike, CSettle, CExerciseDates, CAmericanOpt) calculates the value of a compound option by an ITT trinomial tree.

Price is a NINST-by-1 vector of expected prices at time 0.

PriceTree is a tree structure with a vector of instrument prices at each node.

---

**Note:** The **Settle** date is set to the **ValuationDate** of the stock tree.

---

## Examples

### Price a Compound Option Using an ITT Tree

This example shows how to price a compound option using a ITT tree by loading the file `deriv.mat`, which provides `ITTree`. The `ITTree` structure contains the stock specification and time information needed to price the option.

```
load deriv.mat

UOptSpec = 'Call';
UStrike = 99;
USettle = '01-Jan-2006';
UExerciseDates = '01-Jan-2010';
UAmericanOpt = 1;
COptSpec = 'Put';
CStrike = 5;
CSettle = '01-Jan-2006';
CExerciseDates = '01-Jan-2010';

Price = compoundbyitt(ITTree, UOptSpec, UStrike, USettle, ...
    UExerciseDates, UAmericanOpt, COptSpec, CStrike, CSettle, ...
    CExerciseDates)

Price =

    2.7271
```

## References

Rubinstein, Mark, “Double Trouble,” *Risk* 5, 1991.

### See Also

`instcompound` | `ittree`



## crrprice

Instrument prices from Cox-Ross-Rubinstein tree

### Syntax

```
[Price, PriceTree] = crrprice(CRRTree, InstSet, Options)
```

### Arguments

<b>CRRTree</b>	Stock price tree structure created by <code>crrtree</code> .
<b>InstSet</b>	Variable containing a collection of <code>NINST</code> instruments. Instruments are categorized by type; each type can have different data fields. The stored data field is a row vector or string for each instrument. For more information about how to create the <code>InstSet</code> structure, see <code>instadd</code> .
<b>Options</b>	(Optional) Derivatives pricing options structure created with <code>derivset</code> .

### Description

`[Price, PriceTree] = crrprice(CRRTree, InstSet, Options)` computes stock option prices using a CRR binomial tree created with `crrtree`.

`Price` is a number of instruments (`NINST`)-by-1 vector of prices for each instrument. The prices are computed by backward dynamic programming on the stock tree. If an instrument cannot be priced, NaN is returned.

`PriceTree` is a MATLAB structure of trees containing vectors of instrument prices and a vector of observation times for each node.

`PriceTree.PTree` contains the prices.

`PriceTree.tObs` contains the observation times.

`PriceTree.dObs` contains the observation dates.

`crrprice` handles instrument types: 'Asian', 'Barrier', 'Compound', 'Lookback', 'OptStock'. See `instadd` to construct defined types.

Related single-type pricing functions are:

- `asianbycrr`: Price an Asian option from a CRR tree.
- `barrierbycrr`: Price a barrier option from a CRR tree.
- `compoundbycrr`: Price a compound option from a CRR tree.
- `lookbackbycrr`: Price a lookback option from a CRR tree.
- `optstockbycrr`: Price an American, Bermuda, or European option from a CRR tree.

## Examples

Load the CRR tree and instruments from the data file `deriv.mat`. Price the barrier and lookback options contained in the instrument set.

```
load deriv.mat;
CRRSubSet = instselect(CRRInstSet,'Type', ...
{'Barrier', 'Lookback'});

instdisp(CRRSubSet)

%Table of instrument portfolio partially displayed:
Index Type OptSpec Strike Settle ExerciseDates AmericanOpt BarrierSpec ...
1 Barrier call 105 01-Jan-2003 01-Jan-2006 1 ui ...

Index Type OptSpec Strike Settle ExerciseDates AmericanOpt Name Quantity
2 Lookback call 115 01-Jan-2003 01-Jan-2006 0 Lookback1 7
3 Lookback call 115 01-Jan-2003 01-Jan-2007 0 Lookback2 9

[Price, PriceTree] = crrprice(CRRTree, CRRSubSet)

Price =

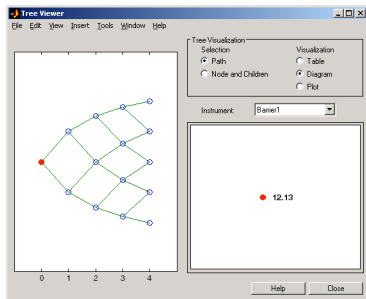
    12.1272
     7.6015
    11.7772

PriceTree =

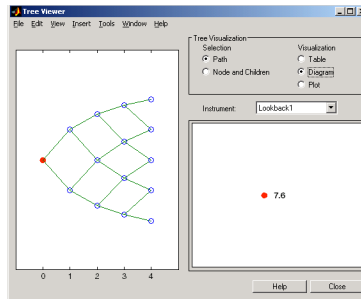
    FinObj: 'BinPriceTree'
     PTree: {1x5 cell}
     tObs: [0 1 2 3 4]
     dObs: [731582 731947 732313 732678 733043]
```

You can use `treeview` to see the prices of these three instruments along the price tree.

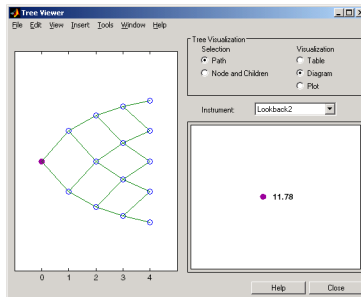
`treeview(PriceTree, CRRSubSet)`



**Barrier1**



**Lookback1**



**Lookback2**

## More About

- “Pricing Options Structure”

## See Also

`crrsens` | `crrtree` | `instadd`

## crrsens

Instrument prices and sensitivities from Cox-Ross-Rubinstein tree

### Syntax

```
[Delta, Gamma, Vega, Price] = crrsens(CRRTree, InstSet,  
Options)
```

### Arguments

CRRTree	Interest-rate tree structure created by <code>crrtree</code> .
InstSet	Variable containing a collection of NINST instruments. Instruments are categorized by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
Options	(Optional) Derivatives pricing options structure created with <code>derivset</code> .

### Description

`[Delta, Gamma, Vega, Price] = crrsens(CRRTree, InstSet, Options)` computes dollar sensitivities and prices for instruments using a binomial tree created with `crrtree`. NINST instruments from a financial instrument variable, `InstSet`, are priced. `crrsens` handles instrument types: 'Asian', 'Barrier', 'Compound', 'Lookback', 'OptStock'. See `instadd` for information on instrument types.

**Delta** is an NINST-by-1 vector of deltas, representing the rate of change of instrument prices with respect to changes in the stock price. **Delta** is computed by finite differences in calls to `crrtree`. See `crrtree` for information on the stock tree.

**Gamma** is an NINST-by-1 vector of gammas, representing the rate of change of instrument deltas with respect to the changes in the stock price. **Gamma** is computed by finite differences in calls to `crrtree`.

Vega is an NINST-by-1 vector of vegas, representing the rate of change of instrument prices with respect to the changes in the volatility of the stock. Vega is computed by finite differences in calls to `crrtree`.

---

**Note** All sensitivities are returned as dollar sensitivities. To find the per-dollar sensitivities, divide by the respective instrument price.

---

## Examples

### Compute Sensitivities for Barrier and Lookback Instruments Using a `crrtree`

Load the CRR tree and instruments from the data file `deriv.mat`. Compute the Delta and Gamma sensitivities of the barrier and lookback options contained in the instrument set.

```
load deriv.mat;
CRRSubSet = instselect(CRRInstSet, 'Type', ...
{'Barrier', 'Lookback'});
```

```
instdisp(CRRSubSet)
```

Index	Type	OptSpec	Strike	Settle	ExerciseDates	AmericanOpt	BarrierSpec	Bar
1	Barrier	call	105	01-Jan-2003	01-Jan-2006	1	ui	102
Index	Type	OptSpec	Strike	Settle	ExerciseDates	AmericanOpt	Name	Quant
2	Lookback	call	115	01-Jan-2003	01-Jan-2006	0	Lookback1	7
3	Lookback	call	115	01-Jan-2003	01-Jan-2007	0	Lookback2	9

Obtain the Delta and Gamma for the barrier and lookback options contained in the instrument set.

```
[Delta, Gamma] = crrsens(CRRTree, CRRSubSet)
```

```
Delta =
```

```
0.6885
0.6049
0.8187
```

Gamma =

```
0.0310  
-0.0000  
0
```

### More About

- “Pricing Options Structure”

### See Also

`crrprice` | `crrtree`

## crrtimespec

Specify time structure for Cox-Ross-Rubinstein tree

### Syntax

```
TimeSpec = crrtimespec(ValuationDate, Maturity, NumPeriods)
```

### Arguments

ValuationDate	Scalar date indicating the pricing date and first observation in the tree. A serial date number or date string.
Maturity	Scalar date indicating depth of the tree.
NumPeriods	Scalar determining number of time steps in the tree.

### Description

`TimeSpec = crrtimespec(ValuationDate, Maturity, NumPeriods)` sets the number of levels and node times for a CRR binomial tree.

`TimeSpec` is a structure specifying the time layout for a CRR binomial tree.

### Examples

#### Set the Number of Levels and Node Times for a CRR Binomial Tree

This example shows how to specify a four-period CRR tree with time steps of 1 year.

```
ValuationDate = '1-July-2002';
Maturity = '1-July-2006';
TimeSpec = crrtimespec(ValuationDate, Maturity, 4)
```

```
TimeSpec =
```

```
      FinObj: 'BinTimeSpec'  
ValuationDate: 731398  
      Maturity: 732859  
      NumPeriods: 4  
      Basis: 0  
EndMonthRule: 1  
      tObs: [0 1 2 3 4]  
      dObs: [731398 731763 732128 732493 732859]
```

### See Also

[crrtree](#) | [stockspec](#)



## crrtree

Construct Cox-Ross-Rubinstein stock tree

### Syntax

```
CRRTree = crrtree(StockSpec, RateSpec, TimeSpec)
```

### Arguments

StockSpec	Stock specification. See <code>stockspec</code> for information on creating a stock specification.
RateSpec	Interest-rate specification for the initial risk free rate curve. See <code>intenvset</code> for information on declaring an interest-rate variable.
TimeSpec	Tree time layout specification. Defines the observation dates of the CRR binomial tree. See <code>crrtimespec</code> for information on the tree structure.

---

**Note** The standard CRR tree assumes a constant interest rate, but `RateSpec` allows you to specify an interest-rate curve with varying rates. If you specify variable interest rates, the resulting tree will not be a standard CRR tree.

---

### Description

`CRRTree = crrtree(StockSpec, RateSpec, TimeSpec)` creates a structure specifying the time layout for a CRR binomial tree.

### Examples

Using the data provided, create a stock specification (`StockSpec`), rate specification (`RateSpec`), and tree time layout specification (`TimeSpec`). Then use these specifications to create a CRR tree with `crrtree`.

```

Sigma = 0.20;
AssetPrice = 50;
DividendType = 'cash';
DividendAmounts = [0.50; 0.50; 0.50; 0.50];
ExDividendDates = {'03-Jan-2003'; '01-Apr-2003'; '05-July-2003';
'01-Oct-2003'}

StockSpec = stockspec(Sigma, AssetPrice, DividendType, ...
DividendAmounts, ExDividendDates)

StockSpec =

        FinObj: 'StockSpec'
        Sigma: 0.2000
        AssetPrice: 50
        DividendType: 'cash'
        DividendAmounts: [4x1 double]
        ExDividendDates: [4x1 double]

RateSpec = intenvset('Rates', 0.05, 'StartDates', ...
'01-Jan-2003', 'EndDates', '31-Dec-2003')

RateSpec =

        FinObj: 'RateSpec'
        Compounding: 2
        Disc: 0.9519
        Rates: 0.0500
        EndTimes: 1.9945
        StartTimes: 0
        EndDates: 731946
        StartDates: 731582
        ValuationDate: 731582
        Basis: 0
        EndMonthRule: 1

ValuationDate = '1-Jan-2003';
Maturity = '31-Dec-2003';
TimeSpec = crrtimespec(ValuationDate, Maturity, 4)

TimeSpec =

        FinObj: 'BinTimeSpec'
        ValuationDate: 731582
        Maturity: 731946
        NumPeriods: 4
        Basis: 0

```

```

EndMonthRule: 1
  tObs: [0 0.2493 0.4986 0.7479 0.9972]
  dObs: [731582 731673 731764 731855 731946]

```

```
CRRTree = crrtree(StockSpec, RateSpec, TimeSpec)
```

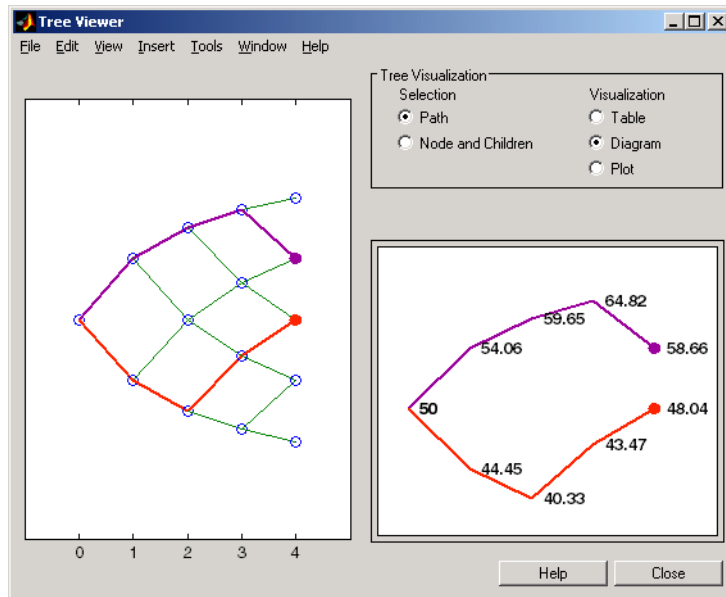
```
CRRTree =
```

```

  FinObj: 'BinStockTree'
  Method: 'CRR'
  StockSpec: [1x1 struct]
  TimeSpec: [1x1 struct]
  RateSpec: [1x1 struct]
    tObs: [0 0.2493 0.4986 0.7479 0.9972]
    dObs: [731582 731672 731763 731856 731946]
  STree: {1x5 cell}
  UpProbs: [0.5370 0.5370 0.5370 0.5370]

```

Use `treeview` to observe the tree you have created.



## See Also

`crrtimespec` | `intenvset` | `stockspec`

## cvtree

Convert inverse-discount tree to interest-rate tree

## Syntax

```
RateTree = cvtree(Tree)
```

## Arguments

Tree	Heath-Jarrow-Morton, Black-Derman-Toy, Hull-White, or Black-Karasinski tree structure using inverse-discount notation for forward rates.
------	--

## Description

`RateTree = cvtree(Tree)` converts a tree structure using inverse-discount notation to a tree structure using rate notation for forward rates.

## Examples

Convert a Hull-White tree using inverse-discount notation to a Hull-White tree displaying interest-rate notation.

```
load deriv.mat;
```

```
HWTTree
```

```
HWTTree =
```

```
    FinObj: 'HWFwdTree'  
    VolSpec: [1x1 struct]  
    TimeSpec: [1x1 struct]  
    RateSpec: [1x1 struct]  
         tObs: [0 1 2 3]  
         dObs: [731947 732313 732678 733043]  
    CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4]}
```

```

    Probs: {[3x1 double] [3x3 double] [3x5 double]}
    Connect: {[2] [2 3 4] [2 2 3 4 4]}
    FwdTree: {1x4 cell}

```

```
HWTTree.FwdTree{1}
```

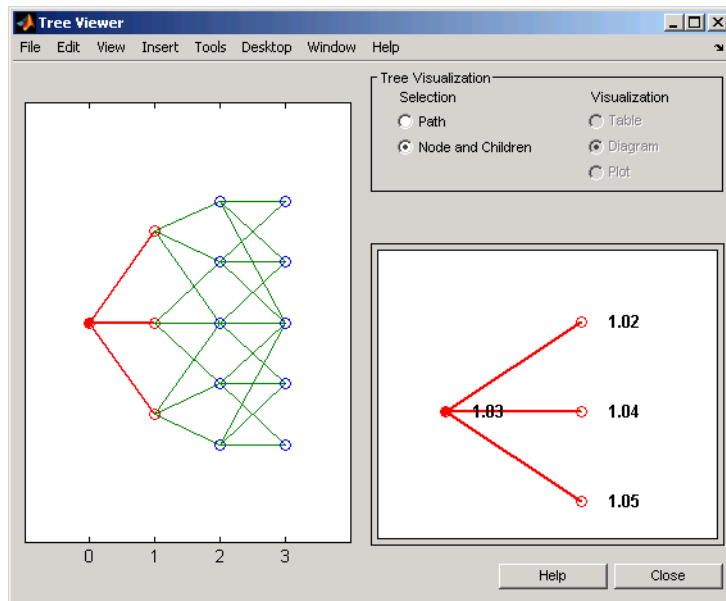
```
ans =
    1.0279
```

```
HWTTree.FwdTree{2}
```

```
ans =
    1.0528    1.0356    1.0186
```

Use `treeviewer` to display the path of interest rates expressed in inverse-discount notation.

```
treeviewer(HWTTree)
```



Use `cvtree` to convert the inverse-discount notation to interest-rate notation.

```
RTree = cvtree(HWTTree)
```

```
RTree =
```

```

    FinObj: 'HWRateTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
        tObs: [0 1 2 3]
        dObs: [731947 732313 732678 733043]
    CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4]}
    Probs: {[3x1 double] [3x3 double] [3x5 double]}
    Connect: {[2] [2 3 4] [2 2 3 4 4]}
    RateTree: {1x4 cell}

```

`RTree.RateTree{1}`

```

ans =
    0.0275

```

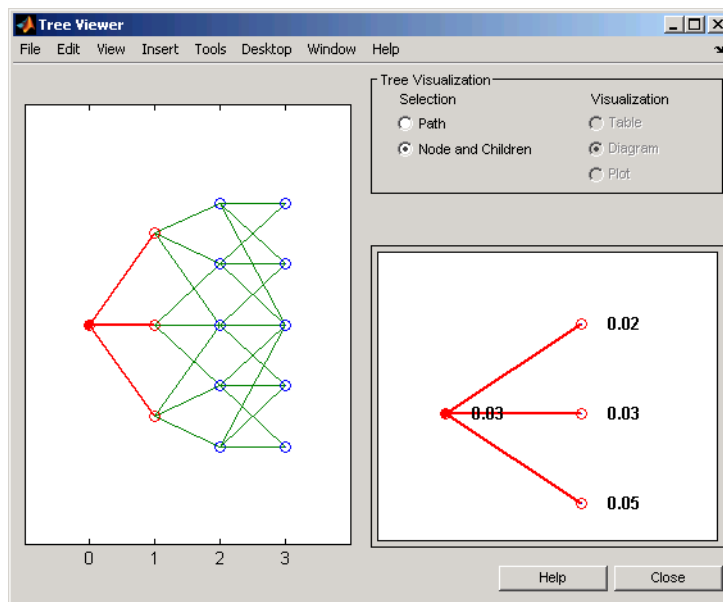
`RTree.RateTree{2}`

```

ans =
    0.0514    0.0349    0.0185

```

Now use `treeview` to display the converted tree, showing the path of interest rates expressed as forward rates.



## **See Also**

disc2rate | rate2disc

## date2time

Time and frequency from dates

### Syntax

[Times, F] = date2time(Settle, Dates, Compounding, Basis, EndMonthRule)

### Arguments

Settle	Settlement date. A vector of serial date numbers or date strings.
Dates	Vector of dates corresponding to the compounding value.
Compounding	<p>(Optional) Scalar value representing the rate at which the input zero rates were compounded when annualized. This argument determines the formula for the discount factors:</p> <p>Compounding = 1, 2, 3, 4, 6, 12 (Default = 2.)</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the compounding frequency, Z is the zero rate, and T is the time in periodic units; for example, T = F is 1 year.</p> <p>Compounding = 365</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the number of days in the basis year and T is a number of days elapsed computed by basis.</p> <p>Compounding = -1</p> <p>Disc = <math>\exp(-T*Z)</math>, where T is time in years.</p>
Basis	<p>(Optional) Day-count basis of the instrument. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> </ul>



	<ul style="list-style-type: none"> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
EndMonthRule	(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

## Description

[Times, F] = date2time(Settle, Dates, Compounding, Basis, EndMonthRule) computes time factors appropriate to compounded rate quotes beyond the settlement date.

Times is a vector of time factors.

F is a scalar of related compounding frequencies.

---

**Note** To obtain accurate results from this function, the **Basis** and **Dates** arguments must be consistent. If the **Dates** argument contains months that have 31 days, **Basis**

must be one of the values that allow months to contain more than 30 days; for example, `Basis = 0, 3, or 7`.

---

`date2time` is the inverse of `time2date`.

### **See Also**

`cftimes` | `disc2rate` | `rate2disc` | `time2date`

# datedisp

Display date entries

## Syntax

```
datedisp(NumMat, DateForm)
CharMat = datedisp(NumMat, DateForm)
```

## Arguments

NumMat	Numeric matrix to display.
DateForm	(Optional) Date format. See <code>datestr</code> for available and default format flags.

## Description

`datedisp(NumMat, DateForm)` displays the matrix with the serial dates formatted as date strings, using a matrix with mixed numeric entries and serial date number entries. Integers between `datenum('01-Jan-1900')` and `datenum('01-Jan-2200')` are assumed to be serial date numbers, while all other values are treated as numeric entries.

`CharMat` is a character array representing `NumMat`. If no output variable is assigned, the function prints the array to the display (`CharMat = datedisp(NumMat, DateForm)`).

## Examples

```
NumMat = [ 730730, 0.03, 1200, 730100;
           730731, 0.05, 1000, NaN]
```

```
NumMat =
```

```
1.0e+05 *
    7.3073    0.0000    0.0120    7.3010
```

```
7.3073    0.0000    0.0100    NaN
datedisp(NumMat)
01-Sep-2000  0.03    1200    11-Dec-1998
02-Sep-2000  0.05    1000    NaN
```

## More About

### Tips

This function is identical to the `datedisp` function in Financial Toolbox software.

### See Also

`datenum` | `datestr`

# derivget

Get derivatives pricing options

## Syntax

```
Value = derivget(Options, 'Parameter')
```

## Arguments

Options	Existing options specification structure, probably created from previous call to <code>derivset</code> .
Parameter	Must be 'Diagnostics', 'Warnings', 'ConstRate', or 'BarrierMethod'. It is sufficient to type only the leading characters that uniquely identify the parameter. Case is ignored for parameter names.

## Description

`Value = derivget(Options, 'Parameter')` extracts the value of the named parameter from the derivative options structure `Options`. Parameter values can be 'off' or 'on', except for 'BarrierMethod', which can be 'unenhanced' or 'interp'. Specifying 'unenhanced' uses no correction calculation. Specifying 'interp' uses an enhanced valuation interpolating between nodes on barrier boundaries.

## Examples

**Example 1.** Create an Options structure with the value of Diagnostics set to 'on'.

```
Options = derivset('Diagnostics', 'on')
```

Use `derivget` to extract the value of Diagnostics from the Options structure.

```
Value = derivget(Options, 'Diagnostics')
```

```
Value =
```

```
on
```

**Example 2.** Use `derivget` to extract the value of `ConstRate`.

```
Value = derivget(Options, 'ConstRate')
```

```
Value =
```

```
on
```

Because the value of `'ConstRate'` was not previously set with `derivset`, the answer represents the default setting for `'ConstRate'`.

**Example 3.** Find the value of `'BarrierMethod'` in this structure.

```
derivget(Options, 'BarrierMethod')
```

```
ans =
```

```
unenhanced
```

## See Also

`barrierbycrr` | `barrierbyeqp` | `derivset`

# derivset

Set or modify derivatives pricing options

## Syntax

```
Options = derivset(Options, 'Parameter1', Value1,
... 'Parameter4', Value4)
Options = derivset(OldOptions, NewOptions)
Options = derivset
derivset
```

## Arguments

Options	(Optional) Existing options specification structure, probably created from a previous call to <code>derivset</code> .
Parameter $n$	The parameter must be 'Diagnostics', 'Warnings', 'ConstRate', or 'BarrierMethod'. Parameters can be entered in any order.
Value $n$	<p>(BDT, BK, HJM, or HW pricing only) The parameter values for the following three options can be 'on' or 'off':</p> <ul style="list-style-type: none"> <li>'Diagnostics' 'on' generates diagnostic information. The default is 'Diagnostics' 'off'.</li> <li>'Warnings' 'on' (default) displays a warning message when executing a pricing function.</li> <li>'ConstRate' 'on' (default) assumes a constant rate between tree nodes.</li> </ul> <p>For pricing barrier options, the 'BarrierMethod' pricing option can be 'unenhanced' (default) or 'interp'. Specifying 'unenhanced' uses no correction calculation. Specifying 'interp' uses an enhanced valuation interpolating between nodes on barrier boundaries.</p>
OldOptions	Existing options specification structure.

NewOptions	New options specification structure.
------------	--------------------------------------

## Description

`Options = derivset(Options, 'Parameter1', Value1, ... 'Parameter4', Value4)` creates a derivatives pricing options structure `Options` in which the named parameters have the specified values. Any unspecified value is set to the default value for that parameter when `Options` is passed to the pricing function. It is sufficient to type only the leading characters that uniquely identify the parameter name. Case is also ignored for parameter names.

If the optional input argument `Options` is specified, `derivset` modifies an existing pricing options structure by changing the named parameters to the specified values.

---

**Note** For parameter *values*, correct case and the complete string are required; if an invalid string is provided, the default is used.

---

`Options = derivset(OldOptions, NewOptions)` combines an existing options structure `OldOptions` with a new options structure `NewOptions`. Any parameters in `NewOptions` with nonempty values overwrite the corresponding old parameters in `OldOptions`.

`Options = derivset` creates an options structure `Options` whose fields are set to the default values.

`derivset` with no input or output arguments displays all parameter names and information about their possible values.

## Examples

```
Options = derivset('Diagnostics','on')
```

enables the display of additional diagnostic information that appears when executing pricing functions.

```
Options = derivset(Options, 'ConstRate', 'off')
```



changes the `ConstRate` parameter in the existing `Options` structure so that the assumption of constant rates between tree nodes no longer applies.

With no input or output arguments `derivset` displays all parameter names and information about their possible values.

`derivset`

```
Diagnostics: [ on      | {off} ]  
Warnings:   [ {on}   | off  ]  
ConstRate:  [ {on}   | off  ]  
BarrierMethod: [ {unenhanced} | interp ]
```

## More About

- “Pricing Options Structure”

## See Also

`barrierbycrr` | `barrierbyeqp` | `derivget`

## disc2rate

Interest rates from cash flow discounting factors

### Syntax

**Usage 1:** Interval points are input as times in periodic units.

```
Rates = disc2rate(Compounding, Disc, EndTimes)
```

```
Rates = disc2rate(Compounding, Disc, EndTimes, StartTimes)
```

**Usage 2:** ValuationDate is passed and interval points are input as dates.

```
[Rates, EndTimes, StartTimes] = disc2rate(Compounding, Disc,
EndDates, StartDates, ValuationDate)
```

```
[Rates, EndTimes, StartTimes] = disc2rate(Compounding, Disc,
EndDates, StartDates, ValuationDate, Basis, EndMonthRule)
```

### Arguments

Compounding	<p>Scalar value representing the rate at which the input zero rates were compounded when annualized. This argument determines the formula for the discount factors:</p> <p>Compounding = 1, 2, 3, 4, 6, 12</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the compounding frequency, Z is the zero rate, and T is the time in periodic units; for example, T = F is 1 year.</p> <p>Compounding = 365</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the number of days in the basis year and T is a number of days elapsed computed by basis.</p> <p>Compounding = -1</p> <p>Disc = <math>\exp(-T*Z)</math>, where T is time in years.</p>
-------------	--

Disc	Number of points (NPOINTS) by number of curves (NCURVES) matrix of discounts. Disc are unit bond prices over investment intervals from StartTimes, when the cash flow is valued, to EndTimes, when the cash flow is received.
EndTimes	NPOINTS-by-1 vector or scalar of times in periodic units ending the interval to discount over.  <b>Note:</b> When ValuationDate is not passed, the EndTimes and StartTimes arguments are interpreted as times.
StartTimes	(Optional) NPOINTS-by-1 vector or scalar of times in periodic units starting the interval to discount over. Default = 0.
EndDates	NPOINTS-by-1 vector or scalar of serial maturity dates ending the interval to discount over.  <b>Note:</b> When ValuationDate is passed, EndDates and StartDates arguments are interpreted as dates. The date ValuationDate is used as the zero point for computing the times.
StartDates	(Optional) NPOINTS-by-1 vector or scalar of serial dates starting the interval to discount over. Default = ValuationDate. StartDates must be earlier than EndDates.
ValuationDate	Scalar value in serial date number form representing the observation date of the investment horizons entered in StartDates and EndDates. Required in <b>Usage 2</b> . Omitted or passed as an empty matrix to invoke <b>Usage 1</b> .

Basis	<p>(Optional) Day-count basis of the instrument when using <b>Usage 2</b>. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
EndMonthRule	<p>(Optional) End-of-month rule when using <b>Usage 2</b>. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.</p>

## Description

**Usage 1:** `Rates = disc2rate(Compounding, Disc, EndTimes)` or `Rates = disc2rate(Compounding, Disc, EndTimes, StartTimes)` where interval points are input as times in periodic units.

**Usage 2:** [Rates, EndTimes, StartTimes] = disc2rate(Compounding, Disc, EndDates, StartDates, ValuationDate) or [Rates, EndTimes, StartTimes] = disc2rate(Compounding, Disc, EndDates, StartDates, ValuationDate, Basis, EndMonthRule) where ValuationDate is passed and interval points are input as dates.

disc2rate computes the yields over a series of NPOINTS time intervals given the cash flow discounts over those intervals. NCURVES different rate curves can be translated at once if they have the same time structure. The time intervals can represent a zero or a forward curve.

Rates is an NPOINTS-by-NCURVES column vector of yields in decimal form over the NPOINTS time intervals.

Specify the investment intervals with either input times (**Usage 1**) or input dates (**Usage 2**). Entering ValuationDate invokes the date interpretation; omitting ValuationDate invokes the default time interpretations.

For **Usage 1**:

- **StartTimes** is an NPOINTS-by-1 column vector of times starting the interval to discount over, measured in periodic units.
- **EndTimes** is an NPOINTS-by-1 column vector of times ending the interval to discount over, measured in periodic units.

For **Usage 2**:

- **StartDates** is an NPOINTS-by-1 column vector of serial dates starting the interval to discount over, measured in days.
- **EndDates** is an NPOINTS-by-1 column vector of serial date ending the interval to discount over, measured in days.

If Compounding = 365 (daily), StartTimes and EndTimes are measured in days for **Usage 2**. Otherwise, for **Usage 1**, the arguments contain values, T, computed from SIA semiannual time factors, Tsemi, by the formula  $T = Tsemi/2 * F$ , where F is the compounding frequency.

## See Also

rate2disc | ratetimes

## eqpprice

Instrument prices from Equal Probabilities binomial tree

### Syntax

```
[Price, PriceTree] = eqpprice(EQPtree, InstSet, Options)
```

### Arguments

EQPtree	Stock price tree structure created by <code>eqptree</code> .
InstSet	Variable containing a collection of NINST instruments. Instruments are categorized by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
Options	(Optional) Derivatives pricing options structure created with <code>derivset</code> .

### Description

`[Price, PriceTree] = eqpprice(EQPtree, InstSet, Options)` computes stock option prices using an EQP binomial tree created with `eqptree`.

`Price` is a number of instruments (NINST)-by-1 vector of prices for each instrument. The prices are computed by backward dynamic programming on the stock tree. If an instrument cannot be priced, NaN is returned.

`PriceTree` is a MATLAB structure of trees containing vectors of instrument prices and a vector of observation times for each node.

`PriceTree.PTree` contains the prices.

`PriceTree.tObs` contains the observation times.

`PriceTree.dObs` contains the observation dates.

eqpprice handles instrument types: 'Asian', 'Barrier', 'Compound', 'Lookback', 'OptStock'. See `instadd` to construct defined types.

Related single-type pricing functions are:

- `asianbyeqp`: Price an Asian option from an EQP tree.
- `barrierbyeqp`: Price a barrier option from an EQP tree.
- `compoundbyeqp`: Price a compound option from an EQP tree.
- `lookbackbyeqp`: Price a lookback option from an EQP tree.
- `optstockbyeqp`: Price an American, Bermuda, or European option from an EQP tree.

## Examples

Load the EQP tree and instruments from the data file `deriv.mat`. Price the put options contained in the instrument set.

```
load deriv.mat;
EQPSubSet = instselect(EQPInstSet, 'FieldName', 'OptSpec', ...
'Data', 'put')

instdisp(EQPSubSet)

%Table of instrument portfolio partially displayed:
Index Type   OptSpec Strike Settle   ExerciseDates AmericanOpt Name...
1   OptStock put    105  01-Jan-2003 01-Jan-2006    0          Put 105...

Index Type   OptSpec Strike Settle   ExerciseDates AmericanOpt AvgType...
2   Asian put    110  01-Jan-2003 01-Jan-2006    0          arithmetic...
3   Asian put    110  01-Jan-2003 01-Jan-2007    0          arithmetic...

[Price, PriceTree] = eqpprice(EQPtree, EQPSubSet)

Price =

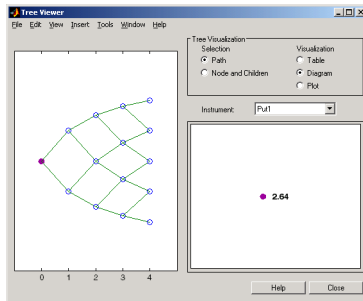
    2.6375
    4.7444
    3.9178

PriceTree =

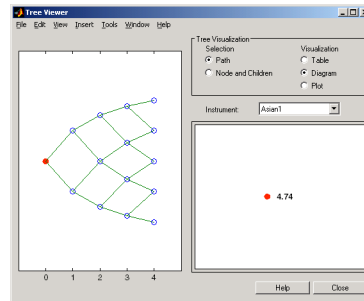
    FinObj: 'BinPriceTree'
    PTree: {1x5 cell}
    tObs: [0 1 2 3 4]
    dObs: [731582 731947 732313 732678 733043]
```

You can use `treeviewer` to see the prices of these three instruments along the price tree.

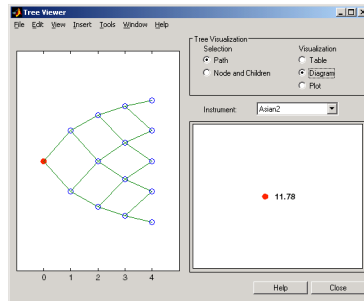
`treeviewer(PriceTree, EQPSubSet)`



Put1



Asian1



Asian2

## More About

- “Pricing Options Structure”

## See Also

`eqpsens` | `eqptimespec` | `eqptree`



## eqpsens

Instrument prices and sensitivities from Equal Probabilities binomial tree

### Syntax

```
[Delta, Gamma, Vega, Price] = eqpsens(EQPTree, InstSet,
Options)
```

### Arguments

EQPTree	Interest-rate tree structure created by eqptree.
InstSet	Variable containing a collection of NINST instruments. Instruments are categorized by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
Options	(Optional) Derivatives pricing options structure created with derivset.

### Description

[Delta, Gamma, Vega, Price] = eqpsens(EQPTree, InstSet, Options) computes dollar sensitivities and prices for instruments using a binomial tree created with eqptree. NINST instruments from a financial instrument variable, InstSet, are priced. eqpsens handles instrument types: 'Asian', 'Barrier', 'Compound', 'Lookback', and 'OptStock'. See instadd for information on instrument types.

Delta is an NINST-by-1 vector of deltas, representing the rate of change of instrument prices with respect to changes in the stock price. Delta is computed by finite differences in calls to eqptree. See eqptree for information on the stock tree.

Gamma is an NINST-by-1 vector of gammas, representing the rate of change of instrument deltas with respect to the changes in the stock price. Gamma is computed by finite differences in calls to eqptree.

Vega is an NINST-by-1 vector of vegas, representing the rate of change of instrument prices with respect to the changes in the volatility of the stock. Vega is computed by finite differences in calls to `eqptree`.

---

**Note** All sensitivities are returned as dollar sensitivities. To find the per-dollar sensitivities, divide by the respective instrument price.

---

## Examples

### Compute Sensitivities for Instruments Using an `eqptree`

Load the EQP tree and instruments from the data file `deriv.mat`. Compute the Delta and Gamma sensitivities of the put options contained in the instrument set.

```
load deriv.mat;
```

```
EQPSubSet = instselect(EQPInstSet, 'FieldName', 'OptSpec', ...
    'Data', 'put')
```

```
instdisp(EQPSubSet)
```

```
EQPSubSet =
```

```
    FinObj: 'Instruments'
  IndexTable: [1x1 struct]
         Type: {5x1 cell}
   FieldName: {5x1 cell}
  FieldClass: {5x1 cell}
   FieldData: {5x1 cell}
```

```
Index Type      OptSpec Strike Settle      ExerciseDates  AmericanOpt Name  Quantity
1   OptStock put    105  01-Jan-2003  01-Jan-2006    0          Put1    5
```

```
Index Type  OptSpec Strike Settle      ExerciseDates  AmericanOpt AvgType  AvgPri
2   Asian put    110  01-Jan-2003  01-Jan-2006    0          arithmetic NaN
3   Asian put    110  01-Jan-2003  01-Jan-2007    0          arithmetic NaN
```

Obtain the Delta and Gamma for the put options contained in the instrument set.

```
[Delta, Gamma] = eqpsens(EQPtree, EQPSubSet)
```

Delta =

-0.2336  
-0.5443  
-0.4516

Gamma =

0.0218  
0.0000  
0.0000

## More About

- “Pricing Options Structure”

## See Also

eqpprice | eqptree

## eqptimespec

Specify time structure for Equal Probabilities binomial tree

### Syntax

```
TimeSpec = eqptimespec(ValuationDate, Maturity, NumPeriods)
```

### Arguments

ValuationDate	Scalar date indicating the pricing date and first observation in the tree. A serial date number or date string.
Maturity	Scalar date indicating depth of the tree.
NumPeriods	Scalar determining number of time steps in the tree.

### Description

`TimeSpec = eqptimespec(ValuationDate, Maturity, NumPeriods)` sets the number of levels and node times for an equal probabilities tree.

`TimeSpec` is a structure specifying the time layout for an equal probabilities tree.

### Examples

#### Set the Number of Levels and Node Times for an EQP Tree

This example shows how to set the number of levels and node times for an EQP tree by specifying a four-period tree with time steps of 1 year.

```
ValuationDate = '1-July-2002';  
Maturity = '1-July-2006';  
TimeSpec = eqptimespec(ValuationDate, Maturity, 4)
```

TimeSpec =

```
      FinObj: 'BinTimeSpec'  
ValuationDate: 731398  
      Maturity: 732859  
      NumPeriods: 4  
      Basis: 0  
EndMonthRule: 1  
      tObs: [0 1 2 3 4]  
      dObs: [731398 731763 732128 732493 732859]
```

## See Also

eqptree | stockspect

## eqptree

Construct Equal Probabilities stock tree

### Syntax

```
EQPTree = eqptree(StockSpec, RateSpec, TimeSpec)
```

### Arguments

StockSpec	Stock specification. See <code>stockspec</code> for information on creating a stock specification.
RateSpec	Interest-rate specification for the initial risk free rate curve. See <code>intenvset</code> for information on declaring an interest-rate variable.
TimeSpec	Tree time layout specification. Defines the observation dates of the equal probabilities binomial tree. See <code>eqptimespec</code> for information on the tree structure.

---

**Note** The standard equal probabilities tree assumes a constant interest rate, but `RateSpec` allows you to specify an interest-rate curve with varying rates. If you specify variable interest rates, the resulting tree will not be a standard equal probabilities tree.

---

### Description

`EQPTree = eqptree(StockSpec, RateSpec, TimeSpec)` constructs an equal probabilities stock tree.

`EQPTree` is a MATLAB structure specifying the time layout for an equal probabilities stock tree.

## Examples

Using the data provided, create a stock specification (`StockSpec`), rate specification (`RateSpec`), and tree time layout specification (`TimeSpec`). Then use these specifications to create an EQP tree with `eqptree`.

```

Sigma = 0.20;
AssetPrice = 50;
DividendType = 'cash';
DividendAmounts = [0.50; 0.50; 0.50; 0.50];
ExDividendDates = {'03-Jan-2003'; '01-Apr-2003'; '05-July-2003';
'01-Oct-2003'}

StockSpec = stockspec(Sigma, AssetPrice, DividendType, ...
DividendAmounts, ExDividendDates)

StockSpec =

    FinObj: 'StockSpec'
    Sigma: 0.2000
    AssetPrice: 50
    DividendType: 'cash'
    DividendAmounts: [4x1 double]
    ExDividendDates: [4x1 double]

RateSpec = intenvset('Rates', 0.05, 'StartDates', ...
'01-Jan-2003', 'EndDates', '31-Dec-2003')

RateSpec =

    FinObj: 'RateSpec'
    Compounding: 2
    Disc: 0.9519
    Rates: 0.0500
    EndTimes: 1.9945
    StartTimes: 0
    EndDates: 731946
    StartDates: 731582
    ValuationDate: 731582
    Basis: 0
    EndMonthRule: 1

ValuationDate = '1-Jan-2003';
Maturity = '31-Dec-2003';
TimeSpec = eqptimespec(ValuationDate, Maturity, 4)

TimeSpec =

```

```
        FinObj: 'BinTimeSpec'  
ValuationDate: 731582  
        Maturity: 731946  
        NumPeriods: 4  
        Basis: 0  
EndMonthRule: 1  
        tObs: [0 0.2493 0.4986 0.7479 0.9972]  
        dObs: [731582 731673 731764 731855 731946]
```

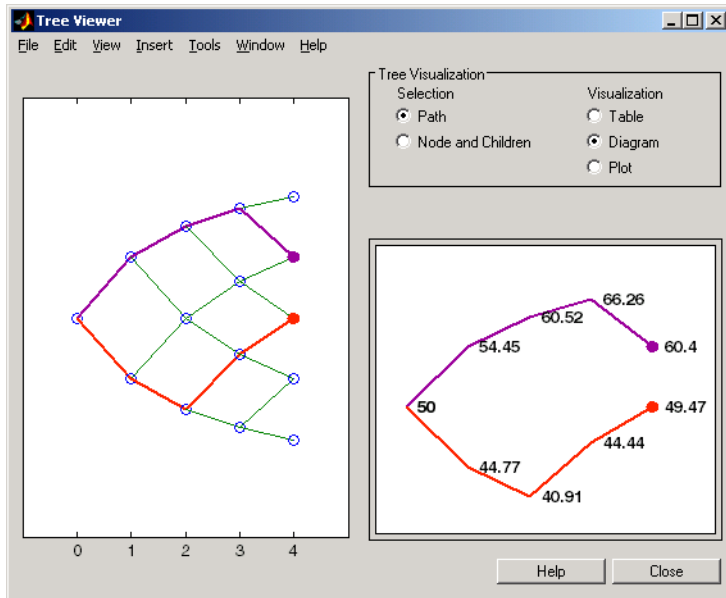
```
EQPTree = eqptree(StockSpec, RateSpec, TimeSpec)
```

```
EQPTree =
```

```
        FinObj: 'BinStockTree'  
        Method: 'EQP'  
StockSpec: [1x1 struct]  
TimeSpec: [1x1 struct]  
RateSpec: [1x1 struct]  
        tObs: [0 0.2493 0.4986 0.7479 0.9972]  
        dObs: [731582 731672 731763 731856 731946]  
        STree: {1x5 cell}  
UpProbs: [0.5000 0.5000 0.5000 0.5000]
```

Use `treeview` to observe the tree you have created.





**See Also**

eqptimespec | intenvset | stockspec

## exposureprofiles

Compute exposure profiles from credit exposures

### Syntax

```
profilestructs = exposureprofiles(dates,exposures)
profilestructs = exposureprofiles( ____,Name,Value)
```

### Description

`profilestructs = exposureprofiles(dates,exposures)` computes common counterparty credit exposures profiles from an array of exposures.

`profilestructs = exposureprofiles( ____,Name,Value)` computes common counterparty credit exposures profiles from an array of exposures using optional name-value pair arguments.

### Examples

#### View Exposure Profiles of a Particular Counterparty

After computing the mark-to-market contract values for a portfolio of swaps over many scenarios, view the exposure profiles of a particular counterparty.

First, load data containing the mark-to-market contract values for a portfolio of swaps over many scenarios.

```
load ccr.mat
```

Compute the exposure by counterparty.

```
[exposures, excpty] = creditexposures(values,swaps.Counterparty,...
'NettingID',swaps.NettingID);
```

Compute the credit exposure profiles for all counterparties.

```
cpProfiles = exposureprofiles(simulationDates, exposures)
```

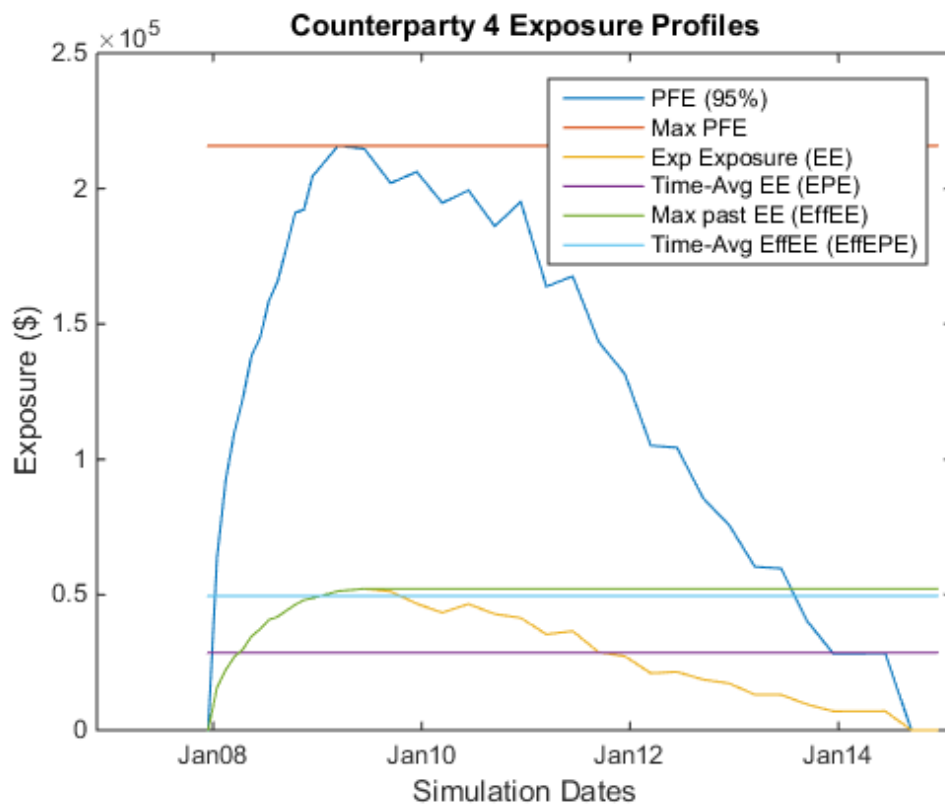
```
cpProfiles =
```

```
5x1 struct array with fields:
```

```
Dates
EE
PFE
MPFE
EffEE
EPE
EffEPE
```

Visualize the exposure profiles for a particular counterparty.

```
cpIdx = find(expcpty == 4);
numDates = numel(simulationDates);
plot(simulationDates, cpProfiles(cpIdx).PFE, ...
      simulationDates, cpProfiles(cpIdx).MPFE * ones(numDates, 1), ...
      simulationDates, cpProfiles(cpIdx).EE, ...
      simulationDates, cpProfiles(cpIdx).EPE * ones(numDates, 1), ...
      simulationDates, cpProfiles(cpIdx).EffEE, ...
      simulationDates, cpProfiles(cpIdx).EffEPE * ones(numDates, 1));
legend({'PFE (95%)', 'Max PFE', 'Exp Exposure (EE)', ...
       'Time-Avg EE (EPE)', 'Max past EE (EffEE)', ...
       'Time-Avg EffEE (EffEPE)'});
datetick('x', 'mmyy', 'keplimits')
title(sprintf('Counterparty %d Exposure Profiles', cpIdx));
ylabel('Exposure ($)')
xlabel('Simulation Dates')
```



## Input Arguments

### **dates** — Simulation dates

vector of date numbers | cell array of date strings

Simulation dates, specified as vector of date numbers or a cell array of string dates in a known format. For more information for known date formats, see the function `datenum`.

Data Types: `char` | `cell`

### **exposures** — 3-D array of potential losses due to counterparty default

array

3-D array of potential losses due to counterparty default on a set of instruments simulated over a series of simulation dates and across many scenarios, specified as a `NumDates-by-NumCounterParties-by-NumScenarios` “cube” of credit exposures. Each row represents a different simulation date, each column a different counterparty, and each “page” is a different scenario from a Monte-Carlo simulation.

Data Types: `double`

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes ( `' '` ). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

Example: `profilestructs = exposureprofiles(dates, exposures, 'ProfileSpec', 'PFE', 'PFEPProbabilityLevel', '.9'`

### 'ProfileSpec' — Exposure profiles

All (generate all profiles) (default) | string with possible values `EE`, `PFE`, `MPE`, `EffEE`, `EPE`, `EffEPE`, `All` | cell array with possible values `EE`, `PFE`, `MPE`, `EffEE`, `EPE`, `EffEPE`

Exposure profiles, specified as a string or cell array with the following possible values:

- `EE` — Expected Exposure. The mean of the distribution of exposures at each date. A `[NumDates-by-1]` vector.
- `PFE` — Potential Future Exposure. A high percentile (default 95%) of the distribution of possible exposures at each date. This is sometimes referred to as “Peak Exposure.” A `[NumDates-by-1]` vector.
- `MPFE` — Maximum Potential Future Exposure. The maximum potential future exposure (`PFE`) over all dates
- `EffEE` — Effective Expected Exposure. The maximum expected exposure (at a specific date) that occurs at that date or any prior date. This is the expected exposure, but constrained to be nondecreasing over time. A `[NumDates-by-1]` vector.
- `EPE` — Expected Positive Exposure. The weighted average over time of expected exposures. A scalar.
- `EffEPE` — Effective Expected Positive Exposure. The weighted average over time of the effective expected exposure (`EffEE`). A scalar.
- `All` — Generate all of the previous profiles.

---

**Note:** Exposure profiles are computed on a per-counterparty basis.

---

Data Types: char | cell

**'PFEProbabilityLevel1' — Level for potential future exposure (PFE) and maximum potential future exposure (MPFE)**

.95 (the 95th percentile) (default) | scalar with value [0..1]

Level for potential future exposure (PFE) and maximum potential future exposure (MPFE), specified as a scalar with value [0..1].

Data Types: double

## Output Arguments

**profilestructs — Structure of credit exposure profiles**

array of structs holding credit exposure profiles for each counterparty

Structure of credit exposure profiles, returned as an array of structs holding credit exposure profiles for each counterparty, returned as a struct, with the fields of the struct as the (abbreviated) names of every exposure profiles. Profiles listed in the `ProfileSpec` (and their related profiles) are populated, while those not requested contain empty (`[]`). `profilestructs` contains the dates information as a vector of MATLAB date numbers requested in the `ProfileSpec` argument.

## References

*Basel II: International Convergence of Capital Measurement and Capital Standards: A Revised Framework - Comprehensive Version* at <http://www.bis.org/publ/bcbs128.htm>, 2006.

## See Also

creditexposures | datenum

## fixedbybdt

Price fixed-rate note from Black-Derman-Toy interest-rate tree

### Syntax

```
[Price, PriceTree] = fixedbybdt(BDTree, CouponRate, Settle,
Maturity)
[Price, PriceTree] = fixedbybdt(BDTree, CouponRate, Settle,
Maturity, Reset, Basis, Principal, Options, EndMonthRule)
[Price, PriceTree] = fixedbybdt(BDTree, CouponRate, Settle,
Maturity, Name, Value)
```

### Input Arguments

BDTree	Interest-rate tree structure created by <code>bdttree</code> .
CouponRate	Decimal annual rate.
Settle	Settlement dates. Number of instruments (NINST)-by-1 vector of dates representing the settlement dates of the fixed-rate note.
Maturity	NINST-by-1 vector of dates representing the maturity dates of the fixed-rate note.

### Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

#### Reset

NINST-by-1 vector representing the frequency of payments per year.

**Default:** 1

#### Basis

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### **Principal**

NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

**Default:** 100

### **Options**

Derivatives pricing options structure created with **derivset**.

**Default:**

### **EndMonthRule**

End-of-month rule. A NINST-by-1 vector. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days.



- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

## Name-Value Pair Arguments

Specify optional comma-separated pairs of Name, Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1, Value1, . . . , NameN, ValueN.

### AdjustCashFlowsBasis

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** False

### BusinessDayConvention

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

### Holidays

Holidays used for business day convention. NHOLIDAYS-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, holidays.m is used.

## Description

`[Price, PriceTree] = fixedbybdt(BDTree, CouponRate, Settle, Maturity)` computes the price of a fixed-rate note from a BDT interest-rate tree.

`[Price, PriceTree] = fixedbybdt(BDTree, CouponRate, Settle, Maturity, Reset, Basis, Principal, Options, EndMonthRule)` computes the price of a fixed-rate note from a BDT interest-rate tree using additional input arguments.

`[Price, PriceTree] = fixedbybdt(BDTree, CouponRate, Settle, Maturity, Name, Value)` computes the price of a price of a fixed-rate note from a BDT interest-rate tree with additional options specified by one or more Name, Value pair arguments.

`Price` is an NINST-by-1 vector of expected prices of the fixed-rate note at time 0.

`PriceTree` is a structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node.

`PriceTree.PTree` contains the clean prices.

`PriceTree.AITree` contains the accrued interest.

`PriceTree.tObs` contains the observation times.

The `Settle` date for every fixed-rate note is set to the `ValuationDate` of the BDT tree. The fixed-rate note argument `Settle` is ignored.

## Examples

### Price a 10% Fixed-Rate Note Using a BDT Interest-Rate Tree

This example shows how to price a 10% fixed-rate note using a BDT interest-rate tree by loading the file `deriv.mat`, which provides `BDTree`. The `BDTree` structure contains the time and interest-rate information needed to price the note.

```
load deriv.mat

CouponRate = 0.10;
Settle = '01-Jan-2000';
```

```
Maturity = '01-Jan-2004';  
Reset = 1;
```

```
Price = fixedbybdt(BDTree, CouponRate, Settle, Maturity, Reset)
```

```
Price =  
    92.9974
```

## More About

- “Pricing Options Structure”

## See Also

bdttree | bondbybdt | capbybdt | cfbybdt | floatbybdt | floorbybdt |  
swapbybdt

## fixedbybk

Price fixed-rate note from Black-Karasinski interest-rate tree

### Syntax

```
[Price, PriceTree] = fixedbybk(BKTree, CouponRate, Settle,
Maturity)
[Price, PriceTree] = fixedbybk(BKTree, CouponRate, Settle,
Maturity, Reset, Basis, Principal, Options, EndMonthRule)
[Price, PriceTree] = fixedbybk(BKTree, CouponRate, Settle,
Maturity, Name, Value)
```

### Input Arguments

BKTree	Interest-rate tree structure created by <code>bktree</code> .
CouponRate	Decimal annual rate.
Settle	Settlement dates. NINST-by-1 vector of dates representing the settlement dates of the fixed-rate note.
Maturity	NINST-by-1 vector of dates representing the maturity dates of the fixed-rate note.

### Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

#### Reset

NINST-by-1 vector representing the frequency of payments per year.

**Default:** 1

#### Basis

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### **Principal**

NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

**Default:** 100

### **Options**

Derivatives pricing options structure created with **derivset**.

**Default:**

### **EndMonthRule**

End-of-month rule. A NINST-by-1 vector. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

### **AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** False

### **BusinessDayConvention**

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

### **Holidays**

Holidays used for business day convention. NHOLIDAYS-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, `holidays.m` is used.

## Description

`[Price, PriceTree] = fixedbybk(BKTree, CouponRate, Settle, Maturity)` computes the price of a fixed-rate note from a Black-Karasinski tree.

`[Price, PriceTree] = fixedbybk(BKTree, CouponRate, Settle, Maturity, Reset, Basis, Principal, Options, EndMonthRule)` computes the price of a fixed-rate note from a Black-Karasinski tree using optional input arguments.

`[Price, PriceTree] = fixedbybk(BKTree, CouponRate, Settle, Maturity, Name, Value)` computes the price of a price of a fixed-rate note from a Black-Karasinski interest-rate tree with additional options specified by one or more Name,Value pair arguments.

`Price` is an NINST-by-1 vector of expected prices of the fixed-rate note at time 0.

`PriceTree` is a structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node.

`PriceTree.PTree` contains the clean prices.

`PriceTree.AITree` contains the accrued interest.

`PriceTree.tObs` contains the observation times.

The `Settle` date for every fixed-rate note is set to the `ValuationDate` of the BK tree. The fixed-rate note argument `Settle` is ignored.

## Examples

### Price a 5% Fixed-Rate Note Using a Black-Karasinski Interest-Rate Tree

Load the file `deriv.mat`, which provides `BKTree`. The `BKTree` structure contains the time and interest-rate information needed to price the note.

```
load deriv.mat;
```

Set the required values. Other arguments will use defaults.

```
CouponRate = 0.05;
Settle = '01-Jan-2005';
```

```
Maturity = '01-Jan-2006';
```

Use `fixedbybk` to compute the price of the note.

```
Price = fixedbybk(BKTree, CouponRate, Settle, Maturity)
```

Warning: Fixed rate notes are valued at Tree ValuationDate rather than Settle

```
Price =
```

```
    103.5126
```

## More About

- “Pricing Options Structure”

## See Also

`bktree` | `bondbybk` | `capbybk` | `cfbybk` | `floatbybk` | `floorbybk` | `swapbybk`



# fixedbyhjm

Price fixed-rate note from Heath-Jarrow-Morton interest-rate tree

## Syntax

```
[Price, PriceTree] = fixedbyhjm(HJMTree, CouponRate, Settle,
Maturity)
[Price, PriceTree] = fixedbyhjm(HJMTree, CouponRate, Settle,
Maturity, Reset, Basis, Principal, Options, EndMonthRule)
[Price, PriceTree] = fixedbyhjm(HJMTree, CouponRate, Settle,
Maturity, Name, Value)
```

## Input Arguments

HJMTree	Forward-rate tree structure created by <code>hjmtree</code> .
CouponRate	Decimal annual rate.
Settle	Settlement dates. Number of instruments (NINST)-by-1 vector of dates representing the settlement dates of the fixed-rate note.
Maturity	NINST-by-1 vector of dates representing the maturity dates of the fixed-rate note.

## Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

### Reset

NINST-by-1 vector representing the frequency of payments per year.

**Default:** 1

### Basis

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### **Principal**

NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

**Default:** 100

### **Options**

Derivatives pricing options structure created with **derivset**.

**Default:**

### **EndMonthRule**

End-of-month rule. A NINST-by-1 vector. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

## Name-Value Pair Arguments

Specify optional comma-separated pairs of Name, Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1, Value1, . . . , NameN, ValueN.

### AdjustCashFlowsBasis

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** False

### BusinessDayConvention

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

### Holidays

Holidays used for business day convention. NHOLIDAYS-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, holidays.m is used.

## Description

`[Price, PriceTree] = fixedbyhjm(HJMTree, CouponRate, Settle, Maturity)` computes the price of a fixed-rate note from a HJM forward-rate tree.

`[Price, PriceTree] = fixedbyhjm(HJMTree, CouponRate, Settle, Maturity, Reset, Basis, Principal, Options, EndMonthRule)` computes the price of a fixed-rate note from a HJM forward-rate tree using optional input arguments.

`[Price, PriceTree] = fixedbyhjm(HJMTree, CouponRate, Settle, Maturity, Name, Value)` computes the price of a price of a fixed-rate note from a HJM forward-rate tree with additional options specified by one or more Name, Value pair arguments.

`Price` is an NINST-by-1 vector of expected prices of the fixed-rate note at time 0.

`PriceTree` is a structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node.

`PriceTree.PBush` contains the clean prices.

`PriceTree.AIBush` contains the accrued interest.

`PriceTree.tObs` contains the observation times.

The `Settle` date for every fixed-rate note is set to the `ValuationDate` of the HJM tree. The fixed-rate note argument `Settle` is ignored.

## Examples

### Price a 4% Fixed-Rate Note Using an HJM Forward-Rate Tree

This example shows how to price a 4% fixed-rate note using an HJM forward-rate tree by loading the file `deriv.mat`, which provides `HJMTree`. The `HJMTree` structure contains the time and forward-rate information needed to price the note.

```
load deriv.mat

CouponRate = 0.04;
Settle = '01-Jan-2000';
```

```
Maturity = '01-Jan-2003';  
Price = fixedbyhjm(HJMTree, CouponRate, Settle, Maturity)  
  
Price =  
    98.7159
```

## More About

- “Pricing Options Structure”

## See Also

[bondbyhjm](#) | [capbyhjm](#) | [cfbyhjm](#) | [floatbyhjm](#) | [floorbyhjm](#) | [hjmtree](#) | [swapbyhjm](#)

## fixedbyhw

Price fixed-rate note from Hull-White interest-rate tree

### Syntax

```
[Price, PriceTree] = fixedbyhw(HWTree, CouponRate, Settle,
Maturity)
[Price, PriceTree] = fixedbyhw(HWTree, CouponRate, Settle,
Maturity, Reset, Basis, Principal, Options, EndMonthRule)
[Price, PriceTree] = fixedbyhw(HWTree, CouponRate, Settle,
Maturity, Name, Value)
```

### Arguments

HWTree	Interest-rate tree structure created by <code>hwtree</code> .
CouponRate	Decimal annual rate.
Settle	Settlement dates. NINST-by-1 vector of dates representing the settlement dates of the fixed-rate note.
Maturity	NINST-by-1 vector of dates representing the maturity dates of the fixed-rate note.

### Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

#### Reset

NINST-by-1 vector representing the frequency of payments per year.

**Default:** 1

#### Basis

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### **Principal**

NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

**Default:** 100

### **Options**

Derivatives pricing options structure created with **derivset**.

**Default:**

### **EndMonthRule**

End-of-month rule. A NINST-by-1 vector. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

### **AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** False

### **BusinessDayConvention**

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- `actual`
- `follow`
- `modifiedfollow`
- `previous`
- `modifiedprevious`

**Default:** `actual`

### **Holidays**

Holidays used for business day convention. NHOLIDAYS-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, `holidays.m` is used.



## Description

`[Price, PriceTree] = fixedbyhw(HWTree, CouponRate, Settle, Maturity)` computes the price of a fixed-rate note from a Hull-White tree.

`[Price, PriceTree] = fixedbyhw(HWTree, CouponRate, Settle, Maturity, Reset, Basis, Principal, Options, EndMonthRule)` computes the price of a fixed-rate note from a Hull-White tree using optional input arguments.

`[Price, PriceTree] = fixedbyhw(HWTree, CouponRate, Settle, Maturity, Name, Value)` computes the price of a price of a fixed-rate note from a Hull-White tree with additional options specified by one or more Name,Value pair arguments.

`Price` is an NINST-by-1 vector of expected prices of the fixed-rate note at time 0.

`PriceTree` is a structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node.

`PriceTree.PTree` contains the clean prices.

`PriceTree.AITree` contains the accrued interest.

`PriceTree.tObs` contains the observation times.

The `Settle` date for every fixed-rate note is set to the `ValuationDate` of the HW tree. The fixed-rate note argument `Settle` is ignored.

## Examples

### Price a 5% Fixed-Rate Note Using a Hull-White Interest-Rate Tree

Load the file `deriv.mat`, which provides `HWTree`. The `HWTree` structure contains the time and interest-rate information needed to price the note.

```
load deriv.mat;
```

Set the required values. Other arguments will use defaults.

```
CouponRate = 0.05;
Settle = '01-Jan-2005';
Maturity = '01-Jan-2006';
```

Use `fixedbyhw` to compute the price of the note.

```
Price = fixedbyhw(HWTree, CouponRate, Settle, Maturity)
```

Warning: Fixed rate notes are valued at `Tree ValuationDate` rather than `Settle`

```
Price =
```

```
103.5126
```

### More About

- “Pricing Options Structure”

### See Also

`bondbyhw` | `capbyhw` | `cfbyhw` | `floatbyhw` | `floorbyhw` | `hwtree` | `swapbyhw`

# fixedbyzero

Price fixed-rate note from set of zero curves

## Syntax

```
[Price, DirtyPrice, CFlowAmounts, CFlowDates] =
fixedbyzero(RateSpec, CouponRate, Settle, Maturity)
[Price, DirtyPrice, CFlowAmounts, CFlowDates] =
fixedbyzero(RateSpec, CouponRate, Settle, Maturity,
Reset, Basis, Principal, EndMonthRule)
[Price, DirtyPrice, CFlowAmounts, CFlowDates] =
fixedbyzero(RateSpec, CouponRate, Settle, Maturity,
Name, Value)
```

## Description

[Price, DirtyPrice, CFlowAmounts, CFlowDates] = fixedbyzero(RateSpec, CouponRate, Settle, Maturity) computes the price of a fixed-rate note from a set of zero curves. All inputs are either scalars or NINST-by-1 vectors unless otherwise specified. Any date may be a serial date number or date string. An optional argument may be passed as an empty matrix [ ].

[Price, DirtyPrice, CFlowAmounts, CFlowDates] = fixedbyzero(RateSpec, CouponRate, Settle, Maturity, Reset, Basis, Principal, EndMonthRule) computes the price of a fixed-rate note from a set of zero curves using optional input arguments. All inputs are either scalars or NINST-by-1 vectors unless otherwise specified. Any date may be a serial date number or date string. An optional argument may be passed as an empty matrix [ ].

[Price, DirtyPrice, CFlowAmounts, CFlowDates] = fixedbyzero(RateSpec, CouponRate, Settle, Maturity, Name, Value) computes the price of a fixed-rate note from a set of zero curves with additional options specified by one or more Name, Value pair arguments.

## Input Arguments

### RateSpec

Structure containing the properties of an interest-rate structure. See `intenvset` for information on creating `RateSpec`.

### CouponRate

Decimal annual rate.

### Settle

Settlement date. `Settle` must be either a scalar or NINST-by-1 vector of serial date numbers or date strings of the same value which represent the settlement date for each bond. `Settle` must be earlier than `Maturity`.

### Maturity

Maturity date.

## Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

### Reset

NINST-by-1 vector representing the frequency of payments per year.

### Default: 1

### Basis

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)

- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### **Principal**

NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

**Default:** 100

### **EndMonthRule**

End-of-month rule. A NINST-by-1 vector. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

### **Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name,Value arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single

quotes (' '). You can specify several name and value pair arguments in any order as Name1, Value1, ..., NameN, ValueN.

**AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** False

**BusinessDayConvention**

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

**Holidays**

Holidays used for business day convention. NHOLIDAYS-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, `holidays.m` is used.

## Output Arguments

**Price**

A number of instruments (NINST) by number of curves (NUMCURVES) matrix of fixed-rate note prices. Each column arises from one of the zero curves.

**DirtyPrice**

A NINST-by-NUMCURVES matrix of dirty bond price (clean + accrued interest). Each column arises from one of the zero curves.

### **CFlowAmounts**

A NINST-by-NUMCFS matrix of cash flows for each bond.

### **CFlowDates**

A NINST-by-NUMCFS matrix of payment dates for each bond.

## **Examples**

### **Price a 4% Fixed-Rate Note Using a Set of Zero Curves**

This example shows how to price a 4% fixed-rate note using a set of zero curves by loading the file `deriv.mat`, which provides `ZeroRateSpec`, the interest-rate term structure needed to price the note.

```
load deriv.mat

CouponRate = 0.04;
Settle = '01-Jan-2000';
Maturity = '01-Jan-2003';

Price = fixedbyzero(ZeroRateSpec, CouponRate, Settle, Maturity)

Price =

    98.7159
```

### **See Also**

| `bondbyzero` | `cfbyzero` | `floatbyzero` | `swapbyzero`

## floatbybdt

Price floating-rate note from Black-Derman-Toy interest-rate tree

### Syntax

```
[Price, PriceTree] = floatbybdt(BDTree, Spread,
Settle, Maturity)
[Price, PriceTree] = floatbybdt(BDTree, Spread,
Settle, Maturity, Reset, Basis, Principal, Options,
EndMonthRule)
[Price, PriceTree] = floatbybdt(BDTree, Spread, Settle,
Maturity, Name, Value)
```

### Input Arguments

BDTree	Interest-rate tree structure created by <code>bdttree</code> .
Spread	Number of instruments (NINST)-by-1 vector of number of basis points over the reference rate.
Settle	Settlement dates. NINST-by-1 vector of dates representing the settlement dates of the floating-rate note.  <b>Note:</b> The <code>Settle</code> date for every floating-rate note is set to the <code>ValuationDate</code> of the BDT Tree. The floating-rate note argument <code>Settle</code> is ignored.
Maturity	NINST-by-1 vector of dates representing the maturity dates of the floating-rate note.

### Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

#### Reset

NINST-by-1 vector representing the frequency of payments per year.



---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates can not be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

**Default:** 1

### **Basis**

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### **Principal**

NINST-by-1 vector of notional principal amounts or NINST-by-1 cell array. For the latter case, each element of the cell array is a NumDates-by-2 matrix where the first column is

dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

**Default:** 100

### **Options**

Derivatives pricing options structure created with `derivset`.

**Default:**

### **EndMonthRule**

End-of-month rule. NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

### **AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** false

### **BusinessDayConvention**

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual

- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

### **Holidays**

Holidays used for business day convention. NHOLIDAYS-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, holidays.m is used.

### **CapRate**

NINST-by-1 decimal annual rate or NINST-by-1 cell array, where each element is a NumDates-by-2 cell array, and the cell array first column is dates, and the second column is associated cap rates. The date indicates the last day that the cap rate is valid.

**Default:**

### **FloorRate**

NINST-by-1 decimal annual rate or NINST-by-1 cell array, where each element is a NumDates-by-2 cell array, and the cell array first column is dates, and the second column is associated floor rates. The date indicates the last day that the floor rate is valid.

**Default:**

## **Description**

[Price, PriceTree] = floatbybdt(BDTree, Spread, Settle, Maturity) computes the price of a floating-rate note from a BDT tree.

[Price, PriceTree] = floatbybdt(BDTree, Spread, Settle, Maturity, Reset, Basis, Principal, Options, EndMonthRule) computes the price of a floating-rate note with optional inputs from a BDT tree.

[Price, PriceTree] = floatbybdt(BDTree, Spread, Settle,

`Maturity, Name, Value`) computes the price of a floating-rate note from a BDT tree with additional options specified by one or more `Name, Value` pair arguments..

`Price` is an `NINST-by-1` vector of expected prices of the floating-rate note at time 0.

`PriceTree` is a structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node.

`PriceTree.PTree` contains the clean prices.

`PriceTree.AITree` contains the accrued interest.

`PriceTree.tObs` contains the observation times.

The `Settle` date for every floating-rate note is set to the `ValuationDate` of the BDT tree. The floating-rate note argument `Settle` is ignored.

## Examples

### Price a Floating-Rate Note Using a BDT Tree

Price a 20-basis point floating-rate note using a BDT interest-rate tree.

Load the file `deriv.mat`, which provides `BDTTree`. The `BDTTree` structure contains the time and interest-rate information needed to price the note.

```
load deriv.mat;
```

Define the floating-rate note using the required arguments. Other arguments use defaults.

```
Spread = 20;  
Settle = '01-Jan-2000';  
Maturity = '01-Jan-2003';
```

Use `floatbybdt` to compute the price of the note.

```
Price = floatbybdt(BDTTree, Spread, Settle, Maturity)
```

```
Price =
```

100.4865

### Price an Amortizing Floating-Rate Note

Price an amortizing floating-rate note using the `Principal` input argument to define the amortization schedule.

Create the `RateSpec`.

```
Rates = [0.03583; 0.042147; 0.047345; 0.052707; 0.054302];
ValuationDate = '15-Nov-2011';
StartDates = ValuationDate;
EndDates = {'15-Nov-2012'; '15-Nov-2013'; '15-Nov-2014' ; '15-Nov-2015'; '15-Nov-2016'};
Compounding = 1;
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

`RateSpec =`

```
    FinObj: 'RateSpec'
  Compounding: 1
        Disc: [5x1 double]
        Rates: [5x1 double]
    EndTimes: [5x1 double]
  StartTimes: [5x1 double]
    EndDates: [5x1 double]
  StartDates: 734822
ValuationDate: 734822
        Basis: 0
  EndMonthRule: 1
```

Create the floating-rate instrument using the following data:

```
Settle = '15-Nov-2011';
Maturity = '15-Nov-2015';
Spread = 15;
```

Define the floating-rate note amortizing schedule.

```
Principal = {'15-Nov-2012' 100; '15-Nov-2013' 70; '15-Nov-2014' 40; '15-Nov-2015' 10};
```

Build the BDT tree and assume volatility is 10%.

```
MatDates = {'15-Nov-2012'; '15-Nov-2013'; '15-Nov-2014'; '15-Nov-2015'; '15-Nov-2016'; '15-Nov-2017'};
BDTTimeSpec = bdttimespec(ValuationDate, MatDates);
Volatility = 0.10;
BDTVolSpec = bdtvolspec(ValuationDate, MatDates, Volatility*ones(1,length(MatDates)))';
BDTT = bdttree(BDTVolSpec, RateSpec, BDTTimeSpec);
```

Compute the price of the amortizing floating-rate note.

```
Price = floatbybdt(BDTT, Spread, Settle, Maturity, 'Principal', Principal)
```

```
Price =
    100.3059
```

### Price a Collar with a Floating-Rate Note

Price a collar with a floating-rate note using the CapRate and FloorRate input argument to define the collar pricing.

Create the RateSpec.

```
Rates = [0.0287; 0.03024; 0.03345; 0.03861; 0.04033];
ValuationDate = '1-April-2012';
StartDates = ValuationDate;
EndDates = {'1-April-2013'; '1-April-2014'; '1-April-2015'; ...
            '1-April-2016'; '1-April-2017'};
Compounding = 1;
```

Create the RateSpec.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
                    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);
```

Build the BDT tree and assume volatility is 5%.

```
MatDates = {'1-April-2013'; '1-April-2014'; '1-April-2015'; '1-April-2016'; '1-April-2017'};
BDTTimeSpec = bdttimespec(ValuationDate, MatDates);
Volatility = 0.05;
BDTVolSpec = bdtvolspec(ValuationDate, MatDates, Volatility*ones(1,length(MatDates)))';
BDTT = bdttree(BDTVolSpec, RateSpec, BDTTimeSpec);
```

Create the floating rate note instrument.

```
Settle = '1-April-2012';
```

```
Maturity = '1-April-2016';
Spread = 10;
Principal = 100;
```

Compute the price of a collared floating-rate note.

```
CapStrike = {'1-April-2013' 0.03; '1-April-2015' 0.055}};
FloorStrike = {'1-April-2013' 0.025; '1-April-2015' 0.04}};

Price = floatbybdt(BDTT, Spread, Settle, Maturity, 'CapRate',...
CapStrike, 'FloorRate', FloorStrike)
```

```
Price =

    101.2414
```

### Pricing a Floating-Rate Note When the Reset Dates Are Not Tree Level Dates

When using `floatbybdt` to price floating-rate notes, there are cases where the dates specified in the BDT tree `TimeSpec` are not aligned with the cash flow dates.

Price floating-rate notes using the following data:

```
ValuationDate = '01-Sep-2013';
Rates = [0.0235; 0.0239; 0.0311; 0.0323];
EndDates = {'01-Sep-2014'; '01-Sep-2015'; '01-Sep-2016'; '01-Sep-2017'};
```

Create the `RateSpec`.

```
RateSpec = intenvset('ValuationDate',ValuationDate,'StartDates',...
ValuationDate,'EndDates',EndDates,'Rates',Rates,'Compounding', 1);
```

Build the BDT tree.

```
VolCurve = [.10; .11; .11; .12];
BDTVolatilitySpec = bdtvolspec(RateSpec.ValuationDate, EndDates,...
VolCurve);
BDTTimeSpec = bdttimespec(RateSpec.ValuationDate, EndDates, 1);
BDTT = bdttree(BDTVolatilitySpec, RateSpec, BDTTimeSpec);
```

Compute the price of the floating-rate note using the following data;

```
Spread = 5;
```

```
Settle = '01-Sep-2013';
Maturity = '01-Dec-2015';
Reset = 2;

Price = floatbybdt(BDTree, Spread, Settle, Maturity, 'Reset', Reset)

Warning: Not all cash flows are aligned with the tree. Result will be approximated.
> In floatengbybdt at 204
  In floatbybdt at 123
  Error using floatengbybdt (line 299)
  Instrument '1' has cash flow dates that span across tree nodes.

Error in floatbybdt (line 123)
[Price, PriceTree, CFTree, TLppal] = floatengbybdt(BDTree, Spread, Settle, Maturity, OArgs{:});
```

This error indicates that it is not possible to determine the applicable rate used to calculate the payoff at the reset dates, given that the applicable rate needed cannot be calculated (the information was lost due to the recombination of the tree nodes). Note, if the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates cannot be uniquely determined because there will be more than one possible path for connecting the two payment dates. The simplest solution is to place the tree levels at the cash flow dates of the instrument, which is done by specifying `BDTreeSpec`. It is also acceptable to have reset dates between tree levels, as long as there are reset dates on the tree levels too.

To recover from this error, build a tree that lines up with the instrument.

```
Basis = intenvget(RateSpec, 'Basis');
EOM = intenvget(RateSpec, 'EndMonthRule');
resetDates = cfdates(ValuationDate, Maturity, Reset, Basis, EOM);
BDTreeSpec = bdtreespec(RateSpec.ValuationDate, resetDates, Reset);
BDTree = bdtree(BDTreeVolatilitySpec, RateSpec, BDTreeSpec);

Price = floatbybdt(BDTree, Spread, RateSpec.ValuationDate, ...
    Maturity, 'Reset', Reset)
```

```
Price =

    100.1087
```

## More About

- “Pricing Options Structure”

## See Also

`bdtree` | `bondbybdt` | `capbybdt` | `cfbybdt` | `fixedbybdt` | `floorbybdt` | `swapbybdt`



# floatbybk

Price floating-rate note from Black-Karasinski interest-rate tree

## Syntax

```
[Price, PriceTree] = floatbybk(BKTree, Spread,
Settle, Maturity)
[Price, PriceTree] = floatbybk(BKTree, Spread,
Settle, Maturity, Reset, Basis, Principal, Options,
EndMonthRule)
[Price, PriceTree] = floatbybk(BKTree, Spread, Settle,
Maturity, Name, Value)
```

## Input Arguments

BKTree	Interest-rate tree structure created by <code>bktree</code> .
Spread	Number of instruments (NINST)-by-1 vector of number of basis points over the reference rate.
Settle	Settlement dates. NINST-by-1 vector of dates representing the settlement dates of the floating-rate note.  <b>Note:</b> The <code>Settle</code> date for every floating-rate note is set to the <code>ValuationDate</code> of the BK tree. The floating-rate note argument <code>Settle</code> is ignored.
Maturity	NINST-by-1 vector of dates representing the maturity dates of the floating-rate note.

## Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

### Reset

NINST-by-1 vector representing the frequency of payments per year.

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates can not be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

**Default:** 1

### **Basis**

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### **Principal**

NINST-by-1 vector of notional principal amounts or NINST-by-1 cell array. For the latter case, each element of the cell array is a NumDates-by-2 matrix where the first column is

dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

**Default:** 100

### **Options**

Derivatives pricing options structure created with `derivset`.

**Default:**

### **EndMonthRule**

End-of-month rule. NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, ..., NameN, ValueN`.

### **AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** false

### **BusinessDayConvention**

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

### **Holidays**

Holidays used for business day convention. NHOLIDAYS-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, `holidays.m` is used.

### **CapRate**

NINST-by-1 decimal annual rate or NINST-by-1 cell array, where each element is a NumDates-by-2 cell array, and the cell array first column is dates, and the second column is associated cap rates. The date indicates the last day that the cap rate is valid.

**Default:**

### **FloorRate**

NINST-by-1 decimal annual rate or NINST-by-1 cell array, where each element is a NumDates-by-2 cell array, and the cell array first column is dates, and the second column is associated floor rates. The date indicates the last day that the floor rate is valid.

**Default:**

## **Description**

[Price, PriceTree] = floatbybk(BKTree, Spread, Settle, Maturity) computes the price of a floating-rate note from a Black-Karasinski tree.

[Price, PriceTree] = floatbybk(BKTree, Spread, Settle, Maturity, Reset, Basis, Principal, Options,

EndMonthRule) computes the price of a floating-rate note with optional inputs from a Black-Karasinski tree.

[Price, PriceTree] = floatbybk(BKTree, Spread, Settle, Maturity, Name, Value) computes the price of a floating-rate note from a Black-Karasinski tree with additional options specified by one or more Name, Value pair arguments.

Price is an NINST-by-1 vector of expected prices of the floating-rate note at time 0.

PriceTree is a structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node.

PriceTree.PTree contains the clean prices.

PriceTree.AITree contains the accrued interest.

PriceTree.tObs contains the observation times.

The Settle date for every floating-rate note is set to the ValuationDate of the BK tree. The floating-rate note argument Settle is ignored.

## Examples

### Price a Floating-Rate Note Using a Black-Karasinski Tree

Price a 20-basis point floating-rate note using a Black-Karasinski interest-rate tree.

Load the file deriv.mat, which provides BKTree. The BKTree structure contains the time and interest-rate information needed to price the note.

```
load deriv.mat;
```

Define the floating-rate note using the required arguments. Other arguments use defaults.

```
Spread = 20;
Settle = '01-Jan-2005';
Maturity = '01-Jan-2006';
```

Use floatbybk to compute the price of the note.

```
Price = floatbybk(BKTree, Spread, Settle, Maturity)
```

```
Warning: Floating range notes are valued at Tree ValuationDate rather than  
Settle.
```

```
Price =  
  
100.3825
```

### Price an Amortizing Floating-Rate Note

Price an amortizing floating-rate note using the `Principal` input argument to define the amortization schedule.

Create the `RateSpec`.

```
Rates = [0.03583; 0.042147; 0.047345; 0.052707; 0.054302];  
ValuationDate = '15-Nov-2011';  
StartDates = ValuationDate;  
EndDates = {'15-Nov-2012'; '15-Nov-2013'; '15-Nov-2014'; '15-Nov-2015'; '15-Nov-2016'};  
Compounding = 1;  
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...  
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =  
  
    FinObj: 'RateSpec'  
    Compounding: 1  
           Disc: [5x1 double]  
           Rates: [5x1 double]  
           EndTimes: [5x1 double]  
           StartTimes: [5x1 double]  
           EndDates: [5x1 double]  
           StartDates: 734822  
           ValuationDate: 734822  
           Basis: 0  
           EndMonthRule: 1
```

Create the floating-rate instrument using the following data:

```
Settle = '15-Nov-2011';  
Maturity = '15-Nov-2015';
```

```
Spread = 15;
```

Define the floating-rate note amortizing schedule.

```
Principal = {{ '15-Nov-2012' 100; '15-Nov-2013' 70; '15-Nov-2014' 40; '15-Nov-2015' 10 }};
```

Build the BK tree and assume the volatility is 10%.

```
VolDates = [ '15-Nov-2012'; '15-Nov-2013'; '15-Nov-2014'; '15-Nov-2015'; '15-Nov-2016'; '15-Nov-2017' ];
VolCurve = 0.1;
AlphaDates = '15-Nov-2017';
AlphaCurve = 0.1;
```

```
BKVolSpec = bkvolspec(RateSpec.ValuationDate, VolDates, VolCurve, ...
AlphaDates, AlphaCurve);
BKTimeSpec = bktimespec(RateSpec.ValuationDate, VolDates, Compounding);
BKT = bktree(BKVolSpec, RateSpec, BKTimeSpec);
```

Compute the price of the amortizing floating-rate note.

```
Price = floatbybk(BKT, Spread, Settle, Maturity, 'Principal', Principal)
```

```
Price =
    100.3059
```

### Price a Collar with a Floating-Rate Note

Price a collar with a floating-rate note using the CapRate and FloorRate input argument to define the collar pricing.

Price a portfolio of collared floating-rate notes using the following data:

```
Rates = [0.0287; 0.03024; 0.03345; 0.03861; 0.04033];
ValuationDate = '1-April-2012';
StartDates = ValuationDate;
EndDates = { '1-April-2013'; '1-April-2014'; '1-April-2015' ; ...
'1-April-2016'; '1-April-2017' };
Compounding = 1;
```

Create the RateSpec.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
```

```
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);
```

Build the BK tree and assume the volatility to be 5%.

```
VolDates = ['1-April-2013'; '1-April-2014'; '1-April-2015'; '1-April-2016'; ...  
'1-April-2017'; '1-April-2018'];  
VolCurve = 0.05;  
AlphaDates = '15-Nov-2018';  
AlphaCurve = 0.1;
```

```
BKVolSpec = bkvolspec(RateSpec.ValuationDate, VolDates, VolCurve, ...  
AlphaDates, AlphaCurve);  
BKTimeSpec = bktimespec(RateSpec.ValuationDate, VolDates, Compounding);  
BKT = bktree(BKVolSpec, RateSpec, BKTimeSpec);
```

Create the floating-rate note instrument.

```
Settle = '1-April-2012';  
Maturity = '1-April-2016';  
Spread = [15;10];  
Principal = 100;
```

Compute the price of the two vanilla floaters.

```
Price = floatbybk(BKT, Spread, Settle, Maturity)
```

```
Price =  
  
100.5519  
100.3680
```

Compute the price of the collared floating-rate notes.

```
CapStrike = {'1-April-2013' 0.045; '1-April-2014' 0.05; ...  
'1-April-2015' 0.06}; 0.06};  
FloorStrike = {'1-April-2013' 0.035; '1-April-2014' 0.04; ...  
'1-April-2015' 0.05}; 0.03};  
PriceCollared = floatbybk(BKT, Spread, Settle, Maturity, ...  
'CapRate', CapStrike, 'FloorRate', FloorStrike)
```

```
PriceCollared =
```



```
102.8537
100.4910
```

## Pricing a Floating-Rate Note When the Reset Dates Are Not Tree Level Dates

When using `floatbybk` to price floating-rate notes, there are cases where the dates specified in the BK tree Time Specs are not aligned with the cash flow dates.

Price floating-rate notes using the following data:

```
ValuationDate      = '13-Sep-2013';
ForwardRatesVector = [ 0.0001; 0.0001; 0.0010; 0.0015];
EndDatesVector     = ['13-Dec-2013'; '14-Mar-2014'; '13-Jun-2014'; '13-Sep-2014'];
```

Create the `RateSpec`.

```
RateSpec = intenvset('ValuationDate',ValuationDate,'StartDates',...
ValuationDate,'EndDates',EndDatesVector,'Rates',ForwardRatesVector,'Compounding', 1);
```

Build the BK tree.

```
Volcurve          = 0.1;
Alpha              = 0.01;
BKVolatilitySpec  = bkvolspec(RateSpec.ValuationDate, ...
                             EndDatesVector, Volcurve,...
                             EndDatesVector, Alpha);

BKTimeSpec        = bktimespec(RateSpec.ValuationDate, EndDatesVector, 1);
BKT               = bktree(BKVolatilitySpec, RateSpec, BKTimeSpec);
```

Create the floating-rate note instrument using the following data;

```
Spread            = 0;
Maturity          = '13-Jun-2014';
reset = 4;
```

Compute the price of the floating-rate note.

```
Price = floatbybk(BKT, Spread, RateSpec.ValuationDate,...
Maturity, 'Reset', reset)
```

Warning: Not all cash flows are aligned with the tree. Result will be approximated.

```
> In floatengbytrintree at 214
```

```
  In floatbybk at 136
```

```
Error using floatengbytrintree (line 319)
```

```
Instrument '1' has cash flow dates that span across tree nodes.
```

```
Error in floatbybk (line 136)
```

```
[Price, PriceTree, CFTree] = floatengbytrintree(BKTree, Spread, Settle, Maturity, OArgs{:});
```

This error indicates that it is not possible to determine the applicable rate used to calculate the payoff at the reset dates, given that the applicable rate needed cannot be

calculated (the information was lost due to the recombination of the tree nodes). Note, if the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates cannot be uniquely determined because there will be more than one possible path for connecting the two payment dates. The simplest solution is to place the tree levels at the cash flow dates of the instrument, which is done by specifying `BKTimeSpec`. It is also acceptable to have reset dates between tree levels, as long as there are reset dates on the tree levels too.

To recover from this error, build a tree that lines up with the instrument.

```
Basis = intenvget(RateSpec, 'Basis');
EOM = intenvget(RateSpec, 'EndMonthRule');
resetDates = cfdates(ValuationDate, Maturity, reset, Basis, EOM);
BKTimeSpec = bktimespec(RateSpec.ValuationDate, resetDates, reset);
BKT = bktree(BKVolatilitySpec, RateSpec, BKTimeSpec);

Price = floatbybk(BKT, Spread, RateSpec.ValuationDate, ...
    Maturity, 'Reset', reset)

Price =

    100.0004
```

## More About

- “Pricing Options Structure”

## See Also

`bktree` | `bondbybk` | `capbybk` | `cfbybk` | `fixedbybk` | `floorbybk` | `swapbybk`

# floatbyhjm

Price floating-rate note from Heath-Jarrow-Morton interest-rate tree

## Syntax

```
[Price, PriceTree] = floatbybk(HJMTree, Spread,
Settle, Maturity)
[Price, PriceTree] = floatbybk(HJMTree, Spread,
Settle, Maturity, Reset, Basis, Principal, Options,
EndMonthRule)
[Price, PriceTree] = floatbybk(HJMTree, Spread, Settle,
Maturity, Name, Value)
```

## Input Arguments

HJMTree	Forward-rate tree structure created by <code>hjmTree</code> .
Spread	Number of instruments (NINST)-by-1 vector of number of basis points over the reference rate.
Settle	Settlement dates. NINST-by-1 vector of dates representing the settlement dates of the floating-rate note.  <b>Note:</b> The <code>Settle</code> date for every floating-rate note is set to the <code>ValuationDate</code> of the HJM tree. The floating-rate note argument <code>Settle</code> is ignored.
Maturity	NINST-by-1 vector of dates representing the maturity dates of the floating-rate note.

## Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

### Reset

NINST-by-1 vector representing the frequency of payments per year.

**Default:** 1

**Basis**

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

**Principal**

NINST-by-1 vector of notional principal amounts or NINST-by-1 cell array. For the latter case, each element of the cell array is a NumDates-by-2 matrix where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

**Default:** 100

**Options**

Derivatives pricing options structure created with **derivset**.

**Default:**

### **EndMonthRule**

End-of-month rule. NINST-by-1 vector. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

### **Name-Value Pair Arguments**

Specify optional comma-separated pairs of **Name**,**Value** arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as **Name1,Value1, . . . ,NameN,ValueN**.

### **AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** false

### **BusinessDayConvention**

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

### **Holidays**

Holidays used for business day convention. NHOLIDAYS-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, `holidays.m` is used.

### **CapRate**

NINST-by-1 decimal annual rate or NINST-by-1 cell array, where each element is a NumDates-by-2 cell array, and the cell array first column is dates, and the second column is associated cap rates. The date indicates the last day that the cap rate is valid.

**Default:**

### **FloorRate**

NINST-by-1 decimal annual rate or NINST-by-1 cell array, where each element is a NumDates-by-2 cell array, and the cell array first column is dates, and the second column is associated floor rates. The date indicates the last day that the floor rate is valid.

**Default:**

## **Description**

`[Price, PriceTree] = floatbybk(HJMTree, Spread, Settle, Maturity)` computes the price of a floating-rate note from an HJM tree.

`[Price, PriceTree] = floatbybk(HJMTree, Spread, Settle, Maturity, Reset, Basis, Principal, Options, EndMonthRule)` computes the price of a floating-rate note with optional inputs from an HJM tree.

`[Price, PriceTree] = floatbybk(HJMTree, Spread, Settle, Maturity, Name, Value)` computes the price of a floating-rate note from an HJM tree with additional options specified by one or more Name, Value pair arguments.

Price is an NINST-by-1 vector of expected prices of the floating-rate note at time 0.

PriceTree is a structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node.

`PriceTree.PBush` contains the clean prices.

`PriceTree.AIBush` contains the accrued interest.

`PriceTree.tObs` contains the observation times.

The `Settle` date for every floating-rate note is set to the `ValuationDate` of the HJM tree. The floating-rate note argument `Settle` is ignored.

## Examples

### Price a Floating-Rate Note Using an HJM Tree

Price a 20-basis point floating-rate note using an HJM forward-rate tree.

Load the file `deriv.mat`, which provides `HJMTree`. The `HJMTree` structure contains the time and interest-rate information needed to price the note.

```
load deriv.mat;
```

Define the floating-rate note using the required arguments. Other arguments use defaults.

```
Spread = 20;
Settle = '01-Jan-2000';
Maturity = '01-Jan-2003';
```

Use `floatbyhjm` to compute the price of the note.

```
Price = floatbyhjm(HJMTree, Spread, Settle, Maturity)
```

```
Price =
    100.5529
```

### Price an Amortizing Floating-Rate Note

Price an amortizing floating-rate note using the `Principal` input argument to define the amortization schedule.

Create the `RateSpec`.

```
Rates = [0.03583; 0.042147; 0.047345; 0.052707; 0.054302];
ValuationDate = '15-Nov-2011';
StartDates = ValuationDate;
EndDates = {'15-Nov-2012'; '15-Nov-2013'; '15-Nov-2014' ; '15-Nov-2015'; '15-Nov-2016'};
Compounding = 1;
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
    Compounding: 1
           Disc: [5x1 double]
           Rates: [5x1 double]
           EndTimes: [5x1 double]
           StartTimes: [5x1 double]
           EndDates: [5x1 double]
           StartDates: 734822
           ValuationDate: 734822
           Basis: 0
           EndMonthRule: 1
```

Create the floating-rate instrument using the following data:

```
Settle = '15-Nov-2011';
Maturity = '15-Nov-2015';
Spread = 15;
```

Define the floating-rate note amortizing schedule.

```
Principal = {'15-Nov-2012' 100; '15-Nov-2013' 70; '15-Nov-2014' 40; '15-Nov-2015' 10};
```

Build the HJM tree using the following data:

```
MatDates = {'15-Nov-2012'; '15-Nov-2013'; '15-Nov-2014'; '15-Nov-2015'; '15-Nov-2016'; '15-Nov-2017'};
HJMTimeSpec = hjmtimespec(RateSpec.ValuationDate, MatDates);
Volatility = [.10; .08; .06; .04];
CurveTerm = [ 1; 2; 3; 4];
HJMVolSpec = hjmvolspec('Proportional', Volatility, CurveTerm, 1e6);
HJMT = hjmtree(HJMVolSpec, RateSpec, HJMTimeSpec);
```

Compute the price of the amortizing floating-rate note.

```
Price = floatbyhjm(HJMT, Spread, Settle, Maturity, 'Principal', Principal)
```



```
Price =
    100.3059
```

### Price a Collar with a Floating-Rate Note

Price a collar with a floating-rate note using the `CapRate` and `FloorRate` input argument to define the collar pricing.

Price a portfolio of collared floating-rate notes using the following data:

```
Rates = [0.0287; 0.03024; 0.03345; 0.03861; 0.04033];
ValuationDate = '1-April-2012';
StartDates = ValuationDate;
EndDates = {'1-April-2013'; '1-April-2014'; '1-April-2015'; ...
            '1-April-2016'; '1-April-2017'};
Compounding = 1;
```

Create the `RateSpec`.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
                    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);
```

Build the HJM tree with the following data:

```
MatDates = {'1-April-2013'; '1-April-2014'; '1-April-2015'; ...
            '1-April-2016'; '1-April-2017'; '1-April-2018'};
HJMTimeSpec = hjmtimespec(RateSpec.ValuationDate, MatDates);
Volatility = [.10; .08; .06; .04];
CurveTerm = [ 1; 2; 3; 4];
HJMVolSpec = hjmvolspec('Proportional', Volatility, CurveTerm, 1e6);
HJMT = hjmtree(HJMVolSpec, RateSpec, HJMTimeSpec);
```

Create the floating-rate note instrument.

```
Settle = '1-April-2012';
Maturity = '1-April-2016';
Spread = 10;
Principal = 100;
```

Compute the price of two capped collared floating-rate notes.

```
CapStrike = [0.04; 0.055];
```

```
PriceCapped = floatbyhjm(HJMT, Spread, Settle, Maturity,...  
'CapRate', CapStrike)
```

```
PriceCapped =
```

```
    98.9986  
    100.2051
```

Compute the price of two collared floating-rate notes.

```
FloorStrike = [0.035;0.040];  
PriceCollared = floatbyhjm(HJMT, Spread, Settle, Maturity,...  
'CapRate', CapStrike, 'FloorRate', FloorStrike)
```

```
PriceCollared =
```

```
    99.9246  
    102.2321
```

## More About

- “Pricing Options Structure”

## See Also

[bondbyhjm](#) | [capbyhjm](#) | [cfbyhjm](#) | [fixedbyhjm](#) | [floorbyhjm](#) | [hjmtree](#) | [swapbyhjm](#)

# floatbyhw

Price floating-rate note from Hull-White interest-rate tree

## Syntax

```
[Price, PriceTree] = floatbyhw(HWTree, Spread,
Settle, Maturity)
[Price, PriceTree] = floatbyhw(HWTree, Spread,
Settle, Maturity, Reset, Basis, Principal, Options,
EndMonthRule)
[Price, PriceTree] = floatbyhw(HWTree, Spread, Settle,
Maturity, Name, Value)
```

## Input Arguments

HWTree	Interest-rate tree structure created by <code>hwtree</code> .
Spread	Number of instruments (NINST)-by-1 vector of number of basis points over the reference rate.
Settle	Settlement dates. NINST-by-1 vector of dates representing the settlement dates of the floating-rate note.  <b>Note:</b> The <code>Settle</code> date for every floating-rate note is set to the <code>ValuationDate</code> of the HW tree. The floating-rate note argument <code>Settle</code> is ignored.
Maturity	NINST-by-1 vector of dates representing the maturity dates of the floating-rate note.

## Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

### Reset

NINST-by-1 vector representing the frequency of payments per year.

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates can not be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

**Default:** 1

### **Basis**

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### **Principal**

NINST-by-1 vector of notional principal amounts or NINST-by-1 cell array. For the latter case, each element of the cell array is a NumDates-by-2 matrix where the first column is

dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

**Default:** 100

### **Options**

Derivatives pricing options structure created with `derivset`.

**Default:**

### **EndMonthRule**

End-of-month rule. NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

### **AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** false

### **BusinessDayConvention**

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual

- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

### **Holidays**

Holidays used for business day convention. NHOLIDAYS-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, holidays.m is used.

### **CapRate**

NINST-by-1 decimal annual rate or NINST-by-1 cell array, where each element is a NumDates-by-2 cell array, and the cell array first column is dates, and the second column is associated cap rates. The date indicates the last day that the cap rate is valid.

**Default:**

### **FloorRate**

NINST-by-1 decimal annual rate or NINST-by-1 cell array, where each element is a NumDates-by-2 cell array, and the cell array first column is dates, and the second column is associated floor rates. The date indicates the last day that the floor rate is valid.

**Default:**

## **Description**

[Price, PriceTree] = floatbyhw(HWTree, Spread, Settle, Maturity) computes the price of a floating-rate note from a Hull-White tree.

[Price, PriceTree] = floatbyhw(HWTree, Spread, Settle, Maturity, Reset, Basis, Principal, Options, EndMonthRule) computes the price of a floating-rate note with optional inputs from a Hull-White tree.

[Price, PriceTree] = floatbyhw(HWTree, Spread, Settle,

`Maturity, Name, Value`) computes the price of a floating-rate note from a Hull-White tree with additional options specified by one or more `Name, Value` pair arguments.

`Price` is an `NINST-by-1` vector of expected prices of the floating-rate note at time 0.

`PriceTree` is a structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node.

`PriceTree.PTree` contains the clean prices.

`PriceTree.AITree` contains the accrued interest.

`PriceTree.tObs` contains the observation times.

The `Settle` date for every floating-rate note is set to the `ValuationDate` of the HW tree. The floating-rate note argument `Settle` is ignored.

## Examples

### Price a Floating-Rate Note Using a Hull-White Tree

Price a 20-basis point floating-rate note using a Hull-White interest-rate tree.

Load the file `deriv.mat`, which provides `HWTtree`. The `HWTtree` structure contains the time and interest-rate information needed to price the note.

```
load deriv.mat;
```

Define the floating-rate note using the required arguments. Other arguments use defaults.

```
Spread = 20;
Settle = '01-Jan-2005';
Maturity = '01-Jan-2006';
```

Use `floatbyhw` to compute the price of the note.

```
Price = floatbyhw(HWTtree, Spread, Settle, Maturity)
```

Warning: Floating range notes are valued at Tree `ValuationDate` rather than `Settle`.

```
Price =  
  
    100.3825
```

### Price an Amortizing Floating-Rate Note

Price an amortizing floating-rate note using the `Principal` input argument to define the amortization schedule.

Create the `RateSpec`.

```
Rates = [0.03583; 0.042147; 0.047345; 0.052707; 0.054302];  
ValuationDate = '15-Nov-2011';  
StartDates = ValuationDate;  
EndDates = {'15-Nov-2012'; '15-Nov-2013'; '15-Nov-2014' ; '15-Nov-2015'; '15-Nov-2016'};  
Compounding = 1;  
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...  
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =  
  
    FinObj: 'RateSpec'  
    Compounding: 1  
        Disc: [5x1 double]  
        Rates: [5x1 double]  
    EndTimes: [5x1 double]  
    StartTimes: [5x1 double]  
    EndDates: [5x1 double]  
    StartDates: 734822  
    ValuationDate: 734822  
        Basis: 0  
    EndMonthRule: 1
```

Create the floating-rate instrument using the following data:

```
Settle = '15-Nov-2011';  
Maturity = '15-Nov-2015';  
Spread = 15;
```

Define the floating-rate note amortizing schedule.

```
Principal = {'15-Nov-2012' 100; '15-Nov-2013' 70; '15-Nov-2014' 40; '15-Nov-2015' 10};
```



Build the HW tree and assume the volatility is 10%.

```
VolDates = ['15-Nov-2012'; '15-Nov-2013'; '15-Nov-2014'; '15-Nov-2015'; '15-Nov-2016'; '15-Nov-2017'];
VolCurve = 0.1;
AlphaDates = '15-Nov-2017';
AlphaCurve = 0.1;
```

```
HWVolSpec = hwwolspec(RateSpec.ValuationDate, VolDates, VolCurve, ...
AlphaDates, AlphaCurve);
HWTimeSpec = hwtimespec(RateSpec.ValuationDate, VolDates, Compounding);
HWT = hwtree(HWVolSpec, RateSpec, HWTimeSpec);
```

Compute the price of the amortizing floating-rate note.

```
Price = floatbyhw(HWT, Spread, Settle, Maturity, 'Principal', Principal)
```

```
Price =
    100.3059
```

### Price a Collar with a Floating-Rate Note

Price a collar with a floating-rate note using the CapRate and FloorRate input argument to define the collar pricing.

Price two collared floating-rate notes using the following data:

```
Rates = [0.0287; 0.03024; 0.03345; 0.03861; 0.04033];
ValuationDate = '1-April-2012';
StartDates = ValuationDate;
EndDates = {'1-April-2013'; '1-April-2014'; '1-April-2015'; ...
'1-April-2016'; '1-April-2017'};
Compounding = 1;
```

Create the RateSpec.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);
```

Build the HW tree and assume the volatility to be 5%.

```
VolDates = ['1-April-2013'; '1-April-2014'; '1-April-2015'; ...
'1-April-2016'; '1-April-2017'; '1-April-2018'];
VolCurve = 0.05;
```

```
AlphaDates = '15-Nov-2018';
AlphaCurve = 0.1;

HWVolSpec = hwvolspec(RateSpec.ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);
HWTimeSpec = hwtimespec(RateSpec.ValuationDate, VolDates, Compounding);
HWT = hwtree(HWVolSpec, RateSpec, HWTimeSpec);
```

Create the floating-rate note instrument.

```
Settle = '1-April-2012';
Maturity = '1-April-2016';
Spread = 10;
Principal = 100;
```

Compute the price of a vanilla floater.

```
Price = floatbyhw(HWT, Spread, Settle, Maturity)
```

```
Price =
    100.3680
```

Compute the price of the collared floating-rate notes.

```
CapStrike = {'1-April-2014' 0.045; '1-April-2015' 0.05;...
'1-April-2016' 0.06}; 0.06};

FloorStrike = {'1-April-2014' 0.035; '1-April-2015' 0.04;...
'1-April-2016' 0.05}; 0.03};
PriceCollared = floatbyhw(HWT, Spread, Settle, Maturity,...
'CapRate', CapStrike, 'FloorRate', FloorStrike)
```

```
PriceCollared =
    102.0317
    100.9189
```

### **Pricing a Floating-Rate Note When the Reset Dates Are Not Tree Level Dates**

When using `floatbyhw` to price floating-rate notes, there are cases where the dates specified in the HW tree `TimeSpec` are not aligned with the cash flow dates.

Price floating-rate notes using the following data:

```
ValuationDate = '01-Sep-2013';
Rates = [0.0001; 0.0001; 0.0010; 0.0015];
EndDates = ['01-Dec-2013'; '01-Mar-2014'; '01-Jun-2014'; '01-Sep-2014'];
```

Create the RateSpec.

```
RateSpec = intenvset('ValuationDate',ValuationDate,'StartDates',...
ValuationDate,'EndDates',EndDates,'Rates',Rates,'Compounding',1);
```

Build the HW tree.

```
Volcurve = 0.1;
Alpha = 0.01;
HWVolatilitySpec = hwwolatilityspec(RateSpec.ValuationDate, ...
                                   EndDates, Volcurve,...
                                   EndDates, Alpha);

HWTimeSpec = hwtimespec(RateSpec.ValuationDate, EndDates, 1);

HWT = hwtree(HWVolatilitySpec, RateSpec, HWTimeSpec);
```

Compute the price of the floating-rate note using the following data.

```
Spread = 10;
Settle = '01-Sep-2013';
Maturity = '01-Jun-2014';
Reset = 2;

Price = floatbyhw(HWT, Spread, Settle, Maturity, 'Reset', Reset)

Error using floatengbytrintree (line 318)
Instrument '1' has cash flow dates that span across tree nodes.

Error in floatbyhw (line 136)
    [Price, PriceTree, CFTree] = floatengbytrintree(HWTTree, Spread, Settle, Maturity, OArgs{:});
```

This error indicates that it is not possible to determine the applicable rate used to calculate the payoff at the reset dates, given that the applicable rate needed cannot be calculated (the information was lost due to the recombination of the tree nodes). Note, if the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates cannot be uniquely determined because there will be more than one possible path for connecting the two payment dates. The simplest solution is to place the tree levels at the cash flow dates of the instrument, which is done by specifying `HWTimeSpec`. It is also acceptable to have reset dates between tree levels, as long as there are reset dates on the tree levels too.

To recover from this error, build a tree that lines up with the instrument.

```
Basis = intenvget(RateSpec, 'Basis');
EOM = intenvget(RateSpec, 'EndMonthRule');
```

```
resetDates = cfdates(ValuationDate, Maturity, Reset, Basis, EOM);
HWTTimeSpec = hwtimespec(RateSpec.ValuationDate, resetDates, Reset);
HWT = hwtree(HWVolatilitySpec, RateSpec, HWTTimeSpec);

Price = floatbyhw(HWT, Spread, RateSpec.ValuationDate, ...
                 Maturity, 'Reset', Reset)

Price =

    100.0748
```

### More About

- “Pricing Options Structure”

### See Also

[bondbyhw](#) | [capbyhw](#) | [cfbyhw](#) | [fixedbyhw](#) | [floorbyhw](#) | [hwtree](#) | [swapbyhw](#)

# floatbyzero

Price floating-rate note from set of zero curves

## Syntax

```
[Price,DirtyPrice,OutputCashFlows,CFlowDates] =  
floatbyzero(RateSpec,Spread,Settle,Maturity)  
[Price,DirtyPrice,OutputCashFlows,CFlowDates] =  
floatbyzero(RateSpec,Spread,Settle,Maturity,  
Reset,Basis,Principal,EndMonthRule)  
[Price,DirtyPrice,OutputCashFlows,CFlowDates] =  
floatbyzero(RateSpec,Spread,Settle,Maturity,Name,Value)
```

## Description

[Price,DirtyPrice,OutputCashFlows,CFlowDates] = floatbyzero(RateSpec,Spread,Settle,Maturity) computes the price of a floating-rate note from a set of zero curves.

[Price,DirtyPrice,OutputCashFlows,CFlowDates] = floatbyzero(RateSpec,Spread,Settle,Maturity,Reset,Basis,Principal,EndMonthRule) computes the price of a floating-rate note from a set of zero curves using optional input arguments.

[Price,DirtyPrice,OutputCashFlows,CFlowDates] = floatbyzero(RateSpec,Spread,Settle,Maturity,Name,Value) computes the price of a floating-rate note from a set of zero curves with additional options specified by one or more Name,Value pair arguments.

## Input Arguments

### RateSpec

Structure containing the properties of an interest-rate structure. See `intenvset` for information on creating `RateSpec`.

**Spread**

Number of basis points over the reference rate.

**Settle**

Settlement date. **Settle** must be either a scalar or NINST-by-1 vector of serial date numbers or date strings of the same value which represent the settlement date for each bond. **Settle** must be earlier than **Maturity**.

**Maturity**

Maturity date.

**Ordered Input or Name-Value Pair Arguments**

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

**Reset**

NINST-by-1 vector representing the frequency of payments per year.

**Default:** 1

**Basis**

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)

- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### **Principal**

NINST-by-1 vector of notional principal amounts or NINST-by-1 cell array. For the latter case, each element of the cell array is a NumDates-by-2 matrix where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

**Default:** 100

### **EndMonthRule**

End-of-month rule. NINST-by-1 vector. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

### **Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name,Value arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1, Value1, . . . , NameN, ValueN.

### **AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** false

**BusinessDayConvention**

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

**Holidays**

Holidays used for business day convention. NHOLIDAYS-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, `holidays.m` is used.

**LatestFloatingRate**

Rate for the next floating payment set at the last reset date. NINST-by-1 of scalars.

**Default:** If no `LatestFloatingRate` is specified, the floating rate at the previous reset date is computed from the `RateSpec`.

**ProjectionCurve**

The rate curve to be used in generating floating cash flows of the floater instruments. This structure must be created using `intenvset`.

**Default:** If no `ProjectionCurve` is specified, the `RateSpec` is used both for discounting and generating floating cash flows for the floater instrument.

## Output Arguments

**Price**

Number of instruments (NINST) by number of curves (NUMCURVES) matrix of floating-rate note prices. Each column arises from one of the zero curves.



**DirtyPrice**

NINST-by-NUMCURVES matrix of dirty bond price (clean + accrued interest). Each column arises from one of the zero curves.

**OutputCashFlows**

NINST-by-NUMCFS matrix of cash flows for each bond.

---

**Note:** If there is more than one curve specified in the `RateSpec` input, then the first NCURVES rows correspond to the first bond, the second NCURVES rows correspond to the second bond, and so on.

---

**CFlowDates**

NINST-by-NUMCFS matrix of payment dates for each bond.

## Examples

**Price a Floating-Rate Note Using a Set of Zero Curves**

Price a 20-basis point floating-rate note using a set of zero curves.

Load `deriv.mat`, which provides `ZeroRateSpec`, the interest-rate term structure, needed to price the bond.

```
load deriv.mat;
```

Define the floating-rate note using the required arguments. Other arguments use defaults.

```
Spread = 20;
Settle = '01-Jan-2000';
Maturity = '01-Jan-2003';
```

Use `floatbyzero` to compute the price of the note.

```
Price = floatbyzero(ZeroRateSpec, Spread, Settle, Maturity)
```

```
Price =  
  
    100.5529
```

### Price an Amortizing Floating-Rate Note

Price an amortizing floating-rate note using the `Principal` input argument to define the amortization schedule.

Create the `RateSpec`.

```
Rates = [0.03583; 0.042147; 0.047345; 0.052707; 0.054302];  
ValuationDate = '15-Nov-2011';  
StartDates = ValuationDate;  
EndDates = {'15-Nov-2012'; '15-Nov-2013'; '15-Nov-2014' ; '15-Nov-2015'; '15-Nov-2016'};  
Compounding = 1;  
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...  
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =  
  
    FinObj: 'RateSpec'  
    Compounding: 1  
        Disc: [5x1 double]  
        Rates: [5x1 double]  
    EndTimes: [5x1 double]  
    StartTimes: [5x1 double]  
    EndDates: [5x1 double]  
    StartDates: 734822  
    ValuationDate: 734822  
        Basis: 0  
    EndMonthRule: 1
```

Create the floating-rate instrument using the following data:

```
Settle = '15-Nov-2011';  
Maturity = '15-Nov-2015';  
Spread = 15;
```

Define the floating-rate note amortizing schedule.

```
Principal = {'15-Nov-2012' 100; '15-Nov-2013' 70; '15-Nov-2014' 40; '15-Nov-2015' 10};
```

Compute the price of the amortizing floating-rate note.

```
Price = floatbyzero(RateSpec, Spread, Settle, Maturity, 'Principal', Principal)
```

```
Price =
    100.3059
```

### Specify the Rate at the Instrument's Starting Date When it Cannot be Obtained From the RateSpec

If `Settle` is not on a reset date of a floating-rate note, `floatbyzero` attempts to obtain the latest floating rate before `Settle` from `RateSpec` or the `LatestFloatingRate` parameter. When the reset date for this rate is out of the range of `RateSpec` (and `LatestFloatingRate` is not specified), `floatbyzero` fails to obtain the rate for that date and generates an error. This example shows how to use the `LatestFloatingRate` input parameter to avoid the error.

Create the error condition when a floating-rate instrument's `StartDate` cannot be determined from the `RateSpec`.

```
load deriv.mat;

Spread = 20;
Settle = '01-Jan-2000';
Maturity = '01-Dec-2003';

Price = floatbyzero(ZeroRateSpec, Spread, Settle, Maturity)

Error using floatbyzero (line 256)
The rate at the instrument starting date cannot be obtained from RateSpec.
Its reset date (01-Dec-1999) is out of the range of dates contained in RateSpec.
This rate is required to calculate cash flows at the instrument starting date.
Consider specifying this rate with the 'LatestFloatingRate' input parameter.
```

Here, the reset date for the rate at `Settle` was 01-Dec-1999, which was earlier than the valuation date of `ZeroRateSpec` (01-Jan-2000). This error can be avoided by specifying the rate at the instrument's starting date using the `LatestFloatingRate` name-value pair argument.

Define `LatestFloatingRate` and calculate the floating-rate price.

```
Price = floatbyzero(ZeroRateSpec, Spread, Settle, Maturity, 'LatestFloatingRate', 0.03)

Price =
```

100.0285

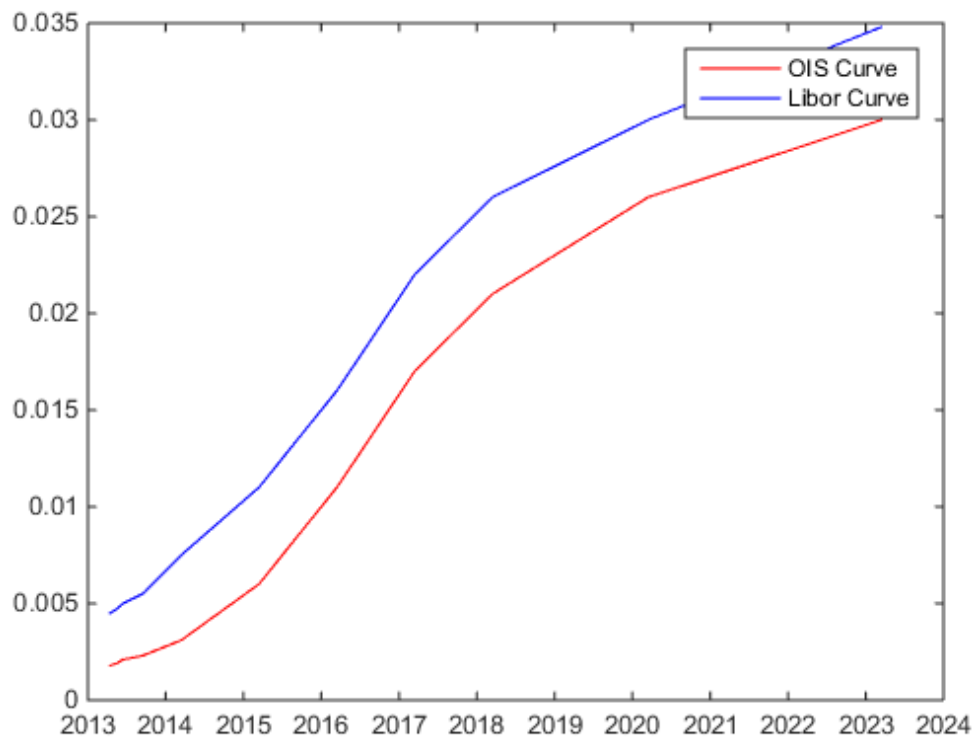
### Price a Floating-Rate Note Using a Different Curve to Generate Floating Cash Flows

Define the OIS and Libor rates.

```
Settle = datenum('15-Mar-2013');
CurveDates = daysadd(Settle,360*[1/12 2/12 3/12 6/12 1 2 3 4 5 7 10],1);
OISRates = [.0018 .0019 .0021 .0023 .0031 .006 .011 .017 .021 .026 .03]';
LiborRates = [.0045 .0047 .005 .0055 .0075 .011 .016 .022 .026 .030 .0348]';
```

Plot the dual curves.

```
figure,plot(CurveDates,OISRates,'r');hold on;plot(CurveDates,LiborRates,'b')
datetick
legend({'OIS Curve', 'Libor Curve'})
```



Create an associated `RateSpec` for the OIS and Libor curves.

```
OISCurve = intenvset('Rates',OISRates,'StartDate',Settle,'EndDates',CurveDates);
LiborCurve = intenvset('Rates',LiborRates,'StartDate',Settle,'EndDates',CurveDates);
```

Define the floating-rate note.

```
SwapMaturity = datenum('15-Mar-2018'); % Five year swap
FloatSpread = 0;
FixedRate = .025;
SwapRates = [FixedRate FloatSpread];
```

Compute the price for the floating-rate note. The `LiborCurve` term structure will be used to generate the floating cash flows of the floater instrument. The `OISCurve` term structure will be used for discounting the cash flows.

```
floatbyzero(OISCurve, 0, Settle, SwapMaturity, 'ProjectionCurve', LiborCurve)
```

```
ans =
```

```
102.4214
```

Some instruments require using different interest-rate curves for generating the floating cash flows and discounting. This is when the `ProjectionCurve` parameter is useful. When you provide both `RateSpec` and `ProjectionCurve`, `floatbyzero` uses the `RateSpec` for the purpose of discounting and it uses the `ProjectionCurve` for generating the floating cash flows.

## See Also

| `bondbyzero` | `cfbyzero` | `fixedbyzero` | `swapbyzero` | `intenvset`

## floorbybdt

Price floor instrument from Black-Derman-Toy interest-rate tree

### Syntax

```
[Price, PriceTree] = floorbybdt(BDTree, Strike, Settle, Maturity,
Reset, Basis, Principal, Options)
```

### Arguments

<b>BDTree</b>	Interest-rate tree structure created by <code>bdttree</code> .
<b>Strike</b>	Number of instruments (NINST)-by-1 vector of rates at which the floor is exercised.
<b>Settle</b>	Settlement date. NINST-by-1 vector of dates representing the settlement dates of the floor. The <b>Settle</b> date for every floor is set to the <b>ValuationDate</b> of the BDT tree. The floor argument <b>Settle</b> is ignored.
<b>Maturity</b>	NINST-by-1 vector of dates representing the maturity dates of the floor.
<b>Reset</b>	(Optional) NINST-by-1 vector representing the frequency of payments per year. Default = 1.
<b>Basis</b>	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> </ul>

	<ul style="list-style-type: none"> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Principal	(Optional) NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid. Default is 100.
Options	(Optional) Derivatives pricing options structure created with derivset.

## Description

[Price, PriceTree] = floorbybdt(BDTree, Strike, Settlement, Maturity, Reset, Basis, Principal, Options) computes the price of a floor instrument from a BDT interest-rate tree.

Price is an NINST-by-1 vector of the expected prices of the floor at time 0.

PriceTree is the tree structure with values of the floor at each node.

---

**Note:** Use the optional name-value pair argument, **Principal**, to pass a schedule to compute price for an amortizing floor.

---

## Examples

### Price a 10% Floor Instrument Using a BDT Interest-Rate Tree

Load the file `deriv.mat`, which provides `BDTree`. `BDTree` contains the time and interest-rate information needed to price the floor instrument.

```
load deriv.mat;
```

Set the required values. Other arguments will use defaults.

```
Strike = 0.10;  
Settle = '01-Jan-2000';  
Maturity = '01-Jan-2004';
```

Use `floorbybdt` to compute the price of the floor instrument.

```
Price = floorbybdt(BDTree, Strike, Settle, Maturity)
```

```
Price =  
  
    0.2428
```

### Price a 10% Floor Instrument Using a Newly Created BDT Interest-Rate Tree

First set the required arguments for the three needed specifications.

```
Compounding = 1;  
ValuationDate = '01-01-2000';  
StartDate = ValuationDate;  
EndDates = ['01-01-2001'; '01-01-2002'; '01-01-2003';  
            '01-01-2004'; '01-01-2005'];  
Rates = [.1; .11; .12; .125; .13];  
Volatility = [.2; .19; .18; .17; .16];
```

Create the specifications.

```
RateSpec = intenvset('Compounding', Compounding,...  
                    'ValuationDate', ValuationDate,...  
                    'StartDates', StartDate,...  
                    'EndDates', EndDates,...  
                    'Rates', Rates);  
BDTTimeSpec = bdttimespec(ValuationDate, EndDates, Compounding);  
BDTVolSpec = bdtvolspec(ValuationDate, EndDates, Volatility);
```

Create the BDT tree from the specifications.

```
BDTree = bdttree(BDTVolSpec, RateSpec, BDTTimeSpec)
```

```
BDTree =
```



```

    FinObj: 'BDTFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
        tObs: [0 1 2 3 4]
        dObs: [730486 730852 731217 731582 731947]
        TFwd: {[5x1 double] [4x1 double] [3x1 double] [2x1 double] [4]}
        CFlowT: {[5x1 double] [4x1 double] [3x1 double] [2x1 double] [5]}
        FwdTree: {1x5 cell}

```

Set the floor arguments. Remaining arguments will use defaults.

```

FloorStrike = 0.10;
Settlement = ValuationDate;
Maturity = '01-01-2002';
FloorReset = 1;

```

Use floorbybdt to find the price of the floor instrument.

```

Price= floorbybdt(BDTree, FloorStrike, Settlement, Maturity,...
FloorReset)

```

```

Price =

    0.0863

```

### Compute the Price of an Amortizing Floor Using the BDT Model

Define the RateSpec.

```

Rates = [0.03583; 0.042147; 0.047345; 0.052707; 0.054302];
ValuationDate = '15-Nov-2011';
StartDates = ValuationDate;
EndDates = {'15-Nov-2012'; '15-Nov-2013'; '15-Nov-2014' ; '15-Nov-2015'; '15-Nov-2016'};
Compounding = 1;
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)

```

```

RateSpec =

    FinObj: 'RateSpec'

```

```
Compounding: 1
  Disc: [5x1 double]
  Rates: [5x1 double]
  EndTimes: [5x1 double]
  StartTimes: [5x1 double]
  EndDates: [5x1 double]
  StartDates: 734822
ValuationDate: 734822
  Basis: 0
EndMonthRule: 1
```

Define the floor instrument.

```
Settle = '15-Nov-2011';
Maturity = '15-Nov-2015';
Strike = 0.039;
Reset = 1;
Principal = {'15-Nov-2012' 100; '15-Nov-2013' 70; '15-Nov-2014' 40; '15-Nov-2015' 10};
```

Build the BDT Tree.

```
BDTTimeSpec = bdttimespec(ValuationDate, EndDates);
Volatility = 0.10;
BDTVolSpec = bdtvolspec(ValuationDate, EndDates, Volatility*ones(1,length(EndDates)))
BDTTree = bdttree(BDTVolSpec, RateSpec, BDTTimeSpec)
```

BDTTree =

```
  FinObj: 'BDTFwdTree'
  VolSpec: [1x1 struct]
  TimeSpec: [1x1 struct]
  RateSpec: [1x1 struct]
    tObs: [0 1 2 3 4]
    dObs: [734822 735188 735553 735918 736283]
    TFwd: {[5x1 double] [4x1 double] [3x1 double] [2x1 double] [4]}
    CFlowT: {[5x1 double] [4x1 double] [3x1 double] [2x1 double] [5]}
    FwdTree: {1x5 cell}
```

Price the amortizing floor.

```
Basis = 0;
Price = floorbybdt(BDTTree, Strike, Settle, Maturity, Reset, Basis, Principal)
```

Price =

0.3060

## More About

- “Pricing Options Structure”

## See Also

bdttree | capbybdt | cfbybdt | swapbybdt

## floorbybk

Price floor instrument from Black-Karasinski interest-rate tree

### Syntax

```
[Price, PriceTree] = floorbybk(BKTree, Strike, Settle, Maturity,
Reset, Basis, Principal, Options)
```

### Arguments

<b>BKTree</b>	Interest-rate tree structure created by <code>bktree</code> .
<b>Strike</b>	Number of instruments (NINST)-by-1 vector of rates at which the floor is exercised.
<b>Settle</b>	Settlement date. NINST-by-1 vector of dates representing the settlement dates of the floor. The <b>Settle</b> date for every floor is set to the <b>ValuationDate</b> of the BK tree. The floor argument <b>Settle</b> is ignored.
<b>Maturity</b>	NINST-by-1 vector of dates representing the maturity dates of the floor.
<b>Reset</b>	(Optional) NINST-by-1 vector representing the frequency of payments per year. Default = 1.
<b>Basis</b>	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> </ul>

	<ul style="list-style-type: none"> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Principal	(Optional) NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid. Default is 100.
Options	(Optional) Derivatives pricing options structure created with derivset.

## Description

[Price, PriceTree] = floorbybk(BKTree, Strike, Settlement, Maturity, Reset, Basis, Principal, Options) computes the price of a floor instrument from a Black-Karasinski tree.

Price is an NINST-by-1 vector of the expected prices of the floor at time 0.

PriceTree is the tree structure with values of the floor at each node.

---

**Note:** Use the optional name-value pair argument, **Principal**, to pass a schedule to compute price for an amortizing floor.

---

## Examples

### Price a 3% Floor Instrument Using a Black-Karasinski Interest-Rate Tree

Load the file `deriv.mat`, which provides `BKTree`. The `BKTree` structure contains the time and interest rate information needed to price the floor instrument.

```
load deriv.mat;
```

Set the required values. Other arguments will use defaults.

```
Strike = 0.03;  
Settle = '01-Jan-2004';  
Maturity = '01-Jan-2007';
```

Use `floorbybk` to compute the price of the floor instrument.

```
Price = floorbybk(BKTree, Strike, Settle, Maturity)
```

```
Price =  
  
    0.2061
```

### Compute the Price of an Amortizing and Vanilla Floors Using the BK Model

Load `deriv.mat` to specify the `BKTree` and then define the floor instrument.

```
load deriv.mat;  
Settle = '01-Jan-2004';  
Maturity = '01-Jan-2008';  
Strike = 0.045;  
Reset = 1;  
Principal ={{'01-Jan-2005' 100;'01-Jan-2006' 60;'01-Jan-2007' 30;'01-Jan-2008' 30};...  
           100};
```

Price the amortizing and vanilla floors.

```
Basis = 1;  
Price = floorbybk(BKTree, Strike, Settle, Maturity, Reset, Basis, Principal)
```

```
Price =  
  
    2.2000  
    2.5564
```

## More About

- “Pricing Options Structure”

## **See Also**

bktree | capbybk | cfbybk | swapbybk

## floorbyblk

Price floors using Black option pricing model

### Syntax

```
[FloorPrice, Floorlets] = floorbyblk(RateSpec, Strike, Settle,
Maturity, Volatility)
```

```
[FloorPrice, Floorlets] = floorbyblk(RateSpec, Strike, Settle,
Maturity, Volatility, 'Name1', Value1...)
```

### Arguments

RateSpec	The annualized, continuously compounded rate term structure. For more information, see <code>intenvset</code> .
Strike	NINST-by-1 vector of rates at which the floor is exercised, as a decimal number.
Settle	Scalar representing the settle date of the floor.
Maturity	Scalar representing the maturity date of the floor.
Volatility	NINST-by-1 vector of volatilities.
Reset	(Optional) NINST-by-1 vector representing the frequency of payments per year. Default is 1.
Principal	(Optional) NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid. Default is 100.
Basis	(Optional) NINST-by-1 vector representing the basis used when annualizing the input forward rate. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> </ul>



	<ul style="list-style-type: none"> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<b>ValuationDate</b>	(Optional) Scalar representing the observation date of the investment horizons. The default is the <b>Settle</b> date.
<b>ProjectionCurve</b>	(Optional) The rate curve to be used in generating the future forward rates. This structure must be created using <b>intenvset</b> . Use this optional input if the forward curve is different from the discount curve. If <b>ProjectionCurve</b> is not specified, then <b>RateSpec</b> is used both for discounting cash flows and projecting future forward rates.

---

**Note:** All optional inputs are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. You can specify parameter name/value pairs in any order. Names are case-insensitive and partial string matches are allowed provided no ambiguities exist.

---

## Description

[FloorPrice, Floorlets] = floorbyblk(RateSpec, Strike, Settle, Maturity, Volatility) to price floors using the Black option pricing model.

[FloorPrice, Floorlets] = floorbyblk(RateSpec, Strike, Settle, Maturity, Volatility, 'Name1', Value1...) to price floors using the Black option pricing model with optional name-value pair arguments.

The outputs `floorbyblk` for are:

- `FloorPrice` — NINST-by-1 expected prices of the floor.
- `Floorlets` — NINST-by-NCF array of floorlets, padded with NaNs.

---

**Note:** Use the optional name-value pair argument, `Principal`, to pass a schedule to compute price for an amortizing floor.

---

## Examples

### Price a Floor Using the Black Option Pricing Model

This example shows how to price a floor using the Black option pricing model. Consider an investor who gets into a contract that floors the interest rate on a \$100,000 loan at 6% quarterly compounded for 3 months, starting on January 1, 2009. Assuming that on January 1, 2008 the zero rate is 6.9394% continuously compounded and the volatility is 20%, use this data to compute the floor price.

```
ValuationDate = 'Jan-01-2008';
EndDates = 'April-01-2010';
Rates = 0.069394;
Compounding = -1;
Basis = 1;

% calculate the RateSpec
RateSpec = intenvset('ValuationDate', ValuationDate, ...
    'StartDates', ValuationDate, 'EndDates', EndDates, ...
    'Rates', Rates, 'Compounding', Compounding, 'Basis', Basis);

Settle = 'Jan-01-2009'; % floor starts in a year
Maturity = 'April-01-2009';
Volatility = 0.20;
FloorRate = 0.06;
FloorReset = 4;
Principal=100000;

FloorPrice = floorbyblk(RateSpec, FloorRate, Settle, Maturity, Volatility,...
    'Reset', FloorReset, 'ValuationDate', ValuationDate, 'Principal', Principal,...
    'Basis', Basis)
```

```
FloorPrice =
```

```
    37.4864
```

### Price a Floor Using a Different Curve to Generate the Future Forward Rates

Define the OIS and Libor rates.

```
Settle = datenum('15-Mar-2013');
CurveDates = daysadd(Settle,360*[1/12 2/12 3/12 6/12 1 2 3 4 5 7 10],1);
OISRates = [.0018 .0019 .0021 .0023 .0031 .006 .011 .017 .021 .026 .03]';
LiborRates = [.0045 .0047 .005 .0055 .0075 .0109 .0162 .0216 .0262 .0309 .0348]';
```

Create an associated RateSpec for the OIS and Libor curves.

```
OISCurve = intenvset('Rates',OISRates,'StartDate',Settle,'EndDates',CurveDates,'Compounding',0);
LiborCurve = intenvset('Rates',LiborRates,'StartDate',Settle,'EndDates',CurveDates,'Compounding',0);
```

Define the Floor instruments.

```
Maturity = {'15-Mar-2018';'15-Mar-2020'};
Strike = [.04;.05];
BlackVol = .2;
```

Price the floor instruments using the term structure OISCurve both for discounting the cash flows and generating future forward rates.

```
[Price, Floorlets] = floorbyblk(OISCurve, Strike, Settle, Maturity, BlackVol)
```

```
Price =
```

```
    9.9808
   16.9057
```

```
Floorlets =
```

```
    3.6783    3.0706    1.8275    0.7280    0.6764         NaN         NaN
    4.6753    4.0587    2.7921    1.4763    1.3442    1.4130    1.1462
```

Price the floor instruments using the term structure LiborCurve to generate future forward rates. The term structure OISCurve is used for discounting the cash flows.

```
[PriceLC, FloorletsLC] = floorbyblk(OISCurve, Strike, Settle, Maturity, BlackVol, 'Proj
```

```
PriceLC =
```

```
8.0524
14.3184
```

```
FloorletsLC =
```

```
3.2385 2.5338 1.2895 0.5889 0.4017 NaN NaN
4.2355 3.5219 2.2286 1.2751 0.9169 1.1698 0.9706
```

### Compute the Price of an Amortizing Floor Using the Black Model

Define the RateSpec.

```
Rates = [0.0358; 0.0421; 0.0473; 0.0527; 0.0543];
ValuationDate = '15-Nov-2011';
StartDates = ValuationDate;
EndDates = {'15-Nov-2012'; '15-Nov-2013'; '15-Nov-2014'; '15-Nov-2015'; '15-Nov-2016'};
Compounding = 1;
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```
FinObj: 'RateSpec'
Compounding: 1
Disc: [5x1 double]
Rates: [5x1 double]
EndTimes: [5x1 double]
StartTimes: [5x1 double]
EndDates: [5x1 double]
StartDates: 734822
ValuationDate: 734822
Basis: 0
EndMonthRule: 1
```

Define the floor instrument.

```
Settle = '15-Nov-2011';
```

```
Maturity = '15-Nov-2015';  
Strike = 0.05;  
Reset = 2;  
Principal ={{'15-Nov-2012' 100;'15-Nov-2013' 70;'15-Nov-2014' 40;'15-Nov-2015' 10}};
```

Price the amortizing floor.

```
Volatility = 0.20;  
Price = floorbyblk(RateSpec, Strike, Settle, Maturity, Volatility,...  
'Reset',Reset,'Principal', Principal)
```

Price =

1.9315

## See Also

capbyblk | intenvset

## floorbyhjm

Price floor instrument from Heath-Jarrow-Morton interest-rate tree

### Syntax

```
[Price, PriceTree] = floorbyhjm(HJMTree, Strike, Settle, Maturity,
Reset, Basis, Principal, Options)
```

### Arguments

HJMTree	Forward-rate tree structure created by <code>hjmtree</code> .
Strike	Number of instruments (NINST)-by-1 vector of rates at which the floor is exercised.
Settle	Settlement date. NINST-by-1 vector of dates representing the settlement dates of the floor. The <b>Settle</b> date for every floor is set to the <b>ValuationDate</b> of the HJM tree. The floor argument <b>Settle</b> is ignored.
Maturity	NINST-by-1 vector of dates representing the maturity dates of the floor.
Reset	(Optional) NINST-by-1 vector representing the frequency of payments per year. Default = 1.
Basis	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> </ul>

	<ul style="list-style-type: none"> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Principal	(Optional) NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid. Default is 100.
Options	(Optional) Derivatives pricing options structure created with derivset.

## Description

[Price, PriceTree] = floorbyhjm(HJMTree, Strike, Settlement, Maturity, Reset, Basis, Principal, Options) computes the price of a floor instrument from an HJM tree.

Price is an NINST-by-1 vector of the expected prices of the floor at time 0.

PriceTree is the tree structure with values of the floor at each node.

---

**Note:** Use the optional name-value pair argument, **Principal**, to pass a schedule to compute price for an amortizing floor.

---

## Examples

### Price a 3% Floor Instrument Using an HJM Forward-Rate Tree

This example shows how to price a 3% floor instrument using an HJM forward-rate tree by loading the file `deriv.mat`, which provides `HJMTree`. The `HJMTree` structure contains the time and forward-rate information needed to price the floor instrument.

```
load deriv.mat;

Strike = 0.03;
Settle = '01-Jan-2000';
Maturity = '01-Jan-2004';

Price = floorbyhjm(HJMTree, Strike, Settle, Maturity)

Price =

    0.0486
```

### Compute the Price of an Amortizing Floor Using the HJM Model

Load `deriv.mat` to specify the `HJMTree` and then define the floor instrument.

```
load deriv.mat;
Settle = '01-Jan-2000';
Maturity = '01-Jan-2004';
Strike = 0.05;
Reset = 1;
Principal = {'01-Jan-2001' 100; '01-Jan-2002' 80; '01-Jan-2003' 70; '01-Jan-2004' 30};

Price the amortizing floor.

Price = floorbyhjm(HJMTree, Strike, Settle, Maturity, Reset, Principal)

Price =

    2.8215
```

## More About

- “Pricing Options Structure”

## See Also

`capbyhjm` | `cfbyhjm` | `hjmTree` | `swapbyhjm`



# floorbyhw

Price floor instrument from Hull-White interest-rate tree

## Syntax

```
[Price, PriceTree] = floorbyhw(HWTree, Strike, Settle, Maturity,
Reset, Basis, Principal, Options)
```

## Arguments

<b>HWTree</b>	Interest-rate tree structure created by <code>hwtree</code> .
<b>Strike</b>	Number of instruments (NINST)-by-1 vector of rates at which the floor is exercised.
<b>Settle</b>	Settlement date. NINST-by-1 vector of dates representing the settlement dates of the floor. The <b>Settle</b> date for every floor is set to the <b>ValuationDate</b> of the HW tree. The floor argument <b>Settle</b> is ignored.
<b>Maturity</b>	NINST-by-1 vector of dates representing the maturity dates of the floor.
<b>Reset</b>	(Optional) NINST-by-1 vector representing the frequency of payments per year. Default = 1.
<b>Basis</b>	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> </ul>

	<ul style="list-style-type: none"> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Principal	(Optional) NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid. Default is 100.
Options	(Optional) Derivatives pricing options structure created with derivset.

## Description

[Price, PriceTree] = floorbyhw(HWTree, Strike, Settlement, Maturity, Reset, Basis, Principal, Options) computes the price of a floor instrument from an HW tree.

Price is an NINST-by-1 vector of the expected prices of the floor at time 0.

PriceTree is the tree structure with values of the floor at each node.

---

**Note:** Use the optional name-value pair argument, **Principal**, to pass a schedule to compute price for an amortizing floor.

---

## Examples

### Price a 3% Floor Instrument Using a Hull-White Interest-Rate Tree

Load the file `deriv.mat`, which provides `HWTree`. The `HWTree` structure contains the time and interest rate information needed to price the floor instrument.

```
load deriv.mat;
```

Set the required values. Other arguments will use defaults.

```
Strike = 0.03;
Settle = '01-Jan-2004';
Maturity = '01-Jan-2007';
```

Use floorbyhw to compute the price of the floor instrument.

```
Price = floorbyhw(HWTree, Strike, Settle, Maturity)
```

```
Price =
    0.4186
```

### Compute the Price of an Amortizing and Vanilla Floors Using the HW Model

Define the RateSpec.

```
Rates = [0.035; 0.042; 0.047; 0.052; 0.054];
ValuationDate = '01-April-2014';
StartDates = ValuationDate;
EndDates = {'01-April-2019'};
Compounding = 1;
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
    FinObj: 'RateSpec'
    Compounding: 1
    Disc: [5x1 double]
    Rates: [5x1 double]
    EndTimes: [5x1 double]
    StartTimes: [5x1 double]
    EndDates: 737516
    StartDates: 735690
    ValuationDate: 735690
    Basis: 0
    EndMonthRule: 1
```

Define the floor instruments.

```
Settle = '01-April-2014';
Maturity = '01-April-2018';
Strike = 0.05;
Reset = 1;
Principal = {{ '01-April-2015' 100; '01-April-2016' 60; '01-April-2017' 40; '01-April-2018'
              100};
```

Build the HW Tree.

```
VolDates = [ '01-April-2015'; '01-April-2016'; '01-April-2017'; '01-April-2018' ];
VolCurve = 0.05;
AlphaDates = '01-April-2018';
AlphaCurve = 0.10;
```

```
HWVolSpec = hwwolspec(RateSpec.ValuationDate, VolDates, VolCurve, ...
                    AlphaDates, AlphaCurve);
HWTTimeSpec = hwtimespec(RateSpec.ValuationDate, VolDates, Compounding);
HWTTree = hwtree(HWVolSpec, RateSpec, HWTTimeSpec)
```

HWTTree =

```
    FinObj: 'HWFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
      tObs: [0 1 2 3]
      dObs: [735690 736055 736421 736786]
    CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4]}
    Probs: {[3x1 double] [3x3 double] [3x5 double]}
    Connect: {[2] [2 3 4] [2 2 3 4 4]}
    FwdTree: {[1.0350] [1.1252 1.0362 0.9542] [1x5 double] [1x5 double]}
```

Price the amortizing and vanilla floors.

```
Basis = 0;
Price = floorbyhw(HWTTree, Strike, Settle, Maturity, Reset, Basis, Principal)
```

Price =

```
    4.7756
```

10.1441

## **More About**

- “Pricing Options Structure”

## **See Also**

capbyhw | cfbyhw | hwtree | swapbyhw

## floorbylg2f

Price floor using Linear Gaussian two-factor model

### Syntax

```
FloorPrice = floorbylg2f(ZeroCurve,a,b,sigma,eta,rho,Strike,  
Maturity)  
FloorPrice = floorbylg2f( ____,Name,Value)
```

### Description

FloorPrice = floorbylg2f(ZeroCurve,a,b,sigma,eta,rho,Strike,  
Maturity) returns the floor price for a two-factor additive Gaussian interest-rate model.

FloorPrice = floorbylg2f( \_\_\_\_,Name,Value) returns the floor price for a two-factor additive Gaussian interest-rate model using optional name-value pairs.

---

**Note:** Use the optional name-value pair argument, Notional, to pass a schedule to compute the price for an amortizing floor.

---

### Examples

#### Price a Floor Using a Linear Gaussian Two-Factor Model

Define the ZeroCurve, a, b, sigma, eta, and rho parameters to compute the floor price.

```
Settle = datenum('15-Dec-2007');  
  
ZeroTimes = [3/12 6/12 1 5 7 10 20 30]';  
ZeroRates = [0.033 0.034 0.035 0.040 0.042 0.044 0.048 0.0475]';  
CurveDates = daysadd(Settle,360*ZeroTimes,1);  
  
irdc = IRDataCurve('Zero',Settle,CurveDates,ZeroRates);
```

```

a = .07;
b = .5;
sigma = .01;
eta = .006;
rho = -.7;

FloorMaturity = daysadd(Settle,360*[1:5 7 10 15 20 25 30],1);

Strike = [0.035 0.037 0.038 0.039 0.040 0.042 0.044 0.046 0.047 0.047 0.047]';

Price = floorbylg2f(irdc,a,b,sigma,eta,rho,Strike,FloorMaturity)

Price =

    0
    0.4041
    0.8282
    1.3103
    1.8346
    3.0636
    4.9172
    7.7614
    9.7166
    11.4163
    12.7628

```

### Price an Amortizing Floor Using a Linear Gaussian Two-Factor Model

Define the ZeroCurve, a, b, sigma, eta, rho, and Notional parameters for the amortizing floor.

```

Settle = datenum('15-Dec-2007');
% Define ZeroCurve
ZeroTimes = [3/12 6/12 1 5 7 10 20 30]';
ZeroRates = [0.033 0.034 0.035 0.040 0.042 0.044 0.048 0.0475]';
CurveDates = daysadd(Settle,360*ZeroTimes);

irdc = IRDataCurve('Zero',Settle,CurveDates,ZeroRates);

% Define a, b, sigma, eta, and rho
a = .07;
b = .5;
sigma = .01;

```

```
eta = .006;
rho = -.7;

% Define the amortizing floors
FloorMaturity = daysadd(Settle,360*[1:5 7 10 15 20 25 30],1);
Strike = [0.025 0.036 0.037 0.038 0.039 0.041 0.043 0.045 0.046 0.046 0.046]';
Notional = {'15-Dec-2012' 100; '15-Dec-2017' 70; '15-Dec-2022' 40; '15-Dec-2037' 10}';

% Price the amortizing floors
Price = floorbylg2f(irdc,a,b,sigma,eta,rho,Strike,FloorMaturity,'Notional',Notional)

Price =

    0
    0.2633
    0.6438
    1.0815
    1.5637
    2.5196
    3.9061
    5.4326
    6.0416
    6.2033
    6.3316
```

## Input Arguments

### **ZeroCurve** — Zero curve for Linear Gaussian two-factor model

structure

Zero curve for the Linear Gaussian two-factor model, specified using `IRDataCurve` or `RateSpec`.

Data Types: `struct`

### **a** — Mean reversion for first factor for Linear Gaussian two-factor model

scalar

Mean reversion for the first factor for the Linear Gaussian two-factor model, specified as a scalar.



Data Types: `single` | `double`

**b — Mean reversion for second factor for Linear Gaussian two-factor model**

scalar

Mean reversion for the second factor for the Linear Gaussian two-factor model, specified as a scalar.

Data Types: `single` | `double`

**sigma — Volatility for first factor for Linear Gaussian two-factor model**

scalar

Volatility for the first factor for the Linear Gaussian two-factor model, specified as a scalar.

Data Types: `single` | `double`

**eta — Volatility for second factor for Linear Gaussian two-factor model**

scalar

Volatility for the second factor for the Linear Gaussian two-factor model, specified as a scalar.

Data Types: `single` | `double`

**rho — Scalar correlation of factors**

scalar

Scalar correlation of the factors, specified as a scalar.

Data Types: `single` | `double`

**Strike — Floor strike price**

nonnegative integer | vector of nonnegative integers

Floor strike price specified, as a nonnegative integer using a `NumFloors-by-1` vector of floor strike prices.

Data Types: `single` | `double`

**Maturity — Floor maturity date**

nonnegative integer | vector of nonnegative integers | string of dates

Floor maturity date, specified using a NumFloors-by-1 vector of serial date numbers or date strings.

Data Types: `single` | `double` | `cell`

## Name-Value Pair Arguments

Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes ( ' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

Example: `Price =`

```
floorbylg2f(irdc,a,b,sigma,eta,rho,Strike,FloorMaturity,'Reset',1,'Notional',1
```

### 'Reset' — Frequency of floor payments per year

2 (default) | positive integer from the set [1,2,3,4,6,12] | vector of positive integers from the set [1,2,3,4,6,12]

Frequency of floor payments per year, specified as positive integers for the values [1,2,4,6,12] in a NumFloors-by-1 vector.

Data Types: `single` | `double`

### 'Notional' — Notional value of floor

100 (default) | nonnegative integer | vector of nonnegative integers

NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is the associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: `single` | `double`

## Output Arguments

### FloorPrice — Floor price

scalar | vector

Floor price, returned as a scalar or a NumFloors-by-1 vector.

## More About

### Algorithms

The following defines the two-factor additive Gaussian interest-rate model, given the ZeroCurve, a, b, sigma, eta, and rho parameters:

$$r(t) = x(t) + y(t) + \phi(t)$$

$$dx(t) = -a(x)(t)dt + \sigma(dW_1(t), x(0) = 0$$

$$dy(t) = -b(y)(t)dt + \eta(dW_2(t), y(0) = 0$$

where  $dW_1(t)dW_2(t) = \rho dt$  is a two-dimensional Brownian motion with correlation  $\rho$  and  $\phi$  is a function chosen to match the initial zero curve.

### References

- [1] Brigo, D. and F. Mercurio, *Interest Rate Models - Theory and Practice*, Springer Finance, 2006.

### See Also

LinearGaussian2F | capbylg2f | swaptionbylg2f

## gapbybls

Determine price of gap digital options using Black-Scholes model

### Syntax

```
Price = gapbybls(RateSpec, StockSpec, Settle, Maturity,  
OptSpec, Strike, StrikeThreshold)
```

### Arguments

RateSpec	The annualized, continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of payoff strike price values.
StrikeThreshold	NINST-by-1 vector of strike values that determine if the option pays off.

### Description

`Price = gapbybls(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike, StrikeThreshold)` computes gap option prices using the Black-Scholes option pricing model.

`Price` is a NINST-by-1 vector of expected option prices.

## Examples

### Compute Gap Option Prices Using the Black-Scholes Option Pricing Model

This example shows how to compute gap option prices using the Black-Scholes option pricing model. Consider a gap call and put options on a nondividend paying stock with a strike of 57 and expiring on January 1, 2008. On July 1, 2008 the stock is trading at 50. Using this data, compute the price of the option if the risk-free rate is 9%, the strike threshold is 50, and the volatility is 20%.

```
Settle = 'Jan-1-2008';
Maturity = 'Jul-1-2008';
Compounding = -1;
Rates = 0.09;
% calculate the RateSpec
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
    'EndDates', Maturity, 'Rates', Rates, 'Compounding', Compounding, 'Basis', 1);
% define the StockSpec
AssetPrice = 50;
Sigma = .2;
StockSpec = stockspec(Sigma, AssetPrice);
% define the call and put options
OptSpec = {'call'; 'put'};
Strike = 57;
StrikeThreshold = 50;
% calculate the price
Pgap = gapbybls(RateSpec, StockSpec, Settle, Maturity, OptSpec,...
    Strike, StrikeThreshold)
```

```
Pgap =
```

```
-0.0053
 4.4866
```

### See Also

assetbybls | cashbybls | gapsensbybls | supersharebybls

## gapsensbybls

Determine price and sensitivities of gap digital options using Black-Scholes model

### Syntax

```
PriceSens = gapsensbybls(RateSpec, StockSpec, Settle,
Maturity, OptSpec, Strike, StrikeThreshold)
PriceSens = gapsensbybls(RateSpec, StockSpec, Settle,
Maturity, OptSpec, Strike, StrikeThreshold, OutSpec)
```

### Arguments

RateSpec	The annualized, continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.
StrikeThreshold	NINST-by-1 vector of strike values that determine if the option pays off.
OutSpec	(Optional) All optional inputs are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. You can specify parameter name/value pairs may in any order. Names are case-insensitive and partial string matches are allowed provided no ambiguities exist. Valid parameter names are: <ul style="list-style-type: none"> <li>• NOUT-by-1 or 1-by-NOUT cell array of strings indicating the nature and order of the outputs for the function. Possible values are 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', or 'All'.</li> </ul>

For example, `OutSpec = {'Price'; 'Lambda'; 'Rho'}` specifies that the output should be Price, Lambda, and Rho, in that order.

To invoke from a function: `[Price, Lambda, Rho] = gapsensbybls(..., 'OutSpec', {'Price', 'Lambda', 'Rho'})`

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec = {'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', 'Price'}`;

- Default is `OutSpec = {'Price'}`.

## Description

`PriceSens = gapsensbybls(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike, StrikeThreshold)` computes gap option prices using the Black-Scholes option pricing model.

`PriceSens = gapsensbybls(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike, StrikeThreshold, OutSpec)` includes an `OutSpec` argument defined as parameter/value pairs, and computes gap option prices and sensitivities using the Black-Scholes option pricing model.

`PriceSens` is a NINST-by-1 vector of expected option prices and sensitivities.

## Examples

### Compute Gap Option Prices and Sensitivities Using the Black-Scholes Option Pricing Model

This example shows how to compute gap option prices and sensitivities using the Black-Scholes option pricing model. Consider a gap call and put options on a nondividend paying stock with a strike of 57 and expiring on January 1, 2008. On July 1, 2008 the stock is trading at 50. Using this data, compute the price and sensitivity of the option if the risk-free rate is 9%, the strike threshold is 50, and the volatility is 20%.

```
Settle = 'Jan-1-2008';
Maturity = 'Jul-1-2008';
Compounding = -1;
Rates = 0.09;
%create the RateSpec
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
    'EndDates', Maturity, 'Rates', Rates, 'Compounding', Compounding, 'Basis', 1);
% define the StockSpec
AssetPrice = 50;
Sigma = .2;
StockSpec = stockspec(Sigma, AssetPrice);
% define the call and put options
OptSpec = {'call'; 'put'};
Strike = 57;
StrikeThreshold = 50;
% compute the price
Pgap = gapbybls(RateSpec, StockSpec, Settle, Maturity, OptSpec,...
    Strike, StrikeThreshold)
% compute the gamma and delta
OutSpec = {'gamma'; 'delta'};
[Gamma ,Delta] = gapsensbybls(RateSpec, StockSpec, Settle, Maturity,...
    OptSpec, Strike, StrikeThreshold, 'OutSpec', OutSpec)
```

Pgap =

```
-0.0053
 4.4866
```

Gamma =

```
0.0724
0.0724
```

Delta =

```
0.2852
-0.7148
```

**See Also**  
gapbybls



# hedgeopt

Allocate optimal hedge for target costs or sensitivities

## Syntax

```
[PortSens, PortCost, PortHolds] = hedgeopt(Sensitivities,
Price, CurrentHolds, FixedInd, NumCosts, TargetCost,
TargetSens, ConSet)
```

## Arguments

Sensitivities	Number of instruments (NINST) by number of sensitivities (NSENS) matrix of dollar sensitivities of each instrument. Each row represents a different instrument. Each column represents a different sensitivity.
Price	NINST-by-1 vector of portfolio instrument unit prices.
CurrentHolds	NINST-by-1 vector of contracts allocated to each instrument.
FixedInd	(Optional) Number of fixed instruments (NFIXED)-by-1 vector of indices of instruments to hold fixed. For example, to hold the first and third instruments of a 10 instrument portfolio unchanged, set <code>FixedInd = [1 3]</code> . Default = <code>[]</code> , no instruments held fixed.
NumCosts	(Optional) Number of points generated along the cost frontier when a vector of target costs ( <code>TargetCost</code> ) is not specified. The default is 10 equally spaced points between the point of minimum cost and the point of minimum exposure. When specifying <code>TargetCost</code> , enter <code>NumCosts</code> as an empty matrix <code>[]</code> .
TargetCost	(Optional) Vector of target cost values along the cost frontier. If <code>TargetCost</code> is empty, or not entered, <code>hedgeopt</code> evaluates <code>NumCosts</code> equally spaced target costs between the minimum cost and minimum exposure. When specified, the elements of <code>TargetCost</code> should be positive numbers that represent the

	maximum amount of money the owner is willing to spend to rebalance the portfolio.
TargetSens	(Optional) 1-by-NSENS vector containing the target sensitivity values of the portfolio. When specifying TargetSens, enter NumCosts and TargetCost as empty matrices [ ].
ConSet	(Optional) Number of constraints (NCONS) by number of instruments (NINST) matrix of additional conditions on the portfolio reallocations. An eligible NINST-by-1 vector of contract holdings, PortWts, satisfies all the inequalities $A * PortWts \leq b$ , where $A = ConSet(:, 1:end-1)$ and $b = ConSet(:, end)$ .

**Notes** The user-specified constraints included in ConSet may be created with the functions pcalims or portcons. However, the portcons default PortHolds positivity constraints are typically inappropriate for hedging problems since short-selling is usually required.

NPOINTS, the number of rows in PortSens and PortHolds and the length of PortCost, is inferred from the inputs. When the target sensitivities, TargetSens, is entered, NPOINTS = 1; otherwise NPOINTS = NumCosts, or is equal to the length of the TargetCost vector.

Not all problems are solvable (for example, the solution space may be infeasible or unbounded, or the solution may fail to converge). When a valid solution is not found, the corresponding rows of PortSens and PortHolds and the elements of PortCost are padded with NaNs as placeholders.

## Description

[PortSens, PortCost, PortHolds] = hedgeopt(Sensitivities, Price, CurrentHolds, FixedInd, NumCosts, TargetCost, TargetSens, ConSet) allocates an optimal hedge by one of two criteria:

- Minimize portfolio sensitivities (exposure) for a given set of target costs.
- Minimize the cost of hedging a portfolio given a set of target sensitivities.

Hedging involves the fundamental tradeoff between portfolio insurance and the cost of insurance coverage. This function lets investors modify portfolio allocations among

instruments to achieve either of the criteria. The chosen criterion is inferred from the input argument list. The problem is cast as a constrained linear least-squares problem.

**PortSens** is a number of points (**NPOINTS**)-by-**NSENS** matrix of portfolio sensitivities. When a perfect hedge exists, **PortSens** is zeros. Otherwise, the best hedge possible is chosen.

**PortCost** is a 1-by-**NPOINTS** vector of total portfolio costs.

**PortHolds** is an **NPOINTS**-by-**NINST** matrix of contracts allocated to each instrument. These are the reallocated portfolios.

### **See Also**

hedgeslf | pcalims | portcons | portopt | lsqlin

## hedgeslf

Self-financing hedge

### Syntax

```
[PortSens, PortValue, PortHolds] = hedgeslf(Sensitivities,  
Price, CurrentHolds, FixedInd, ConSet)
```

### Arguments

Sensitivities	Number of instruments (NINST) by number of sensitivities (NSENS) matrix of dollar sensitivities of each instrument. Each row represents a different instrument. Each column represents a different sensitivity.
Price	NINST-by-1 vector of instrument unit prices.
CurrentHolds	NINST-by-1 vector of contracts allocated in each instrument.
FixedInd	(Optional) Empty or number of fixed instruments (NFIXED)-by-1 vector of indices of instruments to hold fixed. The default is <code>FixedInd = 1</code> ; the holdings in the first instrument are held fixed. If NFIXED instruments will not be changed, enter all their locations in the portfolio in a vector. If no instruments are to be held fixed, enter <code>FixedInd = []</code> .
ConSet	(Optional) Number of constraints (NCONS)-by-NINST matrix of additional conditions on the portfolio reallocations. An eligible NINST-by-1 vector of contract holdings, <code>PortHolds</code> , satisfies all the inequalities $A * PortHolds \leq b$ , where $A = ConSet(:, 1:end-1)$ and $b = ConSet(:, end)$ .

### Description

```
[PortSens, PortValue, PortHolds] = hedgeslf(Sensitivities,
```

`Price`, `CurrentHolds`, `FixedInd`, `ConSet`) allocates a self-financing hedge among a collection of instruments. `hedgeslf` finds the reallocation in a portfolio of financial instruments that hedges the portfolio against market moves and that is closest to being self-financing (maintaining constant portfolio value). By default the first instrument entered is hedged with the other instruments.

`PortSens` is a 1-by-`NSENS` vector of portfolio dollar sensitivities. When a perfect hedge exists, `PortSens` is zeros. Otherwise, the best possible hedge is chosen.

`PortValue` is the total portfolio value (scalar). When a perfectly self-financing hedge exists, `PortValue` is equal to `dot(Price, CurrentWts)` of the initial portfolio.

`PortHolds` is an `NINST`-by-1 vector of contracts allocated to each instrument. This is the reallocated portfolio.

---

## Notes

- The constraints `PortHolds(FixedInd) = CurrentHolds(FixedInd)` are appended to any constraints passed in `ConSet`. Pass `FixedInd = []` to specify all constraints through `ConSet`.
  - The default constraints generated by `portcons` are inappropriate, since they require the sum of all holdings to be positive and equal to one.
  - `hedgeslf` first tries to find the allocations of the portfolio that make it closest to being self-financing, while reducing the sensitivities to 0. If no solution is found, it finds the allocations that minimize the sensitivities. If the resulting portfolio is self-financing, `PortValue` is equal to the value of the original portfolio.
- 

## Examples

**Example 1.** Perfect sensitivity cannot be reached.

```
Sens = [0.44 0.32; 1.0 0.0];
Price = [1.2; 1.0];
WO = [1; 1];
[PortSens, PortValue, PortHolds]= hedgeslf(Sens, Price, WO)

PortSens =

    0.0000
```

```

    0.3200
PortValue =
    0.7600
PortHolds =
    1.0000
   -0.4400

```

**Example 2.** Constraints are in conflict.

```

Sens = [0.44 0.32; 1.0 0.0];
Price = [1.2; 1.0];
W0 = [1; 1];
ConSet = pcalims([2 2])

% O.K. if nothing fixed.

[PortSens, PortValue, PortHolds]= hedgeslf(Sens, Price, W0,...
[], ConSet)

PortSens =
    2.8800
    0.6400

PortValue =
    4.4000

PortHolds =
    2
    2

% W0(1) is not greater than 2.

[PortSens, PortValue, PortHolds] = hedgeslf(Sens, Price, W0,...
1, ConSet)

??? Error using ==> hedgeslf
Overly restrictive allocation constraints implied by ConSet and
by fixing the weight of instrument(s): 1

```

**Example 3.** Constraints are impossible to meet.

```
Sens = [0.44 0.32; 1.0 0.0];  
Price = [1.2; 1.0];  
W0 = [1; 1];  
ConSet = pcalims([2 2],[1 1]);
```

```
[PortSens, PortValue, PortHolds] = hedgeslf(Sens, Price, W0,...  
[],ConSet)
```

```
??? Error using ==> hedgeslf  
Overly restrictive allocation constraints specified in ConSet
```

## See Also

[hedgeopt](#) | [lsqlin](#) | [portcons](#)

## hjmprice

Instrument prices from Heath-Jarrow-Morton interest-rate tree

### Syntax

```
Price = hjmprice(HJMTree, InstSet, Options)
```

### Arguments

HJMTree	Heath-Jarrow-Morton tree sampling a forward-rate process. See <code>hjmtree</code> for information on creating <code>HJMTree</code> .
InstSet	Variable containing a collection of instruments. Instruments are categorized by type. Each type can have different data fields. The stored data field is a row vector or string for each instrument.
Options	(Optional) Derivatives pricing options structure created with <code>derivset</code> .

### Description

`Price = hjmprice(HJMTree, InstSet, Options)` computes arbitrage-free prices for instruments using an interest-rate tree created with `hjmtree`. A subset of `NINST` instruments from a financial instrument variable, `InstSet`, are priced.

`Price` is a `NINST`-by-1 vector of prices for each instrument. The prices are computed by backward dynamic programming on the interest-rate tree. If an instrument cannot be priced, `NaN` is returned.

`PriceTree` is a `MATLAB` structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node.

`PriceTree.PBush` contains the clean prices.

`PriceTree.AIBush` contains the accrued interest.

`PriceTree.tObs` contains the observation times.



hjmprice handles instrument types: 'Bond', 'CashFlow', 'OptBond', 'OptEmBond', 'OptEmBond', 'OptFloat', 'OptEmFloat', 'Fixed', 'Float', 'Cap', 'Floor', 'RangeFloat', 'Swap'. See `instadd` to construct defined types.

Related single-type pricing functions are:

- `bondbyhjm`: Price a bond from an HJM tree.
- `capbyhjm`: Price a cap from an HJM tree.
- `cfbyhjm`: Price an arbitrary set of cash flows from an HJM tree.
- `fixedbyhjm`: Price a fixed-rate note from an HJM tree.
- `floatbyhjm`: Price a floating-rate note from an HJM tree.
- `floorbyhjm`: Price a floor from an HJM tree.
- `optbndbyhjm`: Price a bond option from an HJM tree.
- `optembndbyhjm`: Price a bond with embedded option by an HJM tree.
- `optfloatbybdt`: Price a floating-rate note with an option from an HJM tree.
- `optemfloatbybdt`: Price a floating-rate note with an embedded option from an HJM tree.
- `rangefloatbyhjm`: Price range floating note using an HJM tree.
- `swapbyhjm`: Price a swap from an HJM tree.
- `swaptionbyhjm`: Price a swaption from an HJM tree.

## Examples

Load the HJM tree and instruments from the data file `deriv.mat`. Price the cap and bond instruments contained in the instrument set.

```
load deriv.mat;
HJMSubSet = instselect(HJMInstSet, 'Type', {'Bond', 'Cap'});

instdisp(HJMSubSet)

%Table of instrument portfolio partially displayed:
Index Type CouponRate Settle Maturity Period Basis ... Name Quantity
1 Bond 0.04 01-Jan-2000 01-Jan-2003 1 NaN ... 4% bond 100
2 Bond 0.04 01-Jan-2000 01-Jan-2004 2 NaN ... 4% bond 50

Index Type Strike Settle Maturity CapReset Basis ... Name Quantity
3 Cap 0.03 01-Jan-2000 01-Jan-2004 1 NaN ... 3% Cap 30

[Price, PriceTree] = hjmprice(HJMTree, HJMSubSet)
```

Warning: Not all cash flows are aligned with the tree. Result will

be approximated.

Price =

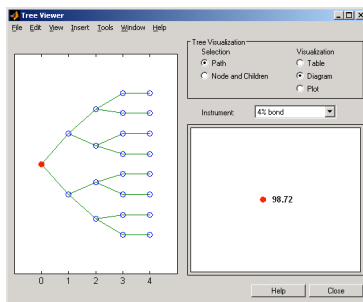
```
98.7159
97.5280
6.2831
```

PriceTree =

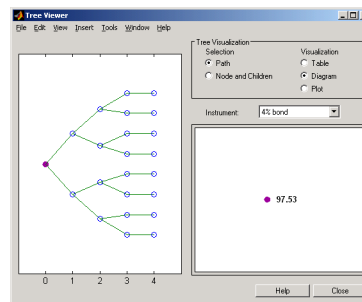
```
FinObj: 'HJMPriceTree'
PBush: {[3x1 double] [3x1x2 double] [3x2x2 double] [3x4x2 double] [3x8 double]}
AIBush: {[3x1 double] [3x1x2 double] [3x2x2 double] [3x4x2 double] [3x8 double]}
tObs: [0 1 2 3 4]
```

You can use `treeviewer` to see the prices of these three instruments along the price tree.

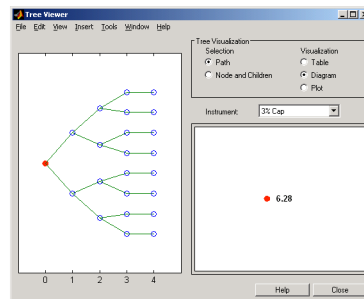
`treeviewer(PriceTree, HJMSubSet)`



First 4% Bond (Maturity 2003)



Second 4% Bond (Maturity 2004)



3% Cap

Price the following multi-stepped coupon bonds using the following data:

```
% The data for the interest rate term structure is as follows:
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2010';
StartDates = ValuationDate;
```

```

EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};
Compounding = 1;

% Create RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% Create a portfolio of stepped coupon bonds with different maturities
Settle = '01-Jan-2010';
Maturity = {'01-Jan-2011'; '01-Jan-2012'; '01-Jan-2013'; '01-Jan-2014'};
CouponRate = {{ '01-Jan-2011' .042; '01-Jan-2012' .05; '01-Jan-2013' .06; '01-Jan-2014' .07}};

ISet = instbond(CouponRate, Settle, Maturity, 1);
instdisp(ISet)

%Table of instrument portfolio partially displayed:
Index Type CouponRate Settle Maturity Period Basis EndMonthRule ... Face
1 Bond [Cell] 01-Jan-2010 01-Jan-2011 1 0 1 ... 100
2 Bond [Cell] 01-Jan-2010 01-Jan-2012 1 0 1 ... 100
3 Bond [Cell] 01-Jan-2010 01-Jan-2013 1 0 1 ... 100
4 Bond [Cell] 01-Jan-2010 01-Jan-2014 1 0 1 ... 100

% Build the tree with the following data
Volatility = [.2; .19; .18; .17];
CurveTerm = [ 1; 2; 3; 4];
HJMTimeSpec = hjmtimespec(ValuationDate, EndDates);
HJMVolSpec = hjmvolspec('Proportional', Volatility, CurveTerm, 1e6);
HJMT = hjmtree(HJMVolSpec, RS, HJMTimeSpec);

% Compute the price of the stepped coupon bonds
PHJM = hjmprice(HJMT, ISet)

PHJM =

100.6763
100.7368
100.9266
101.0115

```

Price a portfolio of stepped callable bonds and stepped vanilla bonds using the following data:

```

% Price a portfolio of stepped callable bonds and stepped vanilla bonds
% using the following data.

% The data for the interest rate term structure is as follows:
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2010';
StartDates = ValuationDate;
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};
Compounding = 1;

%Create RateSpec

```

```

RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% Create an instrument portfolio of 3 stepped callable bonds and three
% stepped vanilla bonds
Settle = '01-Jan-2010';
Maturity = {'01-Jan-2012'; '01-Jan-2013'; '01-Jan-2014'};
CouponRate = {{ '01-Jan-2011' .042; '01-Jan-2012' .05; '01-Jan-2013' .06; '01-Jan-2014' .07}};
OptSpec='call';
Strike=100;
ExerciseDates='01-Jan-2011'; %Callable in one year

% Bonds with embedded option
ISet = instoptembnd(CouponRate, Settle, Maturity, OptSpec, Strike,...
ExerciseDates, 'Period', 1);

% Vanilla bonds
ISet = instbond(ISet, CouponRate, Settle, Maturity, 1);

% Display the instrument portfolio
instdisp(ISet)

%Table of instrument portfolio partially displayed:
Index Type CouponRate Settle Maturity OptSpec Strike ExerciseDates ... AmericanOpt
1 OptEmBond [Cell] 01-Jan-2010 01-Jan-2012 call 100 01-Jan-2011 ... 0
2 OptEmBond [Cell] 01-Jan-2010 01-Jan-2013 call 100 01-Jan-2011 ... 0
3 OptEmBond [Cell] 01-Jan-2010 01-Jan-2014 call 100 01-Jan-2011 ... 0

Index Type CouponRate Settle Maturity Period Basis EndMonthRule ... Face
4 Bond [Cell] 01-Jan-2010 01-Jan-2012 1 0 1 ... 100
5 Bond [Cell] 01-Jan-2010 01-Jan-2013 1 0 1 ... 100
6 Bond [Cell] 01-Jan-2010 01-Jan-2014 1 0 1 ... 100

% Build the tree with the following data
Volatility = [.2; .19; .18; .17];
CurveTerm = [ 1; 2; 3; 4];
HJMTimeSpec = hjmtimespec(ValuationDate, EndDates);
HJMVolSpec = hjmvolspec('Proportional', Volatility, CurveTerm, 1e6);
HJMT = hjmtree(HJMVolSpec,RS,HJMTimeSpec);

%The first three rows corresponds to the price of the stepped callable bonds
% and the last three rows corresponds to the price of the stepped vanilla bonds.
PHJM = hjmprice(HJMT, ISet)

PHJM =

100.3682
100.1557
99.9232
100.7368
100.9266
101.0115

```

Compute the price of a portfolio using the following data:

```
% The data for the interest rate term structure is as follows:
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2011';
StartDates = ValuationDate;
EndDates = {'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'};
Compounding = 1;

% Create RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates',...
StartDates, 'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% Create an instrument portfolio with two range notes and a floating rate
% note with the following data:
Spread = 200;
Settle = 'Jan-1-2011';
Maturity = 'Jan-1-2014';

% First Range Note:
RateSched(1).Dates = {'Jan-1-2012'; 'Jan-1-2013' ; 'Jan-1-2014'};
RateSched(1).Rates = [0.045 0.055; 0.0525 0.0675; 0.06 0.08];

% Second Range Note:
RateSched(2).Dates = {'Jan-1-2012'; 'Jan-1-2013' ; 'Jan-1-2014'};
RateSched(2).Rates = [0.048 0.059; 0.055 0.068 ; 0.07 0.09];

% Create InstSet
InstSet = instadd('RangeFloat', Spread, Settle, Maturity, RateSched);

% Add a floating-rate note
InstSet = instadd(InstSet, 'Float', Spread, Settle, Maturity);

% Display the portfolio instrument
instdisp(InstSet)

Index Type      Spread Settle      Maturity  RateSched FloatReset Basis Principal EndMonthRule
1      RangeFloat 200      01-Jan-2011 01-Jan-2014 [Struct] 1      0      100      1
2      RangeFloat 200      01-Jan-2011 01-Jan-2014 [Struct] 1      0      100      1

Index Type      Spread Settle      Maturity  FloatReset Basis Principal EndMonthRule
3      Float 200      01-Jan-2011 01-Jan-2014 1      0      100      1

% The data to build the tree is as follows:
Volatility = [.2; .19; .18; .17];
CurveTerm = [ 1; 2; 3; 4];
MaTree = {'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'};
HJMTree = hjmtimespec(ValuationDate, MaTree);
HJMVS = hjmvolspec('Proportional', Volatility, CurveTerm, 1e6);
HJMT = hjmtree(HJMVS, RS, HJMTree);

% Price the portfolio
Price = hjmprice(HJMT, InstSet)

Price =
```

91.1555  
90.6656  
105.5147

### **More About**

- “Pricing Options Structure”

### **See Also**

`hjmsens` | `hjmtree` | `hjmvolspec` | `instadd` | `intenvprice` | `intenvsens`

# hjmsens

Instrument prices and sensitivities from Heath-Jarrow-Morton interest-rate tree

## Syntax

```
[Delta, Gamma, Vega, Price] = hjmsens(HJMTree, InstSet,
Options)
```

## Arguments

HJMTree	Heath-Jarrow-Morton tree sampling a forward-rate process. See <code>hjmtree</code> for information on creating <code>HJMTree</code> .
InstSet	Variable containing a collection of instruments. Instruments are categorized by type. Each type can have different data fields. The stored data field is a row vector or string for each instrument.
Options	(Optional) Derivatives pricing options structure created with <code>derivset</code> .

## Description

`[Delta, Gamma, Vega, Price] = hjmsens(HJMTree, InstSet, Options)` computes instrument sensitivities and prices for instruments using an interest-rate tree created with `hjmtree`. `NINST` instruments from a financial instrument variable, `InstSet`, are priced. `hjmsens` handles instrument types: 'Bond', 'CashFlow', 'OptBond', 'OptEmBond', 'OptEmBond', 'OptFloat', 'OptEmFloat', 'Fixed', 'Float', 'Cap', 'Floor', 'RangeFloat', 'Swap'. See `instadd` for information on instrument types.

`Delta` is an `NINST`-by-1 vector of deltas, representing the rate of change of instrument prices with respect to changes in the interest rate. `Delta` is computed by finite differences in calls to `hjmtree`. See `hjmtree` for information on the observed yield curve.

`Gamma` is an `NINST`-by-1 vector of gammas, representing the rate of change of instrument deltas with respect to the changes in the interest rate. `Gamma` is computed by finite differences in calls to `hjmtree`.

Vega is an NINST-by-1 vector of vegas, representing the rate of change of instrument prices with respect to the changes in the volatility  $\sigma(t, T)$ . Vega is computed by finite differences in calls to `hjmtree`. See `hjmvolspec` for information on the volatility process.

---

**Note** All sensitivities are returned as dollar sensitivities. To find the per-dollar sensitivities, divide by the respective instrument price.

---

Price is an NINST-by-1 vector of prices of each instrument. The prices are computed by backward dynamic programming on the interest-rate tree. If an instrument cannot be priced, NaN is returned.

Delta and Gamma are calculated based on yield shifts of 100 basis points. Vega is calculated based on a 1% shift in the volatility process.

## Examples

### Compute Instrument Sensitivities Using an HJM Interest-Rate Tree

Load the tree and instruments from the `deriv.mat` data file. Compute Delta and Gamma for the cap and bond instruments contained in the instrument set.

```
load deriv.mat;
HJMSubSet = instselect(HJMInstSet, 'Type', {'Bond', 'Cap'});
instdisp(HJMSubSet)
```

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate
1	Bond	0.04	01-Jan-2000	01-Jan-2003	1	NaN	NaN	NaN
2	Bond	0.04	01-Jan-2000	01-Jan-2004	2	NaN	NaN	NaN

Index	Type	Strike	Settle	Maturity	CapReset	Basis	Principal	Name	Quantity
3	Cap	0.03	01-Jan-2000	01-Jan-2004	1	NaN	NaN	3% Cap 30	

Compute the Delta and Gamma for the cap and bond instruments.

```
[Delta, Gamma] = hjmsens(HJMTree, HJMSubSet)
```

Warning: Not all cash flows are aligned with the tree. Result will be



approximated.

Delta =

-272.6462

-347.4315

294.9700

Gamma =

1.0e+03 \*

1.0299

1.6227

6.8526

## More About

- “Pricing Options Structure”

## See Also

[hjmtime](#) | [hjmprice](#) | [hjmtree](#) | [hjmvolspec](#) | [instadd](#)

## hjmtimespec

Specify time structure for Heath-Jarrow-Morton interest-rate tree

### Syntax

TimeSpec = hjmtimespec(ValuationDate, Maturity, Compounding)

### Arguments

ValuationDate	Scalar date marking the pricing date and first observation in the tree. Specify as serial date number or date string.
Maturity	Number of levels (depth) of the tree. A number of levels (NLEVELS)-by-1 vector of dates marking the cash flow dates of the tree. Cash flows with these maturities fall on tree nodes. Maturity should be in increasing order.
Compounding	<p>(Optional) Scalar value representing the rate at which the input zero rates were compounded when annualized. Default = 1. This argument determines the formula for the discount factors:</p> <p>Compounding = 1, 2, 3, 4, 6, 12</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the compounding frequency, Z is the zero rate, and T is the time in periodic units; for example, T = F is 1 year.</p> <p>Compounding = 365</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the number of days in the basis year and T is a number of days elapsed computed by basis.</p> <p>Compounding = -1</p> <p>Disc = <math>\exp(-T*Z)</math>, where T is time in years.</p>

## Description

`TimeSpec = hjmtimespec(ValuationDate, Maturity, Compounding)` sets the number of levels and node times for an HJM tree and determines the mapping between dates and time for rate quoting.

`TimeSpec` is a structure specifying the time layout for `hjmtree`. The state observation dates are `[Settle; Maturity(1:end-1)]`. Because a forward rate is stored at the last observation, the tree can value cash flows out to `Maturity`.

## Examples

### Set the Number of Levels and Node Times for an HJM Tree

This example shows how to specify an eight-period tree with semiannual nodes (every six months) and use exponential compounding to report rates.

```
Compounding = -1;
ValuationDate = '15-Jan-1999';
Maturity = datemnth(ValuationDate, 6*(1:8));
TimeSpec = hjmtimespec(ValuationDate, Maturity, Compounding)
```

```
TimeSpec =
    FinObj: 'HJMTimeSpec'
ValuationDate: 730135
    Maturity: [8x1 double]
    Compounding: -1
    Basis: 0
    EndMonthRule: 1
```

### See Also

`hjmtree` | `hjmvolspec`

## hjmtree

Construct Heath-Jarrow-Morton interest-rate tree

### Syntax

```
HJMTree = hjmtree(VolSpec, RateSpec, TimeSpec)
```

### Arguments

VolSpec	Volatility process specification. Sets the number of factors and the rules for computing the volatility $\sigma(t, T)$ for each factor. See <code>hjmvolspec</code> for information on the volatility process.
RateSpec	Interest-rate specification for the initial rate curve. See <code>intenvset</code> for information on declaring an interest-rate variable.
TimeSpec	Tree time layout specification. Defines the observation dates of the HJM tree and the compounding rule for date to time mapping and price-yield formulas. See <code>hjmtimespec</code> for information on the tree structure.

### Description

`HJMTree = hjmtree(VolSpec, RateSpec, TimeSpec)` creates a structure containing time and forward-rate information on a bushy tree.

### Examples

Using the data provided, create an HJM volatility specification (`VolSpec`), rate specification (`RateSpec`), and tree time layout specification (`TimeSpec`). Then use these specifications to create an HJM tree using `hjmtree`.

```
Compounding = 1;
ValuationDate = '01-01-2000';
StartDate = ['01-01-2000'; '01-01-2001'; '01-01-2002'; '01-01-2003'; '01-01-2004'];
EndDates = ['01-01-2001'; '01-01-2002'; '01-01-2003'; '01-01-2004'; '01-01-2005'];
```

```

Rates = [.1; .11; .12; .125; .13];
Volatility = [.2; .19; .18; .17; .16];
CurveTerm = [1; 2; 3; 4; 5];

HJMVolSpec = hjmvolspec('Stationary', Volatility , CurveTerm);

RateSpec = intenvset('Compounding', Compounding,...
    'ValuationDate', ValuationDate,...
    'StartDates', StartDate,...
    'EndDates', EndDates,...
    'Rates', Rates);

HJMTimeSpec = hjmtimespec(ValuationDate, EndDates, Compounding);
HJMTree = hjmtree(HJMVolSpec, RateSpec, HJMTimeSpec)

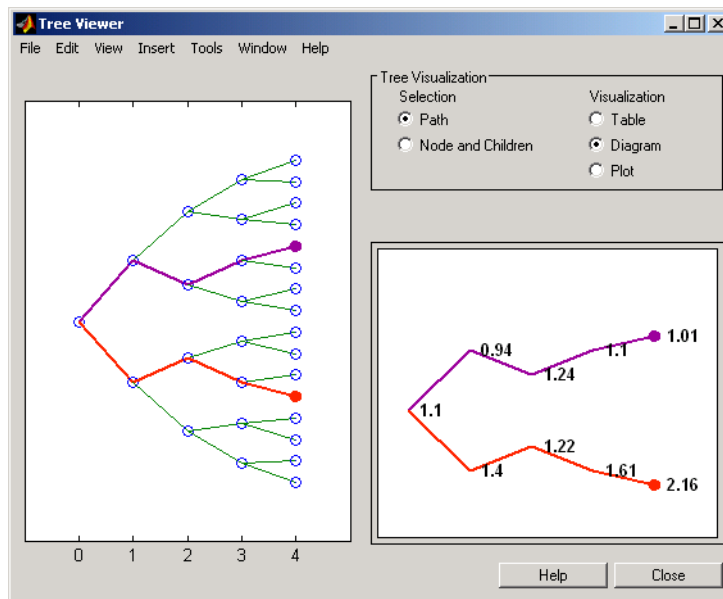
HJMTree =

    FinObj: 'HJMfwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
    tObs: [0 1 2 3 4]
    dObs: [730486 730852 731217 731582 731947]
    TFwd: {[5x1 double] [4x1 double] [3x1 double] [2x1 double] [4]}
    CFlowT: {[5x1 double] [4x1 double] [3x1 double] [2x1 double] [5]}
    FwdTree: {[5x1 double] [4x1x2 double] [3x2x2 double] [2x4x2 double] [1x8x2 double]}

```

Use `treeviewer` to observe the tree you have created.

```
treeviewer(HJMTree)
```



**See Also**

hjmprice | hjmtimespec | hjmvolspec | intenvset

# hjmvolspec

Specify Heath-Jarrow-Morton interest-rate volatility process

## Syntax

```
VolSpec = hjmvolspec(varargin)
```

## Arguments

The arguments to `hjmvolspec` vary according to the type and number of volatility factors specified when calling the function. Factors are specified by pairs of names and parameter sets. Factor names can be 'Constant', 'Stationary', 'Exponential', 'Vasicek', or 'Proportional'. The parameter set is specific for each of these factor types:

- Constant volatility (Ho-Lee):  
`VolSpec = hjmvolspec('Constant', Sigma_0)`
- Stationary volatility:  
`VolSpec = hjmvolspec('Stationary', CurveVol, CurveTerm)`
- Exponential volatility:  
`VolSpec = hjmvolspec('Exponential', Sigma_0, Lambda)`
- Vasicek, Hull-White:  
`VolSpec = hjmvolspec('Vasicek', Sigma_0, CurveDecay, CurveTerm)`
- Nearly proportional stationary:  
`VolSpec = hjmvolspec('Proportional', CurveProp, CurveTerm, MaxSpot)`

You can specify more than one factor by concatenating names and parameter sets.

The following table defines the various arguments to `hjmvolspec`.

Argument	Description
Sigma_0	Scalar base volatility over a unit time.
Lambda	Scalar decay factor.

Argument	Description
CurveVol	Number of curves (NCURVES)-by-1 vector of Vol values at sample points.
CurveDecay	NCURVES-by-1 vector of Decay values at sample points.
CurveProp	NCURVES-by-1 vector of Prop values at sample points.
CurveTerm	NCURVES-by-1 vector of Term sample points.

**Note:** See the volatility specifications formulas below for a description of Vol, Decay, Prop, and Term.

## Description

`Volspec = hjmvolspec(varargin)` computes `Volspec`, a structure that specifies the volatility model for `hjmtree`.

`hjmvolspec` specifies an HJM forward-rate volatility process. Each factor is specified with one of the functional forms.

Volatility Specification	Formula
Constant	$\sigma(t, T) = \text{Sigma}_0$
Stationary	$\sigma(t, T) = \text{Vol}(T-t) = \text{Vol}(\text{Term})$
Exponential	$\sigma(t, T) = \text{Sigma}_0 * \exp(-\text{Lambda} * (T-t))$
Vasicek, Hull-White	$\sigma(t, T) = \text{Sigma}_0 * \exp(-\text{Decay}(T-t))$
Proportional	$\sigma(t, T) = \text{Prop}(T-t) * \max(\text{SpotRate}(t), \text{MaxSpot})$

The volatility process is  $\sigma(t, T)$ , where  $t$  is the observation time and  $T$  is the starting time of a forward rate. In a stationary process, the volatility term is  $T-t$ . Multiple factors can be specified sequentially.

The time values  $T$ ,  $t$ , and `Term` are in coupon interval units specified by the `Compounding` input of `hjmtimespec`. For instance if `Compounding = 2`, `Term = 1` is a semiannual period (six months).



## Examples

### Compute the VolSpec Structure to Specify a Proportional Volatility Model for HJMTree

This example shows how to compute the VolSpec structure to specify the volatility model for `hjmtree` when volatility is single-factor proportional.

```
CurveProp = [0.11765; 0.08825; 0.06865];
CurveTerm = [1; 2; 3];
VolSpec = hjmvolspec('Proportional', CurveProp, CurveTerm, 1e6)
```

VolSpec =

```
      FinObj: 'HJMVolSpec'
  FactorModels: {'Proportional'}
    FactorArgs: {{1x3 cell}}
    SigmaShift: 0
    NumFactors: 1
    NumBranch: 2
      PBranch: [0.5000 0.5000]
    Fact2Branch: [-1 1]
```

### Compute the VolSpec Structure to Specify an Exponential Volatility Model for HJMTree

This example shows how to compute the VolSpec structure to specify the volatility model for `hjmtree` when volatility is two-factor exponential and constant.

```
VolSpec = hjmvolspec('Exponential', 0.1, 1, 'Constant', 0.2)
```

VolSpec =

```
      FinObj: 'HJMVolSpec'
  FactorModels: {'Exponential' 'Constant'}
    FactorArgs: {{1x2 cell} {1x1 cell}}
    SigmaShift: 0
    NumFactors: 2
    NumBranch: 3
      PBranch: [0.2500 0.2500 0.5000]
    Fact2Branch: [2x3 double]
```

**See Also**

hjmtimespec | hjmtree

## HullWhite1F class

Create Hull-White one-factor model

### Description

The Hull-White one-factor model is specified using the zero curve, alpha, and sigma parameters for the equation

$$dr = [\theta(t) - \alpha(t)r]dt + \sigma(t)dW$$

where:

$dr$  is the change in the short-term interest rate over a small interval.

$r$  is the short-term interest rate.

$\theta(t)$  is a function of time determining the average direction in which  $r$  moves, chosen such that movements in  $r$  are consistent with today's zero coupon yield curve.

$\alpha$  is the mean reversion rate.

$dt$  is a small change in time.

$\sigma$  is the annual standard deviation of the short rate.

$W$  is the Brownian motion.

### Construction

`OBJ = HullWhite1F(ZeroCurve,alpha,sigma)` constructs an object for a Hull-White one-factor model.

For example:

```
Settle = datenum('15-Dec-2007');
CurveTimes = [1:5 7 10 20]';
ZeroRates = [.01 .018 .024 .029 .033 .034 .035 .034]';
```

```
CurveDates = daysadd(Settle,360*CurveTimes,1);  
irdc = IRDataCurve('Zero',Settle,CurveDates,ZeroRates);  
alpha = .1;  
sigma = .01;  
HW1F = HullWhite1F(irdc,alpha,sigma);
```

## Properties

The following properties are from the `HullWhite1F` class.

### ZeroCurve

`ZeroCurve` is specified using the output from `IRDataCurve` or `RateSpec`. This is the zero curve used to evolve the path of future interest rates.

#### Attributes:

<code>SetAccess</code>	<code>public</code>
<code>GetAccess</code>	<code>public</code>

### Alpha

Mean reversion specified either as a scalar or function handle which takes time as an input and returns a scalar mean reversion value.

#### Attributes:

<code>SetAccess</code>	<code>public</code>
<code>GetAccess</code>	<code>public</code>

### Sigma

Volatility specified either as a scalar or function handle which takes time as an input and returns a scalar mean volatility.

#### Attributes:

```
SetAccess      public
GetAccess      public
```

## Methods

```
simTermStructs      Simulate term structures for Hull-White
                     one-factor model
```

## Definitions

### Hull-White One-Factor Model

The Hull-White model is a single-factor, no-arbitrage yield curve model in which the short-term rate of interest is the random factor or state variable. No-arbitrage means that the model parameters are consistent with the bond prices implied in the zero coupon yield curve.

## Copy Semantics

Value. To learn how value classes affect copy operations, see “Copying Objects” in the MATLAB documentation.

## Examples

### Construct a Hull-White One-Factor Model

Construct a Hull-White one-factor model.

```
Settle = datenum('15-Dec-2007');
CurveTimes = [1:5 7 10 20]';
ZeroRates = [.01 .018 .024 .029 .033 .034 .035 .034]';
CurveDates = daysadd(Settle,360*CurveTimes,1);
```

```
irdc = IRDataCurve('Zero',Settle,CurveDates,ZeroRates);
```

```
alpha = .1;  
sigma = .01;
```

```
HW1F = HullWhite1F(irdc,alpha,sigma)
```

```
HW1F =
```

```
    HullWhite1F with properties:
```

```
    ZeroCurve: [1x1 IRDataCurve]  
    Alpha: @(t,V)inAlpha  
    Sigma: @(t,V)inSigma
```

Use the `simTermStructs` method with the `HullWhite1F` model to simulate term structures.

```
SimPaths = simTermStructs(HW1F, 10, 'nTrials',100);
```

- “Price Swaptions With Interest-Rate Models Using Simulation”
- “Class Attributes”
- “Property Attributes”

## References

Hull, J. *Options, Futures, and Other Derivatives*, Prentice-Hall, 2011.

## See Also

`hwcalbycap` | `hwcalbyfloor` | `LiborMarketModel` | `LinearGaussian2F` | `simTermStructs`

# simTermStructs

**Class:** HullWhite1F

Simulate term structures for Hull-White one-factor model

## Syntax

```
[ZeroRates,ForwardRates] = simTermStructs(nPeriods)
[ZeroRates,ForwardRates] = simTermStructs(nPeriods,
Name,Value)
```

## Description

[ZeroRates,ForwardRates] = simTermStructs(nPeriods) simulates future zero curve paths using a specified HullWhite1F object.

[ZeroRates,ForwardRates] = simTermStructs(nPeriods, Name,Value) simulates future zero curve paths using a specified HullWhite1F object with additional options specified by one or more Name,Value pair arguments.

## Input Arguments

### nPeriods

Number of simulation periods.

### Name-Value Pair Arguments

Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

### 'deltaTime'

Scalar time step between periods.

**Default:** 1

**'nTrials'**

Positive scalar integer number of simulated trials (sample paths) of `NPERIODS` observations each. If you do not specify a value for this argument, the default is 1, indicating a single path of correlated state variables.

**Default:** 1

**'antithetic'**

Boolean scalar flag indicating whether antithetic sampling is used to generate the Gaussian random variates that drive the zero-drift, unit-variance rate Brownian vector  $dW(t)$ . For details, see `simBySolution`.

**Default:** false

**'Z'**

Direct specification of the dependent random noise process used to generate the zero-drift, unit-variance rate Brownian vector  $dW(t)$  that drives the simulation. For details, see `simBySolution` for the HWV model.

**Default:** Uses default for `simBySolution`. If you do not specify a value for `Z`, `simBySolution` generates Gaussian variates.

**'Tenor'**

Numeric vector of maturities to compute at each time step.

**Default:** tenor of the `HullWhite1F` object's zero curve

## Output Arguments

**ZeroRates**

`nPeriods+1`-by-`nTenors`-by-`nTrials` matrix of simulated zero-rate term structures.

**ForwardRates**

`nPeriods+1`-by-`nTenors`-by-`nTrials` matrix of simulated forward-rate term structures.



## Attributes

Access	public
Static	false
Hidden	false

To learn about attributes of methods, see “Method Attributes” in the MATLAB Object-Oriented Programming documentation.

## Examples

### Simulate Term Structures for the HullWhite1F Model

Create a HW1F object.

```
Settle = datenum('15-Dec-2007');
CurveTimes = [1:5 7 10 20]';
ZeroRates = [.01 .018 .024 .029 .033 .034 .035 .034]';
CurveDates = daysadd(Settle,360*CurveTimes,1);

irdc = IRDataCurve('Zero',Settle,CurveDates,ZeroRates);

alpha = .1;
sigma = .01;

HW1F = HullWhite1F(irdc,alpha,sigma)
```

HW1F =

HullWhite1F with properties:

```
ZeroCurve: [1x1 IRDataCurve]
Alpha: @(t,V)inAlpha
Sigma: @(t,V)inSigma
```

Simulate the term structures for the specified HW1F object.

```
SimPaths = simTermStructs(HW1F, 10, 'nTrials',100);
```

- “Price Swaptions With Interest-Rate Models Using Simulation”

**See Also**

HullWhite1F

# hwcalbycap

Calibrate Hull-White tree using caps

## Syntax

```
[Alpha, Sigma, OptimOut] = hwcalbycap(RateSpec, MarketStrike,
MarketMaturity, MarketVolatility)
[Alpha, Sigma, OptimOut] = hwcalbycap(RateSpec, MarketStrike,
MarketMaturity, MarketVolatility, Strike, Settle, Maturity)
[Alpha, Sigma, OptimOut] = hwcalbycap(RateSpec, MarketStrike,
MarketMaturity, MarketVolatility, Strike, Settle, Maturity,
'Name1', Value1...)
```

## Arguments

RateSpec	The annualized, continuously compounded rate term structure. For more information, see <code>intenvset</code> .
MarketStrike	NSTRIKES-by-1 vector of market cap strikes, as a decimal number.
MarketMaturity	NMATS-by-1 vector of market cap maturity dates.
MarketVolatility	NSTRIKES-by-NMATS matrix of market flat volatilities, where NSTRIKES is the number of caplet strikes from MarketStrike and NMATS is the caplet maturity dates from MarketMaturity.
Strike	(Optional) Scalar representing the rate at which the cap is exercised, as a decimal number.
Settle	(Optional) Scalar representing the settle date of the cap.
Maturity	(Optional) Scalar representing the maturity date of the cap.
Reset	(Optional) Scalar representing the frequency of payments per year. Default is 1.

Principal	(Optional) Scalar representing the notional principal amount. Default is 100.
Basis	<p>(Optional) NINST-by-1 vector representing the basis used when annualizing the input forward rate.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
ValuationDate	(Optional) Scalar representing the observation date of the investment horizons. The default is the <b>Settle</b> date.
LB	(Optional) 2-by-1 vector of the lower bounds, defined as [ <b>LBSigma</b> ; <b>LBAAlpha</b> ], used in the search algorithm function. Default is <b>LB</b> = [0;0]. For more information, see <b>lsqnonlin</b> .
UB	(Optional) 2-by-1 vector of the upper bounds, defined as [ <b>UBSigma</b> ; <b>UBAlpha</b> ], used in the search algorithm function. Default is <b>UB</b> = [ ](unbound). For more information, see <b>lsqnonlin</b> .

X0	(Optional) 2-by-1 vector of the initial values, defined as [ <b>Sigma0</b> ; <b>Alpha0</b> ], used in the search algorithm function. Default is X0 = [0.5;0.5]. For more information, see <code>lsqnonlin</code> .
OptimOptions	(Optional) Structure with optimization parameters. For more information, see <code>optimoptions</code> .

---

**Note:** All optional inputs are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. You can specify parameter name/value pairs in any order. Names are case-insensitive and partial string matches are allowed provided no ambiguities exist.

---

## Description

[Alpha, Sigma, OptimOut] = hwcalbycap(RateSpec, MarketStrike, MarketMaturity, MarketVolatility) to calibrate the Alpha (mean reversion) and Sigma (volatility) using cap market data and the Hull-White model using the entire cap surface.

[Alpha, Sigma, OptimOut] = hwcalbycap(RateSpec, MarketStrike, MarketMaturity, MarketVolatility, Strike, Settle, Maturity) to estimate the Alpha (mean reversion) and Sigma (volatility) using cap market data and the Hull-White model to price a cap at a particular maturity/volatility.

[Alpha, Sigma, OptimOut] = hwcalbycap(RateSpec, MarketStrike, MarketMaturity, MarketVolatility, Strike, Settle, Maturity, 'Name1', Value1...) to estimate the Alpha (mean reversion) and Sigma (volatility) using cap market data and the Hull-White model to price a floor at a particular maturity/volatility with optional name-value pair arguments.

The hwcalbycap outputs are:

- **Alpha** — Scalar representing the mean reversion value obtained from calibrating the cap using market information.
- **Sigma** — Scalar representing the volatility value obtained from calibrating the cap using market information.

- `OptimOut` — Structure with optimization results.

## Examples

For an example of calibrating using the Hull-White model with `Strike`, `Settle`, and `Maturity` input arguments, see “Calibrating Hull-White Model Using Market Data” on page 2-84.

### Calibrate Hull-White Model from Market Data Using the Entire Cap Volatility Surface

This example shows how to use `hwcalbycap` input arguments for `MarketStrike`, `MarketMaturity`, and `MarketVolatility` to calibrate the HW model using the entire cap volatility surface.

Cap market volatility data covering 2 strikes over 12 maturity dates.

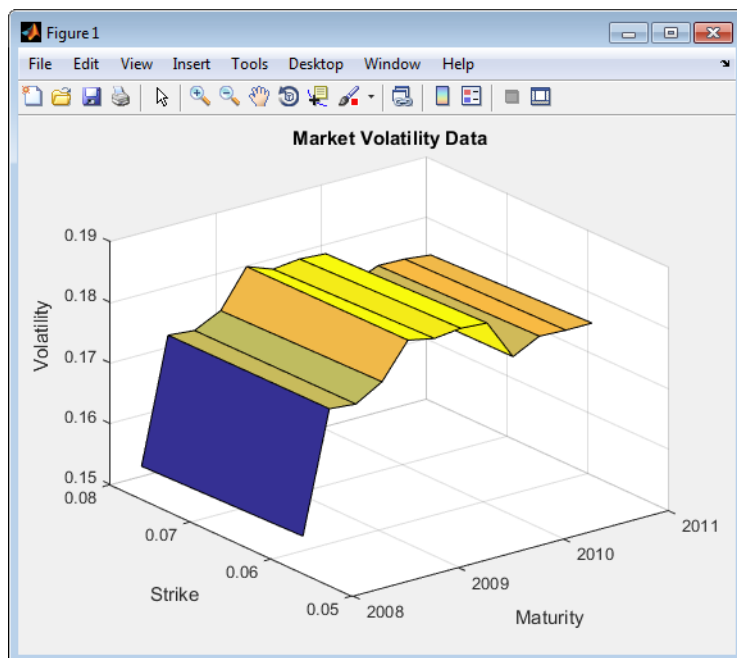
```
Reset = 4;
MarketStrike = [0.0590; 0.0790];

MarketMaturity = {'21-Mar-2008'; '21-Jun-2008'; '21-Sep-2008'; '21-Dec-2008';
                 '21-Mar-2009'; '21-Jun-2009'; '21-Sep-2009'; '21-Dec-2009';
                 '21-Mar-2010'; '21-Jun-2010'; '21-Sep-2010'; '21-Dec-2010'};
MarketMaturity = datenum(MarketMaturity);

MarketVolatility = [0.1533 0.1731 0.1727 0.1752 0.1809 0.1800 0.1805 0.1802...
                   0.1735 0.1757 0.1755 0.1755;
                   0.1526 0.1730 0.1726 0.1747 0.1808 0.1792 0.1797 0.1794...
                   0.1733 0.1751 0.1750 0.1745];
```

Plot market volatility surface.

```
[AllMaturities,AllStrikes] = meshgrid(MarketMaturity,MarketStrike);
figure;
surf(AllMaturities,AllStrikes,MarketVolatility)
datetick
xlabel('Maturity')
ylabel('Strike')
zlabel('Volatility')
title('Market Volatility Data')
```



Set interest rate term structure and create a `RateSpec`.

```
Settle = '21-Jan-2008';
Compounding = 4;
Basis = 0;
Rates = [0.0627; 0.0657; 0.0691; 0.0717; 0.0739; 0.0755; 0.0765; 0.0772;
0.0779; 0.0783; 0.0786; 0.0789];
EndDates = {'21-Mar-2008'; '21-Jun-2008'; '21-Sep-2008'; '21-Dec-2008'; ...
'21-Mar-2009'; '21-Jun-2009'; '21-Sep-2009'; '21-Dec-2009'; ...
'21-Mar-2010'; '21-Jun-2010'; '21-Sep-2010'; '21-Dec-2010'};
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding, ...
'Basis', Basis)
```

RateSpec =

```
FinObj: 'RateSpec'
Compounding: 4
Disc: [12x1 double]
Rates: [12x1 double]
EndTimes: [12x1 double]
StartTimes: [12x1 double]
EndDates: [12x1 double]
StartDates: 733428
```

```
ValuationDate: 733428
      Basis: 0
      EndMonthRule: 1
```

## Calibrate Hull-White model from market data.

```
o = optimoptions('lsqnonlin','TolFun',1e-5,'Display','off');

[Alpha, Sigma] = hwcalbycap(RateSpec, MarketStrike, MarketMaturity,...
    MarketVolatility, 'Reset', Reset, 'Basis', Basis, 'OptimOptions', o)

Warning: LSQNONLIN did not converge to an optimal solution. It exited with exitflag = 3.

> In hwcalbycapfloor>optimizeOverCapSurface at 232
   In hwcalbycapfloor at 79
   In hwcalbycap at 81
```

```
Alpha =
    0.0943
```

```
Sigma =
    0.0146
```

## Compare with Black prices.

```
BlkPrices = capbyblk(RateSpec, AllStrikes(:), Settle, AllMaturities(:),...
    MarketVolatility(:), 'Reset', Reset, 'Basis', Basis);
```

```
BlkPrices =
    0.0604
         0
    0.2729
    0.0006
    0.6498
    0.0412
    1.1121
    0.1426
    1.6426
    0.3131
    2.1869
    0.4998
    2.7056
    0.6894
    3.2124
    0.8815
    3.7311
    1.0686
    4.2246
```



```

1.2790
4.7027
1.4810
5.1877
1.6919

```

Setup Hull-White tree using calibrated parameters, alpha and sigma.

```

VolDates = EndDates;
VolCurve = Sigma*ones(numel(EndDates),1);
AlphaDates = EndDates;
AlphaCurve = Alpha*ones(numel(EndDates),1);
HWVolSpec = hmwolspec(Settle, VolDates, VolCurve, AlphaDates, AlphaCurve);

HWTimeSpec = hwtimespec(Settle, EndDates, Compounding);
HWTTree = hwtree(HWVolSpec, RateSpec, HWTimeSpec, 'Method', 'HW2000')

HWTTree =

    FinObj: 'HWFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
      tObs: [0 0.6593 1.6612 2.6593 3.6612 4.6593 5.6612 6.6593 7.6612 8.6593 9.6612 10.6593]
      dObs: [733428 733488 733580 733672 733763 733853 733945 734037 734128 734218 734310 734402]
    CFlowT: {1x12 cell}
    Probs: {1x11 cell}
    Connect: {1x11 cell}
    FwdTree: {1x12 cell}

```

Compute Hull-White prices based on the calibrated tree.

```
HWPPrices = capbyhw(HWTTree, AllStrikes(:), Settle, AllMaturities(:), Reset, Basis)
```

```

HWPPrices =

    0.0601
         0
    0.2788
         0
    0.6580
    0.0518
    1.1254
    0.1485
    1.6591
    0.3123
    2.2076
    0.5022
    2.7319
    0.6883
    3.2459
    0.8774

```

```

3.7771
1.0900
4.2769
1.2875
4.7645
1.4845
5.2572
1.6921

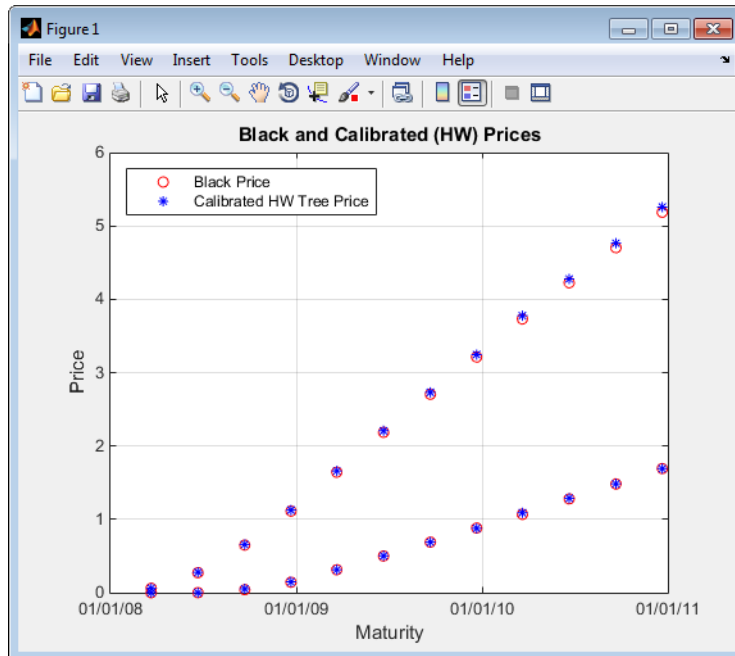
```

Plot Black prices against the calibrated Hull-White tree prices.

```

figure;
plot(AllMaturities(:), BlkPrices, 'or', AllMaturities(:), HWPrices, '*b');
datetick('x', 2)
xlabel('Maturity');
ylabel('Price');
title('Black and Calibrated (HW) Prices');
legend('Black Price', 'Calibrated HW Tree Price', 'Location', 'NorthWest');
grid on

```



# hwcalbyfloor

Calibrate Hull-White tree using floors

## Syntax

```
[Alpha, Sigma, OptimOut] = hwcalbyfloor(RateSpec, MarketStrike,
MarketMaturity, MarketVolatility)
[Alpha, Sigma, OptimOut] = hwcalbyfloor(RateSpec,
MarketStrike, MarketMaturity, MarketVolatility, Strike,
Settle, Maturity)
[Alpha, Sigma, OptimOut] = hwcalbyfloor(RateSpec,
MarketStrike, MarketMaturity, MarketVolatility, Strike,
Settle, Maturity, 'Name1', Value1...)
```

## Arguments

RateSpec	The annualized, continuously compounded rate term structure. For more information, see <code>intenvset</code> .
MarketStrike	NSTRIKES-by-1 vector of market floor strikes as a decimal number.
MarketMaturity	NMATS-by-1 vector of market floor maturity dates.
MarketVolatility	NSTRIKES-by-NMATS matrix of market flat volatilities.
Strike	(Optional) Scalar representing the rate at which the floor is exercised, as a decimal number.
Settle	(Optional) Scalar representing the settle date of the floor.
Maturity	(Optional) Scalar representing the maturity date of the floor.
Reset	(Optional) Scalar representing the frequency of payments per year. Default is 1.

Principal	(Optional) Scalar representing the notional principal amount. Default is 100.
Basis	<p>(Optional) NINST-by-1 vector representing the basis used when annualizing the input forward rate.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
ValuationDate	(Optional) Scalar representing the observation date of the investment horizons. The default is the <b>Settle</b> date.
LB	(Optional) 2-by-1 vector of the lower bounds, defined as [ <b>LB</b> Sigma; <b>LB</b> Alpha], used in the search algorithm function. Default is <b>LB</b> =[0;0]. For more information, see <b>lsqnonlin</b> .
UB	(Optional) 2-by-1 vector of the upper bounds, defined as [ <b>UB</b> Sigma; <b>UB</b> Alpha], used in the search algorithm function. Default is <b>UB</b> =[ ](unbound). For more information, see <b>lsqnonlin</b> .

X0	(Optional) 2-by-1 vector of the initial values, defined as [ <b>Sigma0</b> ; <b>Alpha0</b> ], used in the search algorithm function. Default is $X0 = [0.5; 0.5]$ . For more information, see <code>lsqnonlin</code> .
OptimOptions	(Optional) Structure with optimization parameters. For more information, see <code>optimoptions</code> .

---

**Note:** All optional inputs are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. You can specify parameter name/value pairs in any order. Names are case-insensitive and partial string matches are allowed provided no ambiguities exist.

---

## Description

`[Alpha, Sigma, OptimOut] = hwcalbyfloor(RateSpec, MarketStrike, MarketMaturity, MarketVolatility)` to calibrate the **Alpha** (mean reversion) and **Sigma** (volatility) using cap market data and the Hull-White model using the entire floor surface.

`[Alpha, Sigma, OptimOut] = hwcalbyfloor(RateSpec, MarketStrike, MarketMaturity, MarketVolatility, Strike, Settle, Maturity)` to estimate the **Alpha** (mean reversion) and **Sigma** (volatility) using floor market data and the Hull-White model to price a floor at a particular maturity/volatility.

`[Alpha, Sigma, OptimOut] = hwcalbyfloor(RateSpec, MarketStrike, MarketMaturity, MarketVolatility, Strike, Settle, Maturity, 'Name1', Value1...)` to estimate the **Alpha** (mean reversion) and **Sigma** (volatility) using floor market data and the Hull-White model to price a floor at a particular maturity/volatility with optional name-value pair arguments.

The `hwcalbyfloor` outputs are:

- **Alpha** — Scalar representing the mean reversion value obtained from calibrating the floor using market information.
- **Sigma** — Scalar representing the volatility value obtained from calibrating the floor using market information.

- `OptimOut` — Structure with optimization results.

## Examples

For an example of calibrating using the Hull-White model with `Strike`, `Settle`, and `Maturity` input arguments, see “Calibrating Hull-White Model Using Market Data” on page 2-84.

### Calibrate Hull-White Model from Market Data Using the Entire Floor Volatility Surface

This example shows how to use `hwcalbyfloor` input arguments for `MarketStrike`, `MarketMaturity`, and `MarketVolatility` to calibrate the HW model using the entire floor volatility surface.

Floor market volatility data covering 2 strikes over 12 maturity dates.

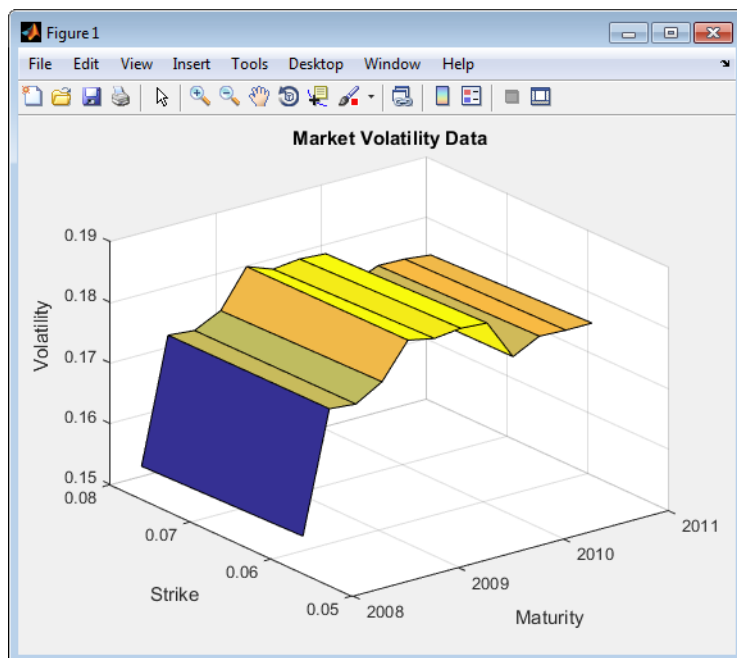
```
Reset = 4;
MarketStrike = [0.0590; 0.0790];

MarketMaturity = {'21-Mar-2008'; '21-Jun-2008'; '21-Sep-2008'; '21-Dec-2008';
                 '21-Mar-2009'; '21-Jun-2009'; '21-Sep-2009'; '21-Dec-2009';
                 '21-Mar-2010'; '21-Jun-2010'; '21-Sep-2010'; '21-Dec-2010'};
MarketMaturity = datenum(MarketMaturity);

MarketVolatility = [0.1533 0.1731 0.1727 0.1752 0.1809 0.1800 0.1805 0.1802...
                   0.1735 0.1757 0.1755 0.1755;
                   0.1526 0.1730 0.1726 0.1747 0.1808 0.1792 0.1797 0.1794...
                   0.1733 0.1751 0.1750 0.1745];
```

Plot market volatility surface.

```
[AllMaturities,AllStrikes] = meshgrid(MarketMaturity,MarketStrike);
figure;
surf(AllMaturities,AllStrikes,MarketVolatility)
datetick
xlabel('Maturity')
ylabel('Strike')
zlabel('Volatility')
title('Market Volatility Data')
```



Set interest rate term structure and create a `RateSpec`.

```
Settle = '21-Jan-2008';
Compounding = 4;
Basis = 0;
Rates = [0.0627; 0.0657; 0.0691; 0.0717; 0.0739; 0.0755; 0.0765; 0.0772;
0.0779; 0.0783; 0.0786; 0.0789];
EndDates = {'21-Mar-2008'; '21-Jun-2008'; '21-Sep-2008'; '21-Dec-2008'; ...
'21-Mar-2009'; '21-Jun-2009'; '21-Sep-2009'; '21-Dec-2009'; ...
'21-Mar-2010'; '21-Jun-2010'; '21-Sep-2010'; '21-Dec-2010'};
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding, ...
'Basis', Basis)
```

RateSpec =

```
FinObj: 'RateSpec'
Compounding: 4
Disc: [12x1 double]
Rates: [12x1 double]
EndTimes: [12x1 double]
StartTimes: [12x1 double]
EndDates: [12x1 double]
StartDates: 733428
```

```
ValuationDate: 733428
      Basis: 0
      EndMonthRule: 1
```

## Calibrate Hull-White model from market data.

```
o = optimoptions('lsqnonlin','TolFun',1e-5,'Display','off');
[Alpha, Sigma] = hwcalbyfloor(RateSpec, MarketStrike, MarketMaturity,...
    MarketVolatility, 'Reset', Reset, 'Basis', Basis, 'OptimOptions', o)
Warning: LSQNONLIN did not converge to an optimal solution. It exited with exitflag = 3.
> In hwcalbycapfloor>optimizeOverCapSurface at 232
   In hwcalbycapfloor at 79
   In hwcalbyfloor at 81
```

```
Alpha =
    0.0835
```

```
Sigma =
    0.0145
```

## Compare with Black prices.

```
BlkPrices = floorbyblk(RateSpec, AllStrikes(:), Settle, AllMaturities(:),...
    MarketVolatility(:), 'Reset', Reset, 'Basis', Basis)
```

```
BlkPrices =
    0
    0.2659
    0.0010
    0.5426
    0.0021
    0.6841
    0.0042
    0.7947
    0.0081
    0.8970
    0.0128
    0.9947
    0.0217
    1.1145
    0.0340
    1.2448
    0.0402
    1.3415
    0.0610
```



```

1.4947
0.0827
1.6458
0.1071
1.7951

```

Setup Hull-White tree using calibrated parameters, alpha and sigma.

```

VolDates    = EndDates;
VolCurve    = Sigma*ones(numel(EndDates),1);
AlphaDates  = EndDates;
AlphaCurve  = Alpha*ones(numel(EndDates),1);
HWVolSpec   = hwvolspec(Settle, VolDates, VolCurve, AlphaDates, AlphaCurve);

HWTimeSpec  = hwtimespec(Settle, EndDates, Compounding);
HWTree      = hwtree(HWVolSpec, RateSpec, HWTimeSpec, 'Method', 'HW2000')

HWTree =
    FinObj: 'HWFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
      tObs: [0 0.6593 1.6612 2.6593 3.6612 4.6593 5.6612 6.6593 7.6612 8.6593 9.6612 10.6593]
      dObs: [733428 733488 733580 733672 733763 733853 733945 734037 734128 734218 734310 734402]
    CFlowT: {1x12 cell}
    Probs: {1x11 cell}
    Connect: {1x11 cell}
    FwdTree: {1x12 cell}

```

Compute Hull-White prices based on the calibrated tree.

```

HWPrices = floorbyhw(HWTree, AllStrikes(:), Settle, AllMaturities(:), Reset, Basis)

```

```

HWPrices =
    0
    0.2644
    0.0067
    0.5404
    0.0101
    0.6924
    0.0169
    0.7974
    0.0236
    0.8919
    0.0320
    0.9919
    0.0460
    1.1074
    0.0649

```



# hwprice

Instrument prices from Hull-White interest-rate tree

## Syntax

```
[Price, PriceTree] = hwprice(HWTree, InstSet, Options)
```

## Arguments

HWTree	Interest-rate tree structure created by <code>hwtree</code> .
InstSet	Variable containing a collection of NINST instruments. Instruments are categorized by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
Options	(Optional) Derivatives pricing options structure created with <code>derivset</code> .

## Description

`[Price, PriceTree] = hwprice(HWTree, InstSet, Options)` computes arbitrage-free prices for instruments using an interest-rate tree created with `hwtree`. All instruments contained in a financial instrument variable, `InstSet`, are priced.

`Price` is a number of instruments (NINST)-by-1 vector of prices for each instrument. The prices are computed by backward dynamic programming on the interest-rate tree. If an instrument cannot be priced, NaN is returned.

`PriceTree` is a MATLAB structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node.

`PriceTree.PTree` contains the clean prices.

`PriceTree.AITree` contains the accrued interest.

`PriceTree.tObs` contains the observation times.

hwprice handles instrument types: 'Bond', 'CashFlow', 'OptBond', 'OptEmBond', 'OptEmBond', 'OptFloat', 'OptEmFloat', 'Fixed', 'Float', 'Cap', 'Floor', 'RangeFloat', 'Swap'. See instadd to construct defined types.

Related single-type pricing functions are:

- bondbyhw: Price a bond from a Hull-White tree.
- capbyhw: Price a cap from a Hull-White tree.
- cfbyhw: Price an arbitrary set of cash flows from a Hull-White tree.
- fixedbyhw: Price a fixed-rate note from a Hull-White tree.
- floatbyhw: Price a floating-rate note from a Hull-White tree.
- floorbyhw: Price a floor from a Hull-White tree.
- optbndbyhw: Price a bond option from a Hull-White tree.
- optembndbyhw: Price a bond with embedded option by a Hull-White tree.
- optfloatbybdt: Price a floating-rate note with an option from a Hull-White tree.
- optemfloatbybdt: Price a floating-rate note with an embedded option from a Hull-White tree.
- rangefloatbyhw: Price range floating note using a Hull-White tree.
- swapbyhw: Price a swap from a Hull-White tree.
- swaptionbyhw: Price a swaption from a Hull-White tree.

## Examples

Load the HW tree and instruments from the data file `deriv.mat`. Price the cap and bond instruments contained in the instrument set.

```
load deriv.mat;
HWSubSet = instselect(HWInstSet,'Type',{'Bond','Cap'});

instdisp(HWSubSet)

%Table of instrument portfolio partially displayed:
Index Type    CouponRate Settle      Maturity    Period ... Name ...
1      Bond     0.04        01-Jan-2004 01-Jan-2007 1      ... 4% bond
2      Bond     0.04        01-Jan-2004 01-Jan-2008 1      ... 4% bond

Index Type Strike Settle      Maturity    CapReset ... Name ...
3      Cap    0.06        01-Jan-2004 01-Jan-2008 1      ... 6% Cap

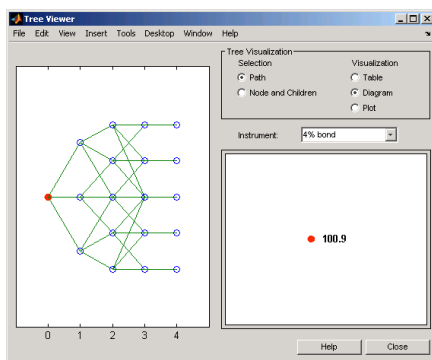
[Price, PriceTree] = hwprice(HWTree, HWSubSet);
```

Price =

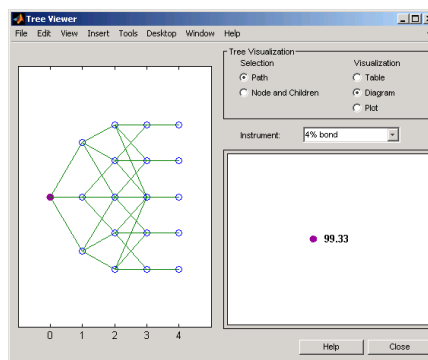
100.9188  
99.3296  
0.5837

You can use `treeview` to see the prices of these three instruments along the price tree.

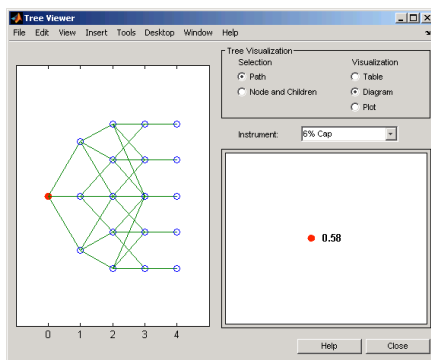
`treeview(PriceTree, HWSubSet)`



First 4% Bond (Maturity 2007)



Second 4% Bond (Maturity 2008)



6% Cap

Price the following multi-stepped coupon bonds using the following data:

% The data for the interest rate term structure is as follows:  
Rates = [0.035; 0.042147; 0.047345; 0.052707];

```

ValuationDate = 'Jan-1-2010';
StartDates = ValuationDate;
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};
Compounding = 1;

% Create RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% Create a portfolio of stepped coupon bonds with different maturities
Settle = '01-Jan-2010';
Maturity = {'01-Jan-2011'; '01-Jan-2012'; '01-Jan-2013'; '01-Jan-2014'};
CouponRate = {'01-Jan-2011' .042; '01-Jan-2012' .05; '01-Jan-2013' .06; '01-Jan-2014' .07}};

ISet = instbond(CouponRate, Settle, Maturity, 1);
instdisp(ISet)

%Table of instrument portfolio partially displayed:
Index Type CouponRate Settle Maturity Period Basis EndMonthRule ... Face
1 Bond [Cell] 01-Jan-2010 01-Jan-2011 1 0 1 ... 100
2 Bond [Cell] 01-Jan-2010 01-Jan-2012 1 0 1 ... 100
3 Bond [Cell] 01-Jan-2010 01-Jan-2013 1 0 1 ... 100
4 Bond [Cell] 01-Jan-2010 01-Jan-2014 1 0 1 ... 100

% Build the tree with the following data
VolDates = ['1-Jan-2011'; '1-Jan-2012'; '1-Jan-2013'; '1-Jan-2014'];
VolCurve = 0.01;
AlphaDates = '01-01-2014';
AlphaCurve = 0.1;

HWVolSpec = hwvolspec(RS.ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);
HWTimeSpec = hwtimespec(RS.ValuationDate, VolDates, Compounding);
HWT = hwtree(HWVolSpec, RS, HWTimeSpec);

% Compute the price of the stepped coupon bonds
PHW = hwprice(HWT, ISet)

PHW =

100.6763
100.7368
100.9266
101.0115

```

Price a portfolio of stepped callable bonds and stepped vanilla bonds using the following data:

```

% The data for the interest rate term structure is as follows:
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2010';
StartDates = ValuationDate;
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};
Compounding = 1;

%Create RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

```

```

% Create an instrument portfolio of 3 stepped callable bonds and three
% stepped vanilla bonds
Settle = '01-Jan-2010';
Maturity = {'01-Jan-2012'; '01-Jan-2013'; '01-Jan-2014'};
CouponRate = {{'01-Jan-2011' .042; '01-Jan-2012' .05; '01-Jan-2013' .06; '01-Jan-2014' .07}};
OptSpec='call';
Strike=100;
ExerciseDates='01-Jan-2011'; %Callable in one year

% Bonds with embedded option
ISet = instoptembnd(CouponRate, Settle, Maturity, OptSpec, Strike,...
ExerciseDates, 'Period', 1);

% Vanilla bonds
ISet = instbond(ISet, CouponRate, Settle, Maturity, 1);

% Display the instrument portfolio
instdisp(ISet)

%Table of instrument portfolio partially displayed:
Index Type CouponRate Settle Maturity OptSpec Strike ExerciseDates ... AmericanOpt
1 OptEmBond [Cell] 01-Jan-2010 01-Jan-2012 call 100 01-Jan-2011 ... 0
2 OptEmBond [Cell] 01-Jan-2010 01-Jan-2013 call 100 01-Jan-2011 ... 0
3 OptEmBond [Cell] 01-Jan-2010 01-Jan-2014 call 100 01-Jan-2011 ... 0

Index Type CouponRate Settle Maturity Period Basis EndMonthRule ... Face
4 Bond [Cell] 01-Jan-2010 01-Jan-2012 1 0 1 ... 100
5 Bond [Cell] 01-Jan-2010 01-Jan-2013 1 0 1 ... 100
6 Bond [Cell] 01-Jan-2010 01-Jan-2014 1 0 1 ... 100

% Build the tree with the following data
VolDates = ['1-Jan-2011'; '1-Jan-2012'; '1-Jan-2013'; '1-Jan-2014'];
VolCurve = 0.01;
AlphaDates = '01-01-2014';
AlphaCurve = 0.1;

HWVolSpec = hwvolspec(RS.ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);
HWTimeSpec = hwtimespec(RS.ValuationDate, VolDates, Compounding);
HWT = hwtree(HWVolSpec, RS, HWTimeSpec);

%The first three rows corresponds to the price of the stepped callable bonds
% and the last three rows corresponds to the price of the stepped vanilla bonds.

PHW = hwprice(HWT, ISet)

PHW =

100.4222
100.2275
100.0502
100.7368
100.9266
101.0115

```

Compute the price of a portfolio using the following data:

```
% The data for the interest rate term structure is as follows:
```

```

Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2011';
StartDates = ValuationDate;
EndDates = {'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'};
Compounding = 1;

% Create RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates',...
StartDates, 'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% Create an instrument portfolio with two range notes and a floating rate
% note with the following data:
Spread = 200;
Settle = 'Jan-1-2011';
Maturity = 'Jan-1-2014';

% First Range Note:
RateSched(1).Dates = {'Jan-1-2012'; 'Jan-1-2013' ; 'Jan-1-2014'};
RateSched(1).Rates = [0.045 0.055; 0.0525 0.0675; 0.06 0.08];

% Second Range Note:
RateSched(2).Dates = {'Jan-1-2012'; 'Jan-1-2013' ; 'Jan-1-2014'};
RateSched(2).Rates = [0.048 0.059; 0.055 0.068 ; 0.07 0.09];

% Create InstSet
InstSet = instadd('RangeFloat', Spread, Settle, Maturity, RateSched);

% Add a floating-rate note
InstSet = instadd(InstSet, 'Float', Spread, Settle, Maturity);

% Display the portfolio instrument
instdisp(InstSet)

Index Type      Spread Settle      Maturity  RateSched FloatReset Basis Principal EndMonthRule
1   RangeFloat  200    01-Jan-2011  01-Jan-2014 [Struct]  1         0    100      1
2   RangeFloat  200    01-Jan-2011  01-Jan-2014 [Struct]  1         0    100      1

Index Type  Spread Settle      Maturity  FloatReset Basis Principal EndMonthRule
3   Float    200    01-Jan-2011  01-Jan-2014  1         0    100      1

% The data to build the tree is as follows:
VolDates = ['1-Jan-2012'; '1-Jan-2013'; '1-Jan-2014'; '1-Jan-2015'];
VolCurve = 0.01;
AlphaDates = '01-01-2015';
AlphaCurve = 0.1;

HWVS = hwwolspec(RS.ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);
HWTS = hwtimespec(RS.ValuationDate, VolDates, Compounding);
HWT = hwtree(HWVS, RS, HWTS);

% Price the portfolio
Price = hwprice(HWT, InstSet)

Price =

    99.4075
    98.1003
   105.5147

```



## More About

- “Pricing Options Structure”

## See Also

hwsens | hwtree | instadd | intenvprice | intenvsens

## hwsens

Instrument prices and sensitivities from Hull-White interest-rate tree

### Syntax

```
[Delta, Gamma, Vega, Price] = hwsens(HWTtree, InstSet,
Options)
```

### Arguments

HWTtree	Interest-rate tree structure created by <code>hwtree</code> .
InstSet	Variable containing a collection of NINST instruments. Instruments are categorized by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
Options	(Optional) Derivatives pricing options structure created with <code>derivset</code> .

### Description

`[Delta, Gamma, Vega, Price] = hwsens(HWTtree, InstSet, Options)` computes instrument sensitivities and prices for instruments using an interest-rate tree created with the `hwtree` function. NINST instruments from a financial instrument variable, `InstSet`, are priced. `hwsens` handles instrument types: 'Bond', 'CashFlow', 'OptBond', 'OptEmBond', 'OptEmBond', 'OptFloat', 'OptEmFloat', 'Fixed', 'Float', 'Cap', 'Floor', 'RangeFloat', 'Swap'. See `instadd` for information on instrument types.

**Delta** is an NINST-by-1 vector of deltas, representing the rate of change of instrument prices with respect to changes in the interest rate. **Delta** is computed by finite differences in calls to `hwtree`. See `hwtree` for information on the observed yield curve.

**Gamma** is an NINST-by-1 vector of gammas, representing the rate of change of instrument deltas with respect to the changes in the interest rate. **Gamma** is computed by finite differences in calls to `hwtree`.

**Vega** is an NINST-by-1 vector of vegas, representing the rate of change of instrument prices with respect to the changes in the volatility  $\sigma(t, T)$ . Vega is computed by finite differences in calls to `hwtree`. See `hwvolspec` for information on the volatility process.

---

**Note** All sensitivities are returned as dollar sensitivities. To find the per-dollar sensitivities, divide by the respective instrument price.

---

**Price** is an NINST-by-1 vector of prices of each instrument. The prices are computed by backward dynamic programming on the interest-rate tree. If an instrument cannot be priced, NaN is returned.

**Delta** and **Gamma** are calculated based on yield shifts of 100 basis points. Vega is calculated based on a 1% shift in the volatility process.

## Examples

### Compute Instrument Sensitivities Using an HW Interest-Rate Tree

Load the tree and instruments from the `deriv.mat` data file. Compute Delta and Gamma for the cap and bond instruments contained in the instrument set.

```
load deriv.mat;
HWSubSet = instselect(HWInstSet, 'Type', {'Bond', 'Cap'});
```

```
instdisp(HWSubSet)
```

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate
1	Bond	0.04	01-Jan-2004	01-Jan-2007	1	0	1	NaN
2	Bond	0.04	01-Jan-2004	01-Jan-2008	1	0	1	NaN

Index	Type	Strike	Settle	Maturity	CapReset	Basis	Principal	Name	Quantity
3	Cap	0.06	01-Jan-2004	01-Jan-2008	1	0	100	6% Cap	10

Compute the Delta and Gamma for the cap and bond instruments.

```
[Delta, Gamma] = hwsens(HWTree, HWSubSet)
```

Delta =

-291.2580  
-374.6368  
59.5474

Gamma =

1.0e+03 \*  
  
0.8584  
1.4609  
4.8436

### More About

- “Pricing Options Structure”

### See Also

hwprice | hwtree | hwvolspec | instadd

# hwtimespec

Specify time structure for Hull-White interest-rate tree

## Syntax

TimeSpec = hwtimespec(ValuationDate, Maturity, Compounding)

## Arguments

ValuationDate	Scalar date marking the pricing date and first observation in the tree. Specify as a serial date number or date string
Maturity	Number of levels (depth) of the tree. A number of levels (NLEVELS)-by-1 vector of dates marking the cash flow dates of the tree. Cash flows with these maturities fall on tree nodes. Maturity should be in increasing order.
Compounding	<p>(Optional) Scalar value representing the rate at which the input zero rates were compounded when annualized. Default = -1 (continuous compounding). This argument determines the formula for the discount factors:</p> <p>Compounding = 1, 2, 3, 4, 6, 12 = F</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the compounding frequency, Z is the zero rate, and T is the time in periodic units; for example, T = F is 1 year.</p> <p>Compounding = 365</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the number of days in the basis year and T is a number of days elapsed computed by basis.</p> <p>Compounding = -1</p> <p>Disc = <math>\exp(-T*Z)</math>, where T is time in years.</p>

## Description

`TimeSpec = hwtimespec(ValuationDate, Maturity, Compounding)` sets the number of levels and node times for a Hull-White tree and determines the mapping between dates and time for rate quoting.

`TimeSpec` is a structure specifying the time layout for `hwtree`. The state observation dates are `[Settle; Maturity(1:end-1)]`. Because a forward rate is stored at the last observation, the tree can value cash flows out to `Maturity`.

## Examples

### Set the Number of Levels and Node Times for a Hull-White Tree

This example shows how to specify a four-period tree with annual nodes and use annual compounding to report rates.

```
ValuationDate = 'Jan-1-2004';
Maturity = ['12-31-2004'; '12-31-2005'; '12-31-2006';
'12-31-2007'];
Compounding = 1;
TimeSpec = hwtimespec(ValuationDate, Maturity, Compounding)
```

```
TimeSpec =
    FinObj: 'HWTimeSpec'
ValuationDate: 731947
    Maturity: [4x1 double]
    Compounding: 1
    Basis: 0
    EndMonthRule: 1
```

### See Also

`bktree` | `hwtree` | `hwvolspec`

# hwtree

Construct Hull-White interest-rate tree

## Syntax

```
HWTTree = hwtree(VolSpec, RateSpec, TimeSpec)  
HWTTree = hwtree(VolSpec, RateSpec, TimeSpec, Name, Value)
```

## Description

`HWTTree = hwtree(VolSpec, RateSpec, TimeSpec)` creates a structure containing time and interest-rate information on a recombining tree.

`HWTTree = hwtree(VolSpec, RateSpec, TimeSpec, Name, Value)` creates a structure containing time and interest-rate information on a recombining tree with additional options specified by one or more `Name, Value` pair arguments.

## Input Arguments

### VolSpec

Volatility process specification. See `hwvolspec` for information on the volatility process.

### RateSpec

Interest-rate specification for the initial rate curve. See `intenvset` for information on declaring an interest-rate variable.

### TimeSpec

Tree time layout specification. Defines the observation dates of the HW tree and the compounding rule for date to time mapping and price-yield formulas. See `hwtimespec` for information on the tree structure.

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes ( ' '). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

### 'Method'

String specifies the Hull-White method upon which the tree-node connectivity algorithm is based. Possible values are `HW1996` and `HW2000`.

---

**Note:** `hwtree` supports two tree-node connectivity algorithms. `HW1996` is based on the original paper published in the *Journal of Derivatives*, and `HW2000` is the general version of the algorithm, as specified in the paper published in August 2000.

---

**Default:** `HW1996`

## Output Arguments

### `HWTtree`

Structure containing time and interest rate information of a trinomial recombining tree.

## Examples

Using the data provided, create a Hull-White volatility specification (`VolSpec`), rate specification (`RateSpec`), and tree time layout specification (`TimeSpec`). Then use these specifications to create a Hull-White tree using `hwtree`.

```
Compounding = -1;  
ValuationDate = '01-01-2004';  
StartDate = ValuationDate;  
VolDates = ['12-31-2004'; '12-31-2005'; '12-31-2006';  
            '12-31-2007'];  
VolCurve = 0.01;  
AlphaDates = '01-01-2008';
```



```

AlphaCurve = 0.1;
Rates = [0.0275; 0.0312; 0.0363; 0.0415];

HWVolSpec = hwwolspec(ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);

RateSpec = intenvset('Compounding', Compounding,...
'ValuationDate', ValuationDate,...
'StartDates', ValuationDate,...
'EndDates', VolDates,...
'Rates', Rates);

HWTTimeSpec = hwtimespec(ValuationDate, VolDates, Compounding);
HWTTree = hwtree(HWVolSpec, RateSpec, HWTTimeSpec)

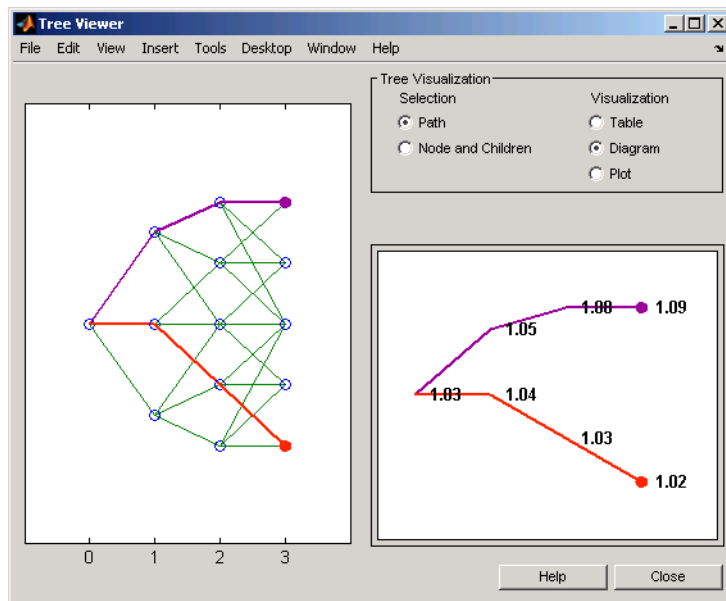
HWTTree =

    FinObj: 'HWFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
      tObs: [0 0.9973 1.9973 2.9973]
      dObs: [731947 732312 732677 733042]
    CFlowT: {[4x1 double] [3x1 double] [2x1 double] [3.9973]}
    Probs: {[3x1 double] [3x3 double] [3x5 double]}
    Connect: {[2] [2 3 4] [2 2 3 4 4]}
    FwdTree: {1x4 cell}

```

Use `treeviewer` to observe the tree you have created.

```
treeviewer(HWTTree)
```



## References

Hull, J., and A. White, "Using Hull-White Interest Rate Trees", *Journal of Derivatives*, 1996.

Hull, J., and A. White, "The General Hull-White Model and Super Calibration", August 2000.

## See Also

| [hwcalbycap](#) | [hwcalbyfloor](#) | [hwprice](#) | [hwtimespec](#) | [hwvolspec](#) | [intenvset](#)

## Tutorials

- "Calibrating Hull-White Model Using Market Data"

# hwvolspec

Specify Hull-White interest-rate volatility process

## Syntax

`Volspec = hwvolspec(ValuationDate, VolDates, VolCurve, AlphaDates, AlphaCurve, InterpMethod)`

## Arguments

ValuationDate	Scalar value representing the observation date of the investment horizon.
VolDates	Number of points (NPOINTS)-by-1 vector of yield volatility end dates.
VolCurve	NPOINTS-by-1 vector or scalar of yield volatility values in decimal form. The term structure of VolCurve is the yield volatility represented by the value of the volatility of the yield from time $t = 0$ to time $t + i$ , where $i$ is any point within the volatility curve.
AlphaDates	MPOINTS-by-1 vector of mean reversion end dates.
AlphaCurve	MPOINTS-by-1 vector of positive mean reversion values or scalar in decimal form.
InterpMethod	(Optional) Interpolation method. Default is 'linear'. See <code>interp1</code> for more information.

---

**Note:** The number of points in VolCurve and AlphaCurve do not have to be the same.

---

## Description

`Volspec = hwvolspec(ValuationDate, VolDates, VolCurve, AlphaDates, AlphaCurve, InterpMethod)` creates a structure specifying the volatility for hwtree.

The volatility process is such that the variance of  $r(t + dt) - r(t)$  is defined as follows:  $V = (\text{Volatility}^2 .* (1 - \exp(-2 * \text{Alpha} .* dt))) ./ (2 * \text{Alpha})$ . For more information on using Hull-White interest rate trees, see “Hull-White (HW) and Black-Karasinski (BK) Modeling” on page C-4.

## Examples

### Create a Structure Specifying the Volatility for hwtree

This example shows how to create a Hull-White volatility specification (`VolSpec`) using the following data.

```
ValuationDate = '01-01-2004';
StartDate = ValuationDate;
VolDates = ['12-31-2004'; '12-31-2005'; '12-31-2006';
'12-31-2007'];
VolCurve = 0.01;
AlphaDates = '01-01-2008';
AlphaCurve = 0.1;

HWVolSpec = hwvolspec(ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve)
```

```
HWVolSpec =

    FinObj: 'HWVolSpec'
  ValuationDate: 731947
    VolDates: [4x1 double]
    VolCurve: [4x1 double]
  AlphaCurve: 0.1000
  AlphaDates: 733408
 VolInterpMethod: 'linear'
```

### See Also

`bktree` | `hwcalbycap` | `hwcalbyfloor` | `interp1`

# impvbybjs

Determine implied volatility using Bjerk Sund-Stensland 2002 option pricing model

## Syntax

```
Volatility = impvbybjs(RateSpec, StockSpec, Settle,
Maturity, OptSpec, Strike, OptPrice, 'Name1', Value1...)
```

## Arguments

RateSpec	The annualized continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.
OptPrice	NINST-by-1 vector of American option prices from which the implied volatility of the underlying asset are derived.
<b>Note:</b> All optional inputs are specified as matching parameter name/parameter value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. You can specify parameter name/parameter value pairs in any order; names are case-insensitive and partial string matches are allowed provided no ambiguities exist.	
Limit	(Optional) 1-by-2 positive vector representing the lower and upper bound of the implied volatility search interval. Default is [0.1 10], or 10% to 1000% per annum.
Tolerance	(Optional) Positive scalar implied volatility termination tolerance. Default is $1e-6$ .

## Description

`Volatility = impvbybjs(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike, OptPrice, 'Name1', Value1...)` computes implied volatility using the Bjerksund-Stensland 2002 option pricing model.

`Volatility` is a NINST-by-1 vector of expected implied volatility values. If no solution is found, a NaN is returned.

---

**Note:** `impvbybjs` computes implied volatility of American options with continuous dividend yield using the Bjerksund-Stensland option pricing model.

---

## Examples

### Compute the Implied Volatility Using the Bjerksund-Stensland 2002 Option Pricing Model

This example shows how to compute implied volatility using the Bjerksund-Stensland 2002 option pricing model. Consider three American call options with exercise prices of \$100 that expire on July 1, 2008. The underlying stock is trading at \$100 on January 1, 2008 and pays a continuous dividend yield of 10%. The annualized continuously compounded risk-free rate is 10% per annum and the option prices are \$4.063, \$6.77 and \$9.46. Using this data, calculate the implied volatility of the stock using the Bjerksund-Stensland 2002 option pricing model.

```
AssetPrice = 100;
Settle = 'Jan-1-2008';
Maturity = 'Jul-1-2008';
Strike = 100;
DivAmount = 0.1;
Rate = 0.1;

% define the RateSpec and StockSpec
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
    'EndDates', Maturity, 'Rates', Rate, 'Compounding', -1, 'Basis', 1);

StockSpec = stockspec(NaN, AssetPrice, {'continuous'}, DivAmount);

OptSpec = {'call'};
OptionPrice = [4.063;6.77;9.46];
```

```
ImpVol = impvbybjs(RateSpec, StockSpec, Settle, Maturity, OptSpec,...  
Strike, OptionPrice)
```

```
ImpVol =  
    0.1500  
    0.2501  
    0.3500
```

The implied volatility is 15% for the first call, and 25% and 35% for the second and third call options.

## References

Bjerk Sund, P. and G. Stensland, *Closed-Form Approximation of American Options*, Scandinavian Journal of Management, 1993, Vol. 9, Suppl., pp. S88-S99.

Bjerk Sund, P. and G. Stensland, *Closed Form Valuation of American Options*, Discussion paper 2002 ([http://brage.bibsys.no/nhh/bitstream/URN:NBN:no-bibsys\\_brage\\_22301/1/bjerk\\_sund%20petter%200902.pdf](http://brage.bibsys.no/nhh/bitstream/URN:NBN:no-bibsys_brage_22301/1/bjerk_sund%20petter%200902.pdf))

## See Also

optstockbybjs | optstocksensbybjs

## impvbyblk

Determine implied volatility using Black option pricing model

### Syntax

```
Volatility = impvbyblk(RateSpec, StockSpec, Settle,
Maturity, Strike, OptPrice, 'Name1', Value1...)
```

### Arguments

RateSpec	The annualized continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.
OptPrice	NINST-by-1 vector of European option prices from which the implied volatility of the underlying asset are derived.
<b>Note:</b> All optional inputs are specified as matching parameter name/parameter value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. You can specify parameter name/parameter value pairs in any order; names are case-insensitive and partial string matches are allowed provided no ambiguities exist.	
Limit	(Optional) Positive scalar representing the upper bound of the implied volatility search interval. Default is 10, or 1000% per annum.
Tolerance	(Optional) Positive scalar implied volatility termination tolerance. Default is 1e-6.



## Description

`Volatility = impvbyblk(RateSpec, StockSpec, Settle, Maturity, Strike, OptPrice, 'Name1', Value1...)` computes implied volatility using the Black option pricing model.

`Volatility` is a NINST-by-1 vector of expected implied volatility values. If no solution is found, a NaN is returned.

## Examples

### Compute the Implied Volatility Using the Black Option Pricing Model

This example shows how to compute the implied volatility using the Black option pricing model. Consider a European call and put options on a futures contract with exercise prices of \$30 for the put and \$40 for the call that expire on September 1, 2008. Assume that on May 1, 2008 the contract is trading at \$35. The annualized continuously compounded risk-free rate is 5% per annum. Find the implied volatilities of the stock, if on that date, the call price is \$1.14 and the put price is \$0.82.

```
AssetPrice = 35;
Strike = [30; 40];
Rates = 0.05;
Settle = 'May-01-08';
Maturity = 'Sep-01-08';

% define the RateSpec and StockSpec
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
'EndDates', Maturity, 'Rates', Rates, 'Compounding', -1);

StockSpec = stockspec(NaN, AssetPrice);

% define the options
OptSpec = {'put'; 'call'};

Price = [1.14; 0.82];
Volatility = impvbyblk(RateSpec, StockSpec, Settle, Maturity, OptSpec,...
Strike, Price)

Volatility =
```

0.4052  
0.3021

The implied volatility is 41% and 30%.

### **See Also**

`optstockbyblk` | `optstocksensbyblk`

# impvbybls

Determine implied volatility using Black-Scholes option pricing model

## Syntax

```
Volatility = impvbybls(RateSpec, StockSpec, Settle,
Maturity, Strike, OptPrice, 'Name1', Value1...)
```

## Arguments

RateSpec	The annualized continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.
OptPrice	NINST-by-1 vector of European option prices from which the implied volatility of the underlying asset are derived.
<p><b>Note:</b> All optional inputs are specified as matching parameter name/parameter value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. You can specify parameter name/parameter value pairs in any order; names are case-insensitive and partial string matches are allowed provided no ambiguities exist.</p>	
Limit	(Optional) Positive scalar representing the upper bound of the implied volatility search interval. Default is 10, or 1000% per annum.
Tolerance	(Optional) Positive scalar implied volatility termination tolerance. Default is 1e-6.

## Description

`Volatility = impvbybls(RateSpec, StockSpec, Settle, Maturity, Strike, OptPrice, 'Name1', Value1...)` computes implied volatility using the Black-Scholes option pricing model.

`Volatility` is a NINST-by-1 vector of expected implied volatility values. If no solution is found, a NaN is returned.

## Examples

### Compute the Implied Volatility Using the Black-Scholes Option Pricing Model

This example shows how to compute the implied volatility using the Black-Scholes option pricing model. Consider a European call and put options with an exercise price of \$40 that expires on June 1, 2008. The underlying stock is trading at \$45 on January 1, 2008 and the risk-free rate is 5% per annum. The option price is \$7.10 for the call and \$2.85 for the put. Using this data, calculate the implied volatility of the European call and put using the Black-Scholes option pricing model.

```
AssetPrice = 45;
Settlement = 'Jan-01-2008';
Maturity = 'June-01-2008';
Strike = 40;
Rates = 0.05;
OptionPrice = [7.10; 2.85];
OptSpec = {'call'; 'put'};

% define the RateSpec and StockSpec
RateSpec = intenvset('ValuationDate', Settlement, 'StartDates', Settlement, ...
    'EndDates', Maturity, 'Rates', Rates, 'Compounding', -1, 'Basis', 1);

StockSpec = stockspec(NaN, AssetPrice);

ImpvVol = impvbybls(RateSpec, StockSpec, Settlement, Maturity, OptSpec, ...
    Strike, OptionPrice)

ImpvVol =

    0.3175
```

0.4878

The implied volatility is 31.75% for the call and 48.78% for the put.

**See Also**

[optstockbybls](#) | [optstocksensbybls](#)

## impvbyrgw

Determine implied volatility using Roll-Geske-Whaley option pricing model for American call option

### Syntax

```
Volatility = impvbyrgw(RateSpec, StockSpec, Settle,
Maturity, Strike, OptPrice, 'Name1', Value1...)
```

### Arguments

RateSpec	The annualized continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
Strike	NINST-by-1 vector of strike price values.
OptPrice	NINST-by-1 vector of American call option prices from which the implied volatility of the underlying asset are derived.
<b>Note:</b> All optional inputs are specified as matching parameter name/parameter value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. You can specify parameter name/parameter value pairs in any order; names are case-insensitive and partial string matches are allowed provided no ambiguities exist.	
Limit	(Optional) Positive scalar representing the upper bound of the implied volatility search interval. Default is 10, or 1000% per annum.
Tolerance	(Optional) Positive scalar implied volatility termination tolerance. Default is 1e-6.

## Description

Volatility = impvbyrgw(RateSpec, StockSpec, Settle, Maturity, Strike, OptPrice, 'Name1', Value1...) computes implied volatility using the Roll-Geske-Whaley option pricing model.

Volatility is a NINST-by-1 vector of expected implied volatility values. If no solution is found, a NaN is returned.

---

**Note:** impvbyrgw computes implied volatility of American calls with a single cash dividend using the Roll-Geske-Whaley option pricing model.

---

## Examples

### Compute the Implied Volatility Using the Roll-Geske-Whaley Option Pricing Model

This example shows how to compute the implied volatility using the Roll-Geske-Whaley option pricing model. Assume that on July 1, 2008 a stock is trading at \$13 and pays a single cash dividend of \$0.25 on November 1, 2008. The American call option with a strike price of \$15 expires on July 1, 2009 and is trading at \$1.346. The annualized continuously compounded risk-free rate is 5% per annum. Calculate the implied volatility of the stock using the Roll-Geske-Whaley option pricing model.

```
AssetPrice = 13;
Strike = 15;
Rates = 0.05;
Settle = 'July-01-08';
Maturity = 'July-01-09';

% define the RateSpec and StockSpec
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
    'EndDates', Maturity, 'Rates', Rates, 'Compounding', -1);

StockSpec = stockspec(NaN, AssetPrice, {'cash'}, 0.25, {'Nov 1,2008'});

Price = [1.346];
Volatility = impvbyrgw(RateSpec, StockSpec, Settle, Maturity, Strike, Price)

Volatility =
```

0.3539

**See Also**

optstockbyrgw | optstocksensbyrgw



# instadd

Add types to instrument collection

## Syntax

```

InstSet = instadd(InstSetOld, TypeString, Data1, Data2, ...)
InstSet = instadd('CashFlow', CFlowAmounts, CFlowDates, Settle,
Basis)
InstSet = instadd('CashFlow', CFlowAmounts, CFlowDates, Settle,
Basis)
InstSet = instadd('Barrier', OptSpec, Strike, Settle,
ExerciseDates, AmericanOpt, BarrierType, Barrier, Rebate)
InstSet = instadd('Bond', CouponRate, Settle, Maturity, Period,
Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate,
StartDate, Face)
InstSet = instadd('OptEmBond', CouponRate, Settle, Maturity,
OptSpec, Strike, ExerciseDates, 'AmericanOpt', AmericanOpt,
'Period',
Period, 'Basis', Basis, 'EndMonthRule', EndMonthRule, 'Face', Face,
'IssueDate', IssueDate, 'FirstCouponDate', FirstCouponDate,
'LastCouponDate', LastCouponDate, 'StartDate', StartDate)
InstSet = instadd('OptBond', BondIndex, OptSpec, Strike,
ExerciseDates, AmericanOpt)
InstSet = instadd('Cap', Strike, Settle, Maturity, Reset, Basis,
Principal)
InstSet = instadd('Compound', UOptSpec, UStrike, USettle,
UExerciseDates, UAmericanOpt, COptSpec, CStrike, CSettle,
CExerciseDates, CAmericanOpt)
InstSet = instadd('Fixed', CouponRate, Settle, Maturity, Reset,
Basis, Principal, EndMonthRule)
InstSet = instadd('Float', Spread, Settle, Maturity, Reset, Basis,
Principal, EndMonthRule, CapRate, FloorRate)
InstSet = instadd('Floor', Strike, Settle, Maturity, Reset, Basis,
Principal)
InstSet = instadd('Lookback', OptSpec, Strike, Settle,
ExerciseDates, AmericanOpt)
InstSet = instadd('OptFloat', OptSpec, Strike, Settle,

```

```
ExerciseDates, AmericanOpt)
InstSet = instadd('OptEmFloat', OptSpec, Strike, Settle,
ExerciseDates, AmericanOpt, Reset, Basis, EndMonthRule, Principal)
InstSet = instadd('RangeFloat', Spread, Settle, Maturity,
RateSched, Reset, Basis, Principal, EndMonthRule)
InstSet = instadd('OptStock', OptSpec, Strike, Settle, Maturity,
AmericanOpt)
InstSet = instadd('Swap', LegRate, Settle, Maturity, LegReset,
Basis, Principal, LegType, EndMonthRule, StartDate)
InstSet = instadd('Swaption', OptSpec, Strike, ExerciseDates,
Spread, Settle, Maturity, AmericanOpt, SwapReset, Basis, Principal)
```

## Description

`InstSet = instadd(InstSetOld, TypeString, Data1, Data2, ...)` adds an instruments to an existing collection.

`InstSet = instadd('CashFlow', CFlowAmounts, CFlowDates, Settle, Basis)` adds an arbitrary cash flow instrument. (See also `instcfl`.)

`InstSet = instadd('CashFlow', CFlowAmounts, CFlowDates, Settle, Basis)` adds an asian instrument. (See also `instasian`.)

`InstSet = instadd('Barrier', OptSpec, Strike, Settle, ExerciseDates, AmericanOpt, BarrierType, Barrier, Rebate)` adds a barrier instrument. (See also `instbarrier`.)

`InstSet = instadd('Bond', CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face)` adds a bond instrument. (See also `instbond`.)

`InstSet = instadd('OptEmBond', CouponRate, Settle, Maturity, OptSpec, Strike, ExerciseDates, 'AmericanOpt', AmericanOpt, 'Period', Period, 'Basis', Basis, 'EndMonthRule', EndMonthRule, 'Face', Face, 'IssueDate', IssueDate, 'FirstCouponDate', FirstCouponDate, 'LastCouponDate', LastCouponDate, 'StartDate', StartDate)` adds a bond with embedded option instrument. (See also `instoptembnd`.)

`InstSet = instadd('OptBond', BondIndex, OptSpec, Strike,`

ExerciseDates, AmericanOpt) adds a bond option instrument. (See also instoptbnd.)

InstSet = instadd('Cap', Strike, Settle, Maturity, Reset, Basis, Principal) adds a cap instrument. (See also instcap.)

InstSet = instadd('Compound', UOptSpec, UStrike, USettle, UExerciseDates, UAmericanOpt, COptSpec, CStrike, CSettle, CExerciseDates, CAmericanOpt) adds a compound instrument. (See also instcompound.)

InstSet = instadd('Fixed', CouponRate, Settle, Maturity, Reset, Basis, Principal, EndMonthRule) adds a fixed-rate note instrument. (See also instfixed.)

InstSet = instadd('Float', Spread, Settle, Maturity, Reset, Basis, Principal, EndMonthRule, CapRate, FloorRate) adds a floating-rate note instrument. (See also instfloat.)

InstSet = instadd('Floor', Strike, Settle, Maturity, Reset, Basis, Principal) adds a floor instrument. (See also instfloor.)

InstSet = instadd('Lookback', OptSpec, Strike, Settle, ExerciseDates, AmericanOpt) adds a lookback instrument. (See also instlookback.)

InstSet = instadd('OptFloat', OptSpec, Strike, Settle, ExerciseDates, AmericanOpt) adds a floating-rate option instrument. (See also instoptfloat.)

InstSet = instadd('OptEmFloat', OptSpec, Strike, Settle, ExerciseDates, AmericanOpt, Reset, Basis, EndMonthRule, Principal) adds a floating-rate embedded option instrument. (See also instoptemfloat.)

InstSet = instadd('RangeFloat', Spread, Settle, Maturity, RateSched, Reset, Basis, Principal, EndMonthRule) adds a range floating note instrument. (See also instrangefloat.)

InstSet = instadd('OptStock', OptSpec, Strike, Settle, Maturity, AmericanOpt) adds a stock option instrument. (See also instoptstock.)

InstSet = instadd('Swap', LegRate, Settle, Maturity, LegReset,

Basis, Principal, LegType, EndMonthRule, StartDate) adds a swap instrument. (See also `instswap`.)

`InstSet = instadd('Swaption', OptSpec, Strike, ExerciseDates, Spread, Settle, Maturity, AmericanOpt, SwapReset, Basis, Principal)` adds a swaption instrument. (See also `instswaption`.)

`instadd` stores instruments of types 'Asian', 'Barrier', 'Bond', 'Cap', 'CashFlow', 'Compound', 'Fixed', 'Float', 'Floor', 'Lookback', 'OptBond', 'OptStock', 'Swap', or 'Swaption'. Financial Instruments Toolbox provides pricing and sensitivity routines for these instruments.

## Input Arguments

### **InstSetOld**

Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument. For more information on instrument data parameters, see the reference entries for individual instrument types. For example, see `instcap` for additional information on the cap instrument.

## Output Arguments

### **InstSet**

`InstSet` is an instrument set variable containing the new input data.

## Examples

### **Create a Portfolio with Two Cap Instruments and a 4% Bond**

Define the bond:

```
Strike = [0.06; 0.07];  
CouponRate = 0.04;  
Settle = '06-Feb-2000';  
Maturity = '15-Jan-2003';
```

Create a portfolio with two cap instruments and a 4% bond and then display the portfolio:

```
InstSet = instadd('Cap', Strike, Settle, Maturity);
InstSet = instadd(InstSet, 'Bond', CouponRate, Settle, Maturity);
instdisp(InstSet)
```

Index	Type	Strike	Settle	Maturity	CapReset	Basis	Principal
1	Cap	0.06	06-Feb-2000	15-Jan-2003	1	0	100
2	Cap	0.07	06-Feb-2000	15-Jan-2003	1	0	100

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate
3	Bond	0.04	06-Feb-2000	15-Jan-2003	2	0	1	NaN

- “Portfolio Creation” on page 1-7
- “Creating Instruments or Properties” on page 1-17

## More About

- “Instrument Constructors” on page 1-16

## See Also

instaddfield | instasian | instbarrier | instbond | instcap | instcf | instcompound | instdisp | instfixed | instfloat | instfloor | instlookback | instoptbnd | instoptembnd | instoptstock | instswap | instswaption

## instaddfield

Add new instruments to instrument collection

### Syntax

```
InstSet = instaddfield('FieldName', FieldList, 'Data',
DataList, 'Type', TypeString)
InstSet = instaddfield('FieldName', FieldList, 'FieldClass',
ClassList, 'Data', DataList, 'Type', TypeString)
InstSetNew = instaddfield(InstSet, 'FieldName', FieldList,
'Data', DataList, 'Type', TypeString)
```

### Arguments

<b>FieldList</b>	String or number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field. <b>FieldList</b> cannot be named with the reserved name <b>Type</b> or <b>Index</b> .
<b>DataList</b>	Number of instruments (NINST)-by-M array or NFIELDS-by-1 cell array of data contents for each field. Each row in a data array corresponds to a separate instrument. Single rows are copied to apply to all instruments to be worked on. The number of columns is arbitrary, and data is padded along columns.
<b>ClassList</b>	(Optional) String or NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how <b>DataList</b> is parsed. Valid strings are 'dble', 'date', and 'char'. The 'FieldClass', <b>ClassList</b> pair is always optional. <b>ClassList</b> is inferred from existing field names or from the data if not entered.
<b>TypeString</b>	String specifying the type of instrument added. Instruments of different types can have different <b>Fieldname</b> collections.
<b>InstSet</b>	Variable containing a collection of instruments. Instruments are classified by type; each type can have different <b>Data</b> fields. The stored <b>Data</b> field is a row vector or string for each instrument.

## Description

InstSet = instaddfield('FieldName', FieldList, 'Data', DataList, 'Type', TypeString) to create your own types of instruments or to append new instruments to an existing collection. Argument value pairs can be entered in any order.

InstSet = instaddfield('FieldName', FieldList, 'FieldClass', ClassList, 'Data', DataList, 'Type', TypeString) creates an instrument variable.

InstSetNew = instaddfield(InstSet, 'FieldName', FieldList, 'Data', DataList, 'Type', TypeString) adds instruments to an existing instrument set, InstSet. The output InstSetNew is a new instrument set containing the input data.

## Examples

Build a portfolio around July options.

Strike	Call	Put
95	12.2	2.9
100	9.2	4.9
105	6.8	7.4

```
Strike = (95:5:105)
CallP = [12.2; 9.2; 6.8]
```

Enter three call options with data fields Strike, Price, and Opt.

```
InstSet = instaddfield('Type','Option','FieldName',...
{'Strike','Price','Opt'}, 'Data',{ Strike, CallP, 'Call'});
instdisp(InstSet)
```

Index	Type	Strike	Price	Opt
1	Option	95	12.2	Call
2	Option	100	9.2	Call
3	Option	105	6.8	Call

Add a futures contract and set the input parsing class.

```
InstSet = instaddfield(InstSet,'Type','Futures',...
'FieldName',{'Delivery','F'}, 'FieldClass',{'date','dble'},...
```

```
'Data' ,{'01-Jul-99',104.4 });
instdisp(InstSet)
```

Index	Type	Strike	Price	Opt
1	Option	95	12.2	Call
2	Option	100	9.2	Call
3	Option	105	6.8	Call

Index	Type	Delivery	F
4	Futures	01-Jul-1999	104.4

Add a put option.

```
FN = instfields(InstSet,'Type','Option')
InstSet = instaddfield(InstSet,'Type','Option',...
'FieldName',FN, 'Data',{105, 7.4, 'Put'});
instdisp(InstSet)
```

Index	Type	Strike	Price	Opt
1	Option	95	12.2	Call
2	Option	100	9.2	Call
3	Option	105	6.8	Call

Index	Type	Delivery	F
4	Futures	01-Jul-1999	104.4

Index	Type	Strike	Price	Opt
5	Option	105	7.4	Put

Make a placeholder for another put.

```
InstSet = instaddfield(InstSet,'Type','Option',...
'FieldName','Opt','Data','Put')
instdisp(InstSet)
```

Index	Type	Strike	Price	Opt
1	Option	95	12.2	Call
2	Option	100	9.2	Call
3	Option	105	6.8	Call

Index	Type	Delivery	F
4	Futures	01-Jul-1999	104.4

Index	Type	Strike	Price	Opt
5	Option	105	7.4	Put
6	Option	NaN	NaN	Put



Add a cash instrument.

```
InstSet = instaddfield(InstSet, 'Type', 'TBill',...  
'FieldName','Price','Data',99)  
instdisp(InstSet)
```

Index	Type	Strike	Price	Opt
1	Option	95	12.2	Call
2	Option	100	9.2	Call
3	Option	105	6.8	Call

Index	Type	Delivery	F
4	Futures	01-Jul-1999	104.4

Index	Type	Strike	Price	Opt
5	Option	105	7.4	Put
6	Option	NaN	NaN	Put

Index	Type	Price
7	TBill	99

## See Also

[instdisp](#) | [instget](#) | [instgetcell](#) | [instsetfield](#) | [instadd](#)

## instasian

Construct Asian option

### Syntax

```
InstSet = instasian(InstSet, OptSpec, Strike, Settle,
ExerciseDates, AmericanOpt, AvgType, AvgPrice, AvgDate)
[FieldList, ClassList, TypeString] = instasian
```

### Arguments

InstSet	Instrument variable. This argument is specified only when adding asian instruments to an existing instrument set. See <code>instget</code> for more information on the <code>InstSet</code> variable.
OptSpec	NINST-by-1 list of string values 'Call' or 'Put'.
Strike	NINST-by-1 vector of strike price values. Each row is the schedule for one option.
Settle	NINST-by-1 vector of <code>Settle</code> dates.
ExerciseDates	For a European option ( <code>AmericanOpt = 0</code> ):  NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.  For an American option ( <code>AmericanOpt = 1</code> ):  NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <code>ExerciseDates</code> is NINST-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.
AmericanOpt	(Optional) If <code>AmericanOpt = 0</code> , NaN, or is unspecified, the option is a European option. If <code>AmericanOpt = 1</code> , the option is an American option.

AvgType	(Optional) String = 'arithmetic' for arithmetic average (default) or 'geometric' for geometric average.
AvgPrice	(Optional) Scalar representing the average price of the underlying asset at <b>Settle</b> . This argument is used when <b>AvgDate</b> < <b>Settle</b> . Default is the current stock price.
AvgDate	(Optional) Scalar representing the date on which the averaging period begins. Default = <b>Settle</b> .

Data arguments are NINST-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument. The others may be omitted or passed as empty matrices [ ].

## Description

`InstSet = instasian(InstSet, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt, AvgType, AvgPrice, AvgDate)` specifies an Asian option.

`[FieldList, ClassList, TypeString] = instasian` displays the classes.

`FieldList` is a number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field for this instrument type.

`ClassList` is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are 'dble', 'date', and 'char'.

`TypeString` is a string specifying the type of instrument added. For an Asian option instrument, `TypeString` = 'Asian'.

## Examples

### Create an Asian Option Instrument

Load the example instrument set, `deriv.mat`, and set the required values for an asian option instrument.

```
load deriv.mat
```

Create a subportfolio with barrier and lookback options.

```
CRRSubSet = instselect(CRRInstSet, 'Type', {'Barrier', 'Lookback'});
```

Define the asian instrument.

```
OptSpec = 'put';  
Strike = NaN;  
Settle = '01-Jan-2003';  
ExerciseDates = '01-Jan-2004';
```

Add a floating strike asian option to the instrument set.

```
InstSet = instasian(CRRSubSet, OptSpec, Strike, Settle, ExerciseDates);  
instdisp(InstSet)
```

Index	Type	OptSpec	Strike	Settle	ExerciseDates	AmericanOpt	BarrierSpec	Barri
1	Barrier	call	105	01-Jan-2003	01-Jan-2006	1	ui	102

Index	Type	OptSpec	Strike	Settle	ExerciseDates	AmericanOpt	Name	Quant
2	Lookback	call	115	01-Jan-2003	01-Jan-2006	0	Lookback1	7
3	Lookback	call	115	01-Jan-2003	01-Jan-2007	0	Lookback2	9

Index	Type	OptSpec	Strike	Settle	ExerciseDates	AmericanOpt	AvgType	AvgPri
4	Asian	put	NaN	01-Jan-2003	01-Jan-2004	0	arithmetic	NaN

## See Also

[instadd](#) | [instdisp](#) | [instget](#)

# instbarrier

Construct barrier option

## Syntax

```
InstSet = instbarrier(InstSet, OptSpec, Strike, Settle,
ExerciseDates, AmericanOpt, BarrierSpec, Barrier, Rebate)
[FieldList, ClassList, TypeString] = instbarrier
```

## Arguments

InstSet	Instrument variable. This argument is specified only when adding barrier instruments to an existing instrument set. See <code>instget</code> for more information on the <code>InstSet</code> variable.
OptSpec	NINST-by-1 list of string values 'Call' or 'Put'.
Strike	NINST-by-1 vector of strike price values. Each row is the schedule for one option.
Settle	NINST-by-1 vector of <code>Settle</code> dates.
ExerciseDates	For a European option ( <code>AmericanOpt</code> = 0):  NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.  For an American option ( <code>AmericanOpt</code> = 1):  NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <code>ExerciseDates</code> is NINST-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.
AmericanOpt	If <code>AmericanOpt</code> = 0, NaN, or is unspecified, the option is a European option. If <code>AmericanOpt</code> = 1, the option is an American option.

BarrierSpec	List of string values:  'UI': Up Knock In  'UO': Up Knock Out  'DI': Down Knock In  'DO': Down Knock Out
Barrier	Vector of barrier values.
Rebate	(Optional) Vector of rebate values.

Data arguments are NINST-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument. The others may be omitted or passed as empty matrices [ ].

## Description

InstSet = instbarrier(InstSet, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt, BarrierSpec, Barrier, Rebate) specifies a barrier option.

[FieldList, ClassList, TypeString] = instbarrier displays the classes.

FieldList is a number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field for this instrument type.

ClassList is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are 'dble', 'date', and 'char'.

TypeString is a string specifying the type of instrument added. For a barrier option instrument, TypeString = 'Barrier'.

## Examples

### Create Two Barrier Option Instruments

Create an instrument set of two barrier options with the following data:

```

OptSpec = {'put';'call'};
Strike = 112;
Settle = '01-Jan-2012';
ExerciseDates = '01-Jan-2015';
BarrierSpec = {'do';'ui'};
Barrier = [101;102];
AmericanOpt = 0;

```

Create the instrument set (InstSet) for the two barrier options.

```
InstSet = instbarrier(OptSpec, Strike, Settle, ExerciseDates,AmericanOpt, BarrierSpec,
```

Display the instrument set.

```
instdisp(InstSet)
```

Index	Type	OptSpec	Strike	Settle	ExerciseDates	AmericanOpt	BarrierSpec	Bar
1	Barrier	put	112	01-Jan-2012	01-Jan-2015	0	do	101
2	Barrier	call	112	01-Jan-2012	01-Jan-2015	0	ui	102

## See Also

instadd | instdisp | instget

## instbond

Construct bond instrument

### Syntax

```
InstSet = instbond(InstSet, CouponRate, Settle, Maturity,
Period, Basis, EndMonthRule, IssueDate, FirstCouponDate,
LastCouponDate, StartDate, Face)
[FieldList, ClassList, TypeString] = instbond
```

### Arguments

InstSet	Instrument variable. This argument is specified only when adding bond instruments to an existing instrument set. See <code>instget</code> for more information on the <code>InstSet</code> variable.
CouponRate	Decimal annual rate indicating the annual percentage rate used to determine the coupons payable on a bond. <code>CouponRate</code> is a NINST-by-1 vector or NINST-by-1 cell array of decimal annual rates, or decimal annual rate schedules. For the latter case of a variable coupon schedule, each element of the cell array is a NumDates-by-2 cell array, where the first column is dates and the second column is its associated rate. The date indicates the last day that the coupon rate is valid.
Settle	Settlement date. A vector of serial date numbers or date strings. <code>Settle</code> must be earlier than <code>Maturity</code> .
Maturity	Maturity date. A vector of serial date numbers or date strings.
Period	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 1, 2, 3, 4, 6, and 12. Default = 2.
Basis	(Optional) Day-count basis of the instrument. A vector of integers.



	<ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<b>EndMonthRule</b>	(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
<b>IssueDate</b>	(Optional) Date when a bond was issued.
<b>FirstCouponDate</b>	(Optional) Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified <b>FirstCouponDate</b> , a specified <b>LastCouponDate</b> determines the coupon structure of the bond. The coupon structure of a bond is truncated at the <b>LastCouponDate</b> , regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a <b>LastCouponDate</b> , the cash flow payment dates are determined from other inputs.

<b>LastCouponDate</b>	(Optional) Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified <b>FirstCouponDate</b> , a specified <b>LastCouponDate</b> determines the coupon structure of the bond. The coupon structure of a bond is truncated at the <b>LastCouponDate</b> , regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a <b>LastCouponDate</b> , the cash flow payment dates are determined from other inputs.
<b>StartDate</b>	(Optional) Date when a bond actually starts (i.e. the date when a bond's cash flows can be considered). To make an instrument forward starting, specify this date as a future date. If <b>StartDate</b> is not explicitly specified, the effective start date is the <b>Settle</b> date.
<b>Face</b>	(Optional) Face or par value. <b>Face</b> is a NINST-by-1 vector or NINST-by-1 cell array of face values, or face value schedules. For the latter case, each element of the cell array is a NumDates-by-2 cell array, where the first column is dates and the second column is its associated face value. The date indicates the last day that the face value is valid. Default = 100.

Data arguments are number of instruments (NINST)-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument. The others may be omitted or passed as empty matrices [ ].

## Description

`InstSet = instbond(InstSet, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face)` creates a new instrument set containing bond instruments or adds bond instruments to a existing instrument set.

`[FieldList, ClassList, TypeString] = instbond` displays the classes.

**FieldList** is a number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field for this instrument type.

`ClassList` is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are 'dble', 'date', and 'char'.

`TypeString` is a string specifying the type of instrument added. For a bond instrument, `TypeString = 'Bond'`.

## Examples

### Create a Bond Instrument

Create a new instrument variable with the following information:

```
CouponRate= [0.035;0.04];
Settle= 'Nov-1-2013';
Maturity = 'Nov-1-2014';
Period =1;
```

```
InstSet = instbond(CouponRate, Settle, Maturity, ...
Period)
```

```
InstSet =
```

```
    FinObj: 'Instruments'
  IndexTable: [1x1 struct]
         Type: {'Bond'}
   FieldName: {{11x1 cell}}
  FieldClass: {{11x1 cell}}
   FieldData: {{11x1 cell}}
```

Display the instrument set.

```
instdisp(InstSet)
```

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate
1	Bond	0.035	01-Nov-2013	01-Nov-2014	1	0	1	NaN
2	Bond	0.04	01-Nov-2013	01-Nov-2014	1	0	1	NaN

### See Also

[hjmprice](#) | [instaddfield](#) | [instdisp](#) | [instget](#) | [intenvprice](#)

## instcap

Construct cap instrument

### Syntax

```
InstSet = instcap(InstSet, Strike, Settle, Maturity, Reset,
Basis, Principal)
[FieldList, ClassList, TypeString] = instcap
```

### Arguments

InstSet	Instrument variable. This argument is specified only when adding cap instruments to an existing instrument set. See <code>instget</code> for more information on the <code>InstSet</code> variable.
Strike	Rate at which the cap is exercised, as a decimal number.
Settle	Settlement date. Serial date number representing the settlement date of the cap.
Maturity	Serial date number representing the maturity date of the cap.
Reset	(Optional) NINST-by-1 vector representing the frequency of payments per year. Default = 1.
Basis	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> </ul>

	<ul style="list-style-type: none"> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Principal	(Optional) NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid. Default is 100.

## Description

InstSet = instcap(InstSet, Strike, Settle, Maturity, Reset, Basis, Principal) creates a new instrument set containing cap instruments or adds cap instruments to an existing instrument set.

[FieldList, ClassList, TypeString] = instcap displays the classes.

FieldList is a number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field for this instrument type.

ClassList is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are 'dble', 'date', and 'char'.

TypeString is a string specifying the type of instrument added. For a cap instrument, TypeString = 'Cap'.

---

**Note:** Use the optional argument, **Principal**, to pass a schedule for an amortizing cap.

---

## Examples

### Create Two Cap Instruments

Create a new instrument variable with the following information:

```
Strike = [0.035; 0.045];  
Settle= 'Jan-1-2013';  
Maturity = 'Jan-1-2014';  
Reset = 1;  
Basis = 1;  
Principal = 1000;
```

Create the new cap instruments.

```
InstSet = instcap(Strike, Settle, Maturity, Reset, Basis, Principal)
```

```
InstSet =  
  
    FinObj: 'Instruments'  
    IndexTable: [1x1 struct]  
              Type: {'Cap'}  
    FieldName: {{6x1 cell}}  
    FieldClass: {{6x1 cell}}  
    FieldData: {{6x1 cell}}
```

Display the cap instruments.

```
instdisp(InstSet)
```

Index	Type	Strike	Settle	Maturity	CapReset	Basis	Principal
1	Cap	0.035	01-Jan-2013	01-Jan-2014	1	1	1000
2	Cap	0.045	01-Jan-2013	01-Jan-2014	1	1	1000

## See Also

[hjmprice](#) | [instaddfield](#) | [instbond](#) | [instdisp](#) | [instfloor](#) | [instswap](#) | [intenvprice](#)

# instcf

Construct cash flow instrument

## Syntax

```
InstSet = instcf(InstSet, CFlowAmounts, CFlowDates, Settle,
Basis)
[FieldList, ClassList, TypeString] = instcf
```

## Arguments

InstSet	Instrument variable. This argument is specified only when adding cash flow instruments to an existing instrument set. See <code>instget</code> for more information on the <code>InstSet</code> variable.
CFlowAmounts	Number of instruments (NINST) by maximum number of cash flows (MOSTCFS) matrix of cash flow amounts. Each row is a list of cash flow values for one instrument. If an instrument has fewer than MOSTCFS cash flows, the end of the row is padded with NaNs.
CFlowDates	NINST-by-MOSTCFS matrix of cash flow dates. Each entry contains the date of the corresponding cash flow in <code>CFlowAmounts</code> .
Settle	Settlement date on which the cash flows are priced.
Basis	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> </ul>

- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

Only one data argument is required to create an instrument. Other arguments can be omitted or passed as empty matrices [ ]. Dates can be input as serial date numbers or date strings.

## Description

`InstSet = instcf(InstSet, CFlowAmounts, CFlowDates, Settle, Basis)` creates a new instrument set from data arrays or adds instruments of type `CashFlow` to an instrument set.

`[FieldList, ClassList, TypeString] = instcf` lists field metadata for an instrument of type `CashFlow`.

`FieldList` is a number of fields (NFIELDSD)-by-1 cell array of strings listing the name of each data field for this instrument type.

`ClassList` is an NFIELDSD-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are 'dble', 'date', and 'char'.

`TypeString` specifies the type of instrument added; for example, `TypeString = 'CashFlow'`.

## See Also

`instadd` | `instdisp` | `instget` | `intenvprice`



# instcompound

Construct compound option

## Syntax

```
InstSet = instcompound(InstSet, UOptSpec, UStrike, USettle,
    UExerciseDates, UAmericanOpt, COptSpec, CStrike, CSettle,
    CExerciseDates, CAmericanOpt)
[FieldList, ClassList, TypeString] = instcompound
```

## Arguments

InstSet	Instrument variable. This argument is specified only when adding compound instruments to an existing instrument set. See <code>instget</code> for more information on the <code>InstSet</code> variable.
UOptSpec	String = 'Call' or 'Put'.
UStrike	1-by-1 vector of strike price values.
USettle	1-by-1 vector of <code>Settle</code> dates.
UExerciseDates	For a European option ( <code>UAmericanOpt = 0</code> ):  1-by-1 vector of exercise dates. For a European option, there is only one exercise date, the option expiry date.  For an American option ( <code>UAmericanOpt = 1</code> ):  1-by-2 vector of exercise date boundaries. The option can be exercised on any tree date. If only one non- <code>NaN</code> date is listed, or if <code>ExerciseDates</code> is 1-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.
UAmericanOpt	If <code>UAmericanOpt = 0</code> , <code>NaN</code> , or is unspecified, the option is a European option. If <code>UAmericanOpt = 1</code> , the option is an American option.

<code>COptSpec</code>	NINST-by-1 list of string values 'Call' or 'Put' of the compound option.
<code>CStrike</code>	NINST-by-1 vector of strike price values. Each row is the schedule for one option.
<code>CSettle</code>	1-by-1 vector containing the settlement or trade date.
<code>CExerciseDates</code>	<p>For a European option (<code>CAmericanOpt = 0</code>):</p> <p>NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option (<code>CAmericanOpt = 1</code>):</p> <p>NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <code>ExerciseDates</code> is NINST-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.</p>
<code>CAmericanOpt</code>	If <code>CAmericanOpt = 0</code> , NaN, or is unspecified, the option is a European option. If <code>CAmericanOpt = 1</code> , the option is an American option.

## Description

`InstSet = instcompound(InstSet, UOptSpec, UStrike, USettle, UExerciseDates, UAmericanOpt, COptSpec, CStrike, CSettle, CExerciseDates, CAmericanOpt)` specifies a compound option.

`[FieldList, ClassList, TypeString] = instcompound` displays the classes.

`FieldList` is a number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field for this instrument type.

`ClassList` is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are 'dble', 'date', and 'char'.

TypeString is a string specifying the type of instrument added. For a compound option instrument, TypeString = 'Compound'.

## Examples

### Create a Compound Option Instrument

Define a compound option instrument with the following data:

```
UOptSpec = 'Call';
UStrike = 130;
USettle = '01-Jan-2012';
UExerciseDates = '01-Jan-2015';
UAmericanOpt = 0;
COptSpec = 'Put';
CStrike = 5;
CSettle = '01-Jan-2012';
CExerciseDates = '01-Jan-2014';
CAmericanOpt = 0;
```

```
InstSet = instcompound(UOptSpec, UStrike, USettle,UExerciseDates, ...
UAmericanOpt, COptSpec, CStrike, CSettle,CExerciseDates, CAmericanOpt)
```

```
InstSet = instcompound(UOptSpec, UStrike, USettle,UExerciseDates, ...
UAmericanOpt, COptSpec, CStrike, CSettle,CExerciseDates)
```

```
InstSet =
```

```
    FinObj: 'Instruments'
  IndexTable: [1x1 struct]
        Type: {'Compound'}
   FieldName: {{10x1 cell}}
  FieldClass: {{10x1 cell}}
   FieldData: {{10x1 cell}}
```

```
InstSet =
```

```
    FinObj: 'Instruments'
  IndexTable: [1x1 struct]
        Type: {'Compound'}
   FieldName: {{10x1 cell}}
```

```
FieldClass: {{10x1 cell}}
FieldData: {{10x1 cell}}
```

Display the instrument set.

```
instdisp(InstSet)
```

Index	Type	UOptSpec	UStrike	USettle	UExerciseDates	UAmericanOpt	COptSpec	CS
1	Compound	Call	130	01-Jan-2012	01-Jan-2015	0	Put	5

## See Also

`instadd` | `instdisp` | `instget`

# instdelete

Complement of instrument set by matching conditions

## Syntax

```
ISubSet = instdelete(InstSet, 'FieldName', FieldList, 'Data',
DataList, 'Index', IndexSet, 'Type', TypeList)
```

## Arguments

InstSet	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
FieldList	String or number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field to match with data values.
DataList	Number of values (NVALUES)-by-M array or NFIELDS-by-1 cell array of acceptable data values for each field. Each row lists a data row value to search for in the corresponding FieldList. The number of columns is arbitrary and matching will ignore trailing NaNs or spaces.
IndexSet	(Optional) Number of instruments (NINST)-by-1 vector restricting positions of instruments to check for matches. The default is all indices available in the instrument variable.
TypeList	(Optional) String or number of types (NTYPES)-by-1 cell array of strings restricting instruments to match one of TypeList types. The default is all types in the instrument variable.

**Note:** Argument value pairs can be entered in any order. The InstSet variable must be the first argument. 'FieldName' and 'Data' arguments must appear together or not at all.

## Description

The output argument `ISubSet` contains instruments *not* matching the input criteria. Instruments are deleted from `ISubSet` if all the `Field`, `Index`, and `Type` conditions are met. An instrument meets an individual `Field` condition if the stored `FieldName` data matches any of the rows listed in the `DataList` for that `FieldName`. See `instfind` for more examples on matching criteria.

## Examples

Retrieve the instrument set variable `ExampleInst` from the data file `InstSetExamples.mat`. The variable contains three types of instruments: `Option`, `Futures`, and `TBill`.

```
load InstSetExamples;
instdisp(ExampleInst)
```

Index	Type	Strike	Price	Opt	Contracts
1	Option	95	12.2	Call	0
2	Option	100	9.2	Call	0
3	Option	105	6.8	Call	1000

Index	Type	Delivery	F	Contracts
4	Futures	01-Jul-1999	104.4	-1000

Index	Type	Strike	Price	Opt	Contracts
5	Option	105	7.4	Put	-1000
6	Option	95	2.9	Put	0

Index	Type	Price	Maturity	Contracts
7	TBill	99	01-Jul-1999	6

Create a new variable, `ISet`, with all options deleted.

```
ISet = instdelete(ExampleInst, 'Type', 'Option');
instdisp(ISet)
```

Index	Type	Delivery	F	Contracts
1	Futures	01-Jul-1999	104.4	-1000

Index	Type	Price	Maturity	Contracts
2	TBill	99	01-Jul-1999	6

## **See Also**

instaddfield | instfind | instget | instselect

## instdisp

Display instruments

### Syntax

```
CharTable = instdisp(InstSet)
```

### Arguments

InstSet	Variable containing a collection of instruments. See <code>instaddfield</code> for examples on constructing the variable.
---------	---

### Description

`CharTable = instdisp(InstSet)` creates a character array displaying the contents of an instrument collection, `InstSet`. If `instdisp` is called without output arguments, the table is displayed in the Command Window.

---

**Note:** When using `instdisp`, a value of NaN in one of the columns for an instrument indicates that the default value for that parameter will be used in the instrument's pricing function.

---

`CharTable` is a character array with a table of instruments in `InstSet`. For each instrument row, the `Index` and `Type` are printed along with the field contents. Field headers are printed at the tops of the columns.

### Examples

Retrieve the instrument set `ExampleInst` from the data file `InstSetExamples.mat`. `ExampleInst` contains three types of instruments: `Option`, `Futures`, and `TBill`.

```
load InstSetExamples;
```



```
instdisp(ExampleInst)
```

Index	Type	Strike	Price	Opt	Contracts
1	Option	95	12.2	Call	0
2	Option	100	9.2	Call	0
3	Option	105	6.8	Call	1000

Index	Type	Delivery	F	Contracts
4	Futures	01-Jul-1999	104.4	-1000

Index	Type	Strike	Price	Opt	Contracts
5	Option	105	7.4	Put	-1000
6	Option	95	2.9	Put	0

Index	Type	Price	Maturity	Contracts
7	TBill	99	01-Jul-1999	6

Create a swap instrument and use `instdisp` to display the instrument. Notice that value of NaN in two columns for this instrument indicates that the default values for `LegReset` and `LegType` parameters will be used in the swap instrument's pricing function.

```
LegRate1 = [0.065, 0];
Settle1 = datenum('jan-1-2007');
Maturity1 = datenum('jan-1-2012');

ISet = instswap(LegRate1, Settle1, Maturity1);
instdisp(ISet)
```

Index	Type	LegRate	Settle	Maturity	LegReset	Basis	Principal	LegType	EndMonthRule
1	Swap	[0.065 0]	01-Jan-2007	01-Jan-2012	[NaN]	0	100	[NaN]	1

## See Also

`datestr` | `num2str` | `instaddfield` | `instget`

## instfields

List field names

### Syntax

```
FieldList = instfields(InstSet, 'Type', TypeList)
```

### Arguments

InstSet	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
TypeList	(Optional) String or number of types (NTYPES)-by-1 cell array of strings listing the instrument types to query.

### Description

`FieldList = instfields(InstSet, 'Type', TypeList)` retrieves the list of fields stored in an instrument variable.

`FieldList` is a number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field corresponding to the listed types.

### Examples

Retrieve the instrument set `ExampleInst` from the data file `InstSetExamples.mat`. `ExampleInst` contains three types of instruments: `Option`, `Futures`, and `TBill`.

```
load InstSetExamples;  
instdisp(ExampleInst)
```

```
Index Type    Strike Price Opt  Contracts  
1     Option  95     12.2 Call    0  
2     Option  100    9.2  Call    0
```

```
3    Option 105    6.8 Call 1000
```

```
Index Type    Delivery      F      Contracts
4    Futures 01-Jul-1999  104.4 -1000
```

```
Index Type    Strike Price Opt  Contracts
5    Option 105    7.4 Put -1000
6    Option 95     2.9 Put 0
```

```
Index Type Price Maturity      Contracts
7    TBill 99    01-Jul-1999  6
```

Get the fields listed for type 'Option'.

```
[FieldList, ClassList] = instfields(ExampleInst, 'Type', ...
'Option')
```

```
FieldList =
```

```
    'Strike'
    'Price'
    'Opt'
    'Contracts'
```

```
ClassList =
```

```
    'double'
    'double'
    'char'
    'double'
```

Get the fields listed for types 'Option' and 'TBill'.

```
FieldList = instfields(ExampleInst, 'Type', {'Option', 'TBill'})
```

```
FieldList =
```

```
    'Strike'
    'Opt'
    'Price'
    'Maturity'
    'Contracts'
```

Get all the fields listed in any type in the variable.

```
FieldList = instfields(ExampleInst)
```

```
FieldList =  
    'Delivery'  
    'F'  
    'Strike'  
    'Opt'  
    'Price'  
    'Maturity'  
    'Contracts'
```

### **See Also**

`instdisp` | `instlength` | `insttypes`

# instfind

Search instruments for matching conditions

## Syntax

```
IndexMatch = instfind(InstSet, 'FieldName', FieldList, 'Data',
DataList, 'Index', IndexSet, 'Type', TypeList)
```

## Arguments

<b>InstSet</b>	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
<b>FieldList</b>	String or number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field to match with data values.
<b>DataList</b>	Number of values (NVALUES)-by-M array or NFIELDS-by-1 cell array of acceptable data values for each field. Each row lists a data row value to search for in the corresponding <b>FieldList</b> . The number of columns is arbitrary, and matching will ignore trailing NaNs or spaces.
<b>IndexSet</b>	(Optional) Number of instruments (NINST)-by-1 vector restricting positions of instruments to check for matches. The default is all indices available in the instrument variable.
<b>TypeList</b>	(Optional) String or number of types (NTYPES)-by-1 cell array of strings restricting instruments to match one of <b>TypeList</b> types. The default is all types in the instrument variable.

Argument value pairs can be entered in any order. The **InstSet** variable must be the first argument. 'FieldName' and 'Data' arguments must appear together or not at all.

## Description

```
IndexMatch = instfind(InstSet, 'FieldName', FieldList, 'Data',
```

`DataList, 'Index', IndexSet, 'Type', TypeList)` returns indices of instruments matching `Type`, `Field`, or `Index` values.

`IndexMatch` is an NINST-by-1 vector of positions of instruments matching the input criteria. Instruments are returned in `IndexMatch` if all the `Field`, `Index`, and `Type` conditions are met. An instrument meets an individual `Field` condition if the stored `FieldName` data matches any of the rows listed in the `DataList` for that `FieldName`.

## Examples

Retrieve the instrument set `ExampleInst` from the data file `InstSetExamples.mat`. `ExampleInst` contains three types of instruments: `Option`, `Futures`, and `TBill`.

```
load InstSetExamples;  
instdisp(ExampleInst)
```

```
Index Type   Strike Price Opt  Contracts  
1   Option  95    12.2 Call   0  
2   Option 100    9.2  Call   0  
3   Option 105    6.8  Call  1000
```

```
Index Type   Delivery      F    Contracts  
4   Futures 01-Jul-1999  104.4 -1000
```

```
Index Type   Strike   Price Opt  Contracts  
5   Option 105     7.4  Put  -1000  
6   Option 95     2.9  Put   0
```

```
Index Type Price Maturity      Contracts  
7   TBill 99    01-Jul-1999  6
```

Make a vector, `Opt95`, containing the indexes within `ExampleInst` of the options struck at 95.

```
Opt95 = instfind(ExampleInst, 'FieldName', 'Strike', 'Data', '95')
```

```
Opt95 =  
  
     1  
     6
```

Locate the futures and Treasury bill instruments within `ExampleInst`.

```
Types = instfind(ExampleInst, 'Type', {'Futures'; 'TBill'})
```

```
Types =
```

```
    4  
    7
```

### **See Also**

`instaddfield` | `instget` | `instgetcell` | `instselect`

## instfixed

Construct fixed-rate instrument

### Syntax

```
InstSet = instfixed(InstSet, CouponRate, Settle, Maturity,
Reset, Basis, Principal, EndMonthRule)
[FieldList, ClassList, TypeString] = instfixed
```

### Arguments

InstSet	Instrument variable. This argument is specified only when adding fixed-rate note instruments to an existing instrument set. See <code>instget</code> for more information on the <code>InstSet</code> variable.
CouponRate	Decimal annual rate.
Settle	Settlement date. Date string or serial date number representing the settlement date of the fixed-rate note.
Maturity	Date string or serial date number representing the maturity date of the fixed-rate note.
Reset	(Optional) NINST-by-1 vector representing the frequency of payments per year. Default = 1.
Basis	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> </ul>



	<ul style="list-style-type: none"> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<b>Principal</b>	(Optional) NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid. Default is 100.
<b>EndMonthRule</b>	(Optional) NINST-by-1 vector representing the End-of-month rule. Default = 1.

Data arguments are number of instruments (NINST)-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument. The others may be omitted or passed as empty matrices [ ].

## Description

`InstSet = instfixed(InstSet, CouponRate, Settle, Maturity, Reset, Basis, Principal, EndMonthRule)` creates a new instrument set containing fixed-rate instruments or adds fixed-rate instruments to an existing instrument set.

`[FieldList, ClassList, TypeString] = instfixed` displays the classes.

**FieldList** is a number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field for this instrument type.

**ClassList** is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are 'dble', 'date', and 'char'.

**TypeString** is a string specifying the type of instrument added. For a fixed-rate instrument, `TypeString = 'Fixed'`.

## Examples

### Create a Fixed-Rate Instrument

Define the characteristics of the fixed-rate instrument.

```
CouponRate = .03;  
Settle = datenum('15-Mar-2013');  
Maturity = datenum('15-Mar-2018');  
Reset = 4;  
Basis = 1;  
Principal = 1000;  
EndMonthRule = 1;
```

Create the new cap instrument.

```
ISet = instfixed(CouponRate, Settle, Maturity, Reset, Basis, Principal,EndMonthRule)
```

```
ISet =
```

```
    FinObj: 'Instruments'  
  IndexTable: [1x1 struct]  
        Type: {'Fixed'}  
   FieldName: {{7x1 cell}}  
  FieldClass: {{7x1 cell}}  
   FieldData: {{7x1 cell}}
```

Display the fixed-rate instrument.

```
instdisp(ISet)
```

Index	Type	CouponRate	Settle	Maturity	FixedReset	Basis	Principal	EndMonthRule
1	Fixed	0.03	15-Mar-2013	15-Mar-2018	4	1	1000	1

### See Also

[hjmprice](#) | [instaddfield](#) | [instbond](#) | [instcap](#) | [instdisp](#) | [instswap](#) | [intenvprice](#)

# instfloat

Construct floating-rate instrument

## Syntax

```
InstSet = instfloat(InstSet, Spread, Settle, Maturity, Reset,
Basis, Principal, EndMonthRule)
InstSet = instfloat(InstSet, Spread, Settle, Maturity, Reset,
Basis, Principal, EndMonthRule, CapRate, FloorRate)
[FieldList, ClassList, TypeString] = instfloat
```

## Arguments

InstSet	Instrument variable. This argument is specified only when adding floating-rate note instruments to an existing instrument set. See <code>instget</code> for more information on the <code>InstSet</code> variable.
Spread	Number of basis points over the reference rate.
Settle	Settlement date. Date string or serial date number representing the settlement date of the floating-rate note.
Maturity	Date string or serial date number representing the maturity date of the floating-rate note.
Reset	(Optional) NINST-by-1 vector representing the frequency of payments per year. Default = 1.
Basis	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> </ul>

	<ul style="list-style-type: none"> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<b>Principal</b>	(Optional) NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid. Default is 100.
<b>EndMonthRule</b>	(Optional) NINST-by-1 vector representing the End-of-month rule. Default = 1.
<b>CapRate</b>	(Optional) NINST-by-1 decimal annual rate or NINST-by-1 cell array, where each element is a NumDates-by-2 cell array, and the cell array first column is dates, and the second column is associated cap rates. The date indicates the last day that the cap rate is valid.
<b>FloorRate</b>	(Optional) NINST-by-1 decimal annual rate or NINST-by-1 cell array, where each element is a NumDates-by-2 cell array, and the cell array first column is dates, and the second column is associated floor rates. The date indicates the last day that the floor rate is valid.

Data arguments are number of instruments (NINST)-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument. The others may be omitted or passed as empty matrices [ ].

## Description

`InstSet = instfloat(InstSet, Spread, Settle, Maturity, Reset, Basis, Principal, EndMonthRule)` creates a new instrument set containing floating-rate instruments or adds floating-rate instruments to an existing instrument set.

`InstSet = instfloat(InstSet, Spread, Settle, Maturity, Reset,`

`Basis`, `Principal`, `EndMonthRule`, `CapRate`, `FloorRate`) creates a new instrument set containing capped floating-rate instruments or adds capped floating-rate instruments to an existing instrument set.

`[FieldList, ClassList, TypeString] = instfloat` displays the classes.

`FieldList` is a number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field for this instrument type.

`ClassList` is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are 'dble', 'date', and 'char'.

`TypeString` is a string specifying the type of instrument added. For a floating-rate instrument, `TypeString = 'Float'`.

## Examples

### Create a Floating-Rate Instrument

Define the characteristics of the floating-rate instrument.

```
Spread = 2;
Settle = datenum('15-Mar-2013');
Maturity = datenum('15-Mar-2018');
Reset = 4;
Basis = 1;
Principal = 1000;
EndMonthRule = 1;
CapRate = 0.35;
FloorRate = 0.27;
```

Create the new floating-rate instrument.

```
ISet = instfloat(Spread, Settle, Maturity, Reset, Basis, Principal, ...
EndMonthRule, CapRate, FloorRate)
```

```
ISet =
```

```
    FinObj: 'Instruments'
  IndexTable: [1x1 struct]
```

```
Type: {'Float'}  
FieldName: {{9x1 cell}}  
FieldClass: {{9x1 cell}}  
FieldData: {{9x1 cell}}
```

Display the floating-rate instrument.

```
instdisp(ISet)
```

Index	Type	Spread	Settle	Maturity	FloatReset	Basis	Principal	EndMonthRU
1	Float	2	15-Mar-2013	15-Mar-2018	4	1	1000	1

### See Also

hjmprice | instaddfield | instbond | instcap | instdisp | instswap |  
intenvprice

# instfloor

Construct floor instrument

## Syntax

```
InstSet = instfloor(InstSet, Strike, Settle, Maturity, Reset,
Basis, Principal)
[FieldList, ClassList, TypeString] = instfloor
```

## Arguments

<b>InstSet</b>	Instrument variable. This argument is specified only when adding floor instruments to an existing instrument set. See <code>instget</code> for more information on the <code>InstSet</code> variable.
<b>Strike</b>	Rate at which the floor is exercised, as a decimal number.
<b>Settle</b>	Settlement date. A vector of serial date numbers or date strings. <b>Settle</b> must be earlier than <b>Maturity</b> .
<b>Maturity</b>	Maturity date. A vector of serial date numbers or date strings.
<b>Reset</b>	(Optional) NINST-by-1 vector representing the frequency of payments per year. Default = 1.
<b>Basis</b>	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> </ul>

	<ul style="list-style-type: none"> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Principal	(Optional) NINST-by-1 of notional principal amounts or NINST-by-1 cell array where each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid. Default is 100.

## Description

InstSet = instfloor(InstSet, Strike, Settle, Maturity, Reset, Basis, Principal) creates a new instrument set containing floor instruments or adds floor instruments to an existing instrument set.

[FieldList, ClassList, TypeString] = instfloor displays the classes.

FieldList is a number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field for this instrument type.

ClassList is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are 'dble', 'date', and 'char'.

TypeString is a string specifying the type of instrument added. For a floor instrument, TypeString = 'Floor'.

---

**Note:** Use the optional argument, **Principal**, to pass a schedule for an amortizing floor.

---

## Examples

### Create a Floor Instrument

Define the characteristics of the floor instrument.



```
Strike = 0.22;  
Settle = datenum('15-Mar-2013');  
Maturity = datenum('15-Mar-2018');  
Reset = 4;  
Basis = 1;  
Principal = 1000;
```

Create the new floor instrument.

```
ISet = instfloor(Strike, Settle, Maturity, Reset, Basis, Principal)
```

```
ISet =
```

```
    FinObj: 'Instruments'  
    IndexTable: [1x1 struct]  
             Type: {'Floor'}  
    FieldName: {{6x1 cell}}  
    FieldClass: {{6x1 cell}}  
    FieldData: {{6x1 cell}}
```

Display the floor instrument.

```
instdisp(ISet)
```

Index	Type	Strike	Settle	Maturity	FloorReset	Basis	Principal
1	Floor	0.22	15-Mar-2013	15-Mar-2018	4	1	1000

## See Also

[hjmprice](#) | [instaddfield](#) | [instbond](#) | [instcap](#) | [instdisp](#) | [instswap](#) | [intenvprice](#)

## instget

Data from instrument variable

### Syntax

```
[Data_1, Data_2,...,Data_n] = instget(InstSet, 'FieldName',
FieldList, 'Index', IndexSet, 'Type', TypeList)
```

### Arguments

<b>InstSet</b>	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
<b>FieldList</b>	(Optional) String or number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field to match with data values. <b>FieldList</b> entries can also be either 'Type' or 'Index'; these return type strings and index numbers respectively. The default is all fields available for the returned set of instruments.
<b>IndexSet</b>	(Optional) Number of instruments (NINST)-by-1 vector of positions of instruments to work on. If <b>TypeList</b> is also entered, instruments referenced must be one of <b>TypeList</b> types and contained in <b>IndexSet</b> . The default is all indices available in the instrument variable.
<b>TypeList</b>	(Optional) String or number of types (NTYPES)-by-1 cell array of strings restricting instruments to match one of <b>TypeList</b> types. The default is all types in the instrument variable.

Argument value pairs can be entered in any order. The **InstSet** variable must be the first argument.

### Description

```
[Data_1, Data_2,...,Data_n] = instget(InstSet, 'FieldName',
```

`FieldList`, 'Index', `IndexSet`, 'Type', `TypeList`) retrieves data arrays from an instrument variable.

`Data_1` is an NINST-by-M array of data contents for the first field in `FieldList`. Each row corresponds to a separate instrument in `IndexSet`. Unavailable data is returned as NaN or as spaces.

`Data_n` is an NINST-by-M array of data contents for the last field in `FieldList`.

## Examples

Retrieve the instrument set `ExampleInst` from the data file. `InstSetExamples.mat`. `ExampleInst` contains three types of instruments: `Option`, `Futures`, and `TBill`.

```
load InstSetExamples;
instdisp(ExampleInst)
```

```
Index Type    Strike Price Opt  Contracts
1    Option  95     12.2 Call   0
2    Option 100     9.2 Call   0
3    Option 105     6.8 Call 1000
```

```
Index Type    Delivery      F    Contracts
4    Futures 01-Jul-1999 104.4 -1000
```

```
Index Type    Strike Price Opt  Contracts
5    Option 105     7.4 Put  -1000
6    Option  95     2.9 Put   0
```

```
Index Type Price Maturity      Contracts
7    TBill 99     01-Jul-1999 6
```

Extract the price from all instruments.

```
P = instget(ExampleInst, 'FieldName', 'Price')
```

```
P =
```

```
12.2000
 9.2000
 6.8000
    NaN
 7.4000
```

```

2.9000
99.0000

```

Get all the prices and the number of contracts held.

```
[P,C] = instget(ExampleInst, 'FieldName', {'Price', 'Contracts'})
```

P =

```

12.2000
9.2000
6.8000
Nan
7.4000
2.9000
99.0000

```

C =

```

0
0
1000
-1000
-1000
0
6

```

Compute a value V. Create a new variable ISet that appends V to ExampleInst.

```

V = P.*C
ISet = instsetfield(ExampleInst, 'FieldName', 'Value', 'Data',...
V);
instdisp(ISet)

```

Index	Type	Strike	Price	Opt	Contracts	Value
1	Option	95	12.2	Call	0	0
2	Option	100	9.2	Call	0	0
3	Option	105	6.8	Call	1000	6800

Index	Type	Delivery	F	Contracts	Value
4	Futures	01-Jul-1999	104.4	-1000	NaN

Index	Type	Strike	Price	Opt	Contracts	Value
5	Option	105	7.4	Put	-1000	-7400
6	Option	95	2.9	Put	0	0

Index	Type	Price	Maturity	Contracts	Value
-------	------	-------	----------	-----------	-------

```
7      TBill 99      01-Jul-1999      6      594
```

Look at only the instruments that have nonzero Contracts.

```
Ind = find(C ~= 0)
```

```
Ind =
```

```
3
4
5
7
```

Get the Type and Opt parameters from those instruments. (Only options have a stored 'Opt' field.)

```
[T,O] = instget(ExampleInst, 'Index', Ind, 'FieldName',...
{'Type', 'Opt'})
```

```
T =
```

```
Option
Futures
Option
TBill
```

```
O =
```

```
Call
```

```
Put
```

Create a string report of holdings Type, Opt, and Value.

```
rstring = [T, O, num2str(V(Ind))]
```

```
rstring =
```

```
Option Call      6800
Futures          NaN
Option Put      -7400
TBill           594
```

## See Also

instaddfield | instdisp | instgetcell

## instgetcell

Data and context from instrument variable

### Syntax

```
[DataList, FieldList, ClassList] =
instgetcell(InstSet, 'FieldName', FieldList, 'Index',
IndexSet, 'Type', TypeList)
```

### Arguments

<b>InstSet</b>	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
<b>FieldList</b>	(Optional) String or number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field to match with data values. <b>FieldList</b> should not be either <b>Type</b> or <b>Index</b> ; these field names are reserved. The default is all fields available for the returned set of instruments.
<b>IndexSet</b>	(Optional) Number of instruments (NINST)-by-1 vector of positions of instruments to work on. If <b>TypeList</b> is also entered, instruments referenced must be one of <b>TypeList</b> types and contained in <b>IndexSet</b> . The default is all indices available in the instrument variable.
<b>TypeList</b>	(Optional) String or number of types (NTYPES)-by-1 cell array of strings restricting instruments to match one of <b>TypeList</b> types. The default is all types in the instrument variable.

Argument value pairs can be entered in any order. The **InstSet** variable must be the first argument.

### Description

```
[DataList, FieldList, ClassList] =
```

`instgetcell(InstSet, 'FieldName', FieldList, 'Index', IndexSet, 'Type', TypeList)` retrieves data and context from an instrument variable.

`DataList` is an NFIELDS-by-1 cell array of data contents for each field. Each cell is an NINST-by-M array, where each row corresponds to a separate instrument in `IndexSet`. Any data which is not available is returned as NaN or as spaces.

`FieldList` is an NFIELDS-by-1 cell array of strings listing the name of each field in `DataList`.

`ClassList` is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are 'dble', 'date', and 'char'.

`IndexSet` is an NINST-by-1 vector of positions of instruments returned in `DataList`.

`TypeSet` is an NINST-by-1 cell array of strings listing the type of each instrument row returned in `DataList`.

## Examples

Retrieve the instrument set `ExampleInst` from the data file `InstSetExamples.mat`. `ExampleInst` contains three types of instruments: `Option`, `Futures`, and `TBill`.

```
load InstSetExamples;
instdisp(ExampleInst)
```

Index	Type	Strike	Price	Opt	Contracts
1	Option	95	12.2	Call	0
2	Option	100	9.2	Call	0
3	Option	105	6.8	Call	1000

Index	Type	Delivery	F	Contracts
4	Futures	01-Jul-1999	104.4	-1000

Index	Type	Strike	Price	Opt	Contracts
5	Option	105	7.4	Put	-1000
6	Option	95	2.9	Put	0

Index	Type	Price	Maturity	Contracts
-------	------	-------	----------	-----------

7 TBill 99 01-Jul-1999 6

Get the prices and contracts from all instruments.

```
FieldList = {'Price'; 'Contracts'}
DataList = instgetcell(ExampleInst, 'FieldName', FieldList )
P = DataList{1}
C = DataList{2}
```

P =

```
12.2000
 9.2000
 6.8000
    NaN
 7.4000
 2.9000
99.0000
```

C =

```
0
0
1000
-1000
-1000
0
6
```

Get all the option data: Strike, Price, Opt, Contracts.

```
[DataList, FieldList, ClassList] = instgetcell(ExampleInst,...
'Type','Option')
```

DataList =

```
[5x1 double]
[5x1 double]
[5x4 char ]
[5x1 double]
```

FieldList =

```
'Strike'
'Price'
'Opt'
```



```
'Contracts'
```

```
ClassList =
```

```
'dbtle'  
'dbtle'  
'char'  
'dbtle'
```

Look at the data as a comma-separated list. Type `help lists` for more information on cell array lists.

```
DataList{:}
```

```
ans =
```

```
95  
100  
105  
105  
95
```

```
ans =
```

```
12.2100  
9.2000  
6.8000  
7.3900  
2.9000
```

```
ans =
```

```
Call  
Call  
Call  
Put  
Put
```

```
ans =
```

```
0  
0  
100  
-100  
0
```

**See Also**

`instaddfield` | `instdisp` | `instget`

# instlength

Count instruments

## Syntax

```
NInst = instlength(InstSet)
```

## Arguments

InstSet	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
---------	---

## Description

`NInst = instlength(InstSet)` computes `NInst`, the number of instruments contained in the variable, `InstSet`.

## See Also

`instdisp` | `instfields` | `insttypes`

## instlookback

Construct lookback option

### Syntax

```
InstSet = instlookback(InstSet, OptSpec, Strike, Settle,
ExerciseDates, AmericanOpt)
[FieldList, ClassList, TypeString] = instlookback
```

### Arguments

InstSet	Instrument variable. This argument is specified only when adding lookback instruments to an existing instrument set. See <code>instget</code> for more information on the <code>InstSet</code> variable.
OptSpec	NINST-by-1 list of string values 'Call' or 'Put'.
Strike	NINST-by-1 vector of strike price values. Each row is the schedule for one option.
Settle	NINST-by-1 vector of <code>Settle</code> dates.
ExerciseDates	For a European option ( <code>AmericanOpt = 0</code> ):  NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.  For an American option ( <code>AmericanOpt = 1</code> ):  NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <code>ExerciseDates</code> is NINST-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.
AmericanOpt	(Optional) If <code>AmericanOpt = 0</code> , NaN, or is unspecified, the option is a European option. If <code>AmericanOpt = 1</code> , the option is an American option.

Data arguments are number of instruments (NINST)-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument. The others may be omitted or passed as empty matrices [ ].

## Description

`InstSet = instlookback(InstSet, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt)` specifies a lookback option.

`[FieldList, ClassList, TypeString] = instlookback` displays the classes.

`FieldList` is a number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field for this instrument type.

`ClassList` is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are 'dble', 'date', and 'char'.

`TypeString` is a string specifying the type of instrument added. For a lookback option instrument, `TypeString = 'Lookback'`.

## Examples

### Create a Lookback Option Instrument

Define a floating strike lookback instrument with the following data:

```
OptSpec = 'call';
Strike = NaN;
Settle = '01-Jan-2012';
ExerciseDates = '01-Jan-2015';
```

Create the instrument set.

```
InstSet = instlookback(OptSpec, Strike, Settle, ExerciseDates);
```

Display the lookback instrument.

```
instdisp(InstSet)
```

```
Index Type      OptSpec Strike Settle      ExerciseDates  AmericanOpt
```

1      Lookback call      NaN      01-Jan-2012      01-Jan-2015      0

### **See Also**

`instadd` | `instdisp` | `instget`

# instoptbnd

Construct bond option

## Syntax

```
InstSet = instoptbnd(InstSet, BondIndex, OptSpec, Strike,
ExerciseDates)
```

```
InstSet = instoptbnd(InstSet, BondIndex, OptSpec, Strike,
ExerciseDates, AmericanOpt)
```

```
[FieldList, ClassList, TypeString] = instoptbnd
```

## Arguments

InstSet	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
BondIndex	Number of instruments (NINST)-by-1 vector of indices pointing to underlying instruments of Type 'Bond' which are also stored in InstSet. See instbond for information on specifying the bond data.
OptSpec	NINST-by-1 list of string values 'Call' or 'Put'.
<b>Note:</b> The interpretation of the Strike and ExerciseDates arguments depends upon the setting of the AmericanOpt argument. If AmericanOpt = 0, NaN, or is unspecified, the option is a European or Bermuda option. If AmericanOpt = 1, the option is an American option.	
Strike	European option: NINST-by-1 vector of strike price values.  Bermuda option: NINST by number of strikes (NSTRIKES) matrix of strike price values.  Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.

	<p>For an American option:</p> <p>NINST-by-1 vector of strike price values for each option.</p>
<b>ExerciseDates</b>	<p>NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option:</p> <p>NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <b>ExerciseDates</b> is NINST-by-1, the option can be exercised between the underlying bond <b>Settle</b> and the single listed exercise date.</p>

Data arguments are NINST-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument. The others may be omitted or passed as empty matrices [ ].

## Description

`InstSet = instoptbnd(InstSet, BondIndex, OptSpec, Strike, ExerciseDates)` specifies a European or Bermuda option.

`InstSet = instoptbnd(InstSet, BondIndex, OptSpec, Strike, ExerciseDates, AmericanOpt)` specifies an American option if `AmericanOpt` is set to 1. If `AmericanOpt` is not set to 1, the function specifies a European or Bermuda option.

`[FieldList, ClassList, TypeString] = instoptbnd` displays the classes.

**FieldList** is a number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field for this instrument type.

**ClassList** is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are 'dble', 'date', and 'char'.



TypeString is a string specifying the type of instrument added. For a bond option instrument, TypeString = 'OptBond'.

## Examples

### Create a Bond Option Instrument

Create a new instrument variable with the following information:

```
BondIndex = 1;
OptSpec = 'call';
Strike= 85;
ExerciseDates = 'Nov-1-2014';
AmericanOpt = 1;
CouponRate= [0.035;0.04];
Settle= 'Nov-1-2013';
Maturity = 'Nov-1-2014';
Period =1;
```

Create the instrument portfolio with two bonds.

```
InstSet = instbond(CouponRate, Settle, Maturity, ...
Period)
```

```
InstSet =
```

```
    FinObj: 'Instruments'
  IndexTable: [1x1 struct]
           Type: {'Bond'}
   FieldName: {{11x1 cell}}
   FieldClass: {{11x1 cell}}
   FieldData: {{11x1 cell}}
```

Create an option on the first bond

```
InstSet = instoptbnd(InstSet, BondIndex, OptSpec, Strike, ExerciseDates, AmericanOpt)
```

```
InstSet =
```

```
    FinObj: 'Instruments'
```

```

IndexTable: [1x1 struct]
    Type: {2x1 cell}
    FieldName: {2x1 cell}
    FieldClass: {2x1 cell}
    FieldData: {2x1 cell}

```

Display the instrument set.

`instdisp(InstSet)`

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate
1	Bond	0.035	01-Nov-2013	01-Nov-2014	1	0	1	NaN
2	Bond	0.04	01-Nov-2013	01-Nov-2014	1	0	1	NaN

Index	Type	UnderInd	OptSpec	Strike	ExerciseDates	AmericanOpt
3	OptBond	1	call	85	01-Nov-2014	1

## See Also

`hjmprice` | `instadd` | `instdisp` | `instget`

# instoptembnd

Construct bond with embedded option

## Syntax

```
InstSet = instoptembnd (CouponRate, Settle, Maturity,
OptSpec, Strike, ExerciseDates, 'AmericanOpt',
AmericanOpt, 'Period', Period, 'Basis', Basis,
'EndMonthRule', EndMonthRule, 'Face', Face, 'IssueDate',
IssueDate, 'FirstCouponDate', FirstCouponDate,
'LastCouponDate', LastCouponDate, 'StartDate', StartDate)
InstSet = instoptembnd(InstSetOld, CouponRate,...)
[FieldList, ClassList, TypeString] = instoptembnd
```

## Arguments

CouponRate	Decimal annual rate indicating the annual percentage rate used to determine the coupons payable on a bond. <b>CouponRate</b> is a NINST-by-1 vector or NINST-by-1 cell array of decimal annual rates, or decimal annual rate schedules. For the latter case of a variable coupon schedule, each element of the cell array is a NumDates-by-2 cell array, where the first column is dates and the second column is its associated rate. The date indicates the last day that the coupon rate is valid.
Settle	NINST-by-1 vector of settlement dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 vector of string values 'Call' or 'Put'.
For a European or Bermuda option	
Strike	NINST-by-NSTRIKES matrix of strike price values. Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaN's.

<b>ExerciseDates</b>	NINST-by-NSTRIKES matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one <b>ExerciseDate</b> on the option expiry date.
<b>AmericanOpt</b>	(Optional) NINST-by-1 vector of flags. <b>AmericanOpt</b> is 0 for each European or Bermuda option. The default is 0 if <b>AmericanOpt</b> is NaN or not entered.
For an American option	
<b>Strike</b>	NINST-by-1 vector of strike price values for each option.
<b>ExerciseDates</b>	NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <b>ExerciseDates</b> is NINST-by-1, the option can be exercised between the underlying bond <b>Settle</b> and the single listed <b>ExerciseDate</b> .
<b>AmericanOpt</b>	NINST-by-1 vector of flags. <b>AmericanOpt</b> is 1 for each American option. The <b>AmericanOpt</b> argument is required to invoke American exercise rules.
<b>Period</b>	(Optional) NINST-by-1 matrix for coupons per year. The default value is 2.

<b>Basis</b>	<p>(Optional) Day-count basis of the instrument. <b>Basis</b> is a vector of integers with the following possible values:</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<b>EndMonthRule</b>	<p>(Optional) NINST-by-1 matrix for the end-of-month rule. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. When the value is 0, the end-of-month rule is ignored, meaning that a bond's coupon payment date is always the same numerical day of the month. When the value is 1, the end-of-month rule is set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.</p>
<b>IssueDate</b>	<p>(Optional) NINST-by-1 matrix for the bond issue date.</p>

<b>FirstCouponDate</b>	(Optional) Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When <b>FirstCouponDate</b> and <b>LastCouponDate</b> are both specified, <b>FirstCouponDate</b> takes precedence in determining the coupon payment structure. If you do not specify a <b>FirstCouponDate</b> , the cash flow payment dates are determined from other inputs.
<b>LastCouponDate</b>	(Optional) Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified <b>FirstCouponDate</b> , a specified <b>LastCouponDate</b> determines the coupon structure of the bond. The coupon structure of a bond is truncated at the <b>LastCouponDate</b> , regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a <b>LastCouponDate</b> , the cash flow payment dates are determined from other inputs.
<b>StartDate</b>	(Optional) NINST-by-1 matrix for date when a bond actually starts (i.e. the date from which a bond's cash flows can be considered). To make an instrument forward starting, specify this date as a future date. If <b>StartDate</b> is not explicitly specified, the effective start date is the <b>Settle</b> date.
<b>Face</b>	(Optional) Face value. <b>Face</b> is a NINST-by-1 vector or NINST-by-1 cell array of face values, or face value schedules. For the latter case, each element of the cell array is a NumDates-by-2 cell array, where the first column is dates and the second column is its associated face value. The date indicates the last day that the face value is valid. Default is 100.

---

**Note:** Data arguments are NINST-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument. The others may be omitted or passed as empty matrices [ ].

---

## Description

```
InstSet = instoptembnd (CouponRate, Settle, Maturity,
OptSpec, Strike, ExerciseDates, 'AmericanOpt',
```

AmericanOpt, 'Period', Period, 'Basis', Basis, 'EndMonthRule', EndMonthRule, 'Face', Face, 'IssueDate', IssueDate, 'FirstCouponDate', FirstCouponDate, 'LastCouponDate', LastCouponDate, 'StartDate', StartDate) creates InstSet, a variable containing a collection of instruments.

---

**Note:** instoptembnd uses optional parameter name/value pairs such that, 'Name1', Value1, 'Name2', Value2, and so on, are a variable length list of name/value pairs.

---

Instruments are broken down by type and each type can have different data fields. Each stored data field has a row vector or string for each instrument. See instget for more information on the InstSet variable.

InstSet = instoptembnd(InstSetOld, CouponRate, ...) adds 'OptEmBond' instruments to an instrument variable.

[FieldList, ClassList, TypeString] = instoptembnd lists field metadata for the 'OptEmBond' instrument.

FieldList is a number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field for this instrument type.

ClassList is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are 'dble', 'date', and 'char'.

TypeString is a string specifying the type of instrument added. For a bond option instrument, TypeString = 'OptEmBond'.

## Examples

### Construct a Bond With an Embedded Option

This example shows how to construct a bond with an embedded option using the following data.

```
Settle = 'jan-1-2007';
Maturity = 'jan-1-2010';
CouponRate = 0.07;
```

```
OptSpec = 'call';
Strike= 100;
ExerciseDates= {'jan-1-2008' '01-Jan-2010'};
AmericanOpt=1;
Period = 1;

InstSet = instoptembnd(CouponRate, ...
Settle, Maturity, OptSpec, Strike, ExerciseDates, 'AmericanOpt', AmericanOpt, ...
'Period', Period);

% display the instrument
instdisp(InstSet)
```

Index	Type	CouponRate	Settle	Maturity	OptSpec	Strike	ExerciseDates
1	OptEmBond	0.07	01-Jan-2007	01-Jan-2010	call	100	01-Jan-2008

## See Also

[instadd](#) | [instdisp](#) | [instget](#)



# instoptfloat

Create option instrument on floating-rate note or add instrument to current portfolio

## Syntax

```
InstSet = instoptfloat(FloatIndex,OptSpec,Strike,ExerciseDates)
InstSet = instoptfloat(FloatIndex,OptSpec,Strike,ExerciseDates,
AmericanOpt)
```

```
InstSet = instoptfloat(InstSetOld, ___ )
```

```
[FieldList,ClassList,TypeString] = instoptfloat
```

## Description

`InstSet = instoptfloat(FloatIndex,OptSpec,Strike,ExerciseDates)` to specify an European option for a floating-rate note.

`InstSet = instoptfloat(FloatIndex,OptSpec,Strike,ExerciseDates, AmericanOpt)` to specify an American or Bermuda option for a floating-rate note.

`InstSet = instoptfloat(InstSetOld, ___ )` to add instruments to an existing portfolio.

`[FieldList,ClassList,TypeString] = instoptfloat` lists the field metadata for the 'OptFloat' instrument.

## Examples

### Create an Instrument Portfolio with a Call Option for a Floating-Rate Note

Define the floating-rate note:

```
Settle = 'Nov-1-2012';
Maturity = 'Nov-1-2015';
Spread = 50;
```

```
Reset = 1;
```

Create InstSet:

```
InstSet = instfloat(Spread, Settle, Maturity, Reset)
```

```
InstSet =
```

```
    FinObj: 'Instruments'
  IndexTable: [1x1 struct]
        Type: {'Float'}
   FieldName: {{9x1 cell}}
  FieldClass: {{9x1 cell}}
   FieldData: {{9x1 cell}}
```

Display the instrument:

```
instdisp(InstSet)
```

Index	Type	Spread	Settle	Maturity	FloatReset	Basis	Principal	EndMonthRu
1	Float	50	01-Nov-2012	01-Nov-2015	1	0	100	1

Add a European call option to the instrument portfolio:

```
OptSpec = 'call';
Strike = 100;
ExerciseDates = 'Nov-1-2015';
```

Create InstSet:

```
InstSet = instoptfloat(InstSet, 1, OptSpec, Strike, ExerciseDates)
```

```
InstSet =
```

```
    FinObj: 'Instruments'
  IndexTable: [1x1 struct]
        Type: {2x1 cell}
   FieldName: {2x1 cell}
  FieldClass: {2x1 cell}
   FieldData: {2x1 cell}
```

Display the instrument:

```
instdisp(InstSet)
```

Index	Type	Spread	Settle	Maturity	FloatReset	Basis	Principal	EndMonthRu
1	Float	50	01-Nov-2012	01-Nov-2015	1	0	100	1

Index	Type	UnderInd	OptSpec	Strike	ExerciseDates	AmericanOpt
2	OptFloat	1	call	100	01-Nov-2015	0

## Input Arguments

### FloatIndex — Indices pointing to underlying instruments

vector of nonnegative integers

Indices pointing to underlying instruments of Type 'Float' specified by a NINST-by-1 vector. The instruments of Type 'Float' are also stored in the InstSet variable. For more information, see instfloat.

Data Types: double

### OptSpec — Definition of option

string | cell array of strings

Definition of option as 'call' or 'put' specified as a NINST-by-1 cell array of strings for 'call' or 'put'.

Data Types: char | cell

### Strike — Option strike price values for European, Bermuda, or American option

nonnegative integer | vector of nonnegative integers

Option strike price values for option (European, Bermuda or American) specified as nonnegative integers using as NINST-by-NSTRIKES vector of strike price values.

- For a European or Bermuda option — NINST-by-NSTRIKES matrix of strike price values. Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.
- For an American Option — NINST-by-1 vector of strike price values for each option.

Data Types: single | double

**ExerciseDates — Exercise date for option (European, Bermuda, or American)**

nonnegative integer | vector of nonnegative integers

Exercise date for option (European, Bermuda, or American) specified as nonnegative integers using a NINST-by-NSTRIKES or NINST-by-2 vector of for the option exercise dates, depending on the option type.

- For a European or Bermuda option — NINST-by-NSTRIKES matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one `ExerciseDate` on the option expiry date
- For an American option — NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if `ExerciseDates` is NINST-by-1, the option can be exercised between the underlying bond `Settle` date and the single listed `ExerciseDate`.

Data Types: char | cell

**AmericanOpt — Option type**0 if `AmericanOpt` is NaN or not entered (default) | scalar | vector of positive integers[0, 1]

Option type specified as NINST-by-1 positive integer scalar flags with values.

- For an European or Bermuda option — `AmericanOpt` is 0 for each European or Bermuda option.
- For an American option — `AmericanOpt` is 1 for each American option. The `AmericanOpt` argument is required to invoke American exercise rules.

Data Types: single | double

## Output Arguments

**InstSet — Variable containing a collection of instruments**

scalar | vector

Variable containing a collection of instruments returned as a scalar or vector with the instruments broken down by type and each type can have different data fields. Each stored data field has a row vector or string for each instrument. For more information on the `InstSet` variable, see `instget`.

**FieldList — Data field for instrument type**

string | cell array

Data field for instrument type returned as a NFIELDS-by-1 cell array of strings listing the name of each data field for this instrument type.

**ClassList — Data class of each field**

string with value: 'dble', 'date', 'char' | cell array with values: 'dble', 'date', 'char'

Data class of each field returned as a NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments will be parsed.

**TypeString — Type of instrument added**

string with value 'OptFloat'

Type of instrument added returned as a string. The string for a floating-rate option instrument is TypeString = 'OptFloat'.

**See Also**

instadd | instoptemfloat

## instoptemfloat

Create embedded option instrument on floating-rate note or add instrument to current portfolio

### Syntax

```
InstSet = instoptemfloat(Spread,Settle,Maturity,OptSpec,  
Strike,ExerciseDates)
```

```
InstSet = instoptemfloat( ____,Name,Value)
```

```
InstSet = instoptemfloat(InstSetOld,Spread,Settle,Maturity,OptSpec,  
Strike,ExerciseDates)
```

```
[FieldList,ClassList,TypeString] = instoptemfloat
```

### Description

`InstSet = instoptemfloat(Spread,Settle,Maturity,OptSpec,Strike,ExerciseDates)` creates an embedded option instrument for a floating-rate note.

`InstSet = instoptemfloat( ____,Name,Value)` creates an embedded option instrument for a floating-rate note using optional name-value pair arguments.

`InstSet = instoptemfloat(InstSetOld,Spread,Settle,Maturity,OptSpec,Strike,ExerciseDates)` to add 'OptEmFloat' instruments to an instrument variable.

`[FieldList,ClassList,TypeString] = instoptemfloat` lists field metadata for the 'OptEmFloat' instrument.

### Examples

#### Create an Instrument Portfolio with a Embedded Option Floating-Rate Note

Define the embedded call option:

```
Settle = 'Nov-1-2012';
```

```

Maturity = 'Nov-1-2015';
Spread = 25;
OptSpec = 'call';
Strike = 100;
ExerciseDates = 'Nov-1-2015';
Reset = 1;

```

Create InstSet:

```

InstSet = instoptemfloat(Spread, Settle, Maturity, OptSpec, ...
Strike, ExerciseDates, 'Reset', Reset)

```

InstSet =

```

    FinObj: 'Instruments'
  IndexTable: [1x1 struct]
        Type: {'OptEmFloat'}
  FieldName: {{13x1 cell}}
  FieldClass: {{13x1 cell}}
  FieldData: {{13x1 cell}}

```

Display the instrument:

```

instdisp(InstSet)

```

Index	Type	Spread	Settle	Maturity	OptSpec	Strike	ExerciseDates	FL
1	OptEmFloat	25	01-Nov-2012	01-Nov-2015	call	100	01-Nov-2015	1

## Input Arguments

### **Spread** — Number of basis points over the reference rate

nonnegative integer | vector of nonnegative integers

Number of basis points over the reference rate specified as a vector nonnegative integers for the number of instruments (NINST)-by-1).

Data Types: single | double

### **Settle** — Settlement dates of floating-rate note

ValuationDate of HW Tree (default) | nonnegative integer | vector of nonnegative integers

Settlement dates of floating-rate note specified as nonnegative integers using a NINST-by-1 vector of dates.

Data Types: char

### **Maturity — Floating-rate note maturity date**

nonnegative integer | vector of nonnegative integers

Floating-rate note maturity date specified as nonnegative integers using a NINST-by-1 vector of dates.

Data Types: char

### **OptSpec — Definition of option**

string | cell array of strings

Definition of option as 'call' or 'put' specified as a NINST-by-1 cell array of strings for 'call' or 'put'.

Data Types: char | cell

### **Strike — Embedded option strike price values**

nonnegative integer | vector of nonnegative integers

Embedded option strike price values for option specified as nonnegative integers using as NINST-by-NSTRIKES or NINST-by-1 vector of strike price values, depending on the type of option.

- For a European or Bermuda Option — NINST-by-NSTRIKES matrix of strike price values where each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.
- For an American Option — NINST-by-1 vector of strike price values for each option.

Data Types: single | double

### **ExerciseDates — Exercise date for embedded option**

nonnegative integer | vector of nonnegative integers

Exercise date for embedded option specified as nonnegative integers using a NINST-by-NSTRIKES or NINST-by-2 vector of the option exercise dates, depending on the type of option.



- For a European or Bermuda Option — NINST-by-NSTRIKES of exercise dates where each row is the schedule for one option. For a European option, there is only one `ExerciseDate` on the option expiry date.
- For an American Option — NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if `ExerciseDates` is NINST-by-1, the option can be exercised between the underlying bond `Settle` date and the single listed `ExerciseDate`.

Data Types: char | cell

### **InstSet01d — Variable containing a collection of instruments**

row vector | string

Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument. For more information on instrument data parameters, see the reference entries for individual instrument types. For example, see `instfloat` for additional information on the float instrument.

Data Types: double | char

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name,Value arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

Example: `InstSet =`

```
instoptemfloat(Spread,Settle,Maturity,OptSpec,Strike,ExerciseDates,'Reset',Res
```

### **'AmericanOpt' — Embedded option type**

0 if `AmericanOpt` is NaN or not entered (default) | scalar | vector of positive integers[0,1]

Embedded option type specified as NINST-by-1 positive integer scalar flags with values.

- For a European or Bermuda option — `AmericanOpt` is 0 for each European or Bermuda option. The default is 0 if `AmericanOpt` is NaN or not entered.
- For an American option — `AmericanOpt` is 1 for each American option. The `AmericanOpt` argument is required to invoke American exercise rules.

Data Types: `single` | `double`

**'Reset' — Frequency of payments per year**

1 (default) | positive integer from the set [1,2,3,4,6, 12] | vector of positive integers from the set [1,2,3,4,6,12]

Frequency of payments per year specified as positive integers for the values 1,2,4,6,12] in a NINST-by-1 vector.

Data Types: `single` | `double`

**'Basis' — Day-count basis of the instrument**

0 (actual/actual) (default) | positive integers of the set [1...13] | vector of positive integers of the set [1...13]

Day-count basis of the instrument specified as a positive integer using a NINST-by-1 vector. The **Basis** value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: `single` | `double`

**'Principal' — Principal values**

100 (default) | nonnegative integer | vector of nonnegative integers | cell array of nonnegative integers

Principal values specified as a nonnegative integer using a NINST-by-1 vector of notional principal amounts.

Data Types: `single` | `double`

### 'Options' — Structure containing derivatives pricing options

structure

Structure containing derivatives pricing options specified using `derivset`.

Data Types: `struct`

### 'EndMonthRule' — End-of-month rule flag

1 (in effect) (default) | nonnegative integer [0,1]

End-of-month rule flag is specified as a nonnegative integer [0, 1] using a NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: `single` | `double`

## Output Arguments

### **InstSet** — Variable containing a collection of instruments

scalar | vector

Variable containing a collection of instruments returned as a scalar or vector with the instruments broken down by type and each type can have different data fields. Each stored data field has a row vector or string for each instrument. For more information on the `InstSet` variable, see `instget`.

### **FieldList** — Name of each data field

string | cell array of strings

NFIELDS-by-1 cell array of strings listing the name of each data field for this instrument type.

### **ClassList** — Determines how arguments are parsed

string with value: 'dble', 'date', or 'char' | cell array of strings with values: 'dble', 'date', or 'char'

NFIELDS-by-1 cell array of strings listing the data class of each field.

### **TypeString** — Type of instrument added

string with value 'OptEmFloat'

String specifying the type of instrument added where TypeString = 'OptEmFloat'.

## **More About**

- **basis**

## **See Also**

instadd | instoptfloat

# instoptstock

Construct stock option

## Syntax

```
InstSet = instoptstock(InstSet, OptSpec, Strike,
Settle, ExerciseDates)
InstSet = instoptstock(InstSet, OptSpec, Strike,
Settle, ExerciseDates, AmericanOpt)
[FieldList, ClassList, TypeString] = instoptstock
```

## Arguments

InstSet	Instrument variable. This argument is specified only when adding stock option instruments to an existing instrument set. See <code>instget</code> for more information on the <code>InstSet</code> variable.
OptSpec	NINST-by-1 list of string values 'Call' or 'Put'.
<p><b>Note</b> The interpretation of the <code>Strike</code> and <code>ExerciseDates</code> arguments depends upon the setting of the <code>AmericanOpt</code> argument. If <code>AmericanOpt</code> = 0, NaN, or is unspecified, the option is a European or Bermuda option. If <code>AmericanOpt</code> = 1, the option is an American option.</p>	
Strike	<p>European option: NINST-by-1 vector of strike price values.</p> <p>Bermuda option: NINST by number of strikes (NSTRIKES) matrix of strike price values.</p> <p>Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.</p> <p>American option: NINST-by-1 vector of strike price values for each option.</p>
Settle	NINST-by-1 vector of settlement dates.
ExerciseDates	NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the

	<p>schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option:</p> <p>NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <code>ExerciseDates</code> is NINST-by-1, the option can be exercised between the underlying bond <code>Settle</code> and the single listed exercise date.</p>
--	---

Data arguments are NINST-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument. The others may be omitted or passed as empty matrices [ ].

## Description

`InstSet = instoptstock(InstSet, OptSpec, Strike, Settle, ExerciseDates)` specifies a European or Bermuda option.

`InstSet = instoptstock(InstSet, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt)` specifies an American option if `AmericanOpt` is set to 1. If `AmericanOpt` is not set to 1, the function specifies a European or Bermuda option.

`[FieldList, ClassList, TypeString] = instoptstock` displays the classes.

`FieldList` is a number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field for this instrument type.

`ClassList` is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are 'dble', 'date', and 'char'.

`TypeString` is a string specifying the type of instrument added. For a stock option instrument, `TypeString = 'OptStock'`.

## Examples

### Create a Stock Option Instrument

Create an instrument set of two stock options with the following data:

```
OptSpec = {'put'; 'call'};
Strike = [95; 98];
Settle = '01-May-2012';
ExerciseDates = {'01-May-2014'; '01-May-2015'};
AmericanOpt = [0; 1];
```

Create the stock option instruments.

```
InstSet = instoptstock(OptSpec, Strike, Settle, ExerciseDates, AmericanOpt)
```

```
InstSet =
```

```
    FinObj: 'Instruments'
  IndexTable: [1x1 struct]
        Type: {'OptStock'}
   FieldName: {{5x1 cell}}
  FieldClass: {{5x1 cell}}
   FieldData: {{5x1 cell}}
```

Display the instrument set.

```
instdisp(InstSet)
```

Index	Type	OptSpec	Strike	Settle	ExerciseDates	AmericanOpt
1	OptStock	put	95	01-May-2012	01-May-2014	0
2	OptStock	call	98	01-May-2012	01-May-2015	1

### See Also

instadd | instdisp | instget

## instrangefloat

Construct range note instrument

### Syntax

```
ISet = instrangefloat(Spread,Settle,Maturity,RateSched,  
Reset,Basis,Principal,EndMonthRule)
```

### Description

`ISet = instrangefloat(Spread,Settle,Maturity,RateSched,Reset,Basis,Principal,EndMonthRule)` creates a new range instrument from data arrays.

### Input Arguments

#### Spread

Number of basis points over the reference rate.

#### Settle

NINST-by-1 vector of dates representing the settle date of the floating-rate note.

#### Maturity

NINST-by-1 vector of dates representing the maturity date of the floating-rate note.

#### RateSched

NINST-by-1 vector of structures representing the range of rates within which cash flows are nonzero. Each element of the structure array contains two fields:

- `RateSched.Dates` — NDates-by-1 cell array of dates corresponding to the range schedule.



- `RateSched.Rates` — `NDates-by-2` array with the first column containing the lower bound of the range and the second column containing the upper bound of the range. Cash flow for date `RateSched.Dates(n)` is nonzero for rates in the range `RateSched.Rates(n,1) < Rate < RateSched.Rate (n,2)`.

**Reset**

(Optional) `NINST-by-1` vector representing the frequency of payments per year.

**Default:** 1

**Basis**

(Optional) Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

**Principal**

(Optional) `NINST-by-1` vector of the notional principal amount.

**Default:** 100

### **EndMonthRule**

(Optional) NINST-by-1 vector for end-of-month rule. Values are 1 (in effect) and 0 (not in effect).

**Default:** 1 (in effect)

---

**Note:** Data arguments are number of instruments NINST-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument. You can omit or pass the others as empty matrices [ ]. However, you cannot price the instrument when using the range note pricing function if you are missing any of the required input arguments.

---

## **Output Arguments**

### **ISet**

Variable containing a collection of instruments. Instruments are divided by type and each type can have different data fields. Each stored data field has a row vector or string for each instrument. Values are:

- **FieldList** — NFIELDS-by-1 cell array of strings listing the name of each data field for this instrument type.
- **ClassList** — NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are 'dble', 'date', and 'char'.
- **TypeString** — String specifying the type of instrument added. **TypeString** = 'RangeFloat'.

For more information, on ISet see `instget`.

## **Examples**

### **Create a Range Note Instrument**

Create an instrument portfolio with a range note.

```

Spread = 100;
Settle = 'Jan-1-2011';
Maturity = 'Jan-1-2014';

RateSched.Dates = {'Jan-1-2012'; 'Jan-1-2013' ; 'Jan-1-2014'};
RateSched.Rates = [0.045 0.055; 0.0525 0.0675; 0.06 0.08];

% Create InstSet
InstSet = instrangefloat(Spread, Settle, Maturity, RateSched);

% Display the portfolio instrument
instdisp(InstSet)

```

Index	Type	Spread	Settle	Maturity	RateSched	FloatReset	Basis	Princ
1	RangeFloat	100	01-Jan-2011	01-Jan-2014	[Struct]	1	0	100

Add a second range note instrument to the portfolio. Second Range Note:

```

Spread2 = 200;
Settle2 = 'Jan-1-2011';
Maturity2 = 'Jan-1-2013';
RateSched2.Dates = {'Jan-1-2012'; 'Jan-1-2013'};
RateSched2.Rates = [0.048 0.059; 0.055 0.068];

InstSet = instrangefloat(InstSet, Spread2, Settle2, Maturity2, RateSched2);

% Display the portfolio instrument
instdisp(InstSet)

```

Index	Type	Spread	Settle	Maturity	RateSched	FloatReset	Basis	Princ
1	RangeFloat	100	01-Jan-2011	01-Jan-2014	[Struct]	1	0	100
2	RangeFloat	200	01-Jan-2011	01-Jan-2013	[Struct]	1	0	100

## More About

### Range Note Instrument

A range note is a structured (market-linked) security whose coupon rate is equal to the reference rate as long as the reference rate is within a certain range. If the reference rate is outside of the range, the coupon rate is 0 for that period. This type of instrument entitles the holder to cash flows that depend on the level of some reference interest rate

and are floored to be positive. The note holder gets direct exposure to the reference rate. In return for the drawback that no interest will be paid for the time the range is left, they offer higher coupon rates than comparable standard products, like vanilla floating notes.

### References

Jarrow, Robert, *Modelling Fixed Income Securities and Interest Rate Options*, Stanford Economics and Finance, 2nd edition, 2002.

### See Also

| `instbond` | `instcap` | `instswap` | `instaddfield` | `instdisp` | `intenvprice` | `rangefloatbybk` | `rangefloatbybdt` | `rangefloatbyhw` | `rangefloatbyhjm`

# instselect

Create instrument subset by matching conditions

## Syntax

```
InstSubSet = instselect(InstSet, 'FieldName', FieldList,
'Data', DataList, 'Index', IndexSet, 'Type', TypeList)
```

## Arguments

InstSet	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
FieldList	String or number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field to match with data values.
DataList	Number of values (NVALUES)-by-M array or NFIELDS-by-1 cell array of acceptable data values for each field. Each row lists a data row value to search for in the corresponding FieldList. The number of columns is arbitrary and matching will ignore trailing NaNs or spaces.
IndexSet	(Optional) Number of instruments (NINST)-by-1 vector restricting positions of instruments to check for matches. The default is all indices available in the instrument variable.
TypeList	(Optional) String or number of types (NTYPES)-by-1 cell array of strings restricting instruments to match one of TypeList types. The default is all types in the instrument variable.

Argument value pairs can be entered in any order. The **InstSet** variable must be the first argument. 'FieldName' and 'Data' arguments must appear together or not at all. 'Index' and 'Type' arguments are each optional.

## Description

```
InstSubSet = instselect(InstSet, 'FieldName', FieldList,
```

'Data', DataList, 'Index', IndexSet, 'Type', TypeList) creates an instrument subset (InstSubSet) from an existing set of instruments (InstSet).

InstSubSet is a variable containing instruments matching the input criteria. Instruments are returned in InstSubSet if all the Field, Index, and Type conditions are met. An instrument meets an individual Field condition if the stored FieldName data matches any of the rows listed in the DataList for that FieldName. See instfind for examples on matching criteria.

## Examples

Retrieve the instrument set ExampleInst from the data file InstSetExamples.mat. The variable contains three types of instruments: Option, Futures, and TBill.

```
load InstSetExamples
instdisp(ExampleInst)
```

Index	Type	Strike	Price	Opt	Contracts
1	Option	95	12.2	Call	0
2	Option	100	9.2	Call	0
3	Option	105	6.8	Call	1000

Index	Type	Delivery	F	Contracts
4	Futures	01-Jul-1999	104.4	-1000

Index	Type	Strike	Price	Opt	Contracts
5	Option	105	7.4	Put	-1000
6	Option	95	2.9	Put	0

Index	Type	Price	Maturity	Contracts
7	TBill	99	01-Jul-1999	6

Make a new portfolio containing only options struck at 95.

```
Opt95 = instselect(ExampleInst, 'FieldName', 'Strike', ...
'Data', '95')
```

```
instdisp(Opt95)
```

```
Opt95 =
```

Index	Type	Strike	Price	Opt	Contracts
-------	------	--------	-------	-----	-----------

1	Option	95	12.2	Call	0
2	Option	95	2.9	Put	0

Make a new portfolio containing only futures and Treasury bills.

```
FutTBill = instselect(ExampleInst, 'Type', {'Futures'; 'TBill'})
```

```
instdisp(FutTBill) =
```

Index	Type	Delivery	F	Contracts
1	Futures	01-Jul-1999	104.4	-1000

Index	Type	Price	Maturity	Contracts
2	TBill	99	01-Jul-1999	6

## See Also

`instaddfield` | `instdelete` | `instfind` | `instget` | `instgetcell`

## instsetfield

Add or reset data for existing instruments

### Syntax

```
InstSet = instsetfield(InstSet, 'FieldName', FieldList,
'Data', DataList)
```

```
InstSet = instsetfield(InstSet, 'FieldName', FieldList,
'Data', DataList, 'Index', IndexSet, 'Type', TypeList)
```

### Arguments

InstSet	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument. <b>InstSet</b> must be the first argument in the list.
FieldList	String or number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field. <b>FieldList</b> cannot be named with the reserved names <b>Type</b> or <b>Index</b> .
DataList	Number of instruments (NINST)-by-M array or NFIELDS-by-1 cell array of data contents for each field. Each row in a data array corresponds to a separate instrument. Single rows are copied to apply to all instruments to be worked on. The number of columns is arbitrary, and data is padded along columns.
IndexSet	NINST-by-1 vector of positions of instruments to work on. If <b>TypeList</b> is also entered, instruments referenced must be one of <b>TypeList</b> types and contained in <b>IndexSet</b> .
TypeList	String or number of types (NTYPES)-by-1 cell array of strings restricting instruments worked on to match one of <b>TypeList</b> types.

Argument value pairs can be entered in any order.



## Description

instsetfield sets data for existing instruments in a collection variable.

```
InstSet = instsetfield(InstSet, 'FieldName', FieldList,
'Data', DataList) resets or adds fields to every instrument.
```

```
InstSet = instsetfield(InstSet, 'FieldName', FieldList,
'Data', DataList, 'Index', IndexSet, 'Type', TypeList) resets or adds
fields to a subset of instruments.
```

The output InstSet is a new instrument set variable containing the input data.

## Examples

Retrieve the instrument set ExampleInstSF from the data file InstSetExamples.mat. ExampleInstSF contains three types of instruments: Option, Futures, and TBill.

```
load InstSetExamples;
ISet = ExampleInstSF;
instdisp(ISet)
```

```
Index Type    Strike Price Opt
1     Option  95     12.2 Call
2     Option  100    9.2  Call
3     Option  105    6.8  Call
```

```
Index Type    Delivery      F
4     Futures  01-Jul-1999  104.4
```

```
Index Type    Strike Price Opt
5     Option  105     7.4  Put
6     Option  NaN     NaN  Put
```

```
Index Type    Price
7     TBill  99
```

Enter data for the option in Index 6: Price 2.9 for a Strike of 95.

```
ISet = instsetfield(ISet, 'Index',6,...
'FieldName',{'Strike','Price'}, 'Data',{ 95 , 2.9 });
instdisp(ISet)
```

```

Index Type   Strike Price Opt
1   Option  95    12.2 Call
2   Option  100   9.2  Call
3   Option  105   6.8  Call
Index Type   Delivery      F
4   Futures 01-Jul-1999  104.4
Index Type   Strike Price Opt
5   Option  105   7.4  Put
6   Option  95    2.9  Put

```

```

Index Type Price
7   TBill 99

```

Create a new field `Maturity` for the cash instrument.

```

MDate = datenum('7/1/99');
ISet = instsetfield(ISet, 'Type', 'TBill', 'FieldName',...
'Maturity', 'FieldClass', 'date', 'Data', MDate);
instdisp(ISet)

```

```

Index Type Price Maturity
7   TBill 99    01-Jul-1999

```

Create a new field `Contracts` for all instruments.

```

ISet = instsetfield(ISet, 'FieldName', 'Contracts', 'Data', 0);
instdisp(ISet)

```

```

Index Type   Strike Price Opt Contracts
1   Option  95    12.2 Call 0
2   Option  100   9.2  Call 0
3   Option  105   6.8  Call 0

```

```

Index Type   Delivery      F    Contracts
4   Futures 01-Jul-1999  104.4 0

```

```

Index Type   Strike Price Opt Contracts
5   Option  105   7.4  Put 0
6   Option  95    2.9  Put 0

```

```

Index Type Price Maturity Contracts
7   TBill 99    01-Jul-1999 0

```

Set the `Contracts` fields for some instruments.

```

ISet = instsetfield(ISet, 'Index', [3; 5; 4; 7],...

```

```
'FieldName','Contracts', 'Data', [1000; -1000; -1000; 6]);
```

```
instdisp(ISet)
```

Index	Type	Strike	Price	Opt	Contracts
1	Option	95	12.2	Call	0
2	Option	100	9.2	Call	0
3	Option	105	6.8	Call	1000

Index	Type	Delivery	F	Contracts
4	Futures	01-Jul-1999	104.4	-1000

Index	Type	Strike	Price	Opt	Contracts
5	Option	105	7.4	Put	-1000
6	Option	95	2.9	Put	0

Index	Type	Price	Maturity	Contracts
7	TBill 99		01-Jul-1999	6

## See Also

instaddfield | instdisp | instget | instgetcell

## instswap

Construct swap instrument

### Syntax

```
InstSet = instswap(InstSet, LegRate, Settle, Maturity)
InstSet = instswap(InstSet, LegRate, Settle, Maturity,
InstSet, LegReset, Basis, Principal, LegType,
EndMonthRule)
InstSet = instswap(InstSet, LegRate, Settle, Maturity, LegReset,
Basis,
Principal, LegType, EndMonthRule, StartDate)
[FieldList, ClassList, TypeString] = instswap
```

### Arguments

InstSet	Instrument variable. This argument is specified only when adding a swap to an existing instrument set. See <code>instget</code> for more information on the <code>InstSet</code> variable.
LegRate	Number of instruments (NINST)-by-2 matrix, with each row defined as:  [CouponRate Spread] or [Spread CouponRate]  CouponRate is the decimal annual rate. Spread is the number of basis points over the reference rate. The first column represents the receiving leg, while the second column represents the paying leg.
Settle	Settlement date. NINST-by-1 vector of serial date numbers or date strings. Settle must be earlier than Maturity.
Maturity	Maturity date. NINST-by-1 vector of dates representing the maturity date for each swap.
LegReset	(Optional) NINST-by-2 matrix representing the reset frequency per year for each swap. Default = [1 1].
Basis	(Optional) Day-count basis of the instrument. A vector of integers.

	<ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<b>Principal</b>	(Optional) NINST-by-1 vector or NINST-by-1 cell array of the notional principal amounts or principal value schedules. For the latter case, each element of the cell array is a NumDates-by-2 matrix where the first column is dates and the second column is its associated notional principal value. The date indicates the last day that the principal value is valid.. Default = 100.
<b>LegType</b>	(Optional) NINST-by-2 matrix. Each row represents an instrument. Each column indicates if the corresponding leg is fixed (1) or floating (0). This matrix defines the interpretation of the values entered in LegRate. Default is [ 1, 0 ] for each instrument.
<b>EndMonthRule</b>	(Optional) NINST-by-1 vector representing the End-of-month rule. Default = 1.
<b>StartDate</b>	(Optional) NINST-by-1 vector of dates when the swaps actually start. Default is <b>Settle</b> .

Data arguments are number of instruments (NINST)-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument; the others may be omitted or passed as empty matrices [ ].

## Description

`InstSet = instswap(InstSet, LegRate, Settle, Maturity)` creates a new instrument set containing swap instruments or adds swap instruments to an existing instrument set.

`InstSet = instswap(InstSet, LegRate, Settle, Maturity, InstSet, LegReset, Basis, Principal, LegType, EndMonthRule)` uses optional input arguments to create a new instrument set containing swap instruments or adds swap instruments to an existing instrument set.

`InstSet = instswap(InstSet, LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType, EndMonthRule, StartDate)` to create a new forward swap instrument or to add a forward swap instrument to an existing portfolio.

`[FieldList, ClassList, TypeString] = instswap` displays the classes.

`FieldList` is a number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field for this instrument type.

`ClassList` is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are 'dble', 'date', and 'char'.

`TypeString` is a string specifying the type of instrument added. For a swap instrument, `TypeString = 'Swap'`.

## Examples

### Create a Vanilla Swap Instrument

Create a vanilla swap using market data.

Use the following market data to create a swap instrument.

```
LegRate = [0.065, 0]
Settle = 'jan-1-2007';
```

```

Maturity = 'jan-1-2012';
LegReset = [1, 1];
Basis = 0
Principal = 100
LegType = [1, 0]

InstSet = instswap(LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType)

LegRate =

    0.0650    0

Basis =

    0

Principal =

    100

LegType =

    1    0

InstSet =

    FinObj: 'Instruments'
    IndexTable: [1x1 struct]
             Type: {'Swap'}
             FieldName: {{9x1 cell}}
             FieldClass: {{9x1 cell}}
             FieldData: {{9x1 cell}}

```

View the swap instrument using `instdisp`.

```
instdisp(InstSet)
```

Index	Type	LegRate	Settle	Maturity	LegReset	Basis	Principal	LegType	Er
1	Swap	[0.065 0]	01-Jan-2007	01-Jan-2012	[1 1]	0	100	[1 0]	1

## More About

### Amortizing Swap

In an amortizing swap, the notional principal decreases periodically because it is tied to an underlying financial instrument with a declining (amortizing) principal balance, such as a mortgage.

### Forward Swap

Agreement to enter into an interest-rate swap arrangement on a fixed date in future.

### See Also

`hjmprice` | `instaddfield` | `instbond` | `instcap` | `instdisp` | `instfloor` | `intenvprice`



# instswaption

Construct swaption instrument

## Syntax

```
InstSet = instswaption(OptSpec, Strike, ExerciseDates,
Spread, Settle, Maturity)
InstSet = instswaption(OptSpec, Strike, ExerciseDates,
Spread, Settle, Maturity, AmericanOpt,
SwapReset, Basis, Principal)
InstSet = instswaption(InstSetOld, OptSpec, Strike,
ExerciseDates, Spread, ...)
[FieldList, ClassList, TypeString] = instswaption;
```

## Arguments

Fill unspecified entries in vectors with the value NaN. Only one data argument is required to create the instruments; the others may be omitted or passed as empty matrices []. Type [FieldList, ClassList] = instswaption to see the classes. Dates can be input as serial date numbers or date strings.

OptSpec	NINST-by-1 cell array of strings 'call' or 'put'. A 'call' swaption entitles the buyer to pay the fixed rate. A 'put' swaption entitles the buyer to receive the fixed rate.
Strike	NINST-by-1 vector of strike swap rate values.
For a European option:	
ExerciseDates	NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one ExerciseDate on the option expiry date.
AmericanOpt	NINST-by-1 vector of flags. AmericanOpt is 0 for each European option. The default is 0 if AmericanOpt is NaN or not entered.
For an American option:	

<b>ExerciseDates</b>	NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <b>ExerciseDates</b> is NINST-by-1, the option can be exercised between the underlying swap <b>Settle</b> and the single listed <b>ExerciseDate</b> .
<b>AmericanOpt</b>	NINST-by-1 vector of flags. <b>AmericanOpt</b> is 1 for each American option. The <b>AmericanOpt</b> argument is required to invoke American exercise rules.
For an American or a European option:	
<b>Spread</b>	NINST-by-1 vector representing the number of basis points over the reference rate.
<b>Settle</b>	NINST-by-1 vector of dates representing the settle date for each swap.
<b>Maturity</b>	NINST-by-1 vector of dates representing the maturity date for each swap.
<b>SwapReset</b>	(Optional) NINST-by-1 vector representing the reset frequency per year for the underlying swap. Default is 1.

Basis	<p>(Optional) Day-count basis of the instrument. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Principal	<p>(Optional) NINST-by-1 vector of the notional principal amounts. Default is 100.</p>

## Description

`InstSet = instswaption(OptSpec, Strike, ExerciseDates, Spread, Settle, Maturity)` to specify a European option.

`InstSet = instswaption(OptSpec, Strike, ExerciseDates, Spread, Settle, Maturity, AmericanOpt, SwapReset, Basis, Principal)` to specify an American option.

`InstSet = instswaption(InstSetOld, OptSpec, Strike, ExerciseDates, Spread, ...)` to add swaption instruments to an instrument variable.

[FieldList, ClassList, TypeString] = instswaption; to list field metadata for the swaption instrument.

Outputs:

InstSet	Variable containing a collection of instruments. Instruments are broken down by type and each type can have different data fields. Each stored data field has a row vector or string for each instrument. For more information on the ISet variable, see instget.
FieldList	NFIELDS-by-1 cell array of strings listing the name of each data field for this instrument type.
ClassList	NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments will be parsed. Valid strings are 'dble', 'date', and 'char'.
TypeString	String specifying the type of instrument added. TypeString = 'Swaption'.

## Examples

### Construct Two Swaption Instruments

This example shows how to create two European swaption instruments using the the following data.

```
OptSpec = {'Call'; 'Put'};
Strike = .05;
ExerciseDates = 'jan-1-2011';
Spread=0;
Settle = 'jan-1-2007';
Maturity = 'jan-1-2012';
AmericanOpt = 0;
```

```
InstSet = instswaption(OptSpec, Strike, ExerciseDates, Spread, Settle, Maturity, ...
    AmericanOpt);
```

```
% view the European swaption instruments using instdisp
instdisp(InstSet)
```

---

Index	Type	OptSpec	Strike	ExerciseDates	Spread	Settle	Maturity	Amer:
1	Swaption	Call	0.05	01-Jan-2011	0	01-Jan-2007	01-Jan-2012	0
2	Swaption	Put	0.05	01-Jan-2011	0	01-Jan-2007	01-Jan-2012	0

**See Also**

instadd | instget | instdisp

## insttypes

List types

### Syntax

```
TypeList = insttypes(InstSet)
```

### Arguments

InstSet	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
---------	---

### Description

`TypeList = insttypes(InstSet)` retrieves a list of types stored in an instrument variable.

`TypeList` is a number of types (NTYPES)-by-1 cell array of strings listing the `Type` of instruments contained in the variable.

### Examples

Retrieve the instrument set variable `ExampleInst` from the data file `InstSetExamples.mat`. `ExampleInst` contains three types of instruments: `Option`, `Futures`, and `TBill`.

```
load InstSetExamples;  
instdisp(ExampleInst)
```

```
Index Type    Strike Price Opt  Contracts  
1    Option  95    12.2 Call    0  
2    Option 100    9.2  Call    0  
3    Option 105    6.8  Call  1000
```

Index	Type	Delivery	F	Contracts
4	Futures	01-Jul-1999	104.4	-1000

Index	Type	Strike	Price	Opt	Contracts
5	Option	105	7.4	Put	-1000
6	Option	95	2.9	Put	0

Index	Type	Price	Maturity	Contracts
7	TBill	99	01-Jul-1999	6

List all of the types included in `ExampleInst`.

```
TypeList = insttypes(ExampleInst)
```

```
TypeList =  
    'Futures'  
    'Option'  
    'TBill'
```

## See Also

`instdisp` | `instfields` | `instlength`

## intenvget

Properties of interest-rate structure

### Syntax

```
ParameterValue = intenvget(RateSpec, 'ParameterName')
```

### Arguments

RateSpec	A structure containing the properties of an interest-rate structure. See <code>intenvset</code> for information on creating <code>RateSpec</code> .
ParameterName	String indicating the parameter name to be accessed. The value of the named parameter is extracted from the structure <code>RateSpec</code> . It is sufficient to type only the leading characters that uniquely identify the parameter. Case is ignored for parameter names.

### Description

`ParameterValue = intenvget(RateSpec, 'ParameterName')` obtains the value of the named parameter `ParameterName` extracted from `RateSpec`.

### Examples

Use `intenvset` to set the interest-rate structure.

```
RateSpec = intenvset('Rates', 0.05, 'StartDates', ...  
'20-Jan-2000', 'EndDates', '20-Jan-2001')
```

Now use `intenvget` to extract the values from `RateSpec`.

```
[R, RateSpec] = intenvget(RateSpec, 'Rates')
```



R =

0.0500  
RateSpec =

FinObj: 'RateSpec'  
Compounding: 2  
Disc: 0.9518  
Rates: 0.0500  
EndTimes: 2  
StartTimes: 0  
EndDates: 730871  
StartDates: 730505  
ValuationDate: 730505  
Basis: 0  
EndMonthRule: 1

**See Also**  
intenvset

## intenvprice

Price instruments from set of zero curves

### Syntax

```
Price = intenvprice(RateSpec, InstSet)
```

### Arguments

RateSpec	A structure containing the properties of an interest-rate structure. See <code>intenvset</code> for information on creating <code>RateSpec</code> .
InstSet	Variable containing a collection of instruments. Instruments are categorized by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.

### Description

`Price = intenvprice(RateSpec, InstSet)` computes arbitrage-free prices for instruments against a set of zero coupon bond rate curves.

`Price` is a number of instruments (`NINST`) by number of curves (`NUMCURVES`) matrix of prices of each instrument. If an instrument cannot be priced, a `NaN` is returned in that entry.

`intenvprice` handles the following instrument types: `'Bond'`, `'CashFlow'`, `'Fixed'`, `'Float'`, `'Swap'`. See `instadd` for information about constructing defined types.

See single-type pricing functions to retrieve pricing information.

<code>bondbyzero</code>	Price bonds from a set of zero curves.
<code>cfbyzero</code>	Price arbitrary cash flow instrument from a set of zero curves.
<code>fixedbyzero</code>	Fixed-rate note prices from a set of zero curves.
<code>floatbyzero</code>	Floating-rate note prices from a set of zero curves.

swapbyzero	Swap prices from a set of zero curves.
------------	--

## Examples

### Load Zero Curves and Instruments from Data File

Load the zero curves and instruments.

```
load deriv.mat
instdisp(ZeroInstSet)
```

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate
1	Bond	0.04	01-Jan-2000	01-Jan-2003	1	NaN	NaN	NaN
2	Bond	0.04	01-Jan-2000	01-Jan-2004	2	NaN	NaN	NaN

Index	Type	CouponRate	Settle	Maturity	FixedReset	Basis	Principal	Name
3	Fixed	0.04	01-Jan-2000	01-Jan-2003	1	NaN	NaN	4% Fixed

Index	Type	Spread	Settle	Maturity	FloatReset	Basis	Principal	Name
4	Float	20	01-Jan-2000	01-Jan-2003	1	NaN	NaN	20BP Float

Index	Type	LegRate	Settle	Maturity	LegReset	Basis	Principal	LegType	Name
5	Swap	[0.06 20]	01-Jan-2000	01-Jan-2003	[1 1]	NaN	NaN	[NaN]	6%

Price the instruments.

```
Price = intenvprice(ZeroRateSpec, ZeroInstSet)
```

```
Price =
    98.7159
    97.5334
    98.7159
   100.5529
     3.6923
```

### See Also

hjmpprice | hjmsens | instadd | intenvsens | intenvset

## intenvsens

Instrument price and sensitivities from set of zero curves

### Syntax

```
[Delta, Gamma, Price] = intenvsens(RateSpec, InstSet)
```

### Arguments

RateSpec	A structure containing the properties of an interest-rate structure. See <code>intenvset</code> for information on creating <code>RateSpec</code> .
InstSet	Variable containing a collection of instruments. Instruments are categorized by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.

### Description

`[Delta, Gamma, Price] = intenvsens(RateSpec, InstSet)` computes dollar prices and price sensitivities for instruments that use a zero coupon bond rate structure.

`Delta` is a number of instruments (`NINST`) by number of curves (`NUMCURVES`) matrix of deltas, representing the rate of change of instrument prices with respect to shifts in the observed zero curve. `Delta` is computed by finite differences.

`Gamma` is an `NINST`-by-`NUMCURVES` matrix of gammas, representing the rate of change of instrument deltas with respect to shifts in the observed zero curve. `Gamma` is computed by finite differences.

---

**Note** Both sensitivities are returned as dollar sensitivities. To find the per-dollar sensitivities, divide by the respective instrument price.

---

`Price` is an `NINST`-by-`NUMCURVES` matrix of prices of each instrument. If an instrument cannot be priced, a `NaN` is returned.

intenvsens handles the following instrument types: 'Bond', 'CashFlow', 'Fixed', 'Float', 'Swap'. See `instadd` for information about constructing defined types.

## Examples

Load the tree and instruments from a data file.

```
load deriv.mat
instdisp(ZeroInstSet)
```

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate	FirstCouponDate	LastCouponDate	Status
1	Bond	0.04	01-Jan-2000	01-Jan-2003	1	NaN	NaN	NaN	NaN	NaN	NaN
2	Bond	0.04	01-Jan-2000	01-Jan-2004	2	NaN	NaN	NaN	NaN	NaN	NaN

Index	Type	CouponRate	Settle	Maturity	FixedReset	Basis	Principal	Name	Quantity
3	Fixed	0.04	01-Jan-2000	01-Jan-2003	1	NaN	NaN	4% Fixed	80

Index	Type	Spread	Settle	Maturity	FloatReset	Basis	Principal	Name	Quantity
4	Float	20	01-Jan-2000	01-Jan-2003	1	NaN	NaN	20BP Float	8

Index	Type	LegRate	Settle	Maturity	LegReset	Basis	Principal	LegType	Name	Quantity
5	Swap	[0.06 20]	01-Jan-2000	01-Jan-2003	[1 1]	NaN	NaN	[NaN]	6%/20BP Swap	10

```
[Delta, Gamma] = intenvsens(ZeroRateSpec, ZeroInstSet)
```

```
Delta =
```

```
-272.6403
-347.4386
-272.6403
-1.0445
-282.0405
```

```
Gamma =
```

```
1.0e+003 *
1.0298
1.6227
1.0298
0.0033
1.0596
```

## See Also

`hjmprice` | `hjmsens` | `instadd` | `intenvprice` | `intenvset`

## intenvset

Set properties of interest-rate structure

### Syntax

```
[RateSpec, RateSpecOld] = intenvset(RateSpec, 'Argument1',
Value1, 'Argument2', Value2, ...)
[RateSpec, RateSpecOld] = intenvset
intenvset
```

### Arguments

RateSpec	(Optional) An existing interest-rate specification structure to be changed, probably created from a previous call to <code>intenvset</code> .
----------	---

Arguments may be chosen from the following table and specified in any order.

Compounding	<p>Scalar value representing the rate at which the input zero rates or forward rates were compounded when annualized. Default = 2. This argument determines the formula for the discount factors:</p> <p>Compounding = 1, 2, 3, 4, 6, 12</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the compounding frequency, Z is the zero rate, and T is the time in periodic units; for example, T = F is 1 year.</p> <p>Compounding = 365</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the number of days in the basis year and T is a number of days elapsed computed by basis.</p> <p>Compounding = -1</p> <p>Disc = <math>\exp(-T*Z)</math>, where T is time in years.</p>
-------------	--

<b>Disc</b>	Number of points (NPOINTS) by number of curves (NCURVES) matrix of unit bond prices over investment intervals from <b>StartDates</b> , when the cash flow is valued, to <b>EndDates</b> , when the cash flow is received.
<b>Rates</b>	Number of points (NPOINTS) by number of curves (NCURVES) matrix of rates in decimal form. For example, 5% is 0.05 in <b>Rates</b> . <b>Rates</b> are the yields over investment intervals from <b>StartDates</b> , when the cash flow is valued, to <b>EndDates</b> , when the cash flow is received.
<b>EndDates</b>	NPOINTS-by-1 vector or scalar of serial maturity dates ending the interval to discount over.
<b>StartDates</b>	NPOINTS-by-1 vector or scalar of serial dates starting the interval to discount over. Default = <b>ValuationDate</b> . <b>StartDates</b> must be earlier than <b>EndDates</b> .
<b>ValuationDate</b>	(Optional) Scalar value in serial date number form representing the observation date of the investment horizons entered in <b>StartDates</b> and <b>EndDates</b> . Default = $\min(\text{StartDates})$ .

<b>Basis</b>	<p>(Optional) Day-count basis of the instrument. A scalar of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<b>EndMonthRule</b>	<p>(Optional) End-of-month rule. A scalar. This rule applies only when <b>EndDates</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.</p>

It is sufficient to type only the leading characters that uniquely identify the parameter. Case is ignored for argument names.

When creating a new **RateSpec**, the set of arguments passed to **intenvset** must include **StartDates**, **EndDates**, and either **Rates** or **Disc**.

Call **intenvset** with no input or output arguments to display a list of argument names and possible values.



## Description

[RateSpec, RateSpecOld] = intenvset(RateSpec, 'Argument1', Value1, 'Argument2', Value2, ...) creates an interest term structure (RateSpec) in which the input argument list is specified as argument name /argument value pairs. The argument name portion of the pair must be recognized as a valid field of the output structure RateSpec; the argument value portion of the pair is then assigned to its paired field.

If the optional argument RateSpec is specified, intenvset modifies an existing interest term structure RateSpec by changing the named argument to the specified values and recalculating the arguments dependent on the new values.

[RateSpec, RateSpecOld] = intenvset creates an interest term structure RateSpec with all fields set to [].

intenvset with no input or output arguments displays a list of argument names and possible values.

RateSpecOld is a structure containing the properties of an interest-rate structure before the changes introduced by the call to intenvset.

## Examples

### Create a RateSpec for a Zero Curve

Use intenvset to create a RateSpec for a zero curve.

```
RateSpec = intenvset('Rates', 0.05, 'StartDates', ...
    '20-Jan-2000', 'EndDates', '20-Jan-2001')
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
  Compounding: 2
        Disc: 0.9518
        Rates: 0.0500
   EndTimes: 2
  StartTimes: 0
```

```
      EndDates: 730871
      StartDates: 730505
ValuationDate: 730505
      Basis: 0
      EndMonthRule: 1
```

Now change the `Compounding` argument to 1 (annual).

```
RateSpec = intenvset(RateSpec, 'Compounding', 1)
```

```
RateSpec =
```

```
      FinObj: 'RateSpec'
      Compounding: 1
      Disc: 0.9518
      Rates: 0.0506
      EndTimes: 1
      StartTimes: 0
      EndDates: 730871
      StartDates: 730505
ValuationDate: 730505
      Basis: 0
      EndMonthRule: 1
```

Calling `intenvset` with no input or output arguments displays a list of argument names and possible values.

```
intenvset
```

```
      Compounding: [ 1 | {2} | 3 | 4 | 6 | 12 | 365 | -1 ]
      Disc: [ scalar | vector (NPOINTS x 1) ]
      Rates: [ scalar | vector (NPOINTS x 1) ]
      EndDates: [ scalar | vector (NPOINTS x 1) ]
      StartDates: [ scalar | vector (NPOINTS x 1) ]
ValuationDate: [ scalar ]
      Basis: [ {0} | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 ]
      EndMonthRule: [ 0 | {1} ]
```

### Create a `RateSpec` for a Forward Curve

Use `intenvset` to create a `RateSpec` for a forward curve.

```
RateSpec = intenvset('Rates', 0.05, 'StartDates', ...
'20-Jan-2001', 'EndDates', '20-Jan-2002', 'ValuationDate', '20-Jan-2000')
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
  Compounding: 2
        Disc: 0.9518
        Rates: 0.0500
    EndTimes: 4
  StartTimes: 2
    EndDates: 731236
  StartDates: 730871
ValuationDate: 730505
        Basis: 0
  EndMonthRule: 1
```

Now change the Compounding argument to 1 (annual).

```
RateSpec = intenvset(RateSpec, 'Compounding', 1)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
  Compounding: 1
        Disc: 0.9518
        Rates: 0.0506
    EndTimes: 2
  StartTimes: 1
    EndDates: 731236
  StartDates: 730871
ValuationDate: 730505
        Basis: 0
  EndMonthRule: 1
```

### Create a RateSpec Using Two Curves

Define data for the interest-rate term structure and use `intenvset` to create a `RateSpec`.

```
StartDates = '01-Oct-2011';
```

```
EndDates = ['01-Oct-2012'; '01-Oct-2013'; '01-Oct-2014'; '01-Oct-2015'];
Rates = [[0.0356;0.041185;0.04489;0.047741],[0.0325;0.0423;0.0437;0.0465]];
RateSpec = intenvset('Rates', Rates, 'StartDates', StartDates, ...
    'EndDates', EndDates, 'Compounding', 1)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
  Compounding: 1
        Disc: [4x2 double]
        Rates: [4x2 double]
    EndTimes: [4x1 double]
  StartTimes: [4x1 double]
    EndDates: [4x1 double]
  StartDates: 734777
ValuationDate: 734777
        Basis: 0
  EndMonthRule: 1
```

To look at the `Rates` for the two interest-rate curves:

```
RateSpec.Rates
```

```
ans =
```

```
    0.0356    0.0325
    0.0412    0.0423
    0.0449    0.0437
    0.0477    0.0465
```

### Create a `RateSpec` to Price Multi-Stepped Coupon Bonds

Price the following multi-stepped coupon bonds using the following data:

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2010';
StartDates = ValuationDate;
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};
Compounding = 1;

% Create RateSpec using intenvset
```

```

RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% Create a portfolio of stepped coupon bonds with different maturities
Settle = '01-Jan-2010';
Maturity = {'01-Jan-2011'; '01-Jan-2012'; '01-Jan-2013'; '01-Jan-2014'};
CouponRate = {'01-Jan-2011' .042; '01-Jan-2012' .05; '01-Jan-2013' .06; '01-Jan-2014' .07};

% Display the instrument portfolio
ISet = instbond(CouponRate, Settle, Maturity, 1);
instdisp(ISet)

```

Index	Type	CouponRate	Settle	Maturity	Period	Basis	EndMonthRule	IssueDate
1	Bond	[Cell]	01-Jan-2010	01-Jan-2011	1	0	1	NaN
2	Bond	[Cell]	01-Jan-2010	01-Jan-2012	1	0	1	NaN
3	Bond	[Cell]	01-Jan-2010	01-Jan-2013	1	0	1	NaN
4	Bond	[Cell]	01-Jan-2010	01-Jan-2014	1	0	1	NaN

Build a BDTTree to price the stepped coupon bonds. Assume the volatility to be 10%

```

Sigma = 0.1;
BDTTimeSpec = bdttimespec(ValuationDate, EndDates, Compounding);
BDTVolSpec = bdtvolspec(ValuationDate, EndDates, Sigma*ones(1, length(EndDates)));
BDTT = bdttree(BDTVolSpec, RS, BDTTimeSpec);

% Compute the price of the stepped coupon bonds
PBDT = bdtprice(BDTT, ISet)

```

```

PBDT =

    100.6763
    100.7368
    100.9266
    101.0115

```

## See Also

intenvget | intenvprice | intenvset

## isafin

True if input argument is financial structure type or financial object class

### Syntax

```
IsFinObj = isafin(Obj, ClassName)
```

### Arguments

Obj	Name of a financial structure.
ClassName	String containing the name of a financial structure class.

### Description

`IsFinObj = isafin(Obj, ClassName)` returns `True (1)` if input argument is a financial structure type or financial object class, otherwise `False (0)` is returned.

### Examples

```
load deriv.mat
IsFinObj = isafin(HJMTree, 'HJMFwdTree')

IsFinObj =

     1
```

### See Also

`classfin`

# itprice

Price instruments using implied trinomial tree (ITT)

## Syntax

```
Price = itprice(ITTTree, InstSet)
Price = itprice(ITTTree, InstSet, Options)
[Price, PriceTree] = itprice(ITTTree, InstSet, Options)
```

## Arguments

ITTTree	Implied trinomial stock tree. See <code>itttree</code> for information on creating the variable <code>ITTTree</code> .
InstSet	Variable containing a collection of <code>NINST</code> instruments. Instruments are broken down by type and each type can have different data fields.
Options	(Optional) Structure created using <code>derivset</code> containing derivative pricing options.

## Description

`Price = itprice(ITTTree, InstSet)` to price instruments using an implied trinomial tree (ITT).

`Price = itprice(ITTTree, InstSet, Options)` to price instruments with derivative pricing options using an implied trinomial tree (ITT).

`[Price, PriceTree] = itprice(ITTTree, InstSet, Options)` to price a collection of instruments with derivative pricing options using an implied trinomial tree (ITT).

The outputs for `itprice` are:

- `Price` is a `NINST`-by-1 vector of prices of each instrument at time 0. The prices are computed by backward dynamic programming on the stock tree. If an instrument cannot be priced, a `NaN` is returned in that entry.

- `PriceTree` is a structure containing trees of vectors of instrument prices and a vector of observation times for each node.
  - `PriceTree.PTree` contains the prices.
  - `PriceTree.tObs` contains the observation times.
  - `PriceTree.dObs` contains the observation dates.

`ittprice` computes prices for instruments using an implied trinomial tree created with `itttree`.

---

**Note:** `ittprice` handles the following instrument types: `optstock`, `barrier`, `Asian`, `lookback`, and `compound`. Use `instadd` to construct the defined types.

---

When using an implied trinomial tree, pricing of path-dependent options is done using Hull-White. Consequently, for these options there are no unique prices on the tree nodes with the exception of the root node. The corresponding nodes of the tree are populated with NaNs for these particular options. For information on single-type pricing functions to retrieve state-by-state pricing tree information, see the following:

- `barrierbyitt` for pricing barrier options using an ITT tree
- `optstockbyitt` for pricing American, European or Bermuda options using an ITT tree
- `asianbyitt` for pricing Asian options using an ITT tree
- `lookbackbyitt` for pricing lookback options using an ITT tree
- `compoundbyitt` for price compound options using an ITT tree

## Examples

### Price Instruments Using Implied Trinomial Tree (ITT)

Load the ITT tree and instruments from the data file `deriv.mat`.

```
load deriv.mat
```

Display the barrier and Asian options contained in the instrument set.

```
ITTSubSet = instselect(ITTInstSet, 'Type', {'Barrier', 'Asian'});
```



```
instdisp(ITTSubSet)
```

Index	Type	OptSpec	Strike	Settle	ExerciseDates	AmericanOpt	BarrierSpec	Barri
1	Barrier	call	85	01-Jan-2006	31-Dec-2008	1	ui	115

Index	Type	OptSpec	Strike	Settle	ExerciseDates	AmericanOpt	AvgType	AvgPri
2	Asian	call	55	01-Jan-2006	01-Jan-2008	0	arithmetic	NaN
3	Asian	call	55	01-Jan-2006	01-Jan-2010	0	arithmetic	NaN

Price the barrier and Asian options contained in the instrument set.

```
[Price, PriceTree] = ittpri(ITTree, ITTSubSet)
```

```
Price =
```

```
2.4074
3.2052
6.6074
```

```
PriceTree =
```

```
FinObj: 'TrinPriceTree'
PTree: {1x5 cell}
tObs: [0 1 2 3 4]
dObs: [732678 733043 733408 733773 734139]
```

## More About

- “Pricing Options Structure”

## See Also

```
ittsens | ittree
```

## ittsens

Instrument sensitivities and prices using implied trinomial tree (ITT)

### Syntax

```
[Delta, Gamma, Vega] = ittsens(ITTTree, InstSet)
[Delta, Gamma, Vega, Price] = ittsens(ITTTree, InstSet)
[Delta, Gamma, Vega, Price] = ittsens(ITTTree, InstSet,
Options)
```

### Arguments

ITTTree	Implied trinomial stock tree. See <code>itttree</code> for information on creating the variable <code>ITTTree</code> .
InstSet	Variable containing a collection of <code>NINST</code> instruments. Instruments are broken down by type and each type can have different data fields.
Options	(Optional) Structure created using <code>derivset</code> containing derivative pricing options.

### Description

`[Delta, Gamma, Vega] = ittsens(ITTTree, InstSet)` to calculate instrument sensitivities and prices using an implied trinomial tree (ITT).

`[Delta, Gamma, Vega, Price] = ittsens(ITTTree, InstSet)` to calculate a collection of instrument sensitivities and prices using an implied trinomial tree (ITT).

`[Delta, Gamma, Vega, Price] = ittsens(ITTTree, InstSet, Options)` to calculate the sensitivities and prices for a collection of instruments that contain derivative pricing options using an implied trinomial tree (ITT).

The outputs for `ittsens` are:

- **Delta** is a NINST-by-1 vector of deltas, representing the rate of change of instruments prices with respect to changes in the stock price.
- **Gamma** is a NINST-by-1 vector of gammas, representing the rate of change of instruments deltas with respect to changes in the stock price.
- **Vega** is a NINST-by-1 vector of vegas, representing the rate of change of instruments prices with respect to changes in the volatility of the stock. **Vega** is computed by finite differences in calls to `itttree`.
- **Price** is a NINST-by-1 vector of prices of each instrument. The prices are computed by backward dynamic programming on the stock tree. If an instrument cannot be priced, a NaN is returned.

`ittsens` computes dollar sensitivities and prices for instruments using an ITT tree created with `itttree`.

---

**Note:** `ittsens` handles the following instrument types: `optstock`, `barrier`, `Asian`, `lookback`, and `compound`. Use `instadd` to construct the defined types.

---

For path-dependent options (lookbacks and Asians), **Delta** and **Gamma** are computed by finite differences in calls to `ittprice`. For the rest of the options (`optstock`, `barrier`, and `compound`), **Delta** and **Gamma** are computed from the ITT tree and the corresponding option price tree.

All sensitivities are returned as dollar sensitivities. To find the per-dollar sensitivities, they must be divided by their respective instrument price.

## Examples

### Compute Instrument Sensitivities Using an Implied Trinomial Tree (ITT)

Load the ITT tree and instruments from the data file `deriv.mat` and display the vanilla options and barrier option instruments.

```
load deriv.mat
ITTSubSet = instselect(ITTInstSet, 'Type', {'OptStock', 'Barrier'});
instdisp(ITTSubSet)
```

Index	Type	OptSpec	Strike	Settle	ExerciseDates	AmericanOpt	Name	Quantity
1	OptStock	call	95	01-Jan-2006	31-Dec-2008	1	Call1	10
2	OptStock	put	80	01-Jan-2006	01-Jan-2010	0	Put1	4
Index	Type	OptSpec	Strike	Settle	ExerciseDates	AmericanOpt	BarrierSpec	Bar
3	Barrier	call	85	01-Jan-2006	31-Dec-2008	1	ui	115

Compute the **Delta** and **Gamma** sensitivities of vanilla options and barrier option contained in the instrument set.

```
[Delta, Gamma] = ittens(ITTree, ITSubSet)
```

Warning: The option set specified in StockOptSpec was too narrow for the generated tree.  
This made extrapolation necessary. Below is a list of the options that were outside of the range of those specified in StockOptSpec.

```
Option Type: 'call'    Maturity: 01-Jan-2007  Strike=67.2897
Option Type: 'put'    Maturity: 01-Jan-2007  Strike=37.1528
Option Type: 'put'    Maturity: 01-Jan-2008  Strike=27.6066
Option Type: 'put'    Maturity: 31-Dec-2008  Strike=20.5132
Option Type: 'call'   Maturity: 01-Jan-2010  Strike=164.0157
Option Type: 'put'    Maturity: 01-Jan-2010  Strike=15.2424
```

Delta =

```
0.2387
-0.4283
0.3482
```

Gamma =

```
0.0260
0.0188
0.0380
```

## More About

- “Pricing Options Structure”

## References

Chriss, Neil. and I. Kawaller, *Black-Scholes and Beyond: Options Pricing Models*, McGraw-Hill, 1996, pp. 308-312.

## See Also

ittprice | ittree

## itttimespec

Specify time structure using implied trinomial tree (ITT)

### Syntax

```
TimeSpec = itttimespec(ValuationDate, Maturity, NumPeriods)
```

### Arguments

ValuationDate	Scalar date marking the pricing date and first observation in the tree. Specify ValuationDate as a serial date number or date string.
Maturity	Scalar date marking the depth of the tree.
NumPeriods	Scalar that determines how many time steps are in the tree.

### Description

`TimeSpec = itttimespec(ValuationDate, Maturity, NumPeriods)` creates the structure specifying the time layout for an ITT tree.

### Examples

#### Creates the Structure Specifying the Time Layout for an ITT Tree

This example shows how to specify a four-period tree with time steps of 1 year.

```
ValuationDate = '1-July-2006';  
Maturity = '1-July-2010';  
TimeSpec = itttimespec(ValuationDate, Maturity, 4)
```

```
TimeSpec =
```

```
      FinObj: 'ITTimeSpec'  
ValuationDate: 732859  
      Maturity: 734320  
      NumPeriods: 4  
      Basis: 0  
EndMonthRule: 1  
      tObs: [0 1 2 3 4]  
      dObs: [732859 733224 733589 733954 734320]
```

## See Also

itttree | stockspect

## ittree

Build implied trinomial stock tree

### Syntax

```
ittree(StockSpec, RateSpec, TimeSpec, StockOptSpec)
```

### Arguments

StockSpec	Stock specification. For more information, see <code>stockspec</code> .
RateSpec	Interest rate specification of the initial risk-free rate curve. For more information on declaring an interest rate variable, see <code>intenvset</code> .
TimeSpec	Tree time layout specification. Defines the observation dates of the implied trinomial tree. For more information on the tree structure, see <code>itttimespec</code> .
StockOptSpec	Option stock specification. For more information, see <code>stockoptspec</code> .

### Description

`ittree(StockSpec, RateSpec, TimeSpec, StockOptSpec)` creates the `ittree` structure specifying stock and time information for an implied trinomial tree.

### Examples

For this example, assume that the interest rate is fixed at 8% annually between the valuation date of the tree (January 1, 2006) until its maturity.

```
Rate = 0.08;  
ValuationDate = '01-01-2006';  
EndDate = '01-01-2008';
```



```
RateSpec = intenvset('StartDates', ValuationDate, 'EndDates', EndDate, ...
    'ValuationDate', ValuationDate, 'Rates', Rate, 'Compounding', -1);
```

To build an ITTTree, create StockSpec, TimeSpec, and StockOptSpec structures.

To create theStockSpec structure:

```
Sigma = 0.20;
AssetPrice = 50;
DividendType = 'cash';
DividendAmounts = [0.50; 0.50; 0.50; 0.50];
ExDividendDates = {'03-Jan-2007'; '01-Apr-2007'; '05-July-2007'; '01-Oct-2007'}

StockSpec = stockspec(Sigma, AssetPrice, DividendType, ...
    DividendAmounts, ExDividendDates)
```

```
StockSpec =

    FinObj: 'StockSpec'
    Sigma: 0.2000
    AssetPrice: 50
    DividendType: 'cash'
    DividendAmounts: [4x1 double]
    ExDividendDates: [4x1 double]
```

The syntax for building a TimeSpec structure is `TimeSpec = itttimespec(ValuationDate, Maturity, NumPeriods)`.

Consider building an ITT tree, with a valuation date of January 1, 2006; a maturity date of January 1, 2008; and four time steps.

```
ValuationDate = '01-01-2006';
EndDate = '01-01-2008';
NumPeriods = 4;
```

```
TimeSpec = itttimespec(ValuationDate, EndDate, NumPeriods)
```

```
TimeSpec =

    FinObj: 'ITTTTimeSpec'
    ValuationDate: 732678
    Maturity: 733408
    NumPeriods: 4
    Basis: 0
    EndMonthRule: 1
    tObs: [0 0.5000 1 1.5000 2]
    dObs: [732678 732860 733043 733225 733408]
```

The syntax for building a `StockOptSpec` structure is `[StockOptSpec] = stockoptspec(OptPrice, Strike, Settle, Maturity, OptSpec)`.

```
Settle = '01/01/06';

Maturity = ['07/01/06';
           '07/01/06';
           '07/01/06';
           '01/01/07';
           '01/01/07';
           '01/01/07';
           '01/01/07';
           '01/01/07';
           '07/01/07';
           '07/01/07';
           '07/01/07';
           '07/01/07';
           '01/01/08';
           '01/01/08';
           '01/01/08';
           '01/01/08'];

Strike = [113;
         101;
         100;
         88;
         128;
         112;
         100;
         78;
         144;
         112;
         100;
         69;
         162;
         112;
         100;
         61];

OptPrice = [
           4.807905472659144;
           1.306321897011867;
           0.048039195057173;
           0;
           2.310953054191461;
           1.421950392866235;
           0.020414826276740;
           0;
           5.091986935627730;
           1.346534812295291;
           0.005101325584140;
           0;
           8.047628153217246;
           1.219653432150932;
           0.001041436654748];
```

```

OptSpec = { 'call';
            'call';
            'put';
            'put';
            'call';
            'call';
            'put';
            'put';
            'call';
            'call';
            'put';
            'put';
            'call';
            'call';
            'put';
            'put'};

StockOptSpec = stockoptspec(OptPrice, Strike, Settle, Maturity, OptSpec)

StockOptSpec =

    FinObj: 'StockOptSpec'
    OptPrice: [16x1 double]
    Strike: [16x1 double]
    Settle: 732678
    Maturity: [16x1 double]
    OptSpec: {16x1 cell}
    InterpMethod: 'price'

```

---

**Note:** In this example, the extrapolation warnings are turned on to display warnings on the Command Window. These warnings are a consequence of having to extrapolate to find the option price of the tree nodes. In this example, the set of inputs options was too narrow for the shift in the tree nodes introduced by the disturbance used to calculate the sensitivities. As a consequence extrapolation for some of the nodes was needed.

---

Use the following command to turn on extrapolation warnings:

```
warning('on', 'fininst:ittree:Extrapolation');
```

Use the `StockSpec`, `RateSpec`, `TimeSpec`, and `StockOptSpec` structure to create an `ITTree`.

```
ITTree = ittree(StockSpec, RateSpec, TimeSpec, StockOptSpec)
```

Warning: The option set specified in `StockOptSpec` was too narrow for the generated tree.

This made extrapolation necessary. Below is a list of the options that were outside of the range of those specified in StockOptSpec.

```
Option Type: 'call'   Maturity: 02-Jul-2006   Strike=60.7466
Option Type: 'put'   Maturity: 02-Jul-2006   Strike=50.0731
Option Type: 'put'   Maturity: 02-Jul-2006   Strike=41.3344
Option Type: 'call'  Maturity: 01-Jan-2007   Strike=73.8592
Option Type: 'call'  Maturity: 01-Jan-2007   Strike=60.8227
Option Type: 'put'   Maturity: 01-Jan-2007   Strike=50.1492
Option Type: 'put'   Maturity: 01-Jan-2007   Strike=41.4105
Option Type: 'put'   Maturity: 01-Jan-2007   Strike=34.2559
Option Type: 'call'  Maturity: 02-Jul-2007   Strike=88.8310
Option Type: 'call'  Maturity: 02-Jul-2007   Strike=72.9081
Option Type: 'call'  Maturity: 02-Jul-2007   Strike=59.8715
Option Type: 'put'   Maturity: 02-Jul-2007   Strike=49.1980
Option Type: 'put'   Maturity: 02-Jul-2007   Strike=40.4594
Option Type: 'put'   Maturity: 02-Jul-2007   Strike=33.3047
Option Type: 'put'   Maturity: 02-Jul-2007   Strike=27.4470
Option Type: 'call'  Maturity: 01-Jan-2008   Strike=107.2895
Option Type: 'call'  Maturity: 01-Jan-2008   Strike=87.8412
Option Type: 'call'  Maturity: 01-Jan-2008   Strike=71.9183
Option Type: 'call'  Maturity: 01-Jan-2008   Strike=58.8817
Option Type: 'put'   Maturity: 01-Jan-2008   Strike=48.2083
Option Type: 'put'   Maturity: 01-Jan-2008   Strike=39.4696
Option Type: 'put'   Maturity: 01-Jan-2008   Strike=32.3150
Option Type: 'put'   Maturity: 01-Jan-2008   Strike=26.4573
Option Type: 'put'   Maturity: 01-Jan-2008   Strike=21.6614
```

```
> In ittree>InterpOptPrices at 675
  In ittree at 277
```

```
ITTree =
```

```
  FinObj: 'ITStockTree'
  StockSpec: [1x1 struct]
  StockOptSpec: [1x1 struct]
  TimeSpec: [1x1 struct]
  RateSpec: [1x1 struct]
  tObs: [0 0.500000000000000 1 1.500000000000000 2]
  dObs: [732678 732860 733043 733225 733408]
  STree: {1x5 cell}
  Probs: {[3x1 double] [3x3 double] [3x5 double] [3x7 double]}
```

## See Also

[intenvset](#) | [itttimespec](#) | [stockoptspec](#) | [stockspec](#)

# LiborMarketModel class

Create LIBOR Market Model

## Description

The LIBOR Market Model (LMM) differs from short rate models in that it evolves a set of discrete forward rates. Specifically, the lognormal LMM specifies the following diffusion equation for each forward rate

$$\frac{dF_i(t)}{F_i} = -\mu_i dt + \sigma_i(t) dW_i$$

where:

$W$  is an  $N$ -dimensional geometric Brownian motion with

$$dW_i(t)dW_j(t) = \rho_{ij}$$

The LMM relates the drifts of the forward rates based on no-arbitrage arguments. Specifically, under the Spot LIBOR measure, the drifts are expressed as

$$\mu_i(t) = -\sigma_i(t) \sum_{j=q(t)}^i \frac{\tau_j \rho_{i,j} \sigma_j(t) F_j(t)}{1 + \tau_j F_j(t)}$$

where:

$\tau_i$  is the time fraction associated with the  $i$  th forward rate

$q(t)$  is an index defined by the relation

$$T_{q(t)-1} < t < T_{q(t)}$$

and the Spot LIBOR numeraire is defined as

$$B(t) = P(t, T_{q(t)}) \prod_{n=0}^{q(t)-1} (1 + \tau_n F_n(T_n))$$

## Construction

`OBJ = LiborMarketModel(ZeroCurve, VolFunc, Correlation)` constructs a LIBOR Market Model object.

For example:

```
Settle = datenum('15-Dec-2007');
CurveTimes = [1:5 7 10 20]';
ZeroRates = [.01 .018 .024 .029 .033 .034 .035 .034]';
CurveDates = daysadd(Settle, 360*CurveTimes, 1);

irdc = IRDataCurve('Zero', Settle, CurveDates, ZeroRates);

LMMVolFunc = @(a,t) (a(1)*t + a(2)).*exp(-a(3)*t) + a(4);
LMMVolParams = [.3 -.02 .7 .14];

numRates = 20;
VolFunc(1:numRates-1) = {@(t) LMMVolFunc(LMMVolParams,t)};

Beta = .08;
CorrFunc = @(i,j,Beta) exp(-Beta*abs(i-j));
Correlation = CorrFunc(meshgrid(1:numRates-1), meshgrid(1:numRates-1), Beta);

LMM = LiborMarketModel(irdc, VolFunc, Correlation, 'Period', 1);
```

## Properties

The following properties are from the `LiborMarketModel` class.

### ZeroCurve

`ZeroCurve` is specified using the output from `IRDataCurve` or `RateSpec`. This is the zero curve used to evolve the path of future interest rates.

**Attributes:**

SetAccess	public
GetAccess	public

**VolFunc**

NumRates-by-1 cell array of function handles. Each function handle must take time as an input and, return a scalar volatility.

**Attributes:**

SetAccess	public
GetAccess	public

**Correlation**

NumRates-by-NumRates correlation matrix.

**Attributes:**

SetAccess	public
GetAccess	public

**NumFactors**

Number of Brownian factors. The default is NaN, where the number of factors is equal to the number of rates.

**Attributes:**

SetAccess	public
GetAccess	public

**Period**

Period of the forward rates. The default is 2, meaning forward rates are spaced at 0, .5, 1, 1.5 and so on. Possible values for **Period** are: 1, 2, 4, and 12.

---

**Note:** `Correlation` and `VolFunc` are sized with `NumRates-by-1` since the first rate is locked in and essentially dead.

---

### Attributes:

<code>SetAccess</code>	<code>public</code>
<code>GetAccess</code>	<code>public</code>

## Methods

<code>simTermStructs</code>	Simulate term structures for LIBOR Market Model
-----------------------------	---

## Definitions

### LIBOR Market Model

The LIBOR Market Model, also called the BGM Model (Brace, Gatarek, Musiela Model) is a financial model of interest rates. The quantities that are modeled are a set of forward rates (also called forward LIBORs) which have the advantage of being directly observable in the market, and whose volatilities are naturally linked to traded contracts.

## Copy Semantics

Value. To learn how value classes affect copy operations, see “Copying Objects” in the MATLAB documentation.

## Examples

### Construct a LIBOR Market Model

Construct a LMM object.



```

Settle = datenum('15-Dec-2007');
CurveTimes = [1:5 7 10 20]';
ZeroRates = [.01 .018 .024 .029 .033 .034 .035 .034]';
CurveDates = daysadd(Settle,360*CurveTimes,1);

irdc = IRDataCurve('Zero',Settle,CurveDates,ZeroRates);

LMMVolFunc = @(a,t) (a(1)*t + a(2)).*exp(-a(3)*t) + a(4);
LMMVolParams = [.3 -.02 .7 .14];

numRates = 20;
VolFunc(1:numRates-1) = {@(t) LMMVolFunc(LMMVolParams,t)};

Beta = .08;
CorrFunc = @(i,j,Beta) exp(-Beta*abs(i-j));
Correlation = CorrFunc(meshgrid(1:numRates-1),meshgrid(1:numRates-1),Beta);

LMM = LiborMarketModel(irdc,VolFunc,Correlation,'Period',1);

Simulate the term structures for the specified LMM object.

[ZeroRates, ForwardRates] = simTermStructs(LMM, 10,'nTrials',100);

```

- “Price Swaptions With Interest-Rate Models Using Simulation”
- “Class Attributes”
- “Property Attributes”

## References

Brigo, D. and F. Mercurio, *Interest Rate Models - Theory and Practice*, Springer Finance, 2006.

## See Also

HullWhite1F | LinearGaussian2F | simTermStructs

## simTermStructs

**Class:** LiborMarketModel

Simulate term structures for LIBOR Market Model

### Syntax

```
[ZeroRates,ForwardRates] = simTermStructs(nPeriods)
[ZeroRates,ForwardRates] = simTermStructs(nPeriods,
Name,Value)
```

### Description

[ZeroRates,ForwardRates] = simTermStructs(nPeriods) simulates future zero curve paths using a specified LiborMarketModel object.

[ZeroRates,ForwardRates] = simTermStructs(nPeriods, Name,Value) simulates future zero curve paths using a specified LiborMarketModel object with additional options specified by one or more Name,Value pair arguments.

### Input Arguments

#### nPeriods

Number of simulation periods.

#### Name-Value Pair Arguments

Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

**'nTrials'**

Positive scalar integer number of simulated trials (sample paths) of `NPERIODS` observations each. If you do not specify a value for this argument, the default is 1, indicating a single path of correlated state variables.

**Default:** 1

**'antithetic'**

Boolean scalar flag indicating whether antithetic sampling is used to generate the Gaussian random variates that drive the zero-drift, unit-variance rate Brownian vector  $dW(t)$ . For details, see `simBySolution`.

**Default:** false

**'Z'**

Direct specification of the dependent random noise process used to generate the zero-drift, unit-variance rate Brownian vector  $dW(t)$  that drives the simulation. For details, see `simBySolution` for the GBM model.

**Default:** Uses default for `simBySolution`. If you do not specify a value for `Z`, `simBySolution` generates Gaussian variates.

**'Tenor'**

Numeric vector of maturities to compute at each time step.

**Default:** `tenor` the number of rates in the `LiborMarketModel` object as specified by the correlation and volatility functions

## Output Arguments

**ZeroRates**

`nPeriods+1-by-nTenors-by-nTrials` matrix of simulated zero-rate term structures.

**ForwardRates**

`nPeriods+1-by-nTenors-by-nTrials` matrix of simulated forward-rate term structures.

## Attributes

Access	public
Static	false
Hidden	false

To learn about attributes of methods, see “Method Attributes” in the MATLAB Object-Oriented Programming documentation.

## Examples

### Simulate Term Structures for a LIBOR Market Model

Create a LMM object.

```
Settle = datenum('15-Dec-2007');
CurveTimes = [1:5 7 10 20]';
ZeroRates = [.01 .018 .024 .029 .033 .034 .035 .034]';
CurveDates = daysadd(Settle,360*CurveTimes,1);

irdc = IRDataCurve('Zero',Settle,CurveDates,ZeroRates);

LMMVolFunc = @(a,t) (a(1)*t + a(2)).*exp(-a(3)*t) + a(4);
LMMVolParams = [.3 -.02 .7 .14];

numRates = 20;
VolFunc(1:numRates-1) = {@(t) LMMVolFunc(LMMVolParams,t)};

Beta = .08;
CorrFunc = @(i,j,Beta) exp(-Beta*abs(i-j));
Correlation = CorrFunc(meshgrid(1:numRates-1),meshgrid(1:numRates-1),Beta);

LMM = LiborMarketModel(irdc,VolFunc,Correlation,'Period',1)

LMM =

    LiborMarketModel with properties:

        ZeroCurve: [1x1 IRDataCurve]
    VolFunctions: {1x19 cell}
```

```
Correlation: [19x19 double]
NumFactors: NaN
Period: 1
```

Simulate the term structures for the specified LMM object.

```
[ZeroRates, ForwardRates] = simTermStructs(LMM, 20, 'nTrials', 100);
```

- “Price Swaptions With Interest-Rate Models Using Simulation”

## See Also

[blackvolbyrebonato](#) | [LiborMarketModel](#)

## LinearGaussian2F class

Create two-factor additive Gaussian interest-rate model

### Description

The two-factor additive Gaussian interest rate-model is specified using the zero curve,  $a$ ,  $b$ ,  $\sigma$ ,  $\eta$ , and  $\rho$  parameters for these equations:

$$r(t) = x(t) + y(t) + \phi(t)$$

$$dx(t) = -a(t)x(t)dt + \sigma(t)dW_1(t), x(0) = 0$$

$$dy(t) = -b(t)y(t)dt + \eta(t)dW_2(t), y(0) = 0$$

where  $dW_1(t)dW_2(t) = \rho dt$  is a two-dimensional Brownian motion with correlation  $\rho$ , and  $\phi$  is a function chosen to match the initial zero curve.

### Construction

`OBJ = LinearGaussian2F(ZeroCurve, a, b, sigma, eta, rho)` constructs an object for a two-factor additive Gaussian interest-rate model.

For example:

```
Settle = datenum('15-Dec-2007');
CurveTimes = [1:5 7 10 20]';
ZeroRates = [.01 .018 .024 .029 .033 .034 .035 .034]';
CurveDates = daysadd(Settle, 360*CurveTimes, 1);

irdc = IRDataCurve('Zero', Settle, CurveDates, ZeroRates);

a = .07;
b = .5;
sigma = .01;
```

```
eta = .006;  
rho = -.7;  
  
G2PP = LinearGaussian2F(irdc,a,b,sigma,eta,rho);
```

## Properties

The following properties are from the `LinearGaussian2F` class.

### ZeroCurve

`ZeroCurve` is specified using `IRDataCurve` or `RateSpec`. This is the zero curve used to evolve the path of future interest rates.

### Attributes:

<code>SetAccess</code>	<code>public</code>
<code>GetAccess</code>	<code>public</code>

### **a**

Mean reversion for the first factor, specified either as a scalar or function handle which takes time as input and returns a scalar mean reversion value.

### Attributes:

<code>SetAccess</code>	<code>public</code>
<code>GetAccess</code>	<code>public</code>

### **b**

Mean reversion for the second factor, specified either as a scalar or as a function handle which takes time as input and returns a scalar mean reversion value.

### Attributes:

<code>SetAccess</code>	<code>public</code>
------------------------	---------------------

GetAccess public

### **sigma**

Volatility for the first factor, specified either as a scalar or function handle which takes time as input and returns a scalar mean volatility.

#### **Attributes:**

SetAccess public

GetAccess public

### **eta**

Volatility for the second factor specified, either as a scalar or function handle which takes time as input and returns a scalar mean volatility.

#### **Attributes:**

SetAccess public

GetAccess public

### **rho**

Scalar correlation of the factors.

#### **Attributes:**

SetAccess public

GetAccess public

## **Methods**

simTermStructs  
Simulate term structures for two-factor additive Gaussian interest-rate model



## Definitions

### Two-Factor Additive Gaussian Interest-Rate Model

Short-rate model based on two factors where the short rate is the sum of the two factors and a deterministic function, in this case  $\#(t)$ , which is chosen to match the initial term structure.

## Copy Semantics

Value. To learn how value classes affect copy operations, see “Copying Objects” in the MATLAB documentation.

## Examples

### Construct a Two-Factor Additive Gaussian Interest-Rate Model

Construct a two-factor additive Gaussian interest-rate model.

```
Settle = datenum('15-Dec-2007');
CurveTimes = [1:5 7 10 20]';
ZeroRates = [.01 .018 .024 .029 .033 .034 .035 .034]';
CurveDates = daysadd(Settle,360*CurveTimes,1);

irdc = IRDataCurve('Zero',Settle,CurveDates,ZeroRates);

a = .07;
b = .5;
sigma = .01;
eta = .006;
rho = -.7;

G2PP = LinearGaussian2F(irdc,a,b,sigma,eta,rho)
```

G2PP =

LinearGaussian2F with properties:

```
ZeroCurve: [1x1 IRDataCurve]
  a: @(t,V)ina
  b: @(t,V)inb
  sigma: @(t,V)insigma
  eta: @(t,V)ineta
  rho: -0.7000
```

Use the `simTermStructs` method to simulate term structures based on the `LinearGaussian2F` model.

```
SimPaths = simTermStructs(G2PP, 10, 'nTrials',100);
```

- “Price Swaptions With Interest-Rate Models Using Simulation”
- “Class Attributes”
- “Property Attributes”

## References

Brigo, D. and F. Mercurio, *Interest Rate Models - Theory and Practice*, Springer Finance, 2006.

## See Also

`capbylg2f` | `floorbylg2f` | `HullWhite1F` | `LiborMarketModel` | `simTermStructs`  
| `swaptionbylg2f`

# simTermStructs

**Class:** LinearGaussian2F

Simulate term structures for two-factor additive Gaussian interest-rate model

## Syntax

```
[ZeroRates,ForwardRates] = simTermStructs(nPeriods)
[ZeroRates,ForwardRates] = simTermStructs(nPeriods,
Name,Value)
```

## Description

[ZeroRates,ForwardRates] = simTermStructs(nPeriods) simulates future zero curve paths using a specified LinearGaussian2F object.

[ZeroRates,ForwardRates] = simTermStructs(nPeriods, Name,Value) simulates future zero curve paths using a specified LinearGaussian2F object with additional options specified by one or more Name,Value pair arguments.

## Input Arguments

### nPeriods

Number of simulation periods.

### Name-Value Pair Arguments

Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

### 'deltaTime'

Scalar time step between periods.

**Default:** 1

**'nTrials'**

Positive scalar integer number of simulated trials (sample paths) of `NPERIODS` observations each. If you do not specify a value for this argument, the default is 1, indicating a single path of correlated state variables.

**Default:** 1

**'antithetic'**

Boolean scalar flag indicating whether antithetic sampling is used to generate the Gaussian random variates that drive the zero-drift, unit-variance rate Brownian vector  $dW(t)$ . For details, see `simBySolution` for the HWV model.

**Default:** false

**'Z'**

Direct specification of the dependent random noise process used to generate the zero-drift, unit-variance rate Brownian vector  $dW(t)$  that drives the simulation. For details, see `simBySolution` for the HWV model.

**Default:** Uses default for `simBySolution`. If you do not specify a value for `Z`, `simBySolution` generates Gaussian variates.

**'Tenor'**

Numeric vector of maturities to compute at each time step.

**Default:** tenor of the `LinearGaussian2F` object's zero curve

## Output Arguments

**ZeroRates**

`nPeriods+1`-by-`nTenors`-by-`nTrials` matrix of simulated zero-rate term structures.

**ForwardRates**

`nPeriods+1`-by-`nTenors`-by-`nTrials` matrix of simulated forward-rate term structures.

## Attributes

Access	public
Static	false
Hidden	false

To learn about attributes of methods, see “Method Attributes” in the MATLAB Object-Oriented Programming documentation.

## Examples

### Simulate Term Structures for the LinearGaussian2F Model

Create a two-factor additive Gaussian interest-rate model.

```
Settle = datenum('15-Dec-2007');
CurveTimes = [1:5 7 10 20]';
ZeroRates = [.01 .018 .024 .029 .033 .034 .035 .034]';
CurveDates = daysadd(Settle,360*CurveTimes,1);

irdc = IRDataCurve('Zero',Settle,CurveDates,ZeroRates);

a = .07;
b = .5;
sigma = .01;
eta = .006;
rho = -.7;

G2PP = LinearGaussian2F(irdc,a,b,sigma,eta,rho)
```

G2PP =

LinearGaussian2F with properties:

```
ZeroCurve: [1x1 IRDataCurve]
    a: @(t,V)ina
    b: @(t,V)inb
sigma: @(t,V)insigma
    eta: @(t,V)ineta
    rho: -0.7000
```

Use the `simTermStructs` method to simulate term structures based on the `LinearGaussian2F` model.

```
SimPaths = simTermStructs(G2PP, 10, 'nTrials', 100);
```

- “Price Swaptions With Interest-Rate Models Using Simulation”

### **See Also**

`LinearGaussian2F`

# lookbackbycrr

Price lookback option from Cox-Ross-Rubinstein tree

## Syntax

```
PriceTree = lookbackbycrr(CRRTree, OptSpec, Strike,
Settle, ExerciseDates, AmericanOpt)
```

## Arguments

<b>CRRTree</b>	Stock tree structure created by <code>crrtree</code> .
<b>OptSpec</b>	Number of instruments (NINST)-by-1 cell array of strings 'call' or 'put'.
<b>Strike</b>	NINST-by-1 vector of strike price values. Each row is the schedule for one option. To calculate the value of a floating-strike lookback option, specify <b>Strike</b> as NaN.
<b>Settle</b>	NINST-by-1 vector of <b>Settle</b> dates. The settle date for every lookback is set to the valuation date of the stock tree. The lookback argument <b>Settle</b> is ignored.
<b>ExerciseDates</b>	<p>For a European option (<b>AmericanOpt</b> = 0):</p> <p>NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option (<b>AmericanOpt</b> = 1):</p> <p>NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <b>ExerciseDates</b> is NINST-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.</p>

AmericanOpt	(Optional) If AmericanOpt = 0, NaN, or is unspecified, the option is a European option. If AmericanOpt = 1, the option is an American option.
-------------	---

## Description

PriceTree = lookbackbycrr(CRRTree, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt) calculates the value of fixed- and floating-strike lookback options. Data arguments are NINST-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument. The others may be omitted or passed as empty matrices [ ].

Price is a NINST-by-1 vector of expected option prices at time 0.

---

**Note:** lookbackbycrr calculates values of fixed and floating strike lookback options. To compute the value of a floating strike lookback option, strike should be specified as NaN. Pricing of lookback options is done using Hull-White (1993). Consequently, for these options there are not unique prices on the tree nodes with the exception of the root node.

---

## Examples

### Price a Lookback Option Using a CRR Binomial Tree

This example shows how to price a lookback option using a CRR binomial tree by loading the file deriv.mat, which provides CRRTree. The CRRTree structure contains the stock specification and time information needed to price the option.

```
load deriv.mat;

OptSpec = 'Call';
Strike = 115;
Settle = '01-Jan-2003';
ExerciseDates = '01-Jan-2006';

Price = lookbackbycrr(CRRTree, OptSpec, Strike, Settle, ...
ExerciseDates)
```



Price =

7.6015

## References

Hull, J., and A. White, "Efficient Procedures for Valuing European and American Path-Dependent Options," *Journal of Derivatives*, Fall 1993, pp. 21-31.

## See Also

crrtree | instlookback

## lookbackbycvgsg

Calculate prices of European lookback options using Conze-Viswanathan and Goldman-Sosin-Gatto models

### Syntax

```
Price = lookbackbycvgsg(RateSpec, StockSpec, OptSpec, Strike, Settle,
ExerciseDates)
Price = lookbackbycvgsg( ____, Name, Value)
```

### Description

`Price = lookbackbycvgsg(RateSpec, StockSpec, OptSpec, Strike, Settle, ExerciseDates)` returns prices of European lookback options using Conze-Viswanathan and Goldman-Sosin-Gatto models. `lookbackbycvgsg` calculates prices of European fixed- and floating-strike lookback options. To compute the value of a floating-strike lookback option, `Strike` must be specified as `NaN`. The Goldman-Sosin-Gatto model is used for floating-strike lookback options. The Conze-Viswanathan model is used for fixed-strike lookback options.

`Price = lookbackbycvgsg( ____, Name, Value)` returns prices of European lookback options using Conze-Viswanathan and Goldman-Sosin-Gatto models with optional name-value pair arguments. `lookbackbycvgsg` calculates prices of European fixed- and floating-strike lookback options. To compute the value of a floating-strike lookback option, `Strike` must be specified as `NaN`. The Goldman-Sosin-Gatto model is used for floating-strike lookback options. The Conze-Viswanathan model is used for fixed-strike lookback options.

### Examples

#### Compute the Price of a Floating Lookback Option Using the Goldman-Sosin-Gatto Model

Define the `RateSpec`.

```
StartDates = 'Jan-1-2013';
```

```

EndDates = 'Jan-1-2014';
Rates = 0.042;
Compounding = -1;
RateSpec = intenvset('ValuationDate', StartDates, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)

```

```

RateSpec =

    FinObj: 'RateSpec'
  Compounding: -1
        Disc: 0.9589
        Rates: 0.0420
    EndTimes: 1
  StartTimes: 0
    EndDates: 735600
  StartDates: 735235
ValuationDate: 735235
        Basis: 0
  EndMonthRule: 1

```

Define the StockSpec.

```

AssetPrice = 50;
Sigma = 0.36;
StockSpec = stockspec(Sigma, AssetPrice)

```

```

StockSpec =

    FinObj: 'StockSpec'
      Sigma: 0.3600
  AssetPrice: 50
  DividendType: []
DividendAmounts: 0
  ExDividendDates: []

```

Define the floating lookback options.

```

Settle = 'Jan-1-2013';
Maturity = 'April-1-2013';
OptSpec = {'put'; 'call'};
Strike = NaN;

```

Compute the price of the European floating lookback options.

```
Price = lookbackbycvgs(RateSpec, StockSpec, OptSpec, Strike, Settle, Maturity)
```

```
Price =
```

```
    7.2581  
    6.9777
```

### Compute the Price of a Fixed Lookback Option Using the Conze-Viswanathan Model

Define the RateSpec.

```
StartDates = 'Jan-1-2013';  
EndDates = 'Jan-1-2014';  
Rates = 0.045;  
Compounding = -1;  
RateSpec = intenvset('ValuationDate', StartDates, 'StartDates', StartDates,...  
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'  
    Compounding: -1  
        Disc: 0.9560  
        Rates: 0.0450  
    EndTimes: 1  
    StartTimes: 0  
    EndDates: 735600  
    StartDates: 735235  
    ValuationDate: 735235  
        Basis: 0  
    EndMonthRule: 1
```

Define the StockSpec.

```
AssetPrice = 102;  
Sigma = 0.45;  
StockSpec = stockspeg(Sigma, AssetPrice)
```

```
StockSpec =
```

```

        FinObj: 'StockSpec'
        Sigma: 0.4500
    AssetPrice: 102
    DividendType: []
    DividendAmounts: 0
    ExDividendDates: []

```

Define the fixed lookback options.

```

Settle = 'Jan-1-2013';
Maturity = 'July-1-2013';
OptSpec = {'put'; 'call'};
Strike = [98; 101];

```

Price the European fixed lookback options.

```
Price = lookbackbycvgsg(RateSpec, StockSpec, OptSpec, Strike, Settle, Maturity)
```

```

Price =
    18.3130
    30.4021

```

## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

Interest-rate term structure (annualized and continuously compounded), specified by the `RateSpec` obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: `struct`

### **StockSpec** — Stock specification for underlying asset

structure

Stock specification for the underlying asset. For information on the stock specification, see `stockspec`.

`stockspec` handles several types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: `struct`

### **OptSpec — Definition of option**

string with values 'call' or 'put' | cell array of strings

Definition of option as 'call' or 'put', specified as a NINST-by-1 cell array of strings.

Data Types: `char` | `cell`

### **Strike — Option strike price values**

integer | vector of integers

Option strike price values, specified as an integer using a NINST-by-1 vector of strike price values.

Data Types: `single` | `double`

### **Settle — Settlement or trade date**

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Settlement or trade date for the lookback option, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: `char` | `cell`

### **ExerciseDates — European option expiry date**

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

European option expiry date, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: `char` | `cell`

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single

quotes (' '). You can specify several name and value pair arguments in any order as Name1, Value1, . . . , NameN, ValueN.

Example: Price =

```
lookbackbycvgsg(RateSpec, StockSpec, OptSpec, Strike, Settle, ExerciseDates, 'AssetM
```

**'AssetMinMax'** — Maximum or minimum underlying asset price

if unspecified, the lookback option is newly issued, and AssetMinMax = StockSpec.AssetPrice (default) | nonnegative integer

Maximum or minimum underlying asset price, specified as a NINST-by-1 vector.

Data Types: single | double

## Output Arguments

**Price** — Expected prices of lookback option

vector

Expected prices of the lookback option, returned as a NINST-by-1 vector.

## More About

- “Lookback Option”

## References

Hull, J. C. *Options, Futures, and Other Derivatives*, 5th ed. Englewood Cliffs, NJ: Prentice Hall, 2002.

## See Also

intenvset | lookbackbyls | lookbacksensbycvgsg | lookbacksensbyls | stockspect

## lookbacksensbycvgs

Calculate prices and sensitivities of European lookback options using Conze-Viswanathan and Goldman-Sosin-Gatto models

### Syntax

```
PriceSens = lookbacksensbycvgs(RateSpec, StockSpec, OptSpec, Strike,  
Settle,  
ExerciseDates)  
PriceSens = lookbacksensbycvgs( ____, Name, Value)
```

### Description

`PriceSens = lookbacksensbycvgs(RateSpec, StockSpec, OptSpec, Strike, Settle, ExerciseDates)` returns prices and sensitivities of European lookback options using Conze-Viswanathan and Goldman-Sosin-Gatto models. `lookbacksensbycvgs` calculates prices of European fixed- and floating-strike lookback options. To compute the value of a floating-strike lookback option, `Strike` must be specified as `NaN`. The Goldman-Sosin-Gatto model is used for floating-strike lookback options. The Conze-Viswanathan model is used for fixed-strike lookback options.

`PriceSens = lookbacksensbycvgs( ____, Name, Value)` returns prices and sensitivities of European lookback options using Conze-Viswanathan and Goldman-Sosin-Gatto models with optional name-value pair arguments. `lookbacksensbycvgs` calculates prices of European fixed- and floating-strike lookback options. To compute the value of a floating-strike lookback option, `Strike` must be specified as `NaN`. The Goldman-Sosin-Gatto model is used for floating-strike lookback options. The Conze-Viswanathan model is used for fixed-strike lookback options.

### Examples

#### Compute the Price and Delta of a Floating Lookback Option Using the Goldman-Sosin-Gatto Model

Define the `RateSpec`.



```

StartDates = 'Jan-1-2013';
EndDates = 'Jan-1-2014';
Rates = 0.41;
Compounding = -1;
RateSpec = intenvset('ValuationDate', StartDates, 'StartDates', StartDates,...
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)

```

```

RateSpec =

    FinObj: 'RateSpec'
    Compounding: -1
    Disc: 0.6637
    Rates: 0.4100
    EndTimes: 1
    StartTimes: 0
    EndDates: 735600
    StartDates: 735235
    ValuationDate: 735235
    Basis: 0
    EndMonthRule: 1

```

Define the **StockSpec** with continuous dividend yield.

```

AssetPrice = 120;
Sigma = 0.3;
Yield = 0.045;
StockSpec = stockspec(Sigma, AssetPrice, 'Continuous', Yield)

```

```

StockSpec =

    FinObj: 'StockSpec'
    Sigma: 0.3000
    AssetPrice: 120
    DividendType: {'continuous'}
    DividendAmounts: 0.0450
    ExDividendDates: []

```

Define the floating lookback option.

```

Settle = 'Jan-1-2013';
Maturity = 'July-1-2013';

```

```
OptSpec = 'call';  
Strike = NaN;  
SMinMax = 100;
```

Compute the price and delta of the European floating lookback option.

```
OutSpec = {'price', 'delta'};  
[Price, Delta] = lookbacksensbycvgsg(RateSpec, StockSpec, OptSpec, Strike,...  
Settle, Maturity, 'AssetMinMax', SMinMax, 'OutSpec', OutSpec)
```

```
Price =  
  
    36.9926
```

```
Delta =  
  
    0.8659
```

### Compute the Price and Delta of a Fixed Lookback Option Using the Conze-Viswanathan Model

Define the RateSpec.

```
StartDates = 'Jan-1-2013';  
EndDates = 'Jan-1-2015';  
Rates = 0.1;  
Compounding = -1;  
RateSpec = intenvset('ValuationDate', StartDates, 'StartDates', StartDates,...  
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =  
  
    FinObj: 'RateSpec'  
    Compounding: -1  
    Disc: 0.8187  
    Rates: 0.1000  
    EndTimes: 2  
    StartTimes: 0  
    EndDates: 735965  
    StartDates: 735235  
    ValuationDate: 735235
```

```
Basis: 0
EndMonthRule: 1
```

Define the StockSpec.

```
AssetPrice = 103;
Sigma = 0.30;
StockSpec = stockspec(Sigma, AssetPrice)
```

```
StockSpec =
```

```
      FinObj: 'StockSpec'
      Sigma: 0.3000
      AssetPrice: 103
      DividendType: []
      DividendAmounts: 0
      ExDividendDates: []
```

Define the fixed lookback option.

```
Settle = 'Jan-1-2013';
Maturity = 'July-1-2013';
OptSpec = 'call';
Strike = 99;
```

Price and delta for the European fixed lookback option.

```
OutSpec = {'price', 'delta'};
[Price, Delta] = lookbacksensbyls(RateSpec, StockSpec, OptSpec, ...
Strike, Settle, Maturity, 'OutSpec', OutSpec)
```

```
Price =
```

```
22.6783
```

```
Delta =
```

```
1.1345
```

## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

Interest-rate term structure (annualized and continuously compounded), specified by the `RateSpec` obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: `struct`

### **StockSpec** — Stock specification for underlying asset

structure

Stock specification for the underlying asset. For information on the stock specification, see `stockspec`.

`stockspec` handles several types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: `struct`

### **OptSpec** — Definition of option

string with values 'call' or 'put' | cell array of strings

Definition of option as 'call' or 'put', specified as a NINST-by-1 cell array of strings.

Data Types: `char` | `cell`

### **Strike** — Option strike price values

integer | vector of integers

Option strike price values, specified as an integer using a NINST-by-1 vector of strike price values.

Data Types: `single` | `double`

### **Settle** — Settlement or trade date

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Settlement or trade date for the lookback option, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: char | cell

### **ExerciseDates — European option expiry date**

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

European option expiry date, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: char | cell

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

Example: PriceSens =

```
lookbacksensbycvgsg(RateSpec,StockSpec,OptSpec,Strike,Settle,ExerciseDates,'As
{'All'})
```

### **'AssetMinMax' — Maximum or minimum underlying asset price**

if unspecified, the lookback option is newly issued, and AssetMinMax = StockSpec.AssetPrice (default) | nonnegative integer

Maximum or minimum underlying asset price, specified as a NINST-by-1 vector.

Data Types: single | double

### **'OutSpec' — Define outputs**

{'Price'} (default) | string with values 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All' | cell array of strings with values 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'

Define outputs, specifying a NOUT-by-1 or a 1-by-NOUT cell array of strings with possible values of 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'.

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec` to include each sensitivity.

Example: `OutSpec =`  
`{'delta', 'gamma', 'vega', 'lambda', 'rho', 'theta', 'price'}`

Data Types: `char` | `cell`

## Output Arguments

### **PriceSens** — Expected prices and sensitivities of lookback option

vector

Expected prices and sensitivities of the lookback option, returned as a NINST-by-1 vector.

## More About

- “Lookback Option”

## References

Hull, J. C. *Options, Futures, and Other Derivatives*, 5th ed. Englewood Cliffs, NJ: Prentice Hall, 2002.

## See Also

`intenvset` | `lookbackbycvgsg` | `lookbackbyls` | `lookbacksensbyls` | `stockspec`

# lookbackbyeqp

Price lookback option from Equal Probabilities binomial tree

## Syntax

```
[Price, PriceTree] = lookbackbyeqp(EQPTree, OptSpec, Strike,
Settle, ExerciseDates, AmericanOpt)
```

## Arguments

EQPTree	Stock tree structure created by <code>eqptree</code> .
OptSpec	Number of instruments (NINST)-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values. Each row is the schedule for one option. To calculate the value of a floating-strike lookback option, specify <b>Strike</b> as NaN.
Settle	NINST-by-1 vector of <b>Settle</b> dates. The settle date for every lookback is set to the valuation date of the stock tree. The lookback argument <b>Settle</b> is ignored.
ExerciseDates	<p>For a European option (<b>AmericanOpt</b> = 0):</p> <p>NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option (<b>AmericanOpt</b> = 1):</p> <p>NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <b>ExerciseDates</b> is NINST-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.</p>

AmericanOpt	(Optional) If AmericanOpt = 0, NaN, or is unspecified, the option is a European option. If AmericanOpt = 1, the option is an American option.
-------------	---

## Description

Price = lookbackbyeqp(EQPTree, OptSpec, Strike, ExerciseDates, AmericanOpt) calculates the value of fixed- and floating-strike lookback options. Data arguments are NINST-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument. The others may be omitted or passed as empty matrices [ ].

Price is a NINST-by-1 vector of expected option prices at time 0.

---

**Note:** lookbackbyeqp calculates values of fixed and floating strike lookback options. To compute the value of a floating strike lookback option, strike should be specified as NaN. Pricing of lookback options is done using Hull-White (1993). Consequently, for these options there are not unique prices on the tree nodes with the exception of the root node.

---

## Examples

### Price a Lookback Option Using an EQP Equity Tree

This example shows how to price a lookback option using an EQP equity tree by loading the file deriv.mat, which provides EQPTree. The EQPTree structure contains the stock specification and time information needed to price the option.

```
load deriv.mat

OptSpec = 'Call';
Strike = 115;
Settle = '01-Jan-2003';
ExerciseDates = '01-Jan-2006';

Price = lookbackbyeqp(EQPTree, OptSpec, Strike, Settle, ...
ExerciseDates)
```



Price =

8.7941

## References

Hull, J., and A. White, "Efficient Procedures for Valuing European and American Path-Dependent Options," *Journal of Derivatives*, Fall 1993, pp. 21-31.

## See Also

eqptree | instlookback

## lookbackbyitt

Price lookback option using implied trinomial tree (ITT)

### Syntax

```
[Price, PriceTree] = lookbackbyitt(ITTTree, OptSpec, Strike,
Settle, ExerciseDates, AmericanOpt)
```

### Arguments

ITTTree	Stock tree structure created by <code>itttree</code> .
OptSpec	Number of instruments (NINST)-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values. Each row is the schedule for one option. To calculate the value of a floating-strike lookback option, specify <b>Strike</b> as NaN.
Settle	NINST-by-1 vector of <b>Settle</b> dates. The settle date for every lookback option is set to the <b>ValuationDate</b> of the stock tree. The lookback argument <b>Settle</b> is ignored.
ExerciseDates	<p>For a European option (<b>AmericanOpt</b> = 0):</p> <p>NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option (<b>AmericanOpt</b> = 1):</p> <p>NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <b>ExerciseDates</b> is NINST-by-1, the option can be exercised between the valuation date of the stock tree and the single listed exercise date.</p>

AmericanOpt	(Optional) If AmericanOpt = 0, NaN, or is unspecified, the option is a European option. If AmericanOpt = 1, the option is an American option.
-------------	---

## Description

Price = lookbackbyitt(ITTree, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt) calculates the value of fixed- and floating-strike lookback options. Data arguments for lookbackbyitt are NINST-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument; the others may be omitted or passed as empty matrices [ ].

Price is a NINST-by-1 vector of expected option prices at time 0.

---

**Note:** lookbackbyitt calculates values of fixed and floating strike lookback options. To compute the value of a floating strike lookback option, strike should be specified as NaN. Pricing of lookback options is done using Hull-White (1993). Consequently, for these options there are not unique prices on the tree nodes with the exception of the root node.

---

## Examples

### Price a Lookback Option Using an ITT Equity Tree

This example shows how to price a lookback option using an ITT equity tree by loading the file deriv.mat, which provides the ITTree. The ITTree structure contains the stock specification and time information needed to price the option.

```
load deriv.mat

OptSpec = 'Call';
Strike = 85;
Settle = '01-Jan-2006';
ExerciseDates = '01-Jan-2008';

Price = lookbackbyitt(ITTree, OptSpec, Strike, Settle, ExerciseDates)

Price =
```

0.5426

## References

Hull, J., and A. White, “Efficient Procedures for Valuing European and American Path-Dependent Options,” *Journal of Derivatives*, Fall 1993, pp. 21-31.

## See Also

instlookback | ittree

# lookbackbyls

Calculate prices of lookback options using Longstaff-Schwartz model

## Syntax

```
[Price,Paths,Times,Z] = lookbackbyls(RateSpec,StockSpec,OptSpec,
Strike,Settle,
ExerciseDates)
[Price,Paths,Times,Z] = lookbackbyls( ____,Name,Value)
```

## Description

[Price,Paths,Times,Z] = lookbackbyls(RateSpec,StockSpec,OptSpec,Strike,Settle,ExerciseDates) returns prices of lookback options using the Longstaff-Schwartz model for Monte Carlo simulations. lookbackbyls computes prices of European and American lookback options. For American options, the Longstaff-Schwartz least squares method calculates the early exercise premium. lookbackbyls calculates values of fixed- and floating-strike lookback options. To compute the value of a floating-strike lookback option, Strike must be specified as NaN.

[Price,Paths,Times,Z] = lookbackbyls( \_\_\_\_,Name,Value) returns prices of lookback options using the Longstaff-Schwartz model for Monte Carlo simulations with optional name-value pair arguments. lookbackbyls computes prices of European and American lookback options. For American options, the Longstaff-Schwartz least squares method calculates the early exercise premium. lookbackbyls calculates values of fixed- and floating-strike lookback options. To compute the value of a floating-strike lookback option, Strike must be specified as NaN.

## Examples

### Compute the Price for a Floating Lookback Option Using Monte Carlo Simulation

Define the RateSpec.

```
StartDates = 'Jan-1-2013';
EndDates = 'Jan-1-2014';
Rates = 0.042;
Compounding = -1;
RateSpec = intenvset('ValuationDate', StartDates, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =

    FinObj: 'RateSpec'
  Compounding: -1
        Disc: 0.9589
        Rates: 0.0420
    EndTimes: 1
  StartTimes: 0
    EndDates: 735600
  StartDates: 735235
ValuationDate: 735235
        Basis: 0
  EndMonthRule: 1
```

Define the `StockSpec`.

```
AssetPrice = 50;
Sigma = 0.36;
StockSpec = stockspec(Sigma, AssetPrice)
```

```
StockSpec =

    FinObj: 'StockSpec'
    Sigma: 0.3600
  AssetPrice: 50
  DividendType: []
  DividendAmounts: 0
  ExDividendDates: []
```

Define the floating lookback option.

```
Settle = 'Jan-1-2013';
Maturity = 'April-1-2013';
OptSpec = 'put';
```

```
Strike = NaN;
```

Compute the price of the European floating lookback option.

```
Price = lookbackbyls(RateSpec, StockSpec, OptSpec, Strike, Settle, Maturity)
```

```
Price =
```

```
    6.5409
```

### Compute the Price of a Fixed Lookback Option Using Monte Carlo Simulation

Define the RateSpec.

```
StartDates = 'Jan-1-2013';
```

```
EndDates = 'Jan-1-2014';
```

```
Rates = 0.045;
```

```
Compounding = -1;
```

```
RateSpec = intenvset('ValuationDate', StartDates, 'StartDates', StartDates, ...
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
  Compounding: -1
        Disc: 0.9560
        Rates: 0.0450
    EndTimes: 1
  StartTimes: 0
    EndDates: 735600
  StartDates: 735235
ValuationDate: 735235
        Basis: 0
  EndMonthRule: 1
```

Define the StockSpec.

```
AssetPrice = 102;
```

```
Sigma = 0.45;
```

```
StockSpec = stockspec(Sigma, AssetPrice)
```

```
StockSpec =  
  
    FinObj: 'StockSpec'  
    Sigma: 0.4500  
    AssetPrice: 102  
    DividendType: []  
    DividendAmounts: 0  
    ExDividendDates: []
```

Define the fixed lookback option.

```
Settle = 'Jan-1-2013';  
Maturity = 'July-1-2013';  
OptSpec = 'call';  
Strike = 98;
```

Compute the price of the European fixed lookback option.

```
Price = lookbackbyls(RateSpec, StockSpec, OptSpec, Strike, Settle, Maturity)
```

```
Price =  
  
    30.0917
```

## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

Interest-rate term structure (annualized and continuously compounded), specified by the `RateSpec` obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: `struct`

### **StockSpec** — Stock specification for underlying asset

structure

Stock specification for the underlying asset. For information on the stock specification, see `stockspec`.



`stockspec` handles several types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: `struct`

### **OptSpec — Definition of option**

string with values 'call' or 'put' | cell array of strings

Definition of option as 'call' or 'put', specified as a NINST-by-1 cell array of strings.

Data Types: `char` | `cell`

### **Strike — Option strike price values**

integer | vector of integers

Option strike price values, specified as an integer using a NINST-by-1 vector of strike price values.

Data Types: `single` | `double`

### **Settle — Settlement or trade date**

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Settlement or trade date for the lookback option, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: `char` | `cell`

### **ExerciseDates — Matrix of exercise callable or puttable dates for European or American options**

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Matrix of exercise callable or puttable dates for European or American options, specified as a date string or as nonnegative integers as follows:

- European option — NINST-by-1 vector of exercise dates. For a European option, there is only one exercise date which is the option expiry date.
- American option — NINST-by-2 vector of exercise date boundaries. For each instrument, the option is exercised on any coupon date between or including the

pair of dates on that row. If only one non-NaN date is listed, or if `ExerciseDates` is a NINST-by-1 vector of serial date numbers or cell array of strings, the option is exercised between `Settle` and the single listed exercise date.

Data Types: `char` | `cell`

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes ( ' '). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

Example: `Price =`

```
lookbackbyls(RateSpec, StockSpec1, StockSpec2, Settle, Maturity, OptSpec, Strike, Cor
```

### 'AmericanOpt' — Option type

0 European (default) | scalar with value [0, 1]

Option type, specified as an integer scalar flag with these values:

- 0 — European
- 1 — American

For American options, the Longstaff-Schwartz least squares method calculates the early exercise premium.

Data Types: `single` | `double`

### 'NumTrials' — Scalar number of independent sample paths

1000 (default) | nonnegative scalar integer

Scalar number of independent sample paths (simulation trials), specified as a nonnegative integer.

Data Types: `single` | `double`

### 'NumPeriods' — Scalar number of simulation periods per trial

100 (default) | nonnegative scalar integer

Scalar number of simulation periods per trial, specified as a nonnegative integer. `NumPeriods` is considered only when pricing European lookback options. For American

lookback options, `NumPeriods` is equal to the number of exercise days during the life of the option.

Data Types: `single` | `double`

### 'Z' — Time series array of dependent random variates

vector

Time series array of dependent random variates, specified as a `NumPeriods`-by-1-by-`NumTrials` 3-D array. The Z value generates the Brownian motion vector (i.e., Wiener processes) that drives the simulation.

Data Types: `single` | `double`

### 'Antithetic' — Indicator for antithetic sampling

`false` (default) | scalar logical flag with value of `true` or `false`

Indicator for antithetic sampling, specified with a value of `true` or `false`.

Data Types: `logical`

## Output Arguments

### Price — Expected price of lookback option

scalar

Expected price of the lookback option, returned as a 1-by-1 scalar.

### Paths — Simulated paths of correlated state variables

vector

Simulated paths of correlated state variables, returned as a `NumPeriods + 1`-by-1-by-`NumTrials` 3-D time series array. Each row of `Paths` is the transpose of the state vector  $X(t)$  at time  $t$  for a given trial.

### Times — Observation times associated with simulated paths

vector

Observation times associated with simulated paths, returned as a `NumPeriods + 1`-by-1 column vector of observation times associated with the simulated paths. Each element of `Times` is associated with the corresponding row of `Paths`.

**Z — Time series array of dependent random variates**

vector

Time series array of dependent random variates, returned as a NumPeriods-by-1-by-NumTrials 3-D array when Z is specified as an input argument. If the Z input argument is not specified, then the Z output argument contains the random variates generated internally.

**More About**

- “Lookback Option”

**References**

Hull, J. C. *Options, Futures, and Other Derivatives*, 5th ed. Englewood Cliffs, NJ: Prentice Hall, 2002.

**See Also**

intenvset | lookbackbycvgsg | lookbacksensbycvgsg | lookbacksensbyls | stockspect

# lookbacksensbyls

Calculate prices and sensitivities of lookback options using Longstaff-Schwartz model

## Syntax

```
[PriceSens,Paths,Times,Z] = lookbacksensbyls(RateSpec,StockSpec,
OptSpec,Strike,Settle,
ExerciseDates)
[PriceSens,Paths,Times,Z] = lookbacksensbyls( ____,Name,Value)
```

## Description

[PriceSens,Paths,Times,Z] = lookbacksensbyls(RateSpec,StockSpec,OptSpec,Strike,Settle,ExerciseDates) returns prices and sensitivities of lookback options using the Longstaff-Schwartz model for Monte Carlo simulations. `lookbacksensbyls` computes prices of European and American lookback options. For American options, the Longstaff-Schwartz least squares method calculates the early exercise premium. `lookbacksensbyls` calculates values of fixed- and floating-strike lookback options. To compute the value of a floating-strike lookback option, Strike must be specified as NaN.

[PriceSens,Paths,Times,Z] = lookbacksensbyls( \_\_\_\_,Name,Value) returns prices and sensitivities of lookback options using the Longstaff-Schwartz model for Monte Carlo simulations with optional name-value pair arguments. `lookbacksensbyls` computes prices of European and American lookback options. For American options, the Longstaff-Schwartz least squares method calculates the early exercise premium. `lookbacksensbyls` calculates values of fixed- and floating-strike lookback options. To compute the value of a floating-strike lookback option, Strike must be specified as NaN.

## Examples

### Compute the Price and Delta of a European Floating Lookback Option Using Monte Carlo Simulation

Define the RateSpec.

```
StartDates = 'Jan-1-2013';
```

```
EndDates = 'Jan-1-2014';
Rates = 0.41;
Compounding = -1;
RateSpec = intenvset('ValuationDate', StartDates, 'StartDates', StartDates,...
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =

    FinObj: 'RateSpec'
    Compounding: -1
    Disc: 0.6637
    Rates: 0.4100
    EndTimes: 1
    StartTimes: 0
    EndDates: 735600
    StartDates: 735235
    ValuationDate: 735235
    Basis: 0
    EndMonthRule: 1
```

Define the `StockSpec` with continuous dividend yield.

```
AssetPrice = 120;
Sigma = 0.3;
Yield = 0.045;
StockSpec = stockspec(Sigma, AssetPrice, 'Continuous', Yield)
```

```
StockSpec =

    FinObj: 'StockSpec'
    Sigma: 0.3000
    AssetPrice: 120
    DividendType: {'continuous'}
    DividendAmounts: 0.0450
    ExDividendDates: []
```

Define the floating lookback option.

```
Settle = 'Jan-1-2013';
Maturity = 'July-1-2013';
OptSpec = 'call';
Strike = NaN;
```

Compute the price and delta of the European floating lookback option.

```
OutSpec = {'price', 'delta'};
[Price, Delta] = lookbacksensbyls(RateSpec, StockSpec, OptSpec, Strike, Settle, Maturity,
'OutSpec', OutSpec)
```

```
Price =
    27.4701
```

```
Delta =
    0.2289
```

### Compute the Price and Delta of a European Fixed Lookback Option Using Monte Carlo Simulation

Define the RateSpec.

```
StartDates = 'Jan-1-2013';
EndDates = 'Jan-1-2015';
Rates = 0.1;
Compounding = -1;
RateSpec = intenvset('ValuationDate', StartDates, 'StartDates', StartDates, ...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
    FinObj: 'RateSpec'
    Compounding: -1
    Disc: 0.8187
    Rates: 0.1000
    EndTimes: 2
    StartTimes: 0
    EndDates: 735965
    StartDates: 735235
    ValuationDate: 735235
    Basis: 0
    EndMonthRule: 1
```

Define the StockSpec.

```
AssetPrice = 103;  
Sigma = 0.30;  
StockSpec = stockspec(Sigma, AssetPrice)
```

```
StockSpec =
```

```
    FinObj: 'StockSpec'  
    Sigma: 0.3000  
    AssetPrice: 103  
    DividendType: []  
    DividendAmounts: 0  
    ExDividendDates: []
```

Define the fixed lookback option.

```
Settle = 'Jan-1-2013';  
Maturity = 'July-1-2013';  
OptSpec = 'call';  
Strike = 99;
```

Compute the price and delta of the European fixed lookback option.

```
OutSpec = {'price', 'delta'};  
[Price, Delta] = lookbacksensbyls(RateSpec, StockSpec, OptSpec, Strike, Settle, Maturity,  
'OutSpec', OutSpec)
```

```
Price =
```

```
    22.6783
```

```
Delta =
```

```
    1.1345
```

## Input Arguments

**RateSpec** — Interest-rate term structure  
structure



Interest-rate term structure (annualized and continuously compounded), specified by the `RateSpec` obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: `struct`

### **StockSpec — Stock specification for underlying asset**

`structure`

Stock specification for the underlying asset. For information on the stock specification, see `stockspec`.

`stockspec` can handle several types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: `struct`

### **OptSpec — Definition of option**

string with values 'call' or 'put' | cell array of strings

Definition of option as 'call' or 'put', specified as a NINST-by-1 cell array of strings.

Data Types: `char` | `cell`

### **Strike — Option strike price values**

integer | vector of integers

Option strike price values, specified as an integer using a NINST-by-1 vector of strike price values.

Data Types: `single` | `double`

### **Settle — Settlement or trade date**

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Settlement or trade date for the lookback option, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: `char` | `cell`

**ExerciseDates** — Matrix of exercise callable or puttable dates for European or American options

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Matrix of exercise callable or puttable dates for European or American options, specified as a date string or as nonnegative integers as follows:

- European option — NINST-by-1 vector of exercise dates. For a European option, there is only one exercise date which is the option expiry date.
- American option — NINST-by-2 vector of exercise date boundaries. For each instrument, the option is exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if `ExerciseDates` is a NINST-by-1 vector of serial date numbers or cell array of strings, the option is exercised between `Settle` and the single listed exercise date.

Data Types: char | cell

**Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, ..., NameN, ValueN`.

```
Example: PriceSens =  
lookbacksensbyls(RateSpec, StockSpec1, StockSpec2, Settle, Maturity, OptSpec, Strike  
{'All'})
```

**'AmericanOpt'** — Option type

0 European (default) | scalar with value [0, 1]

Option type, specified as an integer scalar flag with these values:

- 0 — European
- 1 — American

For American options, the Longstaff-Schwartz least squares method calculates the early exercise premium.

Data Types: single | double

**'NumTrials' — Scalar number of independent sample paths**

1000 (default) | nonnegative scalar integer

Scalar number of independent sample paths (simulation trials), specified as a nonnegative integer.

Data Types: `single` | `double`

**'NumPeriods' — Scalar number of simulation periods per trial**

100 (default) | nonnegative scalar integer

Scalar number of simulation periods per trial, specified as a nonnegative integer. `NumPeriods` is considered only when pricing European lookback options. For American lookback options, `NumPeriod` is equal to the number of exercise days during the life of the option.

Data Types: `single` | `double`

**'Z' — Time series array of dependent random variates**

vector

Time series array of dependent random variates, specified as a `NumPeriods`-by-1-by-`NumTrials` 3-D array. The `Z` value generates the Brownian motion vector (i.e., Wiener processes) that drives the simulation.

Data Types: `single` | `double`

**'Antithetic' — Indicator for antithetic sampling**false (default) | scalar logical flag with value `true` or `false`

Indicator for antithetic sampling, specified with a value of `true` or `false`.

Data Types: `logical`

**'OutSpec' — Define outputs**

{'Price'} (default) | string with values 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All' | cell array of strings with values 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'

Define outputs, specifying a NOUT- by-1 or a 1-by-NOUT cell array of strings with possible values of 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'.

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec` to include each sensitivity.

Example: `OutSpec =`  
`{'delta', 'gamma', 'vega', 'lambda', 'rho', 'theta', 'price'}`

Data Types: `char` | `cell`

## Output Arguments

### **PriceSens** — Expected price and sensitivities of lookback option

vector

Expected price and sensitivities of the lookback option, returned as a `NINST`-by-1 vector.

### **Paths** — Simulated paths of correlated state variables

vector

Simulated paths of correlated state variables, returned as a `NumPeriods + 1`-by-1-by-`NumTrials` 3-D time series array. Each row of `Paths` is the transpose of the state vector  $X(t)$  at time  $t$  for a given trial.

### **Times** — Observation times associated with simulated paths

vector

Observation times associated with simulated paths, returned as a `NumPeriods + 1`-by-1 column vector of observation times associated with the simulated paths. Each element of `Times` is associated with the corresponding row of `Paths`.

### **Z** — Time series array of dependent random variates

vector

Time series array of dependent random variates, returned as a `NumPeriods`-by-1-by-`NumTrials` 3-D array when `Z` is specified as an input argument. If the `Z` input argument is not specified, then the `Z` output argument contains the random variates generated internally.

## More About

- “Lookback Option”

## References

Hull, J. C. *Options, Futures, and Other Derivatives*, 5th ed. Englewood Cliffs, NJ: Prentice Hall, 2002.

## See Also

intenvset | lookbackbycvgs | lookbackbyls | lookbacksensbycvgs |  
stockspec

## **lrtimespec**

Specify time structure for Leisen-Reimer binomial tree

### **Syntax**

```
TimeSpec = lrtimespec(ValuationDate, Maturity, NumPeriods)
```

### **Description**

`TimeSpec = lrtimespec(ValuationDate, Maturity, NumPeriods)` specifies a time structure for a Leisen-Reimer stock tree.

### **Input Arguments**

#### **ValuationDate**

Scalar date marking the pricing date and first observation in the Leisen-Reimer stock tree. Specify `ValuationDate` as a serial date number or date string.

#### **Maturity**

Scalar date marking the depth of the Leisen-Reimer stock tree.

#### **NumPeriods**

Scalar value determining how many time steps are in the Leisen-Reimer stock tree.

---

**Note:** Leisen-Reimer requires the number of steps to be an odd number.

---

### **Output Arguments**

#### **TimeSpec**

Structure specifying the time layout for a Leisen-Reimer stock tree.

## Examples

### Specify the Time Structure for Leisen-Reimer Binomial Tree

This example shows how to specify a 5-period tree with time steps of 1 year.

```
ValuationDate = '1-July-2010';  
Maturity = '1-July-2015';  
TimeSpec = lrtimespec(ValuationDate, Maturity, 5)
```

```
TimeSpec =
```

```
      FinObj: 'BinTimeSpec'  
ValuationDate: 734320  
      Maturity: 736146  
    NumPeriods: 5  
      Basis: 0  
EndMonthRule: 1  
      tObs: [0 1 2 3 4 5]  
      dObs: [734320 734685 735050 735415 735780 736146]
```

## References

Leisen D.P., M. Reimer, “Binomial Models for Option Valuation – Examining and Improving Convergence,” *Applied Mathematical Finance*, Number 3, 1996, pp. 319-346.

## See Also

| stockspec | lrtree

## Lrtree

Build Leisen-Reimer stock tree

### Syntax

```
LRTree = lrtree(StockSpec, RateSpec, TimeSpec, Strike)
LRTree = lrtree(StockSpec, RateSpec, TimeSpec,
Strike, Name,Value)
```

### Description

`LRTree = lrtree(StockSpec, RateSpec, TimeSpec, Strike)` constructs a Leisen-Reimer stock tree.

`LRTree = lrtree(StockSpec, RateSpec, TimeSpec, Strike, Name,Value)` constructs a Leisen-Reimer stock tree with additional options specified by one or more `Name,Value` pair arguments.

### Input Arguments

#### StockSpec

Stock specification. For more information, see `stockspec`.

#### RateSpec

Interest rate specification of the initial risk-free rate curve. For more information, see `intenvset`.

#### TimeSpec

Tree time layout specification. For more information, see `lrtimespec`.

#### Strike

Scalar defining the option strike.



## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

### 'Method'

String value. Use `PP1` for Peizer-Pratt method 1 inversion and `PP2` for Peizer-Pratt method 2 inversion. For more information on `PP1` and `PP2` methods, see “Leisen-Reimer Tree (LR) Modeling” on page C-7.

**Default:** `PP1`

## Output Arguments

### LRTree

Structure specifying stock and time information for a Leisen-Reimer tree.

## Examples

### Build a Leisen-Reimer Stock Tree

This example shows how to build Leisen-Reimer stock tree. Consider a European put option with an exercise price of \$30 that expires on June 1, 2010. The underlying stock is trading at \$30 on January 1, 2010 and has a volatility of 30% per annum. The annualized continuously compounded risk-free rate is 5% per annum. Using this data, create a Leisen-Reimer tree with 101 steps using the `PP1` method.

```
AssetPrice = 30;
Strike = 30;

ValuationDate = 'Jan-1-2010';
Maturity = 'June-1-2010';

% define StockSpec
Sigma = 0.3;
StockSpec = stockspect(Sigma, AssetPrice);
```

```
% define RateSpec
Rates = 0.05;
Settle = ValuationDate;
Basis = 1;
Compounding = -1;

RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', Settle, ...
'EndDates', Maturity, 'Rates', Rates, 'Compounding', Compounding, 'Basis', Basis);

% build the Leisen-Reimer (LR) tree with 101 steps
LRTimeSpec = lrtimespec(ValuationDate, Maturity, 101);

% use the PP1 method
LRMethod = 'PP1';

LRTree = lrtree(StockSpec, RateSpec, LRTimeSpec, Strike, ...
'method', LRMethod)

LRTree =

    FinObj: 'BinStockTree'
    Method: 'LR'
  Submethod: 'PP1'
    Strike: 30
  StockSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
      tObs: [1x102 double]
      dObs: [1x102 double]
      STree: {1x102 cell}
    UpProbs: [101x1 double]
```

## References

Leisen D.P., M. Reimer, “Binomial Models for Option Valuation – Examining and Improving Convergence,” *Applied Mathematical Finance*, Number 3, 1996, pp. 319-346.

## See Also

| [stockspec](#) | [lrtimespec](#) | [intenvset](#) | [optstockbylr](#) | [optstocksensbylr](#)

# maxassetbystulz

Determine European rainbow option price on maximum of two risky assets using Stulz option pricing model

## Syntax

```
Price = maxassetbystulz(RateSpec, StockSpec1, StockSpec2,
Settle, Maturity, OptSpec, Strike, Corr)
```

## Arguments

RateSpec	The annualized, continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec1	Stock specification for asset 1. See <code>stockspec</code> .
StockSpec2	Stock specification for asset 2. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.
Corr	NINST-by-1 vector of correlation between the underlying asset prices.

## Description

`Price = maxassetbystulz(RateSpec, StockSpec1, StockSpec2, Settle, Maturity, OptSpec, Strike, Corr)` computes rainbow option prices using the Stulz option pricing model.

`Price` is a NINST-by-1 vector of expected option prices.

## Examples

### Compute Rainbow Option Prices Using the Stulz Option Pricing Model

Consider a European rainbow option that gives the holder the right to buy either \$100,000 worth of an equity index at a strike price of 1000 (asset 1) or \$100,000 of a government bond (asset 2) with a strike price of 100% of face value, whichever is worth more at the end of 12 months. On January 15, 2008, the equity index is trading at 950, pays a dividend of 2% annually and has a return volatility of 22%. Also on January 15, 2008, the government bond is trading at 98, pays a coupon yield of 6%, and has a return volatility of 15%. The risk-free rate is 5%. Using this data, if the correlation between the rates of return is -0.5, 0, and 0.5, calculate the price of the European rainbow option.

Since the asset prices in this example are in different units, it is necessary to work in either index points (asset 1) or in dollars (asset 2). The European rainbow option allows the holder to buy the following: 100 units of the equity index at \$1000 each (for a total of \$100,000) or 1000 units of the government bonds at \$100 each (for a total of \$100,000). To convert the bond price (asset 2) to index units (asset 1), you must make the following adjustments:

- Multiply the strike price and current price of the government bond by 10 (1000/100).
- Multiply the option price by 100, considering that there are 100 equity index units in the option.

Once these adjustments are introduced, the strike price is the same for both assets (\$1000). First, create the `RateSpec`:

```
Settle = 'Jan-15-2008';
Maturity = 'Jan-15-2009';
Rates = 0.05;
Basis = 1;

RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
    'EndDates', Maturity, 'Rates', Rates, 'Compounding', -1, 'Basis', Basis)
```

```
RateSpec =
    FinObj: 'RateSpec'
    Compounding: -1
    Disc: 0.9512
    Rates: 0.0500
```

```

    EndTimes: 1
    StartTimes: 0
    EndDates: 733788
    StartDates: 733422
    ValuationDate: 733422
    Basis: 1
    EndMonthRule: 1

```

Create the two `StockSpec` definitions.

```

AssetPrice1 = 950;    % Asset 1 => Equity index
AssetPrice2 = 980;    % Asset 2 => Government bond
Sigma1 = 0.22;
Sigma2 = 0.15;
Div1 = 0.02;
Div2 = 0.06;

StockSpec1 = stockspec(Sigma1, AssetPrice1, 'continuous', Div1)
StockSpec2 = stockspec(Sigma2, AssetPrice2, 'continuous', Div2)

```

`StockSpec1 =`

```

    FinObj: 'StockSpec'
    Sigma: 0.2200
    AssetPrice: 950
    DividendType: {'continuous'}
    DividendAmounts: 0.0200
    ExDividendDates: []

```

`StockSpec2 =`

```

    FinObj: 'StockSpec'
    Sigma: 0.1500
    AssetPrice: 980
    DividendType: {'continuous'}
    DividendAmounts: 0.0600
    ExDividendDates: []

```

Calculate the price of the options for different correlation levels.

```
Strike = 1000 ;
```

```
Corr = [-0.5; 0; 0.5];  
OptSpec = 'call';
```

```
Price = maxassetbystulz(RateSpec, StockSpec1, StockSpec2, ...  
Settle, Maturity, OptSpec, Strike, Corr)
```

```
Price =
```

```
111.6683  
103.7715  
92.4412
```

These are the prices of one unit. This means that the premium is 11166.83, 10377.15, and 9244.12 (for 100 units).

### See Also

[intenvset](#) | [maxassetsensbystulz](#) | [minassetbystulz](#) | [stockspec](#)

# maxassetsensbystulz

Determine European rainbow option prices and sensitivities on maximum of two risky assets using Stulz pricing model

## Syntax

```
PriceSens = maxassetsensbystulz(RateSpec, StockSpec1,
StockSpec2, Settle, Maturity, OptSpec, Strike, Corr)
PriceSens = maxassetsensbystulz(RateSpec, StockSpec1,
StockSpec2, Settle, Maturity, OptSpec, Strike, Corr, OutSpec)
```

## Arguments

RateSpec	The annualized, continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec1	Stock specification for asset 1. See <code>stockspec</code> .
StockSpec2	Stock specification for asset 2. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.
Corr	NINST-by-1 vector of correlation between the underlying asset prices.
OutSpec	(Optional) All optional inputs are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. You can specify parameter name/value pairs in any order. Names are case-insensitive and partial string matches are allowed provided no ambiguities exist. Valid parameter names are:

- NOUT-by-1 or 1-by-NOUT cell array of strings indicating the nature and order of the outputs for the function. Possible values are 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', or 'All'.

For example, `OutSpec = {'Price'; 'Lambda'; 'Rho'}` specifies that the output should be Price, Lambda, and Rho, in that order.

To invoke from a function: `[Price, Lambda, Rho] = maxassetsensbystulz(..., 'OutSpec', {'Price', 'Lambda', 'Rho'})`

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec = {'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', 'Price'}`;

- Default is `OutSpec = {'Price'}`.

## Description

`PriceSens = maxassetsensbystulz(RateSpec, StockSpec1, StockSpec2, Settle, Maturity, OptSpec, Strike, Corr)` computes rainbow option prices using the Stulz option pricing model.

`PriceSens = maxassetsensbystulz(RateSpec, StockSpec1, StockSpec2, Settle, Maturity, OptSpec, Strike, Corr, OutSpec)` computes rainbow option prices and sensitivities using the Stulz option pricing model.

`PriceSens` is a NINST-by-1 or NINST-by-2 vector of expected prices and sensitivities values.

## Examples

### Compute Rainbow Option Prices and Sensitivities Using the Stulz Option Pricing Model

Consider a European rainbow option that gives the holder the right to buy either \$100,000 of an equity index at a strike price of 1000 (asset 1) or \$100,000 of a



government bond (asset 2) with a strike price of 100% of face value, whichever is worth more at the end of 12 months. On January 15, 2008, the equity index is trading at 950, pays a dividend of 2% annually, and has a return volatility of 22%. Also on January 15, 2008, the government bond is trading at 98, pays a coupon yield of 6%, and has a return volatility of 15%. The risk-free rate is 5%. Using this data, calculate the price and sensitivity of the European rainbow option if the correlation between the rates of return is -0.5, 0, and 0.5.

Since the asset prices in this example are in different units, it is necessary to work in either index points (for asset 1) or in dollars (for asset 2). The European rainbow option allows the holder to buy the following: 100 units of the equity index at \$1000 each (for a total of \$100,000) or 1000 units of the government bonds at \$100 each (for a total of \$100,000). To convert the bond price (asset 2) to index units (asset 1), you must make the following adjustments:

- Multiply the strike price and current price of the government bond by 10 (1000/100).
- Multiply the option price by 100, considering that there are 100 equity index units in the option.

Once these adjustments are introduced, the strike price is the same for both assets (\$1000). First, create the `RateSpec`:

```
Settle = 'Jan-15-2008';
Maturity = 'Jan-15-2009';
Rates = 0.05;
Basis = 1;
```

```
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
'EndDates', Maturity, 'Rates', Rates, 'Compounding', -1, 'Basis', Basis)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
  Compounding: -1
        Disc: 0.9512
        Rates: 0.0500
    EndTimes: 1
   StartTimes: 0
    EndDates: 733788
   StartDates: 733422
ValuationDate: 733422
        Basis: 1
```

```
EndMonthRule: 1
```

Create the two `StockSpec` definitions.

```
AssetPrice1 = 950; % Asset 1 => Equity index
AssetPrice2 = 980; % Asset 2 => Government bond
Sigma1 = 0.22;
Sigma2 = 0.15;
Div1 = 0.02;
Div2 = 0.06;
```

```
StockSpec1 = stockspec(Sigma1, AssetPrice1, 'continuous', Div1)
StockSpec2 = stockspec(Sigma2, AssetPrice2, 'continuous', Div2)
```

```
StockSpec1 =
```

```
      FinObj: 'StockSpec'
      Sigma: 0.2200
      AssetPrice: 950
      DividendType: {'continuous'}
      DividendAmounts: 0.0200
      ExDividendDates: []
```

```
StockSpec2 =
```

```
      FinObj: 'StockSpec'
      Sigma: 0.1500
      AssetPrice: 980
      DividendType: {'continuous'}
      DividendAmounts: 0.0600
      ExDividendDates: []
```

Calculate the price and delta for different correlation levels.

```
Strike = 1000 ;
Corr = [-0.5; 0; 0.5];
OutSpec = {'price'; 'delta'};
OptSpec = 'call';
[Price, Delta] = maxassetsensbystulz(RateSpec, StockSpec1, StockSpec2,...
Settle, Maturity, OptSpec, Strike, Corr, 'OutSpec', OutSpec)
```

Price =

```
111.6683
103.7715
92.4412
```

Delta =

```
0.4594    0.3698
0.4292    0.3166
0.4053    0.2512
```

The output **Delta** has two columns: the first column represents the **Delta** with respect to the equity index (asset 1), and the second column represents the **Delta** with respect to the government bond (asset 2). The value 0.4595 represents **Delta** with respect to one unit of the equity index. Since there are 100 units of the equity index, the overall **Delta** would be 45.94 ( $100 * 0.4594$ ) for a correlation level of -0.5. To calculate the **Delta** with respect to the government bond, remember that an adjusted price of 980 was used instead of 98. Therefore, for example, the **Delta** with respect to government bond, for a correlation of 0.5 would be 251.2 ( $0.2512 * 100 * 10$ ).

## See Also

[intenvset](#) | [maxassetbystulz](#) | [stockspec](#)

## minassetbystulz

Determine European rainbow option prices on minimum of two risky assets using Stulz option pricing model

### Syntax

Price = minassetbystulz(RateSpec, StockSpec1, StockSpec2, Settle, Maturity, OptSpec, Strike, Corr)

### Arguments

RateSpec	The annualized, continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec1	Stock specification for asset 1. See <code>stockspec</code> .
StockSpec2	Stock specification for asset 2. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.
Corr	NINST-by-1 vector of correlation between the underlying asset prices.

### Description

Price = minassetbystulz(RateSpec, StockSpec1, StockSpec2, Settle, Maturity, OptSpec, Strike, Corr) computes option prices using the Stulz option pricing model.

Price is a NINST-by-1 vector of expected option prices.

## Examples

### Compute Rainbow Option Prices Using the Stulz Option Pricing Model

Consider a European rainbow put option that gives the holder the right to sell either stock A or stock B at a strike of 50.25, whichever has the lower value on the expiration date May 15, 2009. On November 15, 2008, stock A is trading at 49.75 with a continuous annual dividend yield of 4.5% and has a return volatility of 11%. Stock B is trading at 51 with a continuous dividend yield of 5% and has a return volatility of 16%. The risk-free rate is 4.5%. Using this data, if the correlation between the rates of return is -0.5, 0, and 0.5, calculate the price of the minimum of two assets that are European rainbow put options. First, create the RateSpec:

```
Settle = 'Nov-15-2008';
Maturity = 'May-15-2009';
Rates = 0.045;
Basis = 1;

RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
    'EndDates', Maturity, 'Rates', Rates, 'Compounding', -1, 'Basis', Basis)
```

```
RateSpec =

    FinObj: 'RateSpec'
    Compounding: -1
    Disc: 0.9778
    Rates: 0.0450
    EndTimes: 0.5000
    StartTimes: 0
    EndDates: 733908
    StartDates: 733727
    ValuationDate: 733727
    Basis: 1
    EndMonthRule: 1
```

Create the two StockSpec definitions.

```
AssetPriceA = 49.75;
AssetPriceB = 51;
SigmaA = 0.11;
SigmaB = 0.16;
```

```
DivA = 0.045;
DivB = 0.05;
```

```
StockSpecA = stockspec(SigmaA, AssetPriceA, 'continuous', DivA)
StockSpecB = stockspec(SigmaB, AssetPriceB, 'continuous', DivB)
```

```
StockSpecA =
```

```
    FinObj: 'StockSpec'
    Sigma: 0.1100
    AssetPrice: 49.7500
    DividendType: {'continuous'}
    DividendAmounts: 0.0450
    ExDividendDates: []
```

```
StockSpecB =
```

```
    FinObj: 'StockSpec'
    Sigma: 0.1600
    AssetPrice: 51
    DividendType: {'continuous'}
    DividendAmounts: 0.0500
    ExDividendDates: []
```

Compute the price of the options for different correlation levels.

```
Strike = 50.25;
Corr = [-0.5;0;0.5];
OptSpec = 'put';
Price = minassetbystulz(RateSpec, StockSpecA, StockSpecB, Settle,...
Maturity, OptSpec, Strike, Corr)
```

```
Price =
```

```
    3.4320
    3.1384
    2.7694
```

The values 3.43, 3.14, and 2.77 are the price of the European rainbow put options with a correlation level of -0.5, 0, and 0.5 respectively.

**See Also**

intenvset | maxassetbystulz | minassetsensbystulz | stockspec

## minassetsensbystulz

Determine European rainbow option prices and sensitivities on minimum of two risky assets using Stulz pricing model

### Syntax

```
PriceSens = minassetsensbystulz(RateSpec, StockSpec1,
StockSpec2, Settle, Maturity, OptSpec, Strike, Corr)
PriceSens = minassetsensbystulz(RateSpec, StockSpec1,
StockSpec2, Settle, Maturity, OptSpec, Strike, Corr, OutSpec)
```

### Arguments

RateSpec	The annualized continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec1	Stock specification for asset 1. See <code>stockspec</code> .
StockSpec2	Stock specification for asset 2. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.
Corr	NINST-by-1 vector of correlation between the underlying asset prices.
OutSpec	(Optional) All optional inputs are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. You can specify parameter name/value pairs in any order. Names are case-insensitive and partial string matches are allowed provided no ambiguities exist. Valid parameter names are:



- NOUT-by-1 or 1-by-NOUT cell array of strings indicating the nature and order of the outputs for the function. Possible values are 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', or 'All'.

For example, `OutSpec = {'Price'; 'Lambda'; 'Rho'}` specifies that the output should be Price, Lambda, and Rho, in that order.

To invoke from a function: `[Price, Lambda, Rho] = minassetsensbystulz(..., 'OutSpec', {'Price', 'Lambda', 'Rho'})`

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec` as `OutSpec = {'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', 'Price'}`;

- Default is `OutSpec = {'Price'}`.

## Description

`PriceSens = minassetsensbystulz(RateSpec, StockSpec1, StockSpec2, Settle, Maturity, OptSpec, Strike, Corr)` computes rainbow option prices using the Stulz option pricing model.

`PriceSens = minassetsensbystulz(RateSpec, StockSpec1, StockSpec2, Settle, Maturity, OptSpec, Strike, Corr, OutSpec)` computes rainbow option prices and sensitivities using the Stulz option pricing model.

`PriceSens` is a NINST-by-1 or NINST-by-2 vector of expected prices and sensitivities.

## Examples

### Compute Rainbow Option Prices and Sensitivities Using the Stulz Option Pricing Model

Consider a European rainbow put option that gives the holder the right to sell either stock A or stock B at a strike of 50.25, whichever has the lower value on the expiration

date May 15, 2009. On November 15, 2008, stock A is trading at 49.75 with a continuous annual dividend yield of 4.5% and has a return volatility of 11%. Stock B is trading at 51 with a continuous dividend yield of 5% and has a return volatility of 16%. The risk-free rate is 4.5%. Using this data, if the correlation between the rates of return is -0.5, 0, and 0.5, calculate the price and sensitivity of the minimum of two assets that are European rainbow put options. First, create the `RateSpec`:

```
Settle = 'Nov-15-2008';
Maturity = 'May-15-2009';
Rates = 0.045;
Basis = 1;

RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
    'EndDates', Maturity, 'Rates', Rates, 'Compounding', -1, 'Basis', Basis)
```

```
RateSpec =

    FinObj: 'RateSpec'
    Compounding: -1
        Disc: 0.9778
        Rates: 0.0450
        EndTimes: 0.5000
        StartTimes: 0
        EndDates: 733908
        StartDates: 733727
    ValuationDate: 733727
        Basis: 1
    EndMonthRule: 1
```

Create the two `StockSpec` definitions.

```
AssetPriceA = 49.75;
AssetPriceB = 51;
SigmaA = 0.11;
SigmaB = 0.16;
DivA = 0.045;
DivB = 0.05;

StockSpecA = stockspec(SigmaA, AssetPriceA, 'continuous', DivA)
StockSpecB = stockspec(SigmaB, AssetPriceB, 'continuous', DivB)

StockSpecA =
```

```

        FinObj: 'StockSpec'
        Sigma: 0.1100
        AssetPrice: 49.7500
        DividendType: {'continuous'}
        DividendAmounts: 0.0450
        ExDividendDates: []

```

StockSpecB =

```

        FinObj: 'StockSpec'
        Sigma: 0.1600
        AssetPrice: 51
        DividendType: {'continuous'}
        DividendAmounts: 0.0500
        ExDividendDates: []

```

Calculate price and delta for different correlation levels.

```

Strike = 50.25;
Corr = [-0.5;0;0.5];
OptSpec = 'put';
OutSpec = {'Price'; 'delta'};
[P, D] = minassetsensbystulz(RateSpec, StockSpecA, StockSpecB,...
Settle, Maturity, OptSpec, Strike, Corr, 'OutSpec', OutSpec)

```

P =

```

3.4320
3.1384
2.7694

```

D =

```

-0.4183  -0.3496
-0.3746  -0.3189
-0.3304  -0.2905

```

The output **Delta** has two columns: the first column represents the **Delta** with respect to the stock A (asset 1), and the second column represents the **Delta** with respect to the

stock B (asset 2). The value 0.4183 represents **Delta** with respect to the stock A for a correlation level of -0.5. The **Delta** with respect to stock B, for a correlation of zero is -0.3189.

### **See Also**

`intenvset` | `minassetbystulz` | `stockspec`

# mkbush

Create bushy tree

## Syntax

```
[Tree, NumStates] = mkbush(NumLevels, NumChild, NumPos, Trim, NodeVal)
```

## Arguments

NumLevels	Number of time levels of the tree.
NumChild	1-by- number of levels (NUMLEVELS) vector with number of branches (children) of the nodes in each level.
NumPos	1-by-NUMLEVELS vector containing the length of the state vectors in each time level.
Trim	(Optional) Scalar 0 or 1. If Trim = 1, NumPos decreases by 1 when moving from one time level to the next. Otherwise, if Trim = 0 (Default), NumPos does not decrease.
NodeVal	(Optional) Initial value at each node of the tree. Default = NaN.

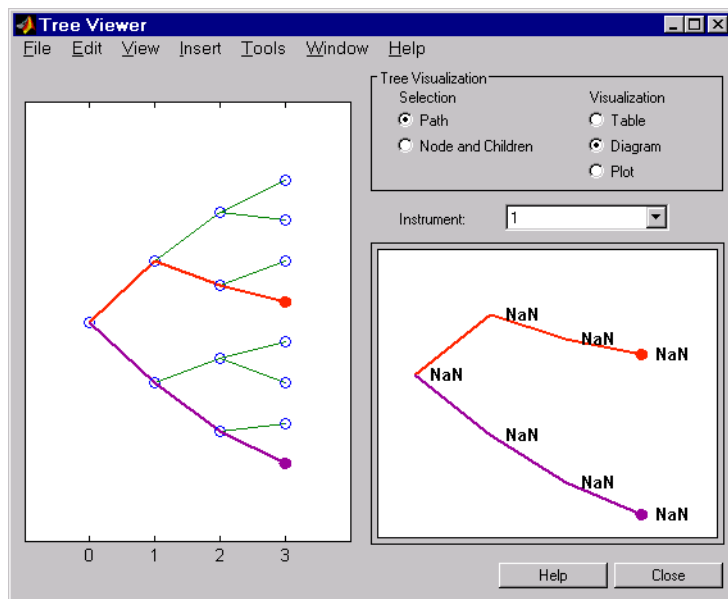
## Description

[Tree, NumStates] = mkbush(NumLevels, NumChild, NumPos, Trim, NodeVal) creates a bushy tree **Tree** with initial values **NodeVal** at each node. **NumStates** is a 1-by-NUMLEVELS vector containing the number of state vectors in each level.

## Examples

Create a tree with four time levels, two branches per node, and a vector of three elements in each node with each element initialized to NaN.

```
Tree = mkbush(4, 2, 3);  
treeviewer(Tree)
```



## See Also

bushpath | bushshape

# mktree

Create recombining binomial tree

## Syntax

```
Tree = mktree(NumLevels, NumPos, NodeVal, IsPriceTree)
```

## Arguments

NumLevels	Number of time levels of the tree.
NumPos	1-by-NUMLEVELS vector containing the length of the state vectors in each time level.
NodeVal	(Optional) Initial value at each node of the tree. Default = NaN.
IsPriceTree	(Optional) Boolean determining if a final horizontal branch is added to the tree. Default = 0.

## Description

`Tree = mktree(NumLevels, NumPos, NodeVal, IsPriceTree)` creates a recombining tree `Tree` with initial values `NodeVal` at each node.

## Examples

Create a recombining tree of four time levels with a vector of two elements in each node and each element initialized to NaN.

```
Tree = mktree(4, 2);
```

## See Also

treepath | treeshape

## mktrintree

Create recombining trinomial tree

### Syntax

```
TrinTree = mktrintree(NumLevels, NumPos, NumStates, NodeVal)
```

### Arguments

NumLevels	Number of time levels of the tree.
NumPos	1-by- <code>NUMLEVELS</code> vector containing the length of the state vectors in each time level.
NumStates	1-by- <code>NUMLEVELS</code> vector containing the number of state vectors in each time level.
NodeVal	(Optional) Initial value at each node of the tree. Default = <code>NaN</code> .

### Description

`TrinTree = mktrintree(NumLevels, NumPos, NumStates, NodeVal)` creates a recombining tree `Tree` with initial values `NodeVal` at each node.

### Examples

Create a recombining trinomial tree of four time levels with a vector of two elements in each node and each element initialized to `NaN`.

```
TrinTree = mktrintree(4, [2 2 2 2], [1 3 5 7]);
```

### See Also

`trintreepath` | `trintreeshape`



# mmktbybdt

Create money-market tree from Black-Derman-Toy interest-rate tree

## Syntax

```
MMktTree = mmktbybdt(BDTree)
```

## Arguments

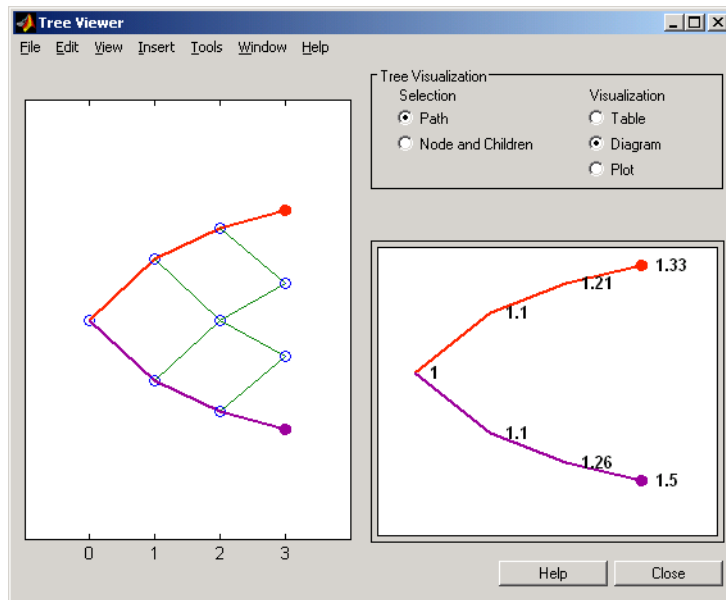
BDTree	Interest-rate tree structure created by <code>bdttree</code> .
--------	--

## Description

`MMktTree = mmktbybdt(BDTree)` creates a money-market tree from an interest-rate tree structure created by `bdttree`.

## Examples

```
load deriv.mat;  
MMktTree = mmktbybdt(BDTree);  
treeviewer(MMktTree)
```



**See Also**  
 bdttree

# mmktbyhjm

Create money-market tree from Heath-Jarrow-Morton interest-rate tree

## Syntax

```
MMktTree = mmktbyhjm(HJMTree)
```

## Arguments

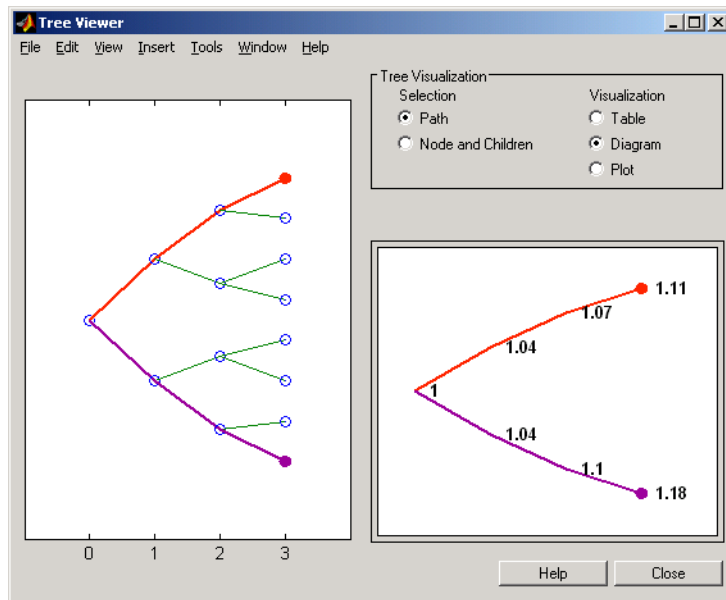
HJMTree	Forward-rate tree structure created by <code>hjmtree</code> .
---------	---

## Description

`MMktTree = mmktbyhjm(HJMTree)` creates a money-market tree from a forward-rate tree structure created by `hjmtree`.

## Examples

```
load deriv.mat;  
MMktTree = mmktbyhjm(HJMTree);  
treeviewer(MMktTree)
```



**See Also**  
 hjmtree

# numerix class

Create numerix object to set up Numerix CAIL environment

## Description

The `numerix` object makes the Numerix engine directly accessible from MATLAB. To use the capabilities of Numerix CAIL, you must have CAIL client software installed on your local desktop.

## Construction

`N = numerix(DATADIRECTORYPATH)` constructs the `numerix` object and sets up the Numerix CrossAsset Integration Layer (CAIL) environment given the path, `DATADIRECTORYPATH`.

## Properties

The following properties are from the `numerix` class.

### Path

Defines the path for `DATADIRECTORYPATH`. This path is the location of the templates and is created by the client installation of CAIL. At the highest level, a template defines the interface; it encapsulates the instructions for performing the calculation, the calculation's required and optional input parameters, and the calculation's outputs.

### Attributes:

<code>SetAccess</code>	<code>public</code>
<code>GetAccess</code>	<code>public</code>

### RepositoryPath

`RepositoryPath` defines the path location for the repository directory in a file system.

**Attributes:**

SetAccess	public
GetAccess	public

**Repository**

Repositories are collections of templates and are defined as a directory in a file system.

**Attributes:**

SetAccess	public
GetAccess	public

**Context**

The calculation context manages all of the CAIL information. `Context` contains the location of the template repository and is responsible for creating a CAIL application context in which to perform the calculations.

**Attributes:**

SetAccess	public
GetAccess	public

**LookupsPath**

Defines the path for the numeric instruments data types.

**Attributes:**

SetAccess	public
GetAccess	public

**MarketsPath**

Defines a the path for the logical schema for naming all of the market data. `MarketsPath` enables you to provide a data dictionary to map business market data to CAIL to reduce the task of inputting market data into CAIL objects directly.

**Attributes:**

SetAccess	public
GetAccess	public

**FixingsPath**

Defines the path for the schema for naming historical fixing data for rates and prices.

**Attributes:**

SetAccess	public
GetAccess	public

**TradesPath**

Defines the path to the trade instrument definitions.

**Attributes:**

SetAccess	public
GetAccess	public

**Parameters**

Defines the calculation parameters and market data, if available.

**Attributes:**

SetAccess	public
GetAccess	public

**Methods**

parseResults	Converts Numerix CAIL data to MATLAB data types
--------------	---

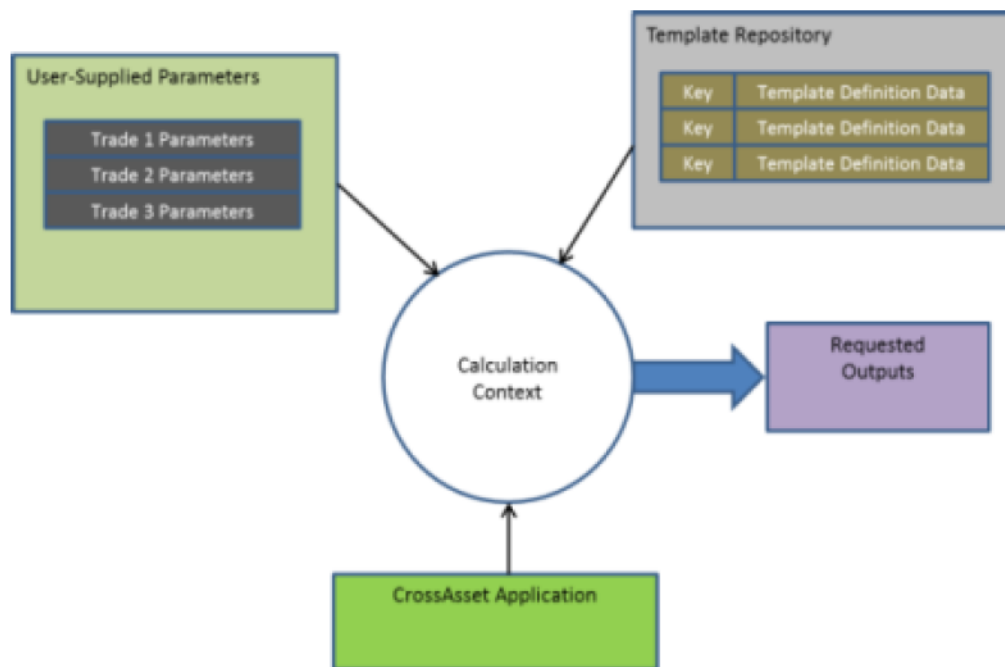
## Definitions

### CrossAsset Integration Layer (CAIL)

The CrossAsset Integration Layer (CAIL) is an application programming interface (API), which extends the data-driven approach of Numerix.

The calculation workflow of CAIL is:

- 1 Select a trade template for a specified deal or trade from the repository. The trade template specifies a set of inputs, a set of outputs, and the dependencies on other information (model, market data, calendar, etc.).
- 2 Provide the input parameters to the trade template and call the calculation context. The calculation context follows the dependency path to collect the needed information and produces the output specified by the template.





## Copy Semantics

Value. To learn how value classes affect copy operations, see “Copying Objects” in the MATLAB documentation.

## Examples

### Construct a Numerix Object

Initialize Numerix CAIL environment.

```
import com.numerix.integration.*;
import com.numerix.integration.implementation.*;
```

Construct a numerix object.

```
n = numerix('i:\NumeriX_java_10_3_0\data')
n =
    Path: 'i:\NumeriX_java_10_3_0\data'
    RepositoryPath: 'i:\NumeriX_java_10_3_0\data\Repository'
    Repository: [1x1 com.numerix.integration.implementation.FileSystemRepository]
    Context: [1x1 com.numerix.integration.implementation.LocalCalculationContext]
    LookupsPath: 'i:\NumeriX_java_10_3_0\data\Data\LookupRules'
    MarketsPath: 'i:\NumeriX_java_10_3_0\data\Data\Markets'
    FixingsPath: 'i:\NumeriX_java_10_3_0\data\Data\Fixings'
    TradesPath: 'i:\NumeriX_java_10_3_0\data\Data\Trades'
    Parameters: [1x1 com.numerix.integration.implementation.CalculationParameters]
```

- “Working with Simple Numerix Trades”
- “Working with Advanced Numerix Trades”
- “Use Numerix to Price Cash Deposits”
- “Use Numerix for Interest-Rate Risk Assessment”
- “Class Attributes”
- “Property Attributes”

### See Also

parseResults

### External Web Sites

- <http://www.numerix.com/cail>

## parseResults

**Class:** numerix

Converts Numerix CAIL data to MATLAB data types

### Syntax

`R = parseResults(N,Results)`

### Description

`R = parseResults(N,Results)` returns Numerix CAIL data in native MATLAB data types.

### Input Arguments

**N**

Numerix object constructed using `numerix`.

**Results**

Result instances for each trade instance.

### Output Arguments

**R**

Results from Numerix table output represented as MATLAB data types.

### Attributes

Access

public

Static	false
Hidden	false

To learn about attributes of methods, see “Method Attributes” in the MATLAB Object-Oriented Programming documentation.

## Examples

### Return Results for Numerix CAIL API to Price a Callable Reverse Floater

Initialize Numerix environment.

```
import com.numerix.integration.*;
import com.numerix.integration.implementation.*;

n = numerix('i:\NumeriX_java_10_3_0\data')

n =
    Path: 'i:\NumeriX_java_10_3_0\data'
    RepositoryPath: 'i:\NumeriX_java_10_3_0\data\Repository'
    Repository: [1x1 com.numerix.integration.implementation.FileSystemRepository]
    Context: [1x1 com.numerix.integration.implementation.LocalCalculationContext]
    LookupsPath: 'i:\NumeriX_java_10_3_0\data\Data\LookupRules'
    MarketsPath: 'i:\NumeriX_java_10_3_0\data\Data\Markets'
    FixingsPath: 'i:\NumeriX_java_10_3_0\data\Data\Fixings'
    TradesPath: 'i:\NumeriX_java_10_3_0\data\Data\Trades'
    Parameters: [1x1 com.numerix.integration.implementation.CalculationParameters]
```

Create a market.

```
quotes = java.util.HashMap;
quotes.put('IR.USD-LIBOR-3M.SWAP-1Y.MID', 0.0066056);
quotes.put('IR.USD-LIBOR-3M.SWAP-10Y.MID', 0.022465005);
quotes.put('IR.USD-LIBOR-3M.SWAP-20Y.MID', 0.027544995);
market = Market('EOD_14-NOV-2011', DateExtensions.date('14-Nov-2011'), quotes.entrySet);
```

Define a trade instance based on instrument template found in the Repository.

```
tradeDescriptor = 'TRADE.IR.CALLBLEREVERSEFLOATER';
tradeParameters = java.util.HashMap;
tradeParameters.put('Trade ID', '1001');
tradeParameters.put('Quote Type', 'MID');
tradeParameters.put('Currency', 'USD');
tradeParameters.put('Notional', 1000000.0);
tradeParameters.put('Effective Date', DateExtensions.date('1-Dec-2011'));
tradeParameters.put('Termination Date', DateExtensions.date('1-Dec-2021'));
tradeParameters.put('IR Index', 'LIBOR');
tradeParameters.put('IR Index Tenor', '3M');
tradeParameters.put('Structured Freq', '3M');
```

```

tradeParameters.put('Structured Side', 'Receive');
tradeParameters.put('Structured Coupon Floor', 0.0);
tradeParameters.put('Structured Coupon UpBd', 0.08);
tradeParameters.put('StructuredCoupon Multiplier', 1.4);
tradeParameters.put('Structured Coupon Cap', 0.05);
tradeParameters.put('Structured Basis', 'ACT/360');
tradeParameters.put('Funding Freq', '3M');
tradeParameters.put('Funding Side', 'Pay');
tradeParameters.put('Funding Spread', 0.003);
tradeParameters.put('Funding Basis', 'ACT/360');
tradeParameters.put('Call Start Date', DateExtensions.date('1-Dec-2013'));
tradeParameters.put('Call End Date', DateExtensions.date('1-Dec-2020'));
tradeParameters.put('Option Side', 'Short');
tradeParameters.put('Option Type', 'Right to Terminate');
tradeParameters.put('Call Frequency', '3M');
tradeParameters.put('Model', 'IR.USD-LIBOR-3M.MID.DET');
tradeParameters.put('Method', 'BackwardAnalytic');

```

Create a trade instance.

```
trade = RepositoryExtensions.createTradeInstance(n.Repository, tradeDescriptor, tradeParameters);
```

Price the trades.

```
results = CalculationContextExtensions.calculate(n.Context, trade, market, Request.getAll);
```

Parse the results for MATLAB and display.

```
r = n.parseResults(results)
disp([r.Name r.Category r.Currency r.Data])
```

r =

```

Category: {13x1 cell}
Currency: {13x1 cell}
Name: {13x1 cell}
Data: {13x1 cell}

'Reporting Currency'      'Price'      ''      'USD'
'Structured Cashflow Log' 'Cashflow'   ''      {41x20 cell}
'Structured Leg PV Accrued' 'Price'      'USD'   [ 0]
'PV'                     'Price'      'USD'   [ 6.4133e+04]
'Structured Leg PV Clean' 'Price'      'USD'   [ 4.2637e+05]
'Option PV'              'Price'      'USD'   [-1.3220e+05]
'Funding Cashflow Log'   'Cashflow'   ''      {41x20 cell}
'Structured Leg PV'      'Price'      'USD'   [ 4.2637e+05]
'Funding Leg PV'        'Price'      'USD'   [-2.3004e+05]
'Funding Leg PV Accrued' 'Price'      'USD'   [ 0]
'Funding Leg PV Clean'  'Price'      'USD'   [-2.3004e+05]
'Yield Risk Report'     ''           ''      { 4x30 cell}
'Messages'              ''           ''      { 4x1 cell}

```

- “Working with Simple Numerix Trades”
- “Working with Advanced Numerix Trades”
- “Use Numerix to Price Cash Deposits”

- “Use Numerix for Interest-Rate Risk Assessment”

## **See Also**

numerix

## **External Web Sites**

- <http://www.numerix.com/cail>

## oasbybdt

Determine option adjusted spread using Black-Derman-Toy model

### Syntax

```
[OAS, OAD, OAC] = oasbybdt(BDTree, Price, CouponRate, Settle,  
Maturity, OptSpec, Strike, ExerciseDates)  
[OAS, OAD, OAC] = oasbybdt(BDTree, Price, CouponRate, Settle,  
Maturity, OptSpec, Strike, ExerciseDates,  
Name, Value)
```

### Description

[OAS, OAD, OAC] = oasbybdt(BDTree, Price, CouponRate, Settle, Maturity, OptSpec, Strike, ExerciseDates) calculates option adjusted spread (OAS), duration (OAD), and convexity (OAC) using a BDT model.

[OAS, OAD, OAC] = oasbybdt(BDTree, Price, CouponRate, Settle, Maturity, OptSpec, Strike, ExerciseDates, Name, Value) calculates option adjusted spread (OAS), duration (OAD), and convexity (OAC) using a BDT model with additional options specified by one or more Name, Value pair arguments.

### Input Arguments

#### **BDTree**

Interest-rate tree structure created by `bdttree`.

#### **Price**

NINST-by-1 vector of market prices of bonds with embedded options.

#### **CouponRate**

NINST-by-1 vector for decimal annual rate.

**Settle**

NINST-by-1 vector for settlement date.

**Maturity**

NINST-by-1 vector for maturity date.

**OptSpec**

NINST-by-1 cell array of strings for 'call' or 'put'.

**Strike**

Matrix of strike price values for supported option types:

- European option: NINST-by-1 vector of strike price values.
- Bermuda option: NINST by number of strikes (NSTRIKES) matrix of strike price values.

Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.

- American option: NINST-by-1 vector of strike price values for each option.

**ExerciseDates**

Matrix of exercise callable or puttable dates for supported option types:

- NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.
- American option: NINST-by-2 vector of exercise date boundaries. For each instrument, the option is exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if `ExerciseDates` is NINST-by-1, the option is exercised between the underlying bond `Settle` and the single listed exercise date.

**Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name, Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single

quotes (' '). You can specify several name and value pair arguments in any order as Name1, Value1, . . . , NameN, ValueN.

**'AmericanOpt'**

NINST-by-1 vector for option flags: 0 (European/Bermuda) or 1 (American).

**Default:** 0 (European/Bermuda)

**'Basis'**

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

**'EndMonthRule'**

NINST-by-1 vector for end-of-month rule. Values are 1 (in effect) and 0 (not in effect).

**Default:** 1 (in effect)



**' IssueDate '**

NINST-by-1 vector of bond issue date.

**Default:** If you do not specify an `IssueDate`, the cash flow payment dates are determined from other inputs.

**' Face '**

NINST-by-1 vector for face value.

**Default:** 100

**' FirstCouponDate '**

NINST-by-1 vector. Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

**Default:** If you do not specify a `FirstCouponDate`, the cash flow payment dates are determined from other inputs.

**' LastCouponDate '**

NINST-by-1 vector. Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate`, regardless of where it falls, and is followed only by the bond's maturity cash flow date.

**Default:** If you do not specify a `LastCouponDate`, the cash flow payment dates are determined from other inputs.

**' Period '**

NINST-by-1 vector for coupons per year.

**Default:** 2 per year

**' Options '**

Structure created with `derivset` containing derivatives pricing options.

**Default:** None

## Output Arguments

### OAS

NINST-by-1 vector for option adjusted spread.

### OAD

NINST-by-1 vector for option adjusted duration.

### OAC

NINST-by-1 vector for option adjusted convexity.

## Examples

### Compute OAS Using the Black-Derman-Toy (BDT) Model

This example shows how to compute OAS using the Black-Derman-Toy (BDT) model with the following data.

```
ValuationDate = 'Oct-1-2010';
Rates = [0.035; 0.042; 0.047; 0.052];
StartDates = ValuationDate;
EndDates = datemnth(ValuationDate, 12:12:48)';
Compounding = 1;
% define RateSpec
RateSpec = intenvset('ValuationDate', ValuationDate, ...
'StartDates', StartDates, 'EndDates', EndDates, ...
'Rates', Rates, 'Compounding', Compounding);

% specify VolSpec and TimeSpec
Sigma = 0.20;
VS = bdtvolspec(ValuationDate, EndDates, Sigma*ones(size(EndDates)));
TS = bdttimespec(ValuationDate, EndDates, Compounding);

% build the BDT tree
```

```
BDTTree = bdttree(VS, RateSpec, TS);
BDTTreenew = cvtree(BDTTree);

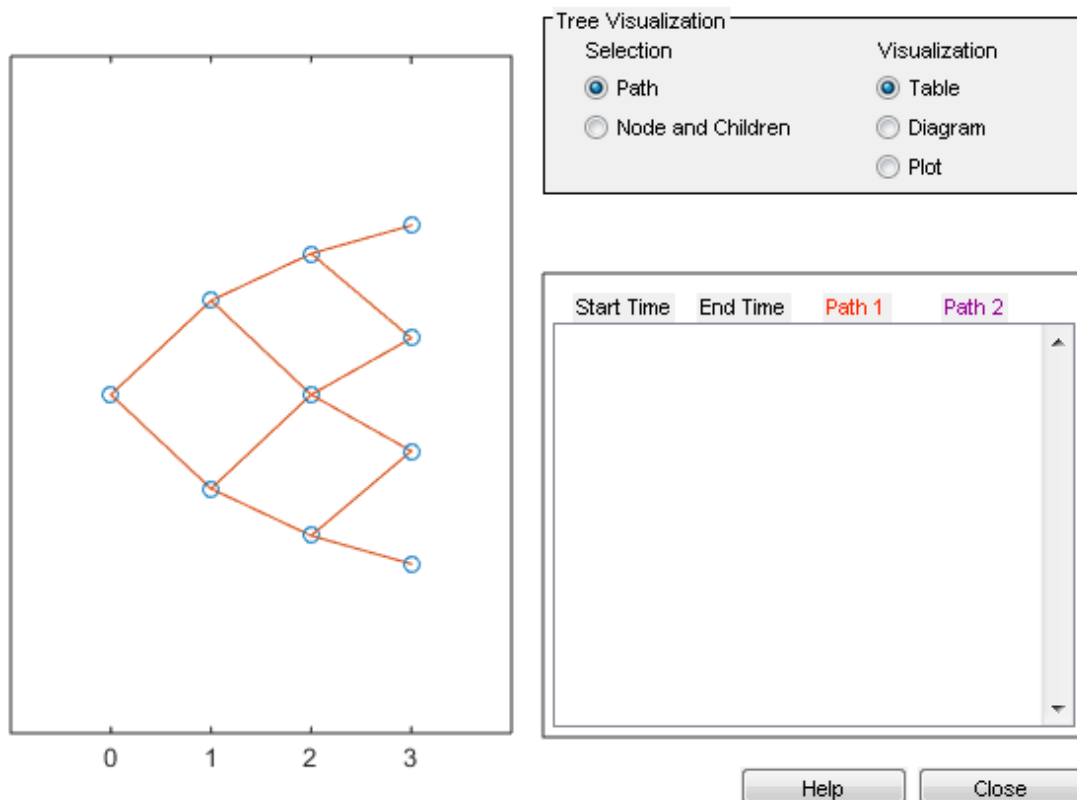
% instrument information
CouponRate = 0.065;
Settle = ValuationDate;
Maturity = '01-Oct-2014';
OptSpec = 'call';
Strike = 100;
ExerciseDates = '01-Oct-2011';
Period = 1;
Price = 101.58;

% compute the OAS
OAS = oasbybdt(BDTTree, Price, CouponRate, Settle, Maturity,...
OptSpec, Strike, ExerciseDates, 'Period', Period)

% use treviewer to observe the tree
treeviewer(BDTTree)

OAS =

    36.5591
```



## More About

### Bond with Embedded Options

A bond with embedded option allows the issuer to buy back (callable) or redeem (puttable) the bond at a predetermined price at specified future dates. Financial Instruments Toolbox software supports American, European, and Bermuda callable and puttable bonds.

The pricing for a bond with embedded options is as follows:

- Callable bond — The holder bought a bond and sold a call option to the issuer. For example, if interest rates go down by the time of the call date, the issuer is able to

refinance its debt at a cheaper level and can call the bond. The price of a callable bond is:

Price callable bond = Price Option free bond – Price call option

- Puttable bond — The holder bought a bond and a put option. For example, if interest rates rise, the future value of coupon payments becomes less valuable. Therefore, the investor can sell the bond back to the issuer and then lend proceeds elsewhere at a higher rate. The price of a puttable bond is:

Price puttable bond = Price Option free bond + Price put option

- “Pricing Options Structure”

## References

Fabozzi, F., *Handbook of Fixed Income Securities*, McGraw-Hill, 7th edition, 2005.

Windas, T., *Introduction to Option-Adjusted Spread Analysis*, Bloomberg Press, 3rd edition, 2007.

## See Also

bdtprice | bdttree | instoptembnd | oasbybk | oasbyhjm | oasbyhw |  
optembndbybdt

## oasbybk

Determine option adjusted spread using Black-Karasinski model

### Syntax

```
[OAS, OAD, OAC] = oasbybk(BKTree, Price, CouponRate, Settle,  
Maturity, OptSpec, Strike, ExerciseDates)  
[OAS, OAD, OAC] = oasbybk(BKTree, Price, CouponRate, Settle,  
Maturity, OptSpec, Strike, ExerciseDates,  
Name, Value)
```

### Description

[OAS, OAD, OAC] = oasbybk(BKTree, Price, CouponRate, Settle, Maturity, OptSpec, Strike, ExerciseDates) calculates option adjusted spread (OAS), duration (OAD), and convexity (OAC) using a BK model.

[OAS, OAD, OAC] = oasbybk(BKTree, Price, CouponRate, Settle, Maturity, OptSpec, Strike, ExerciseDates, Name, Value) calculates option adjusted spread (OAS), duration (OAD), and convexity (OAC) using a BK model with additional options specified by one or more Name, Value pair arguments.

### Input Arguments

#### **BKTree**

Interest-rate tree structure created by `bktree`.

#### **Price**

NINST-by-1 vector of market prices of bonds with embedded options.

#### **CouponRate**

NINST-by-1 vector for decimal annual rate.

**Settle**

NINST-by-1 vector for settlement date.

**Maturity**

NINST-by-1 vector for maturity date.

**OptSpec**

NINST-by-1 cell array of strings for 'call' or 'put'.

**Strike**

Matrix of strike price values for supported option types:

- European option: NINST-by-1 vector of strike price values.
- Bermuda option: NINST by number of strikes (NSTRIKES) matrix of strike price values.

Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.

- American option: NINST-by-1 vector of strike price values for each option.

**ExerciseDates**

Matrix of exercise callable or puttable dates for supported option types:

- NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.
- American option: NINST-by-2 vector of exercise date boundaries. For each instrument, the option is exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if ExerciseDates is NINST-by-1, the option is exercised between the underlying bond Settle and the single listed exercise date.

**Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name, Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single

quotes (' '). You can specify several name and value pair arguments in any order as Name1, Value1, . . . , NameN, ValueN.

**'AmericanOpt'**

NINST-by-1 vector for option flags: 0 (European/Bermuda) or 1 (American).

**Default:** 0 (European/Bermuda)

**'Basis'**

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

**'EndMonthRule'**

NINST-by-1 vector for end-of-month rule. Values are 1 (in effect) and 0 (not in effect).

**Default:** 1 (in effect)



**' IssueDate '**

NINST-by-1 vector of bond issue date.

**Default:** If you do not specify an **IssueDate**, the cash flow payment dates are determined from other inputs

**' Face '**

NINST-by-1 vector for face value.

**Default:** 100

**' FirstCouponDate '**

NINST-by-1 vector. Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When **FirstCouponDate** and **LastCouponDate** are both specified, **FirstCouponDate** takes precedence in determining the coupon payment structure.

**Default:** If you do not specify a **FirstCouponDate**, the cash flow payment dates are determined from other inputs.

**' LastCouponDate '**

NINST-by-1 vector. Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified **FirstCouponDate**, a specified **LastCouponDate** determines the coupon structure of the bond. The coupon structure of a bond is truncated at the **LastCouponDate**, regardless of where it falls, and is followed only by the bond's maturity cash flow date.

**Default:** If you do not specify a **LastCouponDate**, the cash flow payment dates are determined from other inputs.

**' Period '**

NINST-by-1 vector for coupons per year.

**Default:** 2 per year

**' Options '**

Structure created with `derivset` containing derivatives pricing options.

**Default:** None

## Output Arguments

### OAS

NINST-by-1 vector for option adjusted spread.

### OAD

NINST-by-1 vector for option adjusted duration.

### OAC

NINST-by-1 vector for option adjusted convexity.

## Examples

### Compute OAS and OAD Using the Black-Karasinski (BK) Model

This example shows how to compute OAS and OAD using the Black-Karasinski (BK) model using the following data.

```
ValuationDate = 'Aug-2-2010';
Rates = [0.0355; 0.0382; 0.0427; 0.0489];
StartDates = ValuationDate;
EndDates = datemnth(ValuationDate, 12:12:48)';
Compounding = 1;

% define RateSpec
RateSpec = intenvset('ValuationDate', ValuationDate, ...
'StartDates', StartDates, 'EndDates', EndDates, ...
'Rates', Rates, 'Compounding', Compounding);

% specify VolSpec and TimeSpec
Sigma = 0.10;
Alpha = 0.01;
VS = bkvolspec(ValuationDate, EndDates, Sigma*ones(size(EndDates)), ...
EndDates, Alpha*ones(size(EndDates)));
```

```
TS = bktimespec(ValuationDate, EndDates, Compounding);

% build the BK tree
BKTree = bktree(VS, RateSpec, TS);

% instrument information
CouponRate = 0.045;
Settle = ValuationDate;
Maturity = '02-Aug-2014';
OptSpec = 'put';
Strike = 100;
ExerciseDates = '02-Aug-2013';
Period = 1;
AmericanOpt = 1;
Price = 101;

% compute OAS and OAD
[OAS, OAD] = oasbybk(BKTree, Price, CouponRate, Settle, Maturity,...
OptSpec, Strike, ExerciseDates, 'Period', Period, 'AmericanOpt', AmericanOpt)

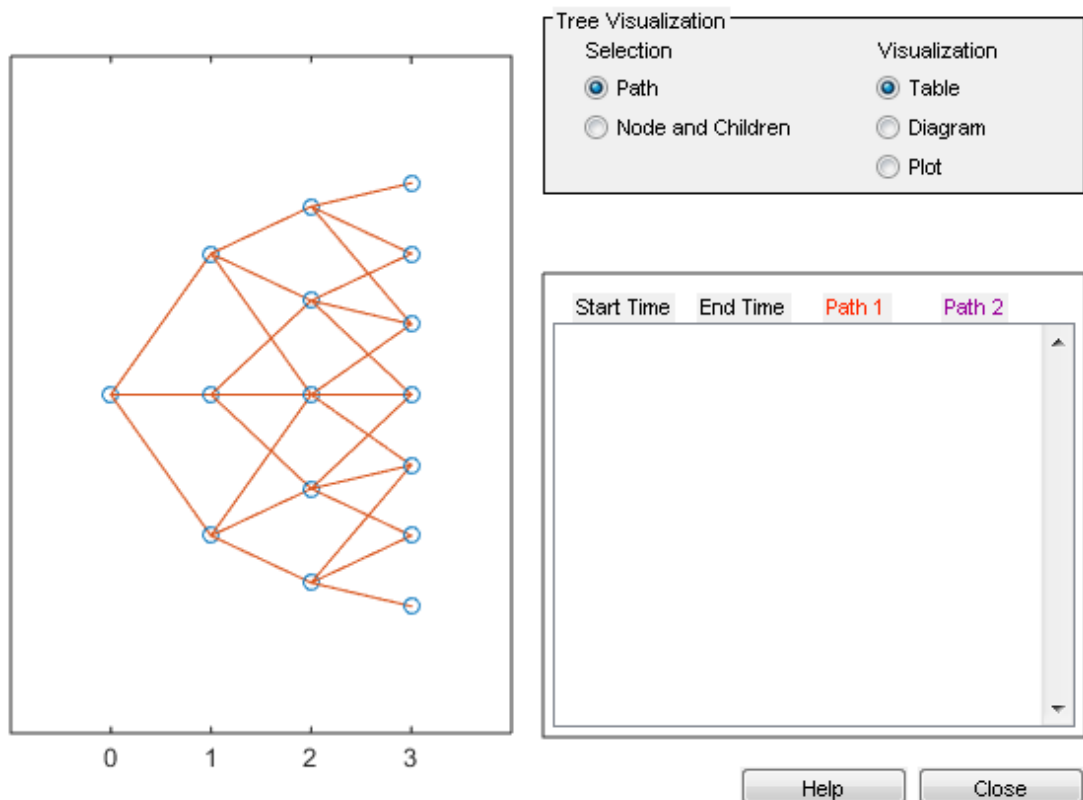
% use treeviewer to observe the tree
treeviewer(BKTree)

OAS =

    21.0839

OAD =

    1.7833
```



## More About

### Bond with Embedded Options

A bond with embedded option allows the issuer to buy back (callable) or redeem (puttable) the bond at a predetermined price at specified future dates. Financial Instruments Toolbox software supports American, European, and Bermuda callable and puttable bonds.

The pricing for a bond with embedded options is as follows:

- Callable bond — The holder bought a bond and sold a call option to the issuer. For example, if interest rates go down by the time of the call date, the issuer is able to

refinance its debt at a cheaper level and can call the bond. The price of a callable bond is:

Price callable bond = Price Option free bond – Price call option

- Puttable bond — The holder bought a bond and a put option. For example, if interest rates rise, the future value of coupon payments becomes less valuable. Therefore, the investor can sell the bond back to the issuer and then lend proceeds elsewhere at a higher rate. The price of a puttable bond is:

Price puttable bond = Price Option free bond + Price put option

- “Pricing Options Structure”

## References

Fabozzi, F., *Handbook of Fixed Income Securities*, McGraw-Hill, 7th edition, 2005.

Windas, T., *Introduction to Option-Adjusted Spread Analysis*, Bloomberg Press, 3rd edition, 2007.

## See Also

bkprice | bktree | instoptembnd | oasbybdt | oasbyhjm | oasbyhw |  
optembndbybk

## oasbyhjm

Determine option adjusted spread using Heath-Jarrow-Morton model

### Syntax

```
[OAS, OAD, OAC] = oasbyhjm(HJMTTree, Price, CouponRate, Settle,  
Maturity, OptSpec, Strike, ExerciseDates)  
[OAS, OAD, OAC] = oasbyhjm(HJMTTree, Price, CouponRate, Settle,  
Maturity, OptSpec, Strike, ExerciseDates,  
Name, Value)
```

### Description

[OAS, OAD, OAC] = oasbyhjm(HJMTTree, Price, CouponRate, Settle, Maturity, OptSpec, Strike, ExerciseDates) calculates option adjusted spread (OAS), duration (OAD), and convexity (OAC) using an HJM model.

[OAS, OAD, OAC] = oasbyhjm(HJMTTree, Price, CouponRate, Settle, Maturity, OptSpec, Strike, ExerciseDates, Name, Value) calculates option adjusted spread (OAS), duration (OAD), and convexity (OAC) using an HJM model with additional options specified by one or more Name, Value pair arguments.

### Input Arguments

#### HJMTTree

Interest-rate tree structure created by `hjmTree`.

#### Price

NINST-by-1 vector of market prices of bonds with embedded options.

#### CouponRate

NINST-by-1 vector for decimal annual rate.

**Settle**

NINST-by-1 vector for settlement date.

**Maturity**

NINST-by-1 vector for maturity date.

**OptSpec**

NINST-by-1 cell array of strings for 'call' or 'put'.

**Strike**

Matrix of strike price values for supported option types:

- European option: NINST-by-1 vector of strike price values.
- Bermuda option: NINST by number of strikes (NSTRIKES) matrix of strike price values.

Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.

- American option: NINST-by-1 vector of strike price values for each option.

**ExerciseDates**

Matrix of exercise callable or puttable dates for supported option types:

- NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.
- American option: NINST-by-2 vector of exercise date boundaries. For each instrument, the option is exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if ExerciseDates is NINST-by-1, the option is exercised between the underlying bond Settle and the single listed exercise date.

**Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name, Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single

quotes (' '). You can specify several name and value pair arguments in any order as Name1, Value1, . . . , NameN, ValueN.

**'AmericanOpt'**

NINST-by-1 vector for option flags: 0 (European/Bermuda) or 1 (American).

**Default:** 0 (European/Bermuda)

**'Basis'**

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

**'EndMonthRule'**

NINST-by-1 vector for end-of-month rule. Values are 1 (in effect) and 0 (not in effect).

**Default:** 1 (in effect)



**' IssueDate '**

NINST-by-1 vector of bond issue date.

**Default:** If you do not specify an `IssueDate`, the cash flow payment dates are determined from other inputs.

**' Face '**

NINST-by-1 vector for face value.

**Default:** 100

**' FirstCouponDate '**

NINST-by-1 vector. Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

**Default:** If you do not specify a `FirstCouponDate`, the cash flow payment dates are determined from other inputs.

**' LastCouponDate '**

NINST-by-1 vector. Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate`, regardless of where it falls, and is followed only by the bond's maturity cash flow date.

**Default:** If you do not specify a `LastCouponDate`, the cash flow payment dates are determined from other inputs.

**' Period '**

NINST-by-1 vector for coupons per year.

**Default:** 2 per year

**' Options '**

Structure created with `derivset` containing derivatives pricing options.

**Default:** None

## Output Arguments

### OAS

NINST-by-1 vector for option adjusted spread.

### OAD

NINST-by-1 vector for option adjusted duration.

### OAC

NINST-by-1 vector for option adjusted convexity.

## Examples

### Compute OAS Using the Heath-Jarrow-Morton (HJM) Model

This example shows how to compute OAS using the Heath-Jarrow-Morton (HJM) model using the following data.

```
ValuationDate = 'Nov-1-2010';
Rates = [0.0356; 0.0427; 0.0478; 0.0529];
StartDates = ValuationDate;
EndDates = datemnth(ValuationDate, 12:12:48)';
Compounding = 1;

% define RateSpec
RateSpec = intenvset('ValuationDate', ValuationDate, ...
'StartDates', StartDates, 'EndDates', EndDates, ...
'Rates', Rates, 'Compounding', Compounding);

% specify VolSpec and TimeSpec
Sigma = 0.02;
VS = hjmvolspec('Constant', Sigma)
TS = hjmtimespec(ValuationDate, EndDates, Compounding);
```

```
% build the HJM tree
HJMTree = hjmtree(VS, RateSpec, TS);
HJMTreeNew = cvtree(HJMTree);

% instrument information
CouponRate = 0.05;
Settle = ValuationDate;
Maturity = '01-Nov-2014';
OptSpec = 'call';
Strike = 100;
ExerciseDates = '01-Nov-2011';
Period = 1;
Price = 97.5;

% compute the OAS
OAS = oasbyhjm(HJMTree, Price, CouponRate, Settle, Maturity, OptSpec, Strike,...
ExerciseDates, 'Period', Period)

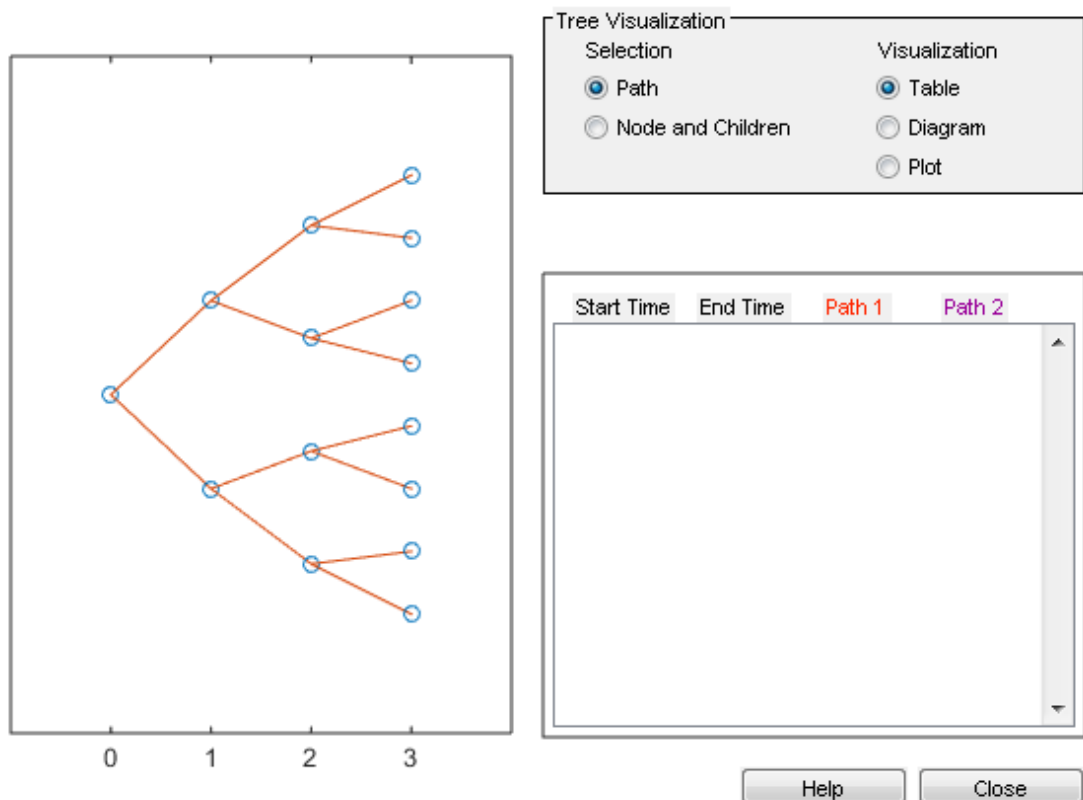
% use treeviewer to view the tree
treeviewer(HJMTree)
```

```
VS =
```

```
    FinObj: 'HJMVolSpec'
  FactorModels: {'Constant'}
  FactorArgs: {{1x1 cell}}
  SigmaShift: 0
  NumFactors: 1
  NumBranch: 2
    PBranch: [0.5000 0.5000]
  Fact2Branch: [-1 1]
```

```
OAS =
```

```
    5.0601
```



## More About

### Bond with Embedded Options

A bond with embedded option allows the issuer to buy back (callable) or redeem (puttable) the bond at a predetermined price at specified future dates. Financial Instruments Toolbox software supports American, European, and Bermuda callable and puttable bonds.

The pricing for a bond with embedded options is as follows:

- Callable bond — The holder bought a bond and sold a call option to the issuer. For example, if interest rates go down by the time of the call date, the issuer is able to

refinance its debt at a cheaper level and can call the bond. The price of a callable bond is:

Price callable bond = Price Option free bond – Price call option

- Puttable bond — The holder bought a bond and a put option. For example, if interest rates rise, the future value of coupon payments becomes less valuable. Therefore, the investor can sell the bond back to the issuer and then lend proceeds elsewhere at a higher rate. The price of a puttable bond is:

Price puttable bond = Price Option free bond + Price put option

- “Pricing Options Structure”

## References

Fabozzi, F., *Handbook of Fixed Income Securities*, McGraw-Hill, 7th edition, 2005.

Windas, T., *Introduction to Option-Adjusted Spread Analysis*, Bloomberg Press, 3rd edition, 2007.

## See Also

hjmprice | hjmtree | instoptembnd | oasbybdt | oasbybk | oasbyhw |  
optembndbyhjm

## oasbyhw

Determine option adjusted spread using Hull-White model

### Syntax

```
[OAS, OAD, OAC] = oasbyhw(HWTree, Price, CouponRate, Settle,  
Maturity, OptSpec, Strike, ExerciseDates)  
[OAS, OAD, OAC] = oasbyhw(HWTree, Price, CouponRate, Settle,  
Maturity, OptSpec, Strike, ExerciseDates,  
Name, Value)
```

### Description

[OAS, OAD, OAC] = oasbyhw(HWTree, Price, CouponRate, Settle, Maturity, OptSpec, Strike, ExerciseDates) calculates option adjusted spread (OAS), duration (OAD), and convexity (OAC) using an HW model.

[OAS, OAD, OAC] = oasbyhw(HWTree, Price, CouponRate, Settle, Maturity, OptSpec, Strike, ExerciseDates, Name, Value) calculates option adjusted spread (OAS), duration (OAD), and convexity (OAC) using an HW model with additional options specified by one or more Name, Value pair arguments.

### Input Arguments

#### **HWTree**

Interest-rate tree structure created by `hwtree`.

#### **Price**

NINST-by-1 vector of market prices of bonds with embedded options.

#### **CouponRate**

NINST-by-1 vector for decimal annual rate.

**Settle**

NINST-by-1 vector for settlement date.

**Maturity**

NINST-by-1 vector for maturity date.

**OptSpec**

NINST-by-1 cell array of strings for 'call' or 'put'.

**Strike**

Matrix of strike price values for supported option types:

- European option: NINST-by-1 vector of strike price values.
- Bermuda option: NINST by number of strikes (NSTRIKES) matrix of strike price values.

Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.

- American option: NINST-by-1 vector of strike price values for each option.

**ExerciseDates**

Matrix of exercise callable or puttable dates for supported option types:

- NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.
- American option: NINST-by-2 vector of exercise date boundaries. For each instrument, the option is exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if ExerciseDates is NINST-by-1, the option is exercised between the underlying bond Settle and the single listed exercise date.

**Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name, Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single

quotes (' '). You can specify several name and value pair arguments in any order as Name1, Value1, . . . , NameN, ValueN.

**'AmericanOpt'**

NINST-by-1 vector for option flags: 0 (European/Bermuda) or 1 (American).

**Default:** 0 (European/Bermuda)

**'Basis'**

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

**'EndMonthRule'**

NINST-by-1 vector for end-of-month rule. Values are 1 (in effect) and 0 (not in effect).

**Default:** 1 (in effect)



**'Face'**

NINST-by-1 vector for face value.

**Default:** 100

**'IssueDate'**

NINST-by-1 vector of bond issue date.

**Default:** If you do not specify an `IssueDate`, the cash flow payment dates are determined from other inputs.

**'FirstCouponDate'**

NINST-by-1 vector. Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

**Default:** If you do not specify a `FirstCouponDate`, the cash flow payment dates are determined from other inputs.

**'LastCouponDate'**

NINST-by-1 vector. Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate`, regardless of where it falls, and is followed only by the bond's maturity cash flow date.

**Default:** If you do not specify a `LastCouponDate`, the cash flow payment dates are determined from other inputs.

**'Period'**

NINST-by-1 vector for coupons per year.

**Default:** 2 per year

**'Options'**

Structure created with `derivset` containing derivatives pricing options.

**Default:** None

## Output Arguments

### OAS

NINST-by-1 vector for option adjusted spread.

### OAD

NINST-by-1 vector for option adjusted duration.

### OAC

NINST-by-1 vector for option adjusted convexity.

## Examples

### Compute OAS and OAD Using the Hull-White (HW) Model

This example shows how to compute OAS and OAD using the Hull-White (HW) model using the following data.

```
ValuationDate = 'October-25-2010';
Rates = [0.0355; 0.0382; 0.0427; 0.0489];
StartDates = ValuationDate;
EndDates = datemnth(ValuationDate, 12:12:48)';
Compounding = 1;

% define RateSpec
RateSpec = intenvset('ValuationDate', ValuationDate, ...
    'StartDates', StartDates, 'EndDates', EndDates, ...
    'Rates', Rates, 'Compounding', Compounding);

% specify VolsSpec and TimeSpec
Sigma = 0.05;
Alpha = 0.01;
VS = hwwolspec(ValuationDate, EndDates, Sigma*ones(size(EndDates)), ...
    EndDates, Alpha*ones(size(EndDates)));
```

```
TS = hwtimespec(ValuationDate, EndDates, Compounding);

% build the HW tree
HWTtree = hwtree(VS, RateSpec, TS);

% instrument information
CouponRate = 0.045;
Settle = ValuationDate;
Maturity = '25-October-2014';
OptSpec = 'call';
Strike = 100;
ExerciseDates = {'25-October-2010', '25-October-2013'};
Period = 1;
AmericanOpt = 0;
Price = 97;

% compute the OAS
[OAS, OAD] = oasbyhw(HWTtree, Price, CouponRate, Settle, Maturity,...
OptSpec, Strike, ExerciseDates, 'Period', Period, 'AmericanOpt', AmericanOpt)

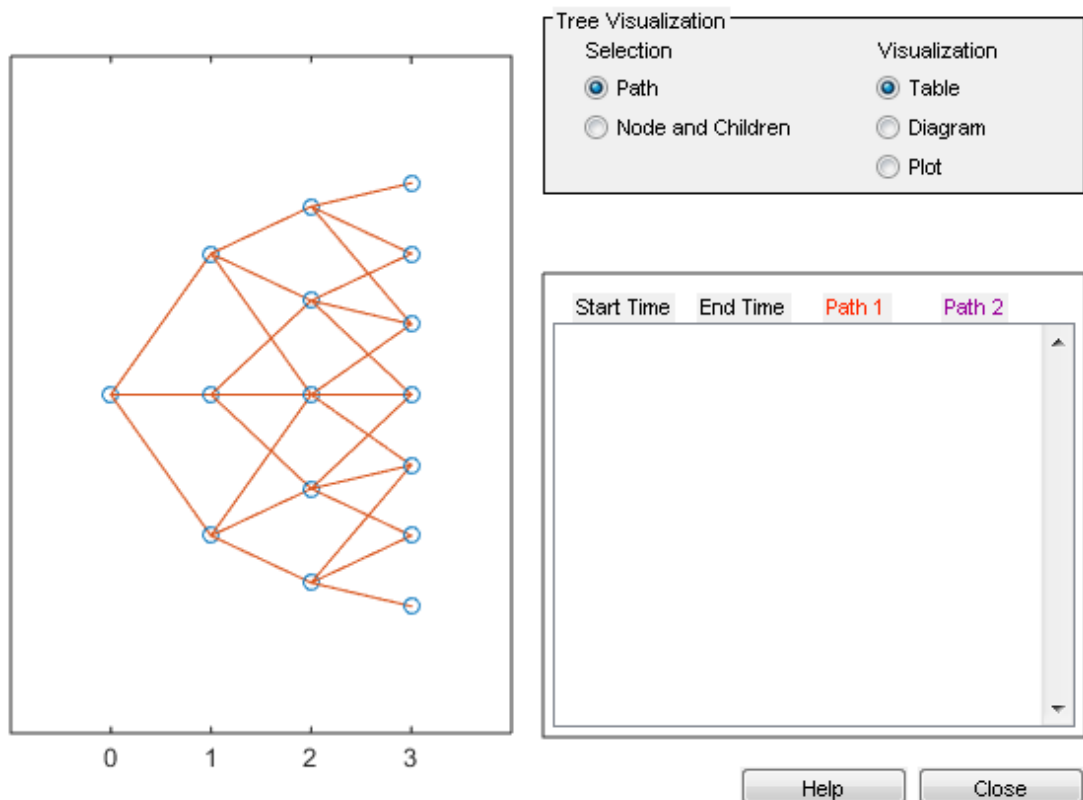
% use treeviewer to observe the tree
treeviewer(HWTtree)

OAS =

    -12.4436

OAD =

     3.3045
```



## More About

### Bond with Embedded Options

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The pricing for a bond with embedded options is as follows:

- Callable bond — The holder bought a bond and sold a call option to the issuer. For example, if interest rates go down by the time of the call date, the issuer is able to

refinance its debt at a cheaper level and can call the bond. The price of a callable bond is:

Price callable bond = Price Option free bond – Price call option

- Puttable bond — The holder bought a bond and a put option. For example, if interest rates rise, the future value of coupon payments becomes less valuable. Therefore, the investor can sell the bond back to the issuer and then lend proceeds elsewhere at a higher rate. The price of a puttable bond is:

Price puttable bond = Price Option free bond + Price put option

- “Pricing Options Structure”

## References

Fabozzi, F., *Handbook of Fixed Income Securities*, McGraw-Hill, 7th edition, 2005.

Windas, T., *Introduction to Option-Adjusted Spread Analysis*, Bloomberg Press, 3rd edition, 2007.

## See Also

hwprice | hwtree | instoptembnd | oasbybdt | oasbybk | oasbyhjm |  
optembndbyhw

## optbndbybdt

Price bond option from Black-Derman-Toy interest-rate tree

### Syntax

```
[Price, PriceTree] = optbndbybdt(BDTree, OptSpec, Strike,
ExerciseDates, AmericanOpt, CouponRate, Settle, Maturity,
Period, Basis, EndMonthRule, IssueDate, FirstCouponDate,
LastCouponDate, StartDate, Face, Options)
```

### Arguments

BDTree	Forward-rate tree structure created by <code>bdttree</code> .
OptSpec	Number of instruments (NINST)-by-1 cell array of string values 'Call' or 'Put'.
Strike	<p>European option: NINST-by-1 vector of strike price values.</p> <p>Bermuda option: NINST by number of strikes (NSTRIKES) matrix of strike price values.</p> <p>Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.</p> <p>For an American option:</p> <p>NINST-by-1 vector of strike price values for each option.</p>
ExerciseDates	<p>NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option:</p>

	NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <b>ExerciseDates</b> is NINST-by-1, the option can be exercised between the underlying bond <b>Settle</b> and the single listed exercise date.
<b>AmericanOpt</b>	NINST-by-1 vector of flags: 0 (European/Bermuda) or 1 (American).
<b>CouponRate</b>	Decimal annual rate. <b>CouponRate</b> is a NINST-by-1 vector.
<b>Settle</b>	Settlement date. A vector of serial date numbers or date strings. <b>Settle</b> must be earlier than <b>Maturity</b> .
<b>Maturity</b>	Maturity date. A vector of serial date numbers or date strings.
<b>Period</b>	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 1, 2, 3, 4, 6, and 12. Default = 2.

Basis	<p>(Optional) Day-count basis of the instrument. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
EndMonthRule	<p>(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.</p>
IssueDate	<p>(Optional) Date when a bond was issued.</p>



<b>FirstCouponDate</b>	(Optional) Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When <b>FirstCouponDate</b> and <b>LastCouponDate</b> are both specified, <b>FirstCouponDate</b> takes precedence in determining the coupon payment structure. If you do not specify a <b>FirstCouponDate</b> , the cash flow payment dates are determined from other inputs.
<b>LastCouponDate</b>	(Optional) Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified <b>FirstCouponDate</b> , a specified <b>LastCouponDate</b> determines the coupon structure of the bond. The coupon structure of a bond is truncated at the <b>LastCouponDate</b> , regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a <b>LastCouponDate</b> , the cash flow payment dates are determined from other inputs.
<b>StartDate</b>	(Optional) Date when a bond actually starts (the date from which a bond cash flow is considered). To make an instrument forward-starting, specify this date as a future date. If you do not specify <b>StartDate</b> , the effective start date is the <b>Settle</b> date.
<b>Face</b>	(Optional) Face or par value. <b>Face</b> is a NINST-by-1 vector. Default = 100.
<b>Options</b>	(Optional) Derivatives pricing options structure created with <b>derivset</b> .

The **Settle** date for every bond is set to the **ValuationDate** of the BDT tree. The bond argument **Settle** is ignored.

## Description

```
[Price, PriceTree] = optbndbybdt(BDTree, OptSpec, Strike,
ExerciseDates, AmericanOpt, CouponRate, Settle, Maturity,
Period, Basis, EndMonthRule, IssueDate, FirstCouponDate,
```

`LastCouponDate`, `StartDate`, `Face`, `Options`) computes the price of a bond option from a BDT interest-rate tree.

`Price` is an NINST-by-1 matrix of expected prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

## Examples

**Example 1.** Using the BDT interest-rate tree in the `deriv.mat` file, price a European call option on a 10% bond with a strike of 95. The exercise date for the option is Jan. 01, 2002. The settle date for the bond is Jan. 01, 2000, and the maturity date is Jan. 01, 2003.

Load the file `deriv.mat`, which provides `BDTTree`. The `BDTTree` structure contains the time and forward-rate information needed to price the bond.

```
load deriv.mat;
```

Use `optbndbybdt` to compute the price of the option.

```
Price = optbndbybdt(BDTTree, 'Call', 95, '01-Jan-2002', ...  
0, 0.10, '01-Jan-2000', '01-Jan-2003', 1)
```

```
Price =
```

```
1.7657
```

**Example 2.** Now use `optbndbybdt` to compute the price of a put option on the same bond.

```
Price = optbndbybdt(BDTTree, 'Put', 95, '01-Jan-2002', ...  
0, 0.10, '01-Jan-2000', '01-Jan-2003', 1)
```

```
Price =
```

```
0.5740
```

## More About

- “Pricing Options Structure”

## **See Also**

bdtprice | bdttree | instoptbnd

## optbndbybk

Price bond option from Black-Karasinski interest-rate tree

### Syntax

```
[Price, PriceTree] = optbndbybk(BKTree, OptSpec, Strike,
ExerciseDates, AmericanOpt, CouponRate, Settle, Maturity,
Period, Basis, EndMonthRule, IssueDate, FirstCouponDate,
LastCouponDate, StartDate, Face, Options)
```

### Arguments

BKTree	Forward-rate tree structure created by <code>bktree</code> .
OptSpec	Number of instruments (NINST)-by-1 cell array of string values 'Call' or 'Put'.
Strike	<p>European option: NINST-by-1 vector of strike price values.</p> <p>Bermuda option: NINST-by-number of strikes (NSTRIKES) matrix of strike price values.</p> <p>Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.</p> <p>For an American option:</p> <p>NINST-by-1 vector of strike price values for each option.</p>
ExerciseDates	<p>NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option:</p>

	NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <b>ExerciseDates</b> is NINST-by-1, the option can be exercised between the underlying bond <b>Settle</b> and the single listed exercise date.
<b>AmericanOpt</b>	NINST-by-1 vector of flags: 0 (European/Bermuda) or 1 (American).
<b>CouponRate</b>	Decimal annual rate. <b>CouponRate</b> is a NINST-by-1 vector.
<b>Settle</b>	Settlement date. A vector of serial date numbers or date strings. <b>Settle</b> must be earlier than <b>Maturity</b> .
<b>Maturity</b>	Maturity date. A vector of serial date numbers or date strings.
<b>Period</b>	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 1, 2, 3, 4, 6, and 12. Default = 2.

<p><b>Basis</b></p>	<p>(Optional) Day-count basis of the instrument. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<p><b>EndMonthRule</b></p>	<p>(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.</p>
<p><b>IssueDate</b></p>	<p>(Optional) Date when a bond was issued.</p>

<b>FirstCouponDate</b>	(Optional) Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When <b>FirstCouponDate</b> and <b>LastCouponDate</b> are both specified, <b>FirstCouponDate</b> takes precedence in determining the coupon payment structure. If you do not specify a <b>FirstCouponDate</b> , the cash flow payment dates are determined from other inputs.
<b>LastCouponDate</b>	(Optional) Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified <b>FirstCouponDate</b> , a specified <b>LastCouponDate</b> determines the coupon structure of the bond. The coupon structure of a bond is truncated at the <b>LastCouponDate</b> , regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a <b>LastCouponDate</b> , the cash flow payment dates are determined from other inputs.
<b>StartDate</b>	(Optional) Date when a bond actually starts (the date from which a bond cash flow is considered). To make an instrument forward-starting, specify this date as a future date. If you do not specify <b>StartDate</b> , the effective start date is the <b>Settle</b> date.
<b>Face</b>	(Optional) Face or par value. <b>Face</b> is a NINST-by-1 vector. Default = 100.
<b>Options</b>	(Optional) Derivatives pricing options structure created with <b>derivset</b> .

The **Settle** date for every bond is set to the **ValuationDate** of the BK tree. The bond argument **Settle** is ignored.

## Description

```
[Price, PriceTree] = optbndbybk(BKTree, OptSpec, Strike,
ExerciseDates, AmericanOpt, CouponRate, Settle, Maturity,
Period, Basis, EndMonthRule, IssueDate, FirstCouponDate,
```

LastCouponDate, StartDate, Face, Options) computes the price of a bond option from a Black-Karasinski interest rate tree.

Price is an NINST-by-1 matrix of expected prices at time 0.

PriceTree is a tree structure with a vector of instrument prices at each node.

## Examples

**Example 1.** Using the BK interest rate tree in the `deriv.mat` file, price a European call option on a 4% bond with a strike of 96. The exercise date for the option is Jan. 01, 2006. The settle date for the bond is Jan. 01, 2005, and the maturity date is Jan. 01, 2009.

Load the file `deriv.mat`, which provides `BKTree`. The `BKTree` structure contains the time and forward-rate information needed to price the bond.

```
load deriv.mat;
```

Use `optbondbybk` to compute the price of the option.

```
Price = optbondbybk(BKTree, 'Call', 96, '01-Jan-2006', ...  
0, 0.04, '01-Jan-2005', '01-Jan-2009')
```

```
Warning: OptBonds are valued at Tree ValuationDate rather than Settle  
> In optbndbytrintree at 43  
   In optbndbybk at 88  
Warning: Not all cash flows are aligned with the tree. Result will be  
approximated.  
> In optbndbytrintree at 151  
   In optbndbybk at 88
```

```
Price =  
  
    0.1512
```

**Example 2.** Now use `optbndbybk` to compute the price of a put option on the same bond.

```
Price = optbndbybk(BKTree, 'Put', 96, '01-Jan-2006', ...  
0, 0.04, '01-Jan-2005', '01-Jan-2009')
```

```
Warning: OptBonds are valued at Tree ValuationDate rather than Settle  
> In optbndbytrintree at 43  
   In optbndbybk at 88
```



Warning: Not all cash flows are aligned with the tree. Result will be approximated.

```
> In optbndbytrintree at 151  
  In optbndbybk at 88
```

Price =

0.0272

## More About

- “Pricing Options Structure”

## See Also

bkprice | bktree | instoptbnd

## optbndbyhjm

Price bond option from Heath-Jarrow-Morton interest-rate tree

### Syntax

```
[Price, PriceTree] = optbndbyhjm(HJMTree, OptSpec, Strike,
ExerciseDates, AmericanOpt, CouponRate, Settle, Maturity,
Period, Basis, EndMonthRule, IssueDate, FirstCouponDate,
LastCouponDate, StartDate, Face, Options)
```

### Arguments

HJMTree	Forward-rate tree structure created by <code>hjmtree</code> .
OptSpec	Number of instruments (NINST)-by-1 cell array of string values 'Call' or 'Put'.
Strike	<p>European option: NINST-by-1 vector of strike price values.</p> <p>Bermuda option: NINST by number of strikes (NSTRIKES) matrix of strike price values.</p> <p>Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.</p> <p>For an American option:</p> <p>NINST-by-1 vector of strike price values for each option.</p>
ExerciseDates	<p>NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option:</p> <p>NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon</p>

	date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <b>ExerciseDates</b> is NINST-by-1, the option can be exercised between the underlying bond <b>Settle</b> and the single listed exercise date.
<b>AmericanOpt</b>	NINST-by-1 vector of flags: 0 (European/Bermuda) or 1 (American).
<b>CouponRate</b>	Decimal annual rate. <b>CouponRate</b> is a NINST-by-1 vector.
<b>Settle</b>	Settlement date. A vector of serial date numbers or date strings. <b>Settle</b> must be earlier than <b>Maturity</b> .
<b>Maturity</b>	Maturity date. A vector of serial date numbers or date strings.
<b>Period</b>	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 1, 2, 3, 4, 6, and 12. Default = 2.

<p><b>Basis</b></p>	<p>(Optional) Day-count basis of the instrument. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<p><b>EndMonthRule</b></p>	<p>(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.</p>
<p><b>IssueDate</b></p>	<p>(Optional) Date when a bond was issued.</p>
<p><b>FirstCouponDate</b></p>	<p>(Optional) Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When <b>FirstCouponDate</b> and <b>LastCouponDate</b> are both specified, <b>FirstCouponDate</b> takes precedence in determining the coupon payment structure. If you do not specify a <b>FirstCouponDate</b>, the cash flow payment dates are determined from other inputs.</p>

<b>LastCouponDate</b>	(Optional) Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified <b>FirstCouponDate</b> , a specified <b>LastCouponDate</b> determines the coupon structure of the bond. The coupon structure of a bond is truncated at the <b>LastCouponDate</b> , regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a <b>LastCouponDate</b> , the cash flow payment dates are determined from other inputs.
<b>StartDate</b>	(Optional) Date when a bond actually starts (the date from which a bond cash flow is considered). To make an instrument forward-starting, specify this date as a future date. If you do not specify <b>StartDate</b> , the effective start date is the <b>Settle</b> date.
<b>Face</b>	(Optional) Face or par value. <b>Face</b> is a NINST-by-1 vector. Default = 100.
<b>Options</b>	(Optional) Derivatives pricing options structure created with <b>derivset</b> .

The **Settle** date for every bond is set to the **ValuationDate** of the HJM tree. The bond argument **Settle** is ignored.

## Description

[Price, PriceTree] = optbndbyhjm(HJMTree, OptSpec, Strike, ExerciseDates, AmericanOpt, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face, Options) computes the price of a bond option from an HJM forward-rate tree.

Price is an NINST-by-1 matrix of expected prices at time 0.

PriceTree is a tree structure with a vector of instrument prices at each node.

## Examples

### Compute the Price of a Bond Option From an HJM Forward-Rate Tree

Using the HJM forward-rate tree in the `deriv.mat` file, price a European call option on a 4% bond with a strike of 96. The exercise date for the option is Jan. 01, 2003. The settle date for the bond is Jan. 01, 2000, and the maturity date is Jan. 01, 2004. Load the file `deriv.mat`, which provides `HJMTree`. The `HJMTree` structure contains the time and forward-rate information needed to price the bond.

```
load deriv.mat;
```

Use the function `| optbondbyhjm |` to compute the price of the option.

```
Price = optbndbyhjm(HJMTree, 'Call', 96, '01-Jan-2003', ...  
0, 0.04, '01-Jan-2000', '01-Jan-2004')
```

Warning: Not all cash flows are aligned with the tree. Result will be approximated.

```
Price =  
  
2.2410
```

## More About

- “Pricing Options Structure”

## See Also

`hjmprice` | `hjmtree` | `instoptbnd`

# optbndbyhw

Price bond option from Hull-White interest-rate tree

## Syntax

```
[Price, PriceTree] = optbndbyhw(HWTree, OptSpec, Strike,
ExerciseDates, AmericanOpt, CouponRate, Settle, Maturity,
Period, Basis, EndMonthRule, IssueDate, FirstCouponDate,
LastCouponDate, StartDate, Face, Options)
```

## Arguments

HWTree	Forward-rate tree structure created by <code>hwtree</code> .
OptSpec	Number of instruments (NINST)-by-1 cell array of string values 'Call' or 'Put'.
Strike	<p>European option: NINST-by-1 vector of strike price values.</p> <p>Bermuda option: NINST by number of strikes (NSTRIKES) matrix of strike price values.</p> <p>Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.</p> <p>For an American option:</p> <p>NINST-by-1 vector of strike price values for each option.</p>
ExerciseDates	<p>NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option:</p>

	NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <b>ExerciseDates</b> is NINST-by-1, the option can be exercised between the underlying bond <b>Settle</b> and the single listed exercise date.
<b>AmericanOpt</b>	NINST-by-1 vector of flags: 0 (European/Bermuda) or 1 (American).
<b>CouponRate</b>	Decimal annual rate. <b>CouponRate</b> is a NINST-by-1 vector.
<b>Settle</b>	Settlement date. A vector of serial date numbers or date strings. <b>Settle</b> must be earlier than <b>Maturity</b> .
<b>Maturity</b>	Maturity date. A vector of serial date numbers or date strings.
<b>Period</b>	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 1, 2, 3, 4, 6, and 12. Default = 2.



<b>Basis</b>	<p>(Optional) Day-count basis of the instrument. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<b>EndMonthRule</b>	<p>(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. <b>0</b> = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. <b>1</b> = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.</p>
<b>IssueDate</b>	<p>(Optional) Date when a bond was issued.</p>

<b>FirstCouponDate</b>	(Optional) Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When <b>FirstCouponDate</b> and <b>LastCouponDate</b> are both specified, <b>FirstCouponDate</b> takes precedence in determining the coupon payment structure. If you do not specify a <b>FirstCouponDate</b> , the cash flow payment dates are determined from other inputs.
<b>LastCouponDate</b>	(Optional) Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified <b>FirstCouponDate</b> , a specified <b>LastCouponDate</b> determines the coupon structure of the bond. The coupon structure of a bond is truncated at the <b>LastCouponDate</b> , regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a <b>LastCouponDate</b> , the cash flow payment dates are determined from other inputs.
<b>StartDate</b>	(Optional) Date when a bond actually starts (the date from which a bond cash flow is considered). To make an instrument forward-starting, specify this date as a future date. If you do not specify <b>StartDate</b> , the effective start date is the <b>Settle</b> date.
<b>Face</b>	(Optional) Face or par value. <b>Face</b> is a NINST-by-1 vector. Default = 100.
<b>Options</b>	(Optional) Derivatives pricing options structure created with <b>derivset</b> .

The **Settle** date for every bond is set to the **ValuationDate** of the HW tree. The bond argument **Settle** is ignored.

## Description

```
[Price, PriceTree] = optbndbyhw(HWTree, OptSpec, Strike,
ExerciseDates, AmericanOpt, CouponRate, Settle, Maturity,
Period, Basis, EndMonthRule, IssueDate, FirstCouponDate,
```

LastCouponDate, StartDate, Face, Options) computes the price of a bond option from a Hull-White interest rate tree.

Price is an NINST-by-1 matrix of expected prices at time 0.

PriceTree is a tree structure with a vector of instrument prices at each node.

## Examples

**Example 1.** Using the HW interest rate tree in the `deriv.mat` file, price a European call option on a 4% bond with a strike of 96. The exercise date for the option is Jan. 01, 2006. The settle date for the bond is Jan. 01, 2005, and the maturity date is Jan. 01, 2009.

Load the file `deriv.mat`, which provides `HWTtree`. The `HWTtree` structure contains the time and forward-rate information needed to price the bond.

```
load deriv.mat;
```

Use `optbndbyhw` to compute the price of the option.

```
Price = optbndbyhw(HWTtree,'Call',96,'01-Jan-2006',...
0,0.04,'01-Jan-2005','01-Jan-2009')
```

```
Warning: OptBonds are valued at Tree ValuationDate rather than Settle
Warning: Not all cash flows are aligned with the tree. Result will
be approximated.
```

```
Price =
    1.1556
```

**Example 2.** Now use `optbndbyhw` to compute the price of a put option on the same bond.

```
Price = optbndbyhw(HWTtree,'Put',96,'01-Jan-2006',...
0,0.04,'01-Jan-2005','01-Jan-2009')
```

```
Warning: OptBonds are valued at Tree ValuationDate rather than Settle
Warning: Not all cash flows are aligned with the tree. Result will
be approximated.
```

```
Price =
```

1.0150

### **More About**

- “Pricing Options Structure”

### **See Also**

`hwprice` | `hwtree` | `instoptbnd`

# optembndbybdt

Price bonds with embedded options by Black-Derman-Toy interest-rate tree

## Syntax

```
[Price, PriceTree] = optembndbybdt(BDTree, CouponRate,
Settle, Maturity, OptSpec, Strike, ExerciseDates,
'Name1', Value1, 'Name2', Value2, ...)
```

## Arguments

BDTree	Interest-rate tree structure created by <code>bdttree</code> .
CouponRate	Decimal annual rate. <code>CouponRate</code> is a NINST-by-1 vector or NINST-by-1 cell array of decimal annual rates, or decimal annual rate schedules. For the latter case of a variable coupon schedule, each element of the cell array is a NumDates-by-2 cell array, where the first column is dates and the second column is its associated rate. The date indicates the last day that the coupon rate is valid.
Settle	NINST-by-1 matrix for the settlement date. A vector of serial date numbers or date strings. <code>Settle</code> must be earlier than <code>Maturity</code> .
Maturity	NINST-by-1 matrix for the maturity date. A vector of serial date numbers or date strings.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	European option: NINST-by-1 vector of strike price values.  Bermuda option: NINST by number of strikes (NSTRIKES) matrix of strike price values.  Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.  For an American option:

	NINST-by-1 vector of strike price values for each option.
ExerciseDates	<p>NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option:</p> <p>NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if ExerciseDates is NINST-by-1, the option can be exercised between the underlying bond <code>Settle</code> and the single listed exercise date.</p>

<p>'Name1', 'Value1' 'Name2', 'Value2'...</p>	<p>(Optional) The name/value pairs are a variable length list of parameters. All optional inputs are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. Parameter name/value pairs may be specified in any order; names are case insensitive and partial string matches are allowed provided no ambiguities exist. Valid parameter names are as follows:</p> <ul style="list-style-type: none"> <li>• <b>AmericanOpt</b> is a NINST-by-1 matrix for flags options: 0 (European/Bermuda) or 1 (American). Default is 0.</li> <li>• <b>Period</b> is a NINST-by-1 matrix for coupons per year. The default value is 2.</li> <li>• <b>Basis</b> is a day-count basis of the instrument. <b>Basis</b> is a vector of integers with the following possible values: <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> </li> </ul> <p>For more information, see <b>basis</b>.</p>
---	---

- **EndMonthRule** is a NINST-by-1 matrix for the end-of-month rule. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days. When the value is 0 the end-of-month rule is ignored; this means that a bond's coupon payment date is always the same numerical day of the month. Use 1 to set the rule on; this is the default value and means that a bond's coupon payment date is always the last actual day of the month.
- **IssueDate** is a NINST-by-1 matrix for the bond issue date.
- **FirstCouponDate** is a NINST-by-1 matrix for a date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When **FirstCouponDate** and **LastCouponDate** are both specified, **FirstCouponDate** takes precedence in determining the coupon payment structure. If you do not specify a **FirstCouponDate**, the cash flow payment dates are determined from other inputs.
- **LastCouponDate** is a NINST-by-1 matrix for a last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified **FirstCouponDate**, a specified **LastCouponDate** determines the coupon structure of the bond. The coupon structure of a bond is truncated at the **LastCouponDate**, regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a **LastCouponDate**, the cash flow payment dates are determined from other inputs.
- **StartDate** is a NINST-by-1 matrix for date when a bond actually starts (the date from which a bond cash flow is considered). To make an instrument forward-starting, specify this date as a future date. If you do not specify **StartDate**, the effective start date is the **Settle** date.
- **Face value.** **Face** is a NINST-by-1 vector or NINST-by-1 cell array of face values, or face value schedules.



For the latter case, each element of the cell array is a `NumDates`-by-2 cell array, where the first column is dates and the second column is its associated face value. The date indicates the last day that the face value is valid. Default is 100.

- `Options` is a derivatives pricing options structure created with `derivset`.

---

**Note:** The `Settle` date for every bond with an embedded option is set to the `ValuationDate` of the BDT tree; the bond's argument for `Settle` date is ignored.

---

## Description

`[Price, PriceTree] = optembndbybdt(BDTree, CouponRate, Settle, Maturity, OptSpec, Strike, ExerciseDates, 'Name1', Value1, 'Name2', Value2, ...)` prices bonds with embedded options using a BDT interest-rate tree.

`Price` is a number of instruments (`NINST`)-by-1 matrix of expected prices at time 0.

`PriceTree` is a MATLAB structure of trees containing vectors of instrument prices and observation times for each node. Within `PriceTree`

- `PriceTree.PTree` contains the clean prices.
- `PriceTree.tObs` contains the observation times.

`optembndbybdt` computes prices of vanilla bonds with embedded options, stepped coupon bonds with embedded options, and bonds with sinking fund option provisions.

## Examples

### Price a Callable Bond Using a BDT Interest-Rate Tree Model

Create a `BDTree` with the following data:

```
ZeroRates = [ 0.035;0.04;0.045];
Compounding = 1;
```

```
StartDates = ['jan-1-2007'; 'jan-1-2008'; 'jan-1-2009'];
EndDates    = ['jan-1-2008'; 'jan-1-2009'; 'jan-1-2010'];
ValuationDate = 'jan-1-2007';
```

Create a RateSpec.

```
RateSpec = intenvset('Rates', ZeroRates, 'StartDates', ValuationDate, 'EndDates', ...
EndDates, 'Compounding', Compounding, 'ValuationDate', ValuationDate)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
  Compounding: 1
        Disc: [3x1 double]
        Rates: [3x1 double]
    EndTimes: [3x1 double]
  StartTimes: [3x1 double]
    EndDates: [3x1 double]
  StartDates: 733043
ValuationDate: 733043
        Basis: 0
  EndMonthRule: 1
```

Create a VolSpec.

```
Volatility = 0.10 * ones(3,1);
VolSpec = bdtvolspec(ValuationDate, EndDates, Volatility)
```

```
VolSpec =
```

```
    FinObj: 'BDTVolSpec'
ValuationDate: 733043
    VolDates: [3x1 double]
    VolCurve: [3x1 double]
VolInterpMethod: 'linear'
```

Create a TimeSpec.

```
TimeSpec = bdttimespec(ValuationDate, EndDates, Compounding);
```

Build the BDTTree.

```
BDTTree = bdttree(VolSpec, RateSpec, TimeSpec)
```

```
BDTTree =
```

```
    FinObj: 'BDTFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
    tObs: [0 1 2]
    dObs: [733043 733408 733774]
    TFwd: {[3x1 double] [2x1 double] [2]}
    CFlowT: {[3x1 double] [2x1 double] [3]}
    FwdTree: {[1.0350] [1.0406 1.0495] [1.0447 1.0546 1.0667]}
```

To compute the price of an American callable bond that pays a 5.25% annual coupon, matures in Jan-1-2010, and is callable on Jan-1-2008 and 01-Jan-2010.

```
BondSettlement = 'jan-1-2007';
```

```
BondMaturity = 'jan-1-2010';
```

```
CouponRate = 0.0525;
```

```
Period = 1;
```

```
OptSpec = 'call';
```

```
Strike = [100];
```

```
ExerciseDates = {'jan-1-2008' '01-Jan-2010'};
```

```
AmericanOpt = 1;
```

```
PriceCallBond = optembndbybdt(BDTTree, CouponRate, BondSettlement, BondMaturity,...
```

```
OptSpec, Strike, ExerciseDates, 'Period', 1, 'AmericanOp', 1)
```

```
PriceCallBond =
```

```
101.4750
```

### Price Single Stepped Callable Bonds Using a BDT Interest-Rate Tree Model

Price the following single stepped callable bonds using the following data: The data for the interest rate term structure is as follows:

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];
```

```
ValuationDate = 'Jan-1-2010';
```

```
StartDates = ValuationDate;
```

```

EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};
Compounding = 1;

% Create RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% Instrument
Settle = '01-Jan-2010';
Maturity = {'01-Jan-2013'; '01-Jan-2014'};
CouponRate = {'01-Jan-2012' .0425; '01-Jan-2014' .0750};
OptSpec='call';
Strike=100;
ExerciseDates='01-Jan-2012'; %Callable in two years

% Build the tree
% Assume the volatility to be 10%
Sigma = 0.1;
BDTTimeSpec = bdttimespec(ValuationDate, EndDates, Compounding);
BDTVolSpec = bdtvolspec(ValuationDate, EndDates, Sigma*ones(1, length(EndDates))');
BDTT = bdttree(BDTVolSpec, RS, BDTTimeSpec);

% The first row corresponds to the price of the callable bond with maturity
% of three years. The second row corresponds to the price of the callable bond
% with maturity of four years.
PBDT= optembndbybdt(BDTT, CouponRate, Settle, Maturity ,OptSpec, Strike,...
ExerciseDates, 'Period', 1)

PBDT =

    100.0945
    100.0297

```

### Price a Sinking Fund Bond Using a BDT Interest-Rate Tree Model

A corporation issues a three year bond with a sinking fund obligation requiring the company to sink 1/3 of face value after the first year and 1/3 after the second year. The company has the option to buy the bonds in the market or call them at \$98. The following data describes the details needed for pricing the sinking fund bond:

```

Rates = [0.1;0.1;0.1;0.1];
ValuationDate = 'Jan-1-2011';
StartDates = ValuationDate;

```

```

EndDates = {'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'};
Compounding = 1;

% Create RateSpec
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates',...
StartDates, 'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% Build the BDT tree
% Assume the volatility to be 10%
Sigma = 0.1;
BDTTimeSpec = bdttimespec(ValuationDate, EndDates);
BDTVolSpec = bdtvolspec(ValuationDate, EndDates, Sigma*ones(1, length(EndDates)));
BDTT = bdttree(BDTVolSpec, RateSpec, BDTTimeSpec);

% Instrument
% The bond has a coupon rate of 9%, a period of one year and matures in
% 1-Jan-2014. Face decreases 1/3 after the first year and 1/3 after the
% second year.
CouponRate = 0.09;
Settle = 'Jan-1-2011';
Maturity = 'Jan-1-2014';
Period = 1;
Face = { ...
        {'Jan-1-2012' 100; ...
         'Jan-1-2013' 66.6666; ...
         'Jan-1-2014' 33.3333};
};

% Option provision
OptSpec = 'call';
Strike = [98 98];
ExerciseDates = {'Jan-1-2012', 'Jan-1-2013'};

% Price of non-sinking fund bond.
PNSF = bondbybdt(BDTT, CouponRate, Settle, Maturity, Period)

PNSF =

    97.5131

Price of the bond with the option sinking provision.
PriceSF = optembndbybdt(BDTT, CouponRate, Settle, Maturity,...

```

OptSpec, Strike, ExerciseDates, 'Period', Period, 'Face', Face)

PriceSF =

96.8364

## More About

### Vanilla Bond with Embedded Option

A vanilla coupon bond is a security representing an obligation to repay a borrowed amount at a designated time and to make periodic interest payments until that time. The issuer of a bond makes the periodic interest payments until the bond matures. At maturity, the issuer pays to the holder of the bond the principal amount owed (face value) and the last interest payment. A vanilla bond with an embedded option is where an option contract has an underlying asset of a vanilla bond.

### Stepped Coupon Bond with Callable and Puttable Features

A step-up and step-down bond is a debt security with a predetermined coupon structure over time. With these instruments, coupons increase (step up) or decrease (step down) at specific times during the life of the bond. Stepped coupon bonds can have options features (call and puts).

### Sinking Fund Bond with Embedded Option

A sinking fund bond is a coupon bond with a sinking fund provision. This provision obligates the issuer to amortize portions of the principal prior to maturity, affecting bond prices since the time of the principal repayment changes. This means that investors receive the coupon and a portion of the principal paid back over time. These types of bonds reduce credit risk, since it lowers the probability of investors not receiving their principal payment at maturity.

The bond may have a sinking fund option provision allowing the issuer to retire the sinking fund obligation either by purchasing the bonds to be redeemed from the market or by calling the bond via a sinking fund call, whichever is cheaper. If interest rates are high, then the issuer will buy back the requirement amount of bonds from the market since bonds will be cheap, but if interest rates are low (bond prices are high), then most likely the issuer will be buying the bonds at the call price. Unlike a call feature, however,

if a bond has a sinking fund option provision, it is an obligation, not an option, for the issuer to buy back the increments of the issue as stated. Because of this, a sinking fund bond trades at a lower price than a non-sinking fund bond.

- “Pricing Options Structure”

### **See Also**

`bdtpprice` | `bdttree` | `cfamounts` | `instoptembnd`

## optembndbybk

Price bonds with embedded options by Black-Karasinski interest-rate tree

### Syntax

```
[Price, PriceTree] = optembndbybk(BKTree, CouponRate,
Settle, Maturity, OptSpec, Strike, Strike, ExerciseDates,
'Name1', Value1, 'Name2', Value2, ...)
```

### Arguments

BKTree	Interest-rate tree structure created by <code>bktree</code> .
CouponRate	Decimal annual rate. <code>CouponRate</code> is a NINST-by-1 vector or NINST-by-1 cell array of decimal annual rates, or decimal annual rate schedules. For the latter case of a variable coupon schedule, each element of the cell array is a NumDates-by-2 cell array, where the first column is dates and the second column is its associated rate. The date indicates the last day that the coupon rate is valid.
Settle	NINST-by-1 matrix for the settlement date. A vector of serial date numbers or date strings. <code>Settle</code> must be earlier than <code>Maturity</code> .
Maturity	NINST-by-1 matrix for the maturity date. A vector of serial date numbers or date strings.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	European option: NINST-by-1 vector of strike price values.  Bermuda option: NINST by number of strikes (NSTRIKES) matrix of strike price values.  Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.  For an American option:



	NINST-by-1 vector of strike price values for each option.
<b>ExerciseDates</b>	<p>NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option:</p> <p>NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <b>ExerciseDates</b> is NINST-by-1, the option can be exercised between the underlying bond <b>Settle</b> and the single listed exercise date.</p>

'Name1', Value1, 'Name2', Value2 ...	<p>(Optional) The name/value pairs are a variable length list of parameters. All optional inputs are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. Parameter name/value pairs may be specified in any order; names are case insensitive and partial string matches are allowed provided no ambiguities exist. Valid parameter names are as follows:</p> <ul style="list-style-type: none"><li>• <b>AmericanOpt</b> is a NINST-by-1 matrix for flags options: 0 (European/Bermuda) or 1 (American). Default is 0.</li><li>• <b>Period</b> is a NINST-by-1 matrix for coupons per year. Default is 2.</li><li>• <b>Basis</b> is a day-count basis of the instrument. <b>Basis</b> is a vector of integers with the following supported values:<ul style="list-style-type: none"><li>• 0 = actual/actual (default)</li><li>• 1 = 30/360 (SIA)</li><li>• 2 = actual/360</li><li>• 3 = actual/365</li><li>• 4 = 30/360 (BMA)</li><li>• 5 = 30/360 (ISDA)</li><li>• 6 = 30/360 (European)</li><li>• 7 = actual/365 (Japanese)</li><li>• 8 = actual/actual (ICMA)</li><li>• 9 = actual/360 (ICMA)</li><li>• 10 = actual/365 (ICMA)</li><li>• 11 = 30/360E (ICMA)</li><li>• 12 = actual/actual (ISDA)</li><li>• 13 = BUS/252</li></ul></li></ul> <p>For more information, see <b>basis</b>.</p>
---	---

- **EndMonthRule** is a NINST-by-1 matrix for the end-of-month rule. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days. When the value is 0, the end-of-month rule is ignored, meaning that a bond's coupon payment date is always the same numerical day of the month. When the value is 1, the end-of-month rule is set on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
- **IssueDate** is a NINST-by-1 matrix for the bond issue date.
- **FirstCouponDate** is a NINST-by-1 matrix for a date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When **FirstCouponDate** and **LastCouponDate** are both specified, **FirstCouponDate** takes precedence in determining the coupon payment structure. If you do not specify a **FirstCouponDate**, the cash flow payment dates are determined from other inputs.
- **LastCouponDate** is a NINST-by-1 matrix for a last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified **FirstCouponDate**, a specified **LastCouponDate** determines the coupon structure of the bond. The coupon structure of a bond is truncated at the **LastCouponDate**, regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a **LastCouponDate**, the cash flow payment dates are determined from other inputs.
- **StartDate** is a NINST-by-1 matrix for date when a bond actually starts (the date from which a bond cash flow is considered). To make an instrument forward-starting, specify this date as a future date. If you do not specify **StartDate**, the effective start date is the **Settle** date.
- **Face value.** **Face** is a NINST-by-1 vector or NINST-by-1 cell array of face values, or face value schedules.

For the latter case, each element of the cell array is a `NumDates`-by-2 cell array, where the first column is dates and the second column is its associated face value. The date indicates the last day that the face value is valid. Default is 100.

- `Options` is a derivatives pricing options structure created with `derivset`.

---

**Note:** The `Settle` date for every bond with embedded option is set to the `ValuationDate` of the `BKTree`; the bond's argument for `Settle` date is ignored.

---

## Description

`[Price, PriceTree] = optembndbybk(BKTree, CouponRate, Settle, Maturity, OptSpec, Strike, Strike, ExerciseDates, 'Name1', Value1, 'Name2', Value2, ...)` prices bonds with embedded options by a BK interest-rate tree.

`Price` is a number of instruments (`NINST`)-by-1 matrix of expected prices at time 0.

`PriceTree` is a structure of trees containing vectors of instrument prices and observation times for each node. Within `PriceTree`:

- `PriceTree.PTree` contains the clean prices.
- `PriceTree.tObs` contains the observation times.

`optembndbybk` computes prices of vanilla bonds with embedded options, stepped coupon bonds with embedded options, and bonds with sinking fund option provisions.

## Examples

### Price a Callable Bond Using a BK Interest-Rate Tree Model

Create a `BKTree` with the following data:

```
ZeroRates = [ 0.035;0.04;0.045];
Compounding = 1;
StartDates = [ 'jan-1-2007'; 'jan-1-2008'; 'jan-1-2009' ];
EndDates    = [ 'jan-1-2008'; 'jan-1-2009'; 'jan-1-2010' ];
```

```
ValuationDate = 'jan-1-2007';
```

Create a RateSpec.

```
RateSpec = intenvset('Rates', ZeroRates, 'StartDates', ValuationDate, 'EndDates', ...
EndDates, 'Compounding', Compounding, 'ValuationDate', ValuationDate)
```

```
RateSpec =
```

```

    FinObj: 'RateSpec'
  Compounding: 1
        Disc: [3x1 double]
        Rates: [3x1 double]
    EndTimes: [3x1 double]
  StartTimes: [3x1 double]
    EndDates: [3x1 double]
  StartDates: 733043
ValuationDate: 733043
        Basis: 0
  EndMonthRule: 1
```

Create a VolSpec.

```
VolDates = ['jan-1-2008'; 'jan-1-2009'; 'jan-1-2010'];
```

```
VolCurve = 0.01;
```

```
AlphaDates = 'jan-1-2010';
```

```
AlphaCurve = 0.1;
```

```
BKVolSpec = bkvolspec(ValuationDate, VolDates, VolCurve, AlphaDates, AlphaCurve)
```

```
BKVolSpec =
```

```

    FinObj: 'BKVolSpec'
ValuationDate: 733043
    VolDates: [3x1 double]
    VolCurve: [3x1 double]
  AlphaCurve: 0.1000
  AlphaDates: 734139
VolInterpMethod: 'linear'
```

Create a TimeSpec.

```
BKTimeSpec = bktimespec(ValuationDate, EndDates, Compounding);
```

Build the BKTree.

```
BKTree = bktree(BKVolSpec, RateSpec, BKTimeSpec)
```

```
BKTree =
```

```
    FinObj: 'BKFwdTree'  
    VolSpec: [1x1 struct]  
    TimeSpec: [1x1 struct]  
    RateSpec: [1x1 struct]  
        tObs: [0 1 2]  
        dObs: [733043 733408 733774]  
    CFlowT: {[3x1 double] [2x1 double] [3]}  
    Probs: {[3x1 double] [3x3 double]}  
    Connect: {[2] [2 3 4]}  
    FwdTree: {[1.0350] [1.0458 1.0450 1.0443] [1x5 double]}
```

To compute the price of an American puttable bond that pays an annual coupon of 5.25% , matures on January 1, 2010, and is callable on January 1, 2008 and January 1, 2010.

```
BondSettlement = 'jan-1-2007';  
BondMaturity   = 'jan-1-2010';  
CouponRate    = 0.0525;  
Period        = 1;  
OptSpec       = 'put';  
Strike        = [100];  
ExerciseDates = {'jan-1-2008' '01-Jan-2010'};  
AmericanOpt   = 1;  
  
PricePutBondBK = optembndbybk(BKTree, CouponRate, BondSettlement, BondMaturity,...  
    OptSpec, Strike, ExerciseDates, 'Period', 1, 'AmericanOpt', 1)  
  
PricePutBondBK =  
  
    102.3820
```

### Price Single Stepped Callable Bonds Using a BK Interest-Rate Tree Model

Price the following single stepped callable bonds using the following data: The data for the interest rate term structure is as follows:

```

Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2010';
StartDates = ValuationDate;
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};
Compounding = 1;

% Create RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% Instrument
Settle = '01-Jan-2010';
Maturity = {'01-Jan-2013'; '01-Jan-2014'};
CouponRate = {'01-Jan-2012' .0425; '01-Jan-2014' .0750};;
OptSpec='call';
Strike=100;
ExerciseDates='01-Jan-2012'; %Callable in two years

% Build the tree with the following data
VolDates = ['1-Jan-2011'; '1-Jan-2012'; '1-Jan-2013'; '1-Jan-2014'];
VolCurve = 0.01;
AlphaDates = '01-01-2014';
AlphaCurve = 0.1;

BKVolSpec = bkvolSpec(RS.ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);
BKTimeSpec = bktimespec(RS.ValuationDate, VolDates, Compounding);
BKT = bktree(BKVolSpec, RS, BKTimeSpec);

% The first row corresponds to the price of the callable bond with maturity
% of three years. The second row corresponds to the price of the callable bond
% with maturity of four years.
PBK= optembndbybk(BKT, CouponRate, Settle, Maturity ,OptSpec, Strike,...
ExerciseDates, 'Period', 1)

PBK =

    100.0945
    100.0945

```

## More About

### Vanilla Bond with Embedded Option

A vanilla coupon bond is a security representing an obligation to repay a borrowed amount at a designated time and to make periodic interest payments until that time. The issuer of a bond makes the periodic interest payments until the bond matures. At maturity, the issuer pays to the holder of the bond the principal amount owed (face value) and the last interest payment. A vanilla bond with an embedded option is where an option contract has an underlying asset of a vanilla bond.

### Stepped Coupon Bond with Callable and Puttable Features

A step-up and step-down bond is a debt security with a predetermined coupon structure over time. With these instruments, coupons increase (step up) or decrease (step down) at specific times during the life of the bond. Stepped coupon bonds can have options features (call and puts).

### Sinking Fund Bond with Embedded Option

A sinking fund bond is a coupon bond with a sinking fund provision. This provision obligates the issuer to amortize portions of the principal prior to maturity, affecting bond prices since the time of the principal repayment changes. This means that investors receive the coupon and a portion of the principal paid back over time. These types of bonds reduce credit risk, since it lowers the probability of investors not receiving their principal payment at maturity.

The bond may have a sinking fund option provision allowing the issuer to retire the sinking fund obligation either by purchasing the bonds to be redeemed from the market or by calling the bond via a sinking fund call, whichever is cheaper. If interest rates are high, then the issuer will buy back the requirement amount of bonds from the market since bonds will be cheap, but if interest rates are low (bond prices are high), then most likely the issuer will be buying the bonds at the call price. Unlike a call feature, however, if a bond has a sinking fund option provision, it is an obligation, not an option, for the issuer to buy back the increments of the issue as stated. Because of this, a sinking fund bond trades at a lower price than a non-sinking fund bond.

- “Pricing Options Structure”



**See Also**

bkprice | bktree | cfamounts | instoptembnd

## optembndbyhjm

Price bonds with embedded options by Heath-Jarrow-Morton interest-rate tree

### Syntax

```
[Price, PriceTree] = optembndbyhjm(HJMTTree, CouponRate,
Settle, Maturity, OptSpec, Strike, ExerciseDates,
'Name1', Value1, 'Name2', Value2, ...)
```

### Arguments

HJMTTree	Interest-rate tree structure created by <code>hjmtree</code> .
CouponRate	Decimal annual rate. <code>CouponRate</code> is a NINST-by-1 vector or NINST-by-1 cell array of decimal annual rates, or decimal annual rate schedules. For the latter case of a variable coupon schedule, each element of the cell array is a NumDates-by-2 cell array, where the first column is dates and the second column is its associated rate. The date indicates the last day that the coupon rate is valid.
Settle	NINST-by-1 matrix for the settlement date. A vector of serial date numbers or date strings. <code>Settle</code> must be earlier than <code>Maturity</code> .
Maturity	NINST-by-1 matrix for the maturity date. A vector of serial date numbers or date strings.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	European option: NINST-by-1 vector of strike price values.  Bermuda option: NINST by number of strikes (NSTRIKES) matrix of strike price values.  Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.  For an American option:

	NINST-by-1 vector of strike price values for each option.
<b>ExerciseDates</b>	<p>NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option:</p> <p>NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <b>ExerciseDates</b> is NINST-by-1, the option can be exercised between the underlying bond <b>Settle</b> and the single listed exercise date.</p>

<p>'Name1', Value1, 'Name2', Value2 ...</p>	<p>(Optional) The name/value pairs are a variable length list of parameters. All optional inputs are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. Parameter name/value pairs may be specified in any order; names are case insensitive and partial string matches are allowed provided no ambiguities exist. Valid parameter names are as follows:</p> <ul style="list-style-type: none"> <li>• <b>AmericanOpt</b> is a NINST-by-1 matrix for flags options: 0 (European/Bermuda) or 1 (American). Default is 0.</li> <li>• <b>Period</b> is a NINST-by-1 matrix for coupons per year. Default is 2.</li> <li>• <b>Basis</b> is a day-count basis of the instrument. <b>Basis</b> is a vector of integers with the following supported values: <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> </li> </ul> <p>For more information, see <b>basis</b>.</p>
---	--

- **EndMonthRule** is a NINST-by-1 matrix for the end-of-month rule. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days. When the value is 0, the end-of-month rule is ignored, meaning that a bond's coupon payment date is always the same numerical day of the month. When the value is 1, the end-of-month rule is set on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
- **IssueDate** is a NINST-by-1 matrix for the bond issue date.
- **FirstCouponDate** is a NINST-by-1 matrix for a date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When **FirstCouponDate** and **LastCouponDate** are both specified, **FirstCouponDate** takes precedence in determining the coupon payment structure. If you do not specify a **FirstCouponDate**, the cash flow payment dates are determined from other inputs.
- **LastCouponDate** is a NINST-by-1 matrix for a last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified **FirstCouponDate**, a specified **LastCouponDate** determines the coupon structure of the bond. The coupon structure of a bond is truncated at the **LastCouponDate**, regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a **LastCouponDate**, the cash flow payment dates are determined from other inputs.
- **StartDate** is a NINST-by-1 matrix for date when a bond actually starts (the date from which a bond cash flow is considered). To make an instrument forward-starting, specify this date as a future date. If you do not specify **StartDate**, the effective start date is the **Settle** date.
- **Face value.** **Face** is a NINST-by-1 vector or NINST-by-1 cell array of face values, or face value schedules.

For the latter case, each element of the cell array is a `NumDates`-by-2 cell array, where the first column is dates and the second column is its associated face value. The date indicates the last day that the face value is valid. Default is 100.

- `Options` is a derivatives pricing options structure created with `derivset`.

---

**Note:** The `Settle` date for every bond with embedded option is set to the `ValuationDate` of the HJM tree; the bond's argument for `Settle` date is ignored.

---

## Description

`[Price, PriceTree] = optembndbyhjm(HJMTree, CouponRate, Settle, Maturity, OptSpec, Strike, ExerciseDates, 'Name1', Value1, 'Name2', Value2, ...)` prices bonds with embedded options by an HJM interest-rate tree.

`Price` is a number of instruments (`NINST`)-by-1 matrix of expected prices at time 0.

`PriceTree` is a structure of trees containing vectors of instrument prices and observation times for each node. Within `PriceTree`:

- `PriceTree.PBush` contains the clean prices.
- `PriceTree.tObs` contains the observation times.

`optembndbyhjm` computes prices of vanilla bonds with embedded options, stepped coupon bonds with embedded options, and bonds with sinking fund option provisions.

## Examples

### Price a Callable Bond Using an HJM Interest-Rate Tree Model

Create a `HJMTree` with the following data:

```
Rates = [0.05;0.06;0.07];  
Compounding = 1;
```

```

StartDates = ['jan-1-2007'; 'jan-1-2008'; 'jan-1-2009'];
EndDates   = ['jan-1-2008'; 'jan-1-2009'; 'jan-1-2010'];
ValuationDate = 'jan-1-2007';

```

Create a RateSpec.

```

RateSpec = intenvset('Rates', Rates, 'StartDates', ValuationDate, 'EndDates', ...
EndDates, 'Compounding', Compounding, 'ValuationDate', ValuationDate)

```

RateSpec =

```

    FinObj: 'RateSpec'
  Compounding: 1
        Disc: [3x1 double]
        Rates: [3x1 double]
    EndTimes: [3x1 double]
    StartTimes: [3x1 double]
        EndDates: [3x1 double]
    StartDates: 733043
  ValuationDate: 733043
        Basis: 0
  EndMonthRule: 1

```

Create a VolSpec.

```

VolSpec = hjmvolspec('Constant', 0.01)

```

VolSpec =

```

    FinObj: 'HJMVolSpec'
  FactorModels: {'Constant'}
  FactorArgs: {{1x1 cell}}
  SigmaShift: 0
  NumFactors: 1
  NumBranch: 2
    PBranch: [0.5000 0.5000]
  Fact2Branch: [-1 1]

```

Create a TimeSpec.

```

TimeSpec = hjmtimespec(ValuationDate, EndDates, Compounding)

```

```
TimeSpec =
    FinObj: 'HJMTimeSpec'
    ValuationDate: 733043
    Maturity: [3x1 double]
    Compounding: 1
    Basis: 0
    EndMonthRule: 1
```

Build the HJMTree.

```
HJMTree = hjmtree(VolSpec, RateSpec, TimeSpec)
```

```
HJMTree =
    FinObj: 'HJMFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
    tObs: [0 1 2]
    dObs: [733043 733408 733774]
    TFwd: {[3x1 double] [2x1 double] [2]}
    CFlowT: {[3x1 double] [2x1 double] [3]}
    FwdTree: {[3x1 double] [2x1x2 double] [1x2x2 double]}
```

To compute the price of an American callable bond that pays a 6% annual coupon and matures and is callable on January 1, 2010.

```
BondSettlement = 'jan-1-2007';
BondMaturity = 'jan-1-2010';
CouponRate = 0.06;
Period = 1;
OptSpec = 'call';
Strike = [98];
ExerciseDates = '01-Jan-2010';
AmericanOpt = 1;

[PriceCallBond,PT] = optembndbyhjm(HJMTree, CouponRate, BondSettlement, BondMaturity, .
OptSpec, Strike, ExerciseDates, 'Period', 1, 'AmericanOp', 1)
```



```
PriceCallBond =
```

```
    95.9492
```

```
PT =
```

```
    FinObj: 'HJMPriceTree'
         tObs: [0 1 2 3]
         PBush: {[95.9492] [1x1x2 double] [1x2x2 double] [98 98 98 98]}
```

### Price Single Stepped Callable Bonds Using an HJM Interest-Rate Tree Model

Price the following single stepped callable bonds using the following data: The data for the interest rate term structure is as follows:

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2010';
StartDates = ValuationDate;
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};
Compounding = 1;

% Create RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% Instrument
Settle = '01-Jan-2010';
Maturity = {'01-Jan-2013'; '01-Jan-2014'};
CouponRate = {'01-Jan-2012' .0425; '01-Jan-2014' .0750};;
OptSpec='call';
Strike=100;
ExerciseDates='01-Jan-2012'; %Callable in two years

% Build the tree with the following data
Volatility = [.2; .19; .18; .17];
CurveTerm = [ 1; 2; 3; 4];
HJMTimeSpec = hjmtimespec(ValuationDate, EndDates);
HJMVolSpec = hjmvolspec('Proportional', Volatility, CurveTerm, 1e6);
HJMT = hjmtree(HJMVolSpec, RS, HJMTimeSpec);

% The first row corresponds to the price of the callable bond with maturity
% of three years. The second row corresponds to the price of the callable
% bond with maturity of four years.
```

```
PHJM= optembndbyhjm(HJMT, CouponRate, Settle, Maturity ,OptSpec, Strike,...  
ExerciseDates, 'Period', 1)
```

```
PHJM =
```

```
100.0484  
99.8009
```

### Price a Sinking Fund Bond Using an HJM Interest-Rate Tree Model

A corporation issues a three year bond with a sinking fund obligation requiring the company to sink 1/3 of face value after the first year and 1/3 after the second year. The company has the option to buy the bonds in the market or call them at \$99. The following data describes the details needed for pricing the sinking fund bond:

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];  
ValuationDate = 'Jan-1-2011';  
StartDates = ValuationDate;  
EndDates = {'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'};  
Compounding = 1;
```

Create the RateSpec.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates',...  
StartDates, 'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'  
  Compounding: 1  
        Disc: [4x1 double]  
        Rates: [4x1 double]  
    EndTimes: [4x1 double]  
  StartTimes: [4x1 double]  
    EndDates: [4x1 double]  
  StartDates: 734504  
  ValuationDate: 734504  
        Basis: 0  
  EndMonthRule: 1
```

Build the HJM tree.

```

Sigma = 0.1;
HJMTimeSpec = hjmtimespec(ValuationDate, EndDates, Compounding);
HJMVolSpec = hjmvolspec('Constant', Sigma);
HJMT = hjmtree(HJMVolSpec, RateSpec, HJMTimeSpec)

```

```
HJMT =
```

```

    FinObj: 'HJMFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
    tObs: [0 1 2 3]
    dObs: [734504 734869 735235 735600]
    TFwd: {[4x1 double] [3x1 double] [2x1 double] [3]}
    CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4]}
    FwdTree: {[4x1 double] [3x1x2 double] [2x2x2 double] [1x4x2 double]}

```

Define the sinking fund instrument. The bond has a coupon rate of 4.5%, a period of one year and matures in 1-Jan-2013. Face decreases 1/3 after the first year.

```

CouponRate = 0.045;
Settle = 'Jan-1-2011';
Maturity = 'Jan-1-2013';
Period = 1;
Face = { {'Jan-1-2012' 100; ...
         'Jan-1-2013' 66.6666}};

```

Define the option provision.

```

OptSpec = 'call';
Strike = 99;
ExerciseDates = 'Jan-1-2012';

```

Price of non-sinking fund bond.

```
PNSF = bondbyhjm(HJMT, CouponRate, Settle, Maturity, Period)
```

```
PNSF =
```

```
100.5663
```

Price of the bond with the option sinking provision.

```
PriceSF = optembndbyhjm(HJMT, CouponRate, Settle, Maturity,...  
OptSpec, Strike, ExerciseDates, 'Period', Period, 'Face', Face)
```

```
PriceSF =  
98.8736
```

## More About

### Vanilla Bond with Embedded Option

A vanilla coupon bond is a security representing an obligation to repay a borrowed amount at a designated time and to make periodic interest payments until that time. The issuer of a bond makes the periodic interest payments until the bond matures. At maturity, the issuer pays to the holder of the bond the principal amount owed (face value) and the last interest payment. A vanilla bond with an embedded option is where an option contract has an underlying asset of a vanilla bond.

### Stepped Coupon Bond with Callable and Puttable Features

A step-up and step-down bond is a debt security with a predetermined coupon structure over time. With these instruments, coupons increase (step up) or decrease (step down) at specific times during the life of the bond. Stepped coupon bonds can have options features (call and puts).

### Sinking Fund Bond with Embedded Option

A sinking fund bond is a coupon bond with a sinking fund provision. This provision obligates the issuer to amortize portions of the principal prior to maturity, affecting bond prices since the time of the principal repayment changes. This means that investors receive the coupon and a portion of the principal paid back over time. These types of bonds reduce credit risk, since it lowers the probability of investors not receiving their principal payment at maturity.

The bond may have a sinking fund option provision allowing the issuer to retire the sinking fund obligation either by purchasing the bonds to be redeemed from the market or by calling the bond via a sinking fund call, whichever is cheaper. If interest rates are high, then the issuer will buy back the requirement amount of bonds from the market since bonds will be cheap, but if interest rates are low (bond prices are high), then most

likely the issuer will be buying the bonds at the call price. Unlike a call feature, however, if a bond has a sinking fund option provision, it is an obligation, not an option, for the issuer to buy back the increments of the issue as stated. Because of this, a sinking fund bond trades at a lower price than a non-sinking fund bond.

- “Pricing Options Structure”

### **See Also**

cfamounts | hjmprice | hjmtree | instoptembnd

## optembndbyhw

Price bonds with embedded options by Hull-White interest-rate tree

### Syntax

```
[Price, PriceTree] = optembndbyhw(HWTree, CouponRate,
Settle, Maturity, OptSpec, Strike, ExerciseDates,
'Name1', Value1, 'Name2', Value2, ...)
```

### Arguments

HWTree	Interest-rate tree structure created by <code>hwtree</code> .
CouponRate	Decimal annual rate. <code>CouponRate</code> is a NINST-by-1 vector or NINST-by-1 cell array of decimal annual rates, or decimal annual rate schedules. For the latter case of a variable coupon schedule, each element of the cell array is a NumDates-by-2 cell array, where the first column is dates and the second column is its associated rate. The date indicates the last day that the coupon rate is valid.
Settle	NINST-by-1 matrix for the settlement date. A vector of serial date numbers or date strings. <code>Settle</code> must be earlier than <code>Maturity</code> .
Maturity	NINST-by-1 matrix for the maturity date. A vector of serial date numbers or date strings.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	<p>European option: NINST-by-1 vector of strike price values.</p> <p>Bermuda option: NINST by number of strikes (NSTRIKES) matrix of strike price values.</p> <p>Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.</p> <p>For an American option:</p>

	NINST-by-1 vector of strike price values for each option.
ExerciseDates	<p>NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option:</p> <p>NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if ExerciseDates is NINST-by-1, the option can be exercised between the underlying bond <b>Settle</b> and the single listed exercise date.</p>

<pre>'Name1', Value1 'Name2', Value2 ...</pre>	<p>(Optional) The name/value pairs are a variable length list of parameters. All optional inputs are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. Parameter name/value pairs may be specified in any order; names are case insensitive and partial string matches are allowed provided no ambiguities exist. Valid parameter names are as follows:</p> <ul style="list-style-type: none"> <li>• <b>AmericanOpt</b> is a NINST-by-1 matrix for flags options: 0 (European/Bermuda) or 1 (American). Default is 0.</li> <li>• <b>Period</b> is a NINST-by-1 matrix for coupons per year. Default is 2.</li> <li>• <b>Basis</b> is a day-count basis of the instrument. <b>Basis</b> is a vector of integers with the following supported values: <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> </li> </ul> <p>For more information, see <b>basis</b>.</p>
--	--



- **EndMonthRule** is a NINST-by-1 matrix for the end-of-month rule. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days. When the value is 0, the end-of-month rule is ignored, meaning that a bond's coupon payment date is always the same numerical day of the month. When the value is 1, the end-of-month rule is set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
- **IssueDate** is a NINST-by-1 matrix for the bond issue date.
- **FirstCouponDate** is a NINST-by-1 matrix for a date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When **FirstCouponDate** and **LastCouponDate** are both specified, **FirstCouponDate** takes precedence in determining the coupon payment structure. If you do not specify a **FirstCouponDate**, the cash flow payment dates are determined from other inputs.
- **LastCouponDate** is a NINST-by-1 matrix for a last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified **FirstCouponDate**, a specified **LastCouponDate** determines the coupon structure of the bond. The coupon structure of a bond is truncated at the **LastCouponDate**, regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a **LastCouponDate**, the cash flow payment dates are determined from other inputs.
- **StartDate** is a NINST-by-1 matrix for date when a bond actually starts (the date from which a bond cash flow is considered). To make an instrument forward-starting, specify this date as a future date. If you do not specify **StartDate**, the effective start date is the **Settle** date.
- **Face value.** **Face** is a NINST-by-1 vector or NINST-by-1 cell array of face values, or face value schedules.

For the latter case, each element of the cell array is a `NumDates`-by-2 cell array, where the first column is dates and the second column is its associated face value. The date indicates the last day that the face value is valid. Default is 100.

- `Options` is a derivatives pricing options structure created with `derivset`.

---

**Note:** The `Settle` date for every bond with embedded option is set to the `ValuationDate` of the HW tree; the bond's argument for `Settle` date is ignored.

---

## Description

`[Price, PriceTree] = optembndbyhw(HWTree, CouponRate, Settle, Maturity, OptSpec, Strike, ExerciseDates, 'Name1', Value1, 'Name2', Value2, ...)` prices bonds with embedded options by a HW interest-rate tree.

`Price` is a number of instruments (`NINST`)-by-1 matrix of expected prices at time 0.

`PriceTree` is a structure of trees containing vectors of instrument prices and observation times for each node. Within `PriceTree`:

- `PriceTree.PTree` contains the clean prices.
- `PriceTree.tObs` contains the observation times.

`optembndbyhw` computes prices of vanilla bonds with embedded options, stepped coupon bonds with embedded options, and bonds with sinking fund option provisions.

## Examples

### Price a Callable Bond Using an HW Interest-Rate Tree Model

Create a `HWTtree` with the following data:

```
ZeroRates = [ 0.035;0.04;0.045];
```

```

Compounding = 1;
StartDates = ['jan-1-2007'; 'jan-1-2008'; 'jan-1-2009'];
EndDates    = ['jan-1-2008'; 'jan-1-2009'; 'jan-1-2010'];
ValuationDate = 'jan-1-2007';

```

Create a RateSpec.

```

RateSpec = intenvset('Rates', ZeroRates, 'StartDates', ValuationDate, 'EndDates', ...
EndDates, 'Compounding', Compounding, 'ValuationDate', ValuationDate)

```

RateSpec =

```

    FinObj: 'RateSpec'
  Compounding: 1
        Disc: [3x1 double]
        Rates: [3x1 double]
    EndTimes: [3x1 double]
  StartTimes: [3x1 double]
    EndDates: [3x1 double]
  StartDates: 733043
ValuationDate: 733043
        Basis: 0
  EndMonthRule: 1

```

Create a VolSpec.

```

VolDates = ['jan-1-2008'; 'jan-1-2009'; 'jan-1-2010'];
VolCurve = 0.01;
AlphaDates = 'jan-1-2010';
AlphaCurve = 0.1;
HWVolSpec = hwwolspec(ValuationDate, VolDates, VolCurve, AlphaDates, AlphaCurve)

```

HWVolSpec =

```

    FinObj: 'HWVolSpec'
ValuationDate: 733043
    VolDates: [3x1 double]
    VolCurve: [3x1 double]
  AlphaCurve: 0.1000
  AlphaDates: 734139
VolInterpMethod: 'linear'

```

Create a `TimeSpec`.

```
HWTimeSpec = hwtimespec(ValuationDate, EndDates, Compounding)
```

```
HWTimeSpec =
```

```
    FinObj: 'HWTimeSpec'  
ValuationDate: 733043  
    Maturity: [3x1 double]  
    Compounding: 1  
    Basis: 0  
    EndMonthRule: 1
```

Build the `HWTree`.

```
HWTree = hwtree(HWVolSpec, RateSpec, HWTimeSpec)
```

```
HWTree =
```

```
    FinObj: 'HWFwdTree'  
    VolSpec: [1x1 struct]  
    TimeSpec: [1x1 struct]  
    RateSpec: [1x1 struct]  
    tObs: [0 1 2]  
    dObs: [733043 733408 733774]  
    CFlowT: {[3x1 double] [2x1 double] [3]}  
    Probs: {[3x1 double] [3x3 double]}  
    Connect: {[2] [2 3 4]}  
    FwdTree: {[1.0350] [1.0624 1.0451 1.0280] [1x5 double]}
```

Compute the price of an American puttable bond that pays an annual coupon of 5.25%, matures on January 1, 2010, and is puttable from January 1, 2008 to January 1, 2010.

```
BondSettlement = 'jan-1-2007';  
BondMaturity = 'jan-1-2010';  
CouponRate = 0.0525;  
Period = 1;  
OptSpec = 'put';  
Strike = [100];  
ExerciseDates = {'jan-1-2008' '01-Jan-2010'};  
AmericanOpt = 1;
```

```
PricePutBondHW = optembndbyhw(HWTree, CouponRate, BondSettlement, BondMaturity,...
OptSpec, Strike, ExerciseDates, 'Period', 1, 'AmericanOpt', 1)
```

```
PricePutBondHW =
    102.8801
```

### Price Single Stepped Callable Bonds Using an HW Interest-Rate Tree Model

Price the following single stepped callable bonds using the following data: The data for the interest rate term structure is as follows:

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2010';
StartDates = ValuationDate;
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'};
Compounding = 1;

% Create RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% Instrument
Settle = '01-Jan-2010';
Maturity = {'01-Jan-2013'; '01-Jan-2014'};
CouponRate = {'01-Jan-2012' .0425; '01-Jan-2014' .0750};
OptSpec='call';
Strike=100;
ExerciseDates='01-Jan-2012'; %Callable in two years

% Build the tree with the following data
VolDates = ['1-Jan-2011'; '1-Jan-2012'; '1-Jan-2013'; '1-Jan-2014'];
VolCurve = 0.01;
AlphaDates = '01-01-2014';
AlphaCurve = 0.1;

HWVolSpec = hwvolspec(RS.ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);
HWTimeSpec = hwtimespec(RS.ValuationDate, VolDates, Compounding);
HWT = hwtree(HWVolSpec, RS, HWTimeSpec);
```

```
% The first row corresponds to the price of the callable bond with maturity
% of three years. The second row corresponds to the price of the callable
% bond with maturity of four years.
```

```
PHW= optembndbyhw(HWT, CouponRate, Settle, Maturity,OptSpec, Strike,...
ExerciseDates, 'Period', 1)
```

```
PHW =
```

```
100.0521
 99.8322
```

### Price a Sinking Fund Bond Using an HW Interest-Rate Tree Model

A corporation issues a two year bond with a sinking fund obligation requiring the company to sink 1/3 of face value after the first year. The company has the option to buy the bonds in the market or call them at \$99. The following data describes the details needed for pricing the sinking fund bond:

```
Rates = [0.1;0.1;0.1;0.1];
ValuationDate = 'Jan-1-2011';
StartDates = ValuationDate;
EndDates = {'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'};
Compounding = 1;

% Create RateSpec
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates',...
StartDates, 'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% Build the HW tree
% The data to build the tree is as follows:
VolDates = ['1-Jan-2012'; '1-Jan-2013'; '1-Jan-2014'; '1-Jan-2015'];
VolCurve = 0.01;
AlphaDates = '01-01-2015';
AlphaCurve = 0.1;

HWVolSpec = hwwolspec(RateSpec.ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);
HWTTimeSpec = hwtimespec(RateSpec.ValuationDate, VolDates, Compounding);
HWT = hwtree(HWVolSpec, RateSpec, HWTTimeSpec);

% Instrument
```

```
% The bond has a coupon rate of 9%, a period of one year and matures in
% 1-Jan-2013. Face decreases 1/3 after the first year.
```

```
CouponRate = 0.09;
Settle = 'Jan-1-2011';
Maturity = 'Jan-1-2013';
Period = 1;
Face = { ...
        {'Jan-1-2012' 100; ...
         'Jan-1-2013' 66.6666}; ...
    };
```

```
% Option provision
OptSpec = 'call';
Strike = 99;
ExerciseDates = 'Jan-1-2012';
```

```
% Price of non-sinking fund bond.
```

```
PNSF = bondbyhw(HWT, CouponRate, Settle, Maturity, Period)
```

```
PNSF =
```

```
98.2645
```

Price of the bond with the option sinking provision.

```
PriceSF = optembndbyhw(HWT, CouponRate, Settle, Maturity,...
OptSpec, Strike, ExerciseDates, 'Period', Period, 'Face', Face)
```

```
PriceSF =
```

```
98.1594
```

## More About

### Vanilla Bond with Embedded Option

A vanilla coupon bond is a security representing an obligation to repay a borrowed amount at a designated time and to make periodic interest payments until that time. The issuer of a bond makes the periodic interest payments until the bond matures. At

maturity, the issuer pays to the holder of the bond the principal amount owed (face value) and the last interest payment. A vanilla bond with an embedded option is where an option contract has an underlying asset of a vanilla bond.

### **Stepped Coupon Bond with Callable and Puttable Features**

A step-up and step-down bond is a debt security with a predetermined coupon structure over time. With these instruments, coupons increase (step up) or decrease (step down) at specific times during the life of the bond. Stepped coupon bonds can have options features (call and puts).

### **Sinking Fund Bond with Embedded Option**

A sinking fund bond is a coupon bond with a sinking fund provision. This provision obligates the issuer to amortize portions of the principal prior to maturity, affecting bond prices since the time of the principal repayment changes. This means that investors receive the coupon and a portion of the principal paid back over time. These types of bonds reduce credit risk, since it lowers the probability of investors not receiving their principal payment at maturity.

The bond may have a sinking fund option provision allowing the issuer to retire the sinking fund obligation either by purchasing the bonds to be redeemed from the market or by calling the bond via a sinking fund call, whichever is cheaper. If interest rates are high, then the issuer will buy back the requirement amount of bonds from the market since bonds will be cheap, but if interest rates are low (bond prices are high), then most likely the issuer will be buying the bonds at the call price. Unlike a call feature, however, if a bond has a sinking fund option provision, it is an obligation, not an option, for the issuer to buy back the increments of the issue as stated. Because of this, a sinking fund bond trades at a lower price than a non-sinking fund bond.

- “Pricing Options Structure”

### **See Also**

`cfamounts` | `hwprice` | `hwtree` | `instoptembnd`



# optemfloatbybdt

Price embedded option on floating-rate note BDT interest-rate tree

## Syntax

Price = optemfloatbybdt(BDTree,Spread,Settle,Maturity,  
OptSpec,Strike,ExerciseDates)

Price = optemfloatbybdt(BDTree,Spread,Settle,Maturity,OptSpec,  
Strike,ExerciseDates,AmericanOpt,Reset,Basis,Principal,  
Options,EndMonthRule)

[Price,PriceTree] = optemfloatbybdt( \_\_\_ )

Price = optemfloatbybdt(BDTree,Spread,Settle,Maturity,OptSpec,  
Strike,ExerciseDates)

Price = optemfloatbybdt( \_\_\_ , Name,Value)

[Price,PriceTree] = optemfloatbybdt( \_\_\_ )

## Description

Price = optemfloatbybdt(BDTree,Spread,Settle,Maturity,  
OptSpec,Strike,ExerciseDates) returns the embedded option price of the  
instrument(s) at valuation date.

Price = optemfloatbybdt(BDTree,Spread,Settle,Maturity,OptSpec,  
Strike,ExerciseDates,AmericanOpt,Reset,Basis,Principal,  
Options,EndMonthRule) returns the embedded option price of the instrument(s) at  
valuation date using optional arguments.

[Price,PriceTree] = optemfloatbybdt( \_\_\_ ) returns the option price of the  
instrument(s) at valuation date and a structure of trees containing vectors of option  
prices at each node.

Price = optemfloatbybdt(BDTree,Spread,Settle,Maturity,OptSpec,  
Strike,ExerciseDates) returns the embedded option price of the instrument(s) at  
valuation date.

Price = optemfloatbybdt( \_\_\_ , Name,Value) returns the embedded option price  
of the instrument(s) at valuation date using optional name-value pair arguments.

[Price,PriceTree] = optemfloatbybdt( \_\_\_ ) returns the embedded option price of the instrument(s) at valuation date and a structure of trees containing vectors of option prices at each node using optional name-value pair arguments.

## Examples

### Price Callable Embedded Option for Floating-Rate Note

Define the interest-rate term structure.

```
Rates = [0.03;0.034;0.038;0.04];
ValuationDate = 'Jan-1-2012';
StartDates = ValuationDate;
EndDates = {'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'; 'Jan-1-2016'};
Compounding = 1;
```

Create the RateSpec.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates',...
StartDates, 'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
  Compounding: 1
        Disc: [4x1 double]
        Rates: [4x1 double]
    EndTimes: [4x1 double]
  StartTimes: [4x1 double]
    EndDates: [4x1 double]
  StartDates: 734869
ValuationDate: 734869
        Basis: 0
  EndMonthRule: 1
```

Build the BDT tree and assume a volatility of 10%.

```
Sigma = 0.1;
BDTTimeSpec = bdttimespec(ValuationDate, EndDates);
BDTVolSpec = bdtvolspec(ValuationDate, EndDates, Sigma*ones(1, length(EndDates)));
BDTT = bdttree(BDTVolSpec, RateSpec, BDTTimeSpec);
```

Define the floater instruments with the embedded call option.

```
Spread = 10;
Settle = 'Jan-1-2012';
Maturity = {'Jan-1-2015'; 'Jan-1-2016'};
Period = 1;
OptSpec = {'call'};
Strike = 101;
ExerciseDates = 'Jan-1-2015';
```

Compute the price of the floaters with the embedded call.

```
Price= optemfloatbybdt(BDTree, Spread, Settle, Maturity, OptSpec, Strike,...
ExerciseDates)
```

```
Price =
    100.2800
    100.3655
```

## Input Arguments

### **BDTree** — Interest-rate tree structure

binomial tree structure

Interest-rate tree specified as a structure by using `bdttree`.

Data Types: `struct`

### **Spread** — Number of basis points over the reference rate

nonnegative integer | vector of nonnegative integers

Number of basis points over the reference rate specified as a vector nonnegative integers for the number of instruments (NINST)-by-1).

Data Types: `single` | `double`

### **Settle** — Settlement dates of floating-rate note

ValuationDate of HW Tree (default) | nonnegative integer | vector of nonnegative integers

Settlement dates of floating-rate note specified as nonnegative integers using a NINST-by-1 vector of dates.

---

**Note:** The `Settle` date for every floating-rate note is set to the `ValuationDate` of the HW Tree. The floating-rate note argument `Settle` is ignored.

---

Data Types: `char`

### **OptSpec — Definition of option**

`string` | cell array of strings

Definition of option as 'call' or 'put' specified as a NINST-by-1 cell array of strings for 'call' or 'put'.

Data Types: `cell` | `char`

### **Strike — Option strike price values**

nonnegative integer | vector of nonnegative integers

Option strike price values specified nonnegative integers using as NINST-by-NSTRIKES vector of strike price values.

Data Types: `single` | `double`

### **ExerciseDates — Exercise date for option (European, Bermuda, or American)**

nonnegative integer | vector of nonnegative integers

Exercise date for option (European, Bermuda, or American) specified as nonnegative integers using a NINST-by-NSTRIKES or NINST-by-2 vector of for the option exercise dates.

- If a European or Bermuda option, the `ExerciseDates` is a 1-by-1 (European) or 1-by-NSTRIKES (Bermuda) vector of exercise dates. For a European option, there is only one `ExerciseDate` on the option expiry date.
- If an American option, then `ExerciseDates` is a 1-by-2 vector of exercise date boundaries. The option exercises on any date between or including the pair of dates on that row. If there is only one non-NaN date, or if `ExerciseDates` is 1-by-1, the option exercises between the `Settle` date and the single listed `ExerciseDate`.

Data Types: `char` | `cell`

**AmericanOpt — (Optional) Option type**

scalar | vector of positive integers[0, 1]

Option type specified as NINST-by-1 positive integer scalar flags with values:

- 0 — European/Bermuda
- 1 — American

Data Types: single | double

**Reset — (Optional) Frequency of payments per year**

1 (default) | positive integer from the set [1, 2, 3, 4, 6, 12] | vector of positive integers from the set [1, 2, 3, 4, 6, 12]

Frequency of payments per year specified as positive integers for the values [1, 2, 3, 4, 6, 12] in a NINST-by-1 vector.

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates can not be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

Data Types: double

**Basis — (Optional) Day-count basis of the instrument**

0 (actual/actual) (default) | positive integers of the set [1 . . . 13] | vector of positive integers of the set [1 . . . 13]

Day-count basis of the instrument specified as a positive integer using a NINST-by-1 vector. The **Basis** value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)

- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: `double`

**Principal** — (Optional) Principal values

100 (default) | vector of nonnegative values | cell array of nonnegative values

Principal values specified as nonnegative values using a `NINST`-by-1 vector or `NINST`-by-1 cell array of notional principal amounts. When using a `NINST`-by-1 cell array, each element is a `NumDates`-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: `double` | `cell`

**Options** — (Optional) Structure containing derivatives pricing options

structure

Structure containing derivatives pricing options specified using `derivset`.

Data Types: `struct`

**EndMonthRule** — (Optional) End-of-month rule flag

1 (in effect) (default) | nonnegative integer [0,1]

End-of-month rule flag is specified as nonnegative integer [0, 1] using a `NINST`-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.

- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: double

## Name-Value Pair Arguments

Specify optional comma-separated pairs of Name,Value arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes ( ' '). You can specify several name and value pair arguments in any order as Name1,Value1, . . . ,NameN,ValueN.

Example: Price =

optemfloatbybdt(BDTTree,Spread,Settle,Maturity,OptSpec,Strike,ExerciseDates,'A

### 'AmericanOpt' — Option type

scalar | vector of positive integers[0,1]

Option type specified as NINST-by-1 positive integer scalar flags with values:

- 0 — European/Bermuda
- 1 — American

Data Types: single | double

### 'Reset' — Frequency of payments per year

1 (default) | positive integer from the set [1,2,3,4,6,12] | vector of positive integers from the set [1,2,3,4,6,12]

Frequency of payments per year specified as positive integers for the values [1,2,3,4,6,12] in a NINST-by-1 vector.

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates can not be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

Data Types: char

**'Basis' — Day-count basis of the instrument**

0 (actual/actual) (default) | positive integers of the set [1...13] | vector of positive integers of the set [1...13]

Day-count basis of the instrument specified as a positive integer using a NINST-by-1 vector. The **Basis** value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: char

**'Principal' — (Optional) Principal values**

100 (default) | vector of nonnegative values | cell array of nonnegative values

Principal values specified as nonnegative values using a NINST-by-1 vector or NINST-by-1 cell array of notional principal amounts. When using a NINST-by-1 cell array, each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: double | cell

**'Options' — Structure containing derivatives pricing options**

structure



Structure containing derivatives pricing options specified using `derivset`.

Data Types: `struct`

**'EndMonthRule' — End-of-month rule flag**

1 (in effect) (default) | nonnegative integer [0,1]

End-of-month rule flag is specified as a nonnegative integer [0, 1] using a NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: `char`

## Output Arguments

**Price — Expected prices of the floating-rate note embedded option at time 0**

scalar | vector

Expected prices of the floating-rate note embedded option at time 0 is returned as a scalar or an NINST-by-1 vector.

**PriceTree — Structure of trees containing vectors of embedded option prices at each node**

tree structure

Structure of trees containing vectors of instrument prices and accrued interest and a vector of observation times for each node returned as:

- `PriceTree.PTree` contains embedded option prices.

## More About

- `basis`
- “Pricing Options Structure”

**See Also**

instoptemfloat | optembndbybdt | optemfloatbybk | optemfloatbyhjm |  
optemfloatbyhw

# optemfloatbybk

Price embedded option on floating-rate note BK interest-rate tree

## Syntax

```
Price = optemfloatbybk(BKTree,Spread,Settle,Maturity,
OptSpec,Strike,ExerciseDates)
Price = optemfloatbybk(BKTree,Spread,Settle,Maturity,OptSpec,
Strike,ExerciseDates,AmericanOpt,Reset,Basis,Principal,
Options,EndMonthRule)
[Price,PriceTree] = optemfloatbybk( ___ )
```

```
Price = optemfloatbybk(BKTree,Spread,Settle,Maturity,OptSpec,
Strike,ExerciseDates)
Price = optemfloatbybk( ___, Name,Value)
[Price,PriceTree] = optemfloatbybk( ___ )
```

## Description

Price = optemfloatbybk(BKTree,Spread,Settle,Maturity,OptSpec,Strike,ExerciseDates) returns the embedded option price of the instrument(s) at valuation date.

Price = optemfloatbybk(BKTree,Spread,Settle,Maturity,OptSpec,Strike,ExerciseDates,AmericanOpt,Reset,Basis,Principal,Options,EndMonthRule) returns the embedded option price of the instrument(s) at valuation date using optional arguments.

[Price,PriceTree] = optemfloatbybk( \_\_\_ ) returns the option price of the instrument(s) at valuation date and a structure of trees containing vectors of option prices at each node.

Price = optemfloatbybk(BKTree,Spread,Settle,Maturity,OptSpec,Strike,ExerciseDates) returns the embedded option price of the instrument(s) at valuation date.

`Price = optemfloatbybk( ____, Name, Value)` returns the embedded option price of the instrument(s) at valuation date using optional name-value pair arguments.

`[Price, PriceTree] = optemfloatbybk( ____, )` returns the embedded option price of the instrument(s) at valuation date and a structure of trees containing vectors of option prices at each node using optional name-value pair arguments.

## Examples

### Price European Callable Embedded Option for Floating-Rate Note

Define the interest-rate term structure.

```
Rates = [0.03;0.034;0.038;0.04];
ValuationDate = 'Jan-1-2012';
StartDates = ValuationDate;
EndDates = {'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'; 'Jan-1-2016'};
Compounding = 1;
```

Create the `RateSpec`.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', ...
StartDates, 'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

`RateSpec =`

```
    FinObj: 'RateSpec'
  Compounding: 1
        Disc: [4x1 double]
        Rates: [4x1 double]
    EndTimes: [4x1 double]
    StartTimes: [4x1 double]
    EndDates: [4x1 double]
    StartDates: 734869
  ValuationDate: 734869
        Basis: 0
  EndMonthRule: 1
```

Build the BK tree.

```

VolDates = ['1-Jan-2013'; '1-Jan-2014'; '1-Jan-2015'; '1-Jan-2016'];
VolCurve = 0.01;
AlphaDates = '01-01-2016';
AlphaCurve = 0.1;

BKVolSpec = bkvolspec(RateSpec.ValuationDate, VolDates, VolCurve,...
    AlphaDates, AlphaCurve);
BKTimeSpec = bktimespec(RateSpec.ValuationDate, VolDates, Compounding);
BKT = bktree(BKVolSpec, RateSpec, BKTimeSpec)

```

BKT =

```

    FinObj: 'BKFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
    tObs: [0 1 2 3]
    dObs: [734869 735235 735600 735965]
    CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4]}
    Probs: {[3x1 double] [3x3 double] [3x5 double]}
    Connect: {[2] [2 3 4] [2 2 3 4 4]}
    FwdTree: {[1.0300] [1.0387 1.0380 1.0374] [1x5 double] [1x5 double]}

```

The floater instrument has a spread of 15, a period of one year, and matures and is callable on Jan-1-2015.

```

Spread = 15;
Settle = 'Jan-1-2012';
Maturity = 'Jan-1-2015';
Period = 1;
OptSpec = {'call'};
Strike = 101;
ExerciseDates = 'Jan-1-2015';

```

Compute the price of the floater with the embedded call.

```

Price= optemfloatbybk(BKT, Spread, Settle, Maturity,...
    OptSpec, Strike, ExerciseDates)

```

Price =

100.4201

## Input Arguments

### **BKTree** — Interest-rate tree structure

binomial tree structure

Interest-rate tree specified as a structure by using `bktree`.

Data Types: `struct`

### **Spread** — Number of basis points over the reference rate

nonnegative integer | vector of nonnegative integers

Number of basis points over the reference rate specified as a vector nonnegative integers for the number of instruments (NINST)-by-1).

Data Types: `single` | `double`

### **Settle** — Settlement dates of floating-rate note

ValuationDate of HW Tree (default) | nonnegative integer | vector of nonnegative integers

Settlement dates of floating-rate note specified as nonnegative integers using a NINST-by-1 vector of dates.

---

**Note:** The `Settle` date for every floating-rate note is set to the `ValuationDate` of the HW Tree. The floating-rate note argument `Settle` is ignored.

---

Data Types: `char`

### **OptSpec** — Definition of option

string | cell array of strings

Definition of option as 'call' or 'put' specified as a NINST-by-1 cell array of strings for 'call' or 'put'.

Data Types: `cell` | `char`

### **Strike** — Option strike price values

nonnegative integer | vector of nonnegative integers

Option strike price values specified nonnegative integers using as NINST-by-NSTRIKES vector of strike price values.

Data Types: `single` | `double`

### **ExerciseDates** — Exercise date for option (European, Bermuda, or American)

nonnegative integer | vector of nonnegative integers

Exercise date for option (European, Bermuda, or American) specified as nonnegative integers using a NINST-by-NSTRIKES or NINST-by-2 vector of for the option exercise dates.

- If a European or Bermuda option, the `ExerciseDates` is a 1-by-1 (European) or 1-by-NSTRIKES (Bermuda) vector of exercise dates. For a European option, there is only one `ExerciseDate` on the option expiry date.
- If an American option, then `ExerciseDates` is a 1-by-2 vector of exercise date boundaries. The option exercises on any date between or including the pair of dates on that row. If there is only one non-NaN date, or if `ExerciseDates` is 1-by-1, the option exercises between the `Settle` date and the single listed `ExerciseDate`.

Data Types: `char` | `cell`

### **AmericanOpt** — (Optional) Option type

scalar | vector of positive integers[0,1]

Option type specified as NINST-by-1 positive integer scalar flags with values:

- 0 — European/Bermuda
- 1 — American

Data Types: `single` | `double`

### **Reset** — (Optional) Frequency of payments per year

1 (default) | positive integer from the set [1,2,3,4,6,12] | vector of positive integers from the set [1,2,3,4,6,12]

Frequency of payments per year specified as positive integers for the values [1,2,3,4,6,12] in a NINST-by-1 vector. .

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level,

calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates can not be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

Data Types: double

**Basis — (Optional) Day-count basis of the instrument**

0 (actual/actual) (default) | positive integers of the set [ 1 . . . 13 ] | vector of positive integers of the set [ 1 . . . 13 ]

Day-count basis of the instrument specified as a positive integer using a NINST-by-1 vector. The **Basis** value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: double

**Principal — (Optional) Principal values**

100 (default) | vector of nonnegative values | cell array of nonnegative values

Principal values specified as nonnegative values using a NINST-by-1 vector or NINST-by-1 cell array of notional principal amounts. When using a NINST-by-1 cell array, each



element is a `NumDates`-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: `double` | `cell`

### **Options** — (Optional) Structure containing derivatives pricing options

structure

Structure containing derivatives pricing options specified using `derivset`.

Data Types: `struct`

### **EndMonthRule** — (Optional) End-of-month rule flag

1 (in effect) (default) | nonnegative integer [0,1]

End-of-month rule flag is specified as nonnegative integer [0, 1] using a `NINST`-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: `double`

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, ..., NameN, ValueN`.

Example: `Price =`

`optemfloatbybk(BKTree, Spread, Settle, Maturity, OptSpec, Strike, ExerciseDates, 'Ame`

### **'AmericanOpt'** — Option type

scalar | vector of positive integers [0, 1]

Option type specified as `NINST`-by-1 positive integer scalar flags with values:

- 0 — European/Bermuda
- 1 — American

Data Types: single | double

**'Reset' — Frequency of payments per year**

1 (default) | positive integer from the set [1,2,3,4,6,12] | vector of positive integers from the set [1,2,3,4,6,12]

Frequency of payments per year specified as positive integers for the values [1,2,3,4,6,12] in a NINST-by-1 vector. .

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates can not be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

Data Types: char

**'Basis' — Day-count basis of the instrument**

0 (actual/actual) (default) | positive integers of the set [1...13] | vector of positive integers of the set [1...13]

Day-count basis of the instrument specified as a positive integer using a NINST-by-1 vector. The **Basis** value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)

- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: char

### 'Principal' — (Optional) Principal values

100 (default) | vector of nonnegative values | cell array of nonnegative values

Principal values specified as nonnegative values using a NINST-by-1 vector or NINST-by-1 cell array of notional principal amounts. When using a NINST-by-1 cell array, each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: double | cell

### 'Options' — Structure containing derivatives pricing options

structure

Structure containing derivatives pricing options specified using `derivset`.

Data Types: struct

### 'EndMonthRule' — End-of-month rule flag

1 (in effect) (default) | nonnegative integer [0,1]

End-of-month rule flag is specified as a nonnegative integer [0, 1] using a NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: char

## Output Arguments

### **Price** — Expected prices of the floating-rate note embedded option at time 0

scalar | vector

Expected prices of the floating-rate note embedded option at time 0 is returned as a scalar or an NINST-by-1 vector.

### **PriceTree** — Structure of trees containing vectors of embedded option prices at each node

tree structure

Structure of trees containing vectors of instrument prices and accrued interest and a vector of observation times for each node returned as:

- `PriceTree.PTree` contains embedded option prices.

## More About

- `basis`
- “Pricing Options Structure”

## See Also

`instoptemfloat` | `optembndbybk` | `optemfloatbybdt` | `optemfloatbyhjm` | `optemfloatbyhw`

# optemfloatbyhjm

Price embedded option on floating-rate note HJM interest-rate tree

## Syntax

```
Price = optemfloatbyhjm(HJMTree,Spread,Settle,Maturity,
OptSpec,Strike,ExerciseDates)
```

```
Price = optemfloatbyhjm(HJMTree,Spread,Settle,Maturity,OptSpec,
Strike,ExerciseDates,AmericanOpt,Reset,Basis,Principal,
Options,EndMonthRule)
```

```
[Price,PriceTree] = optemfloatbyhjm( ___ )
```

```
Price = optemfloatbyhjm(HJMTree,Spread,Settle,Maturity,OptSpec,
Strike,ExerciseDates)
```

```
Price = optemfloatbyhjm( ___ ,Name,Value)
```

```
[Price,PriceTree] = optemfloatbyhjm( ___ )
```

## Description

`Price = optemfloatbyhjm(HJMTree,Spread,Settle,Maturity,OptSpec,Strike,ExerciseDates)` returns the embedded option price of the instrument(s) at the valuation date.

`Price = optemfloatbyhjm(HJMTree,Spread,Settle,Maturity,OptSpec,Strike,ExerciseDates,AmericanOpt,Reset,Basis,Principal,Options,EndMonthRule)` returns the embedded option price of the instrument(s) at the valuation date using optional arguments.

`[Price,PriceTree] = optemfloatbyhjm( ___ )` returns the option price of the instrument(s) at the valuation date and a structure of trees containing vectors of option prices at each node.

`Price = optemfloatbyhjm(HJMTree,Spread,Settle,Maturity,OptSpec,Strike,ExerciseDates)` returns the embedded option price of the instrument(s) at the valuation date.

`Price = optemfloatbyhjm( ___ ,Name,Value)` returns the embedded option price of the instrument(s) at the valuation date using optional name-value pair arguments.

[Price,PriceTree] = optemfloatbyhjm( \_\_\_ ) returns the embedded option price of the instrument(s) at the valuation date and a structure of trees containing vectors of option prices at each node using optional name-value pair arguments.

## Examples

### Price European Callable Embedded Option for a Floating-Rate Note

Define the interest-rate term structure.

```
Rates = [0.03;0.035;0.040;0.045];
ValuationDate = 'Jan-1-2012';
StartDates = {'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'};
EndDates = {'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'; 'Jan-1-2016'};
Compounding = 1;
```

Create the RateSpec.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates',...
StartDates, 'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
  Compounding: 1
        Disc: [4x1 double]
        Rates: [4x1 double]
    EndTimes: [4x1 double]
  StartTimes: [4x1 double]
    EndDates: [4x1 double]
  StartDates: [4x1 double]
ValuationDate: 734869
          Basis: 0
  EndMonthRule: 1
```

Build the HJM tree.

```
VolSpec = hjmvolspec('Constant', 0.01);
TimeSpec = hjmtimespec(RateSpec.ValuationDate, EndDates, Compounding);
HJMTree = hjmtree(VolSpec, RateSpec, TimeSpec)
```

```
HJMTree =
    FinObj: 'HJMFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
        tObs: [0 1 2 3]
        dObs: [734869 735235 735600 735965]
        TFwd: {[4x1 double] [3x1 double] [2x1 double] [3]}
        CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4]}
        FwdTree: {[4x1 double] [3x1x2 double] [2x2x2 double] [1x4x2 double]}
```

The floater instrument has a spread of 15, a period of one year, and matures and is callable on Jan-1-2016.

```
Spread = 15;
Settle = 'Jan-1-2012';
Maturity = 'Jan-1-2016';
Period = 1;
OptSpec = {'call'};
Strike = 95;
ExerciseDates = 'Jan-1-2016';
```

Compute the price of the floater with the embedded call.

```
Price = optemfloatbyhjm(HJMTree, Spread, Settle, Maturity, ...
    OptSpec, Strike, ExerciseDates)
```

```
Price =
    96.2355
```

## Input Arguments

### **HJMTree** — Interest-rate tree structure

binomial tree structure

Interest-rate tree, specified as a structure by using `hjmTree`.

Data Types: `struct`

**Spread — Number of basis points over reference rate**

nonnegative integer | vector of nonnegative integers

Number of basis points over the reference rate, specified as a vector of nonnegative integers for the number of instruments (NINST)-by-1).

Data Types: single | double

**Settle — Settlement dates of floating-rate note**

ValuationDate of HW tree (default) | nonnegative integer | vector of nonnegative integers

Settlement dates of floating-rate note, specified as nonnegative integers using a NINST-by-1 vector of dates.

---

**Note:** The **Settle** date for every floating-rate note is set to the **ValuationDate** of the HW tree. The floating-rate note argument **Settle** is ignored.

---

Data Types: char

**OptSpec — Option definition**

string | cell array of strings

Option definition specified as a 'call' or 'put' using a NINST-by-1 cell array of strings.

Data Types: cell | char

**Strike — Option strike price values**

nonnegative integer | vector of nonnegative integers

Option strike price values, specified as nonnegative integers using a NINST-by-NSTRIKES vector of strike price values.

Data Types: single | double

**ExerciseDates — Exercise date for European, Bermuda, or American option**

nonnegative integer | vector of nonnegative integers

Exercise date for European, Bermuda, or American option, specified as nonnegative integers using a NINST-by-NSTRIKES or NINST-by-2 vector of option exercise dates.



- For a European or Bermuda option, `ExerciseDates` is a 1-by-1 (European) or 1-by-NSTRIKES (Bermuda) vector of exercise dates. For a European option, there is only one `ExerciseDate` on the option expiry date.
- For an American option, `ExerciseDates` is a 1-by-2 vector of exercise date boundaries. The option exercises on any date between or including the pair of dates on that row. If there is only one non-NaN date, or if `ExerciseDates` is 1-by-1, the option exercises between the `Settle` date and the single listed `ExerciseDate`.

Data Types: char | cell

### **AmericanOpt — (Optional) Option type**

scalar | vector of positive integers[0, 1]

Option type, specified as NINST-by-1 positive integer flags with values:

- 0 — European/Bermuda
- 1 — American

Data Types: single | double

### **Reset — (Optional) Frequency of payments per year**

1 (default) | positive integer from the set [1, 2, 3, 4, 6, 12] | vector of positive integers from the set [1, 2, 3, 4, 6, 12]

Frequency of payments per year, specified as positive integers for the values [1, 2, 3, 4, 6, 12] in a NINST-by-1 vector.

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates cannot be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

Data Types: double

### **Basis — (Optional) Day-count basis of instrument**

0 (actual/actual) (default) | positive integers of the set [1...13] | vector of positive integers of the set [1...13]

Day-count basis of the instrument, specified as a positive integer using a `NINST-by-1` vector. The `Basis` value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: `double`

#### **Principal** — (Optional) Principal values

100 (default) | vector of nonnegative values | cell array of nonnegative values

Principal values specified as nonnegative values using a `NINST-by-1` vector or `NINST-by-1` cell array of notional principal amounts. When using a `NINST-by-1` cell array, each element is a `NumDates-by-2` cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: `double` | `cell`

#### **Options** — (Optional) Structure containing derivatives pricing options

structure

Structure containing derivatives pricing options, specified using `derivset`.

Data Types: `struct`

**EndMonthRule — (Optional) End-of-month rule flag**

1 (in effect) (default) | nonnegative integer [0, 1]

End-of-month rule flag, specified as nonnegative integer 0 or 1 using a NINST-by-1 vector. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: double

**Name-Value Pair Arguments**

Specify optional comma-separated pairs of **Name**,**Value** arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as **Name1**,**Value1**, . . . ,**NameN**,**ValueN**.

Example: Price =

optemfloatbyhjm(HJMTree,Spread,Settle,Maturity,OptSpec,Strike,ExerciseDates,'A

**'AmericanOpt' — Option type**

scalar | vector of positive integers[0, 1]

Option type, specified as NINST-by-1 positive integer scalar flags with values:

- 0 — European/Bermuda
- 1 — American

Data Types: single | double

**'Reset' — Frequency of payments per year**

1 (default) | positive integer from the set [1, 2, 3, 4, 6, 12] | vector of positive integers from the set [1, 2, 3, 4, 6, 12]

Frequency of payments per year, specified as positive integers for the values [1, 2, 3, 4, 6, 12] in a NINST-by-1 vector.

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates cannot be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

Data Types: char

**'Basis' — Day-count basis of instrument**

0 (actual/actual) (default) | positive integers of the set [ 1 . . . 13 ] | vector of positive integers of the set [ 1 . . . 13 ]

Day-count basis of the instrument, specified as a positive integer using a NINST-by-1 vector. The **Basis** value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: char

**'Principal' — (Optional) Principal values**

100 (default) | vector of nonnegative values | cell array of nonnegative values

Principal values specified as nonnegative values using a NINST-by-1 vector or NINST-by-1 cell array of notional principal amounts. When using a NINST-by-1 cell array, each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: double | cell

### 'Options' — Structure containing derivatives pricing options

structure

Structure containing derivatives pricing options specified using `derivset`.

Data Types: struct

### 'EndMonthRule' — End-of-month rule flag

1 (in effect) (default) | nonnegative integer [0, 1]

End-of-month rule flag, specified as a nonnegative integer [0, 1] using a NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: char

## Output Arguments

### Price — Expected prices of floating-rate note embedded option at time 0

scalar | vector

Expected prices of the floating-rate note embedded option at time 0, returned as a scalar or a NINST-by-1 vector.

### PriceTree — Structure of trees containing vectors of embedded option prices at each node

tree structure

Structure of trees containing vectors of instrument prices and accrued interest and a vector of observation times for each node, returned as:

- `PriceTree.PTree` contains embedded option prices.

### More About

- `basis`
- “Pricing Options Structure”

### See Also

`instoptemfloat` | `optembndbyhjm` | `optemfloatbybdt` | `optemfloatbybk` | `optemfloatbyhw`

# optemfloatbyhw

Price embedded option on floating-rate note HW interest-rate tree

## Syntax

```
Price = optemfloatbyhw(HWTree,Spread,Settle,Maturity,
OptSpec,Strike,ExerciseDates)
Price = optemfloatbyhw(HWTree,Spread,Settle,Maturity,OptSpec,
Strike,ExerciseDates,AmericanOpt,Reset,Basis,Principal,
Options,EndMonthRule)
[Price,PriceTree] = optemfloatbyhw( ___ )
```

```
Price = optemfloatbyhw(HWTree,Spread,Settle,Maturity,OptSpec,
Strike,ExerciseDates)
Price = optemfloatbyhw( ___,Name,Value)
[Price,PriceTree] = optemfloatbyhw( ___ )
```

## Description

Price = optemfloatbyhw(HWTree,Spread,Settle,Maturity,OptSpec,Strike,ExerciseDates) returns the embedded option price of the instrument(s) at the valuation date.

Price = optemfloatbyhw(HWTree,Spread,Settle,Maturity,OptSpec,Strike,ExerciseDates,AmericanOpt,Reset,Basis,Principal,Options,EndMonthRule) returns the embedded option price of the instrument(s) at the valuation date using optional arguments.

[Price,PriceTree] = optemfloatbyhw( \_\_\_ ) returns the option price of the instrument(s) at the valuation date and a structure of trees containing vectors of option prices at each node.

Price = optemfloatbyhw(HWTree,Spread,Settle,Maturity,OptSpec,Strike,ExerciseDates) returns the embedded option price of the instrument(s) at the valuation date.

`Price = optemfloatbyhw( ____, Name, Value)` returns the embedded option price of the instrument(s) at the valuation date using optional name-value pair arguments.

`[Price, PriceTree] = optemfloatbyhw( ____, ...)` returns the embedded option price of the instrument(s) at the valuation date and a structure of trees containing vectors of option prices at each node using optional name-value pair arguments.

## Examples

### Price European Callable Embedded Option for Floating-Rate Note

Define the interest-rate term structure.

```
Rates = [0.03;0.034;0.038;0.04];
ValuationDate = 'Jan-1-2012';
StartDates = ValuationDate;
EndDates = {'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'; 'Jan-1-2016'};
Compounding = 1;
```

Create the `RateSpec`.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', ...
StartDates, 'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

`RateSpec =`

```
    FinObj: 'RateSpec'
  Compounding: 1
        Disc: [4x1 double]
        Rates: [4x1 double]
    EndTimes: [4x1 double]
    StartTimes: [4x1 double]
    EndDates: [4x1 double]
    StartDates: 734869
  ValuationDate: 734869
        Basis: 0
  EndMonthRule: 1
```

Build the HW tree using the following:



```

VolDates = ['1-Jan-2013'; '1-Jan-2014'; '1-Jan-2015'; '1-Jan-2016'];
VolCurve = 0.01;
AlphaDates = '01-01-2016';
AlphaCurve = 0.1;

HWVolSpec = hwwolspec(RateSpec.ValuationDate, VolDates, VolCurve,...
    AlphaDates, AlphaCurve);
HWTTimeSpec = hwtimespec(RateSpec.ValuationDate, VolDates, Compounding);
HWT = hwtree(HWVolSpec, RateSpec, HWTTimeSpec)

```

HWT =

```

    FinObj: 'HWFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
    tObs: [0 1 2 3]
    dObs: [734869 735235 735600 735965]
    CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4]}
    Probs: {[3x1 double] [3x3 double] [3x5 double]}
    Connect: {[2] [2 3 4] [2 2 3 4 4]}
    FwdTree: {[1.0300] [1.0553 1.0381 1.0211] [1x5 double] [1x5 double]}

```

Define the floater instruments with the embedded call option.

```

Spread = 10;
Settle = 'Jan-1-2012';
Maturity = {'Jan-1-2015'; 'Jan-1-2016'};
Period = 1;
OptSpec = {'call'};
Strike = 101;
ExerciseDates = 'Jan-1-2015';

```

Compute the price of the floaters with the embedded call.

```

Price= optemfloatbyhw(HWT, Spread, Settle, Maturity, OptSpec, Strike,...
    ExerciseDates)

```

Price =

```

    100.2800
    100.3655

```

## Input Arguments

### **HWTree** — Interest-rate tree structure

binomial tree structure

Interest-rate tree, specified as a structure by using `hwtree`.

Data Types: `struct`

### **Spread** — Number of basis points over reference rate

nonnegative integer | vector of nonnegative integers

Number of basis points over the reference rate, specified as a vector of nonnegative integers for the number of instruments (NINST)-by-1).

Data Types: `single` | `double`

### **Settle** — Settlement dates of floating-rate note

ValuationDate of HW tree (default) | nonnegative integer | vector of nonnegative integers

Settlement dates of the floating-rate note, specified as nonnegative integers using a NINST-by-1 vector of dates.

---

**Note:** The `Settle` date for every floating-rate note is set to the `ValuationDate` of the HW tree. The floating-rate note argument `Settle` is ignored.

---

Data Types: `char`

### **OptSpec** — Option definition

string | cell array of strings

Option definition, specified as 'call' or 'put' using a NINST-by-1 cell array of strings.

Data Types: `cell` | `char`

### **Strike** — Option strike price values

nonnegative integer | vector of nonnegative integers

Option strike price values specified as nonnegative integers using a NINST-by-NSTRIKES vector of strike price values.

Data Types: `single` | `double`

### **ExerciseDates** — Exercise date for option European, Bermuda, or American option

nonnegative integer | vector of nonnegative integers

Exercise date for European, Bermuda, or American option, specified as nonnegative integers using a NINST-by-NSTRIKES or NINST-by-2 vector of option exercise dates.

- For a European or Bermuda option, `ExerciseDates` is a 1-by-1 (European) or 1-by-NSTRIKES (Bermuda) vector of exercise dates. For a European option, there is only one `ExerciseDate` on the option expiry date.
- For an American option, `ExerciseDates` is a 1-by-2 vector of exercise date boundaries. The option exercises on any date between or including the pair of dates on that row. If there is only one non-NaN date, or if `ExerciseDates` is 1-by-1, the option exercises between the `Settle` date and the single listed `ExerciseDate`.

Data Types: `char` | `cell`

### **AmericanOpt** — (Optional) Option type

scalar | vector of positive integers [0,1]

Option type, specified as NINST-by-1 positive integer scalar flags with values:

- 0 — European/Bermuda
- 1 — American

Data Types: `single` | `double`

### **Reset** — (Optional) Frequency of payments per year

1 (default) | positive integer from the set [1,2,3,4,6,12] | vector of positive integers from the set [1,2,3,4,6,12]

Frequency of payments per year specified as positive integers for the values [1,2,3,4,6,12] in a NINST-by-1 vector.

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree.

That is, the tree path connecting the two consecutive reset dates cannot be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

Data Types: double

**Basis — (Optional) Day-count basis of instrument**

0 (actual/actual) (default) | positive integers of the set [ 1 . . . 13 ] | vector of positive integers of the set [ 1 . . . 13 ]

Day-count basis of the instrument, specified as a positive integer using a NINST-by-1 vector. The **Basis** value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: double

**Principal — (Optional) Principal values**

100 (default) | vector of nonnegative values | cell array of nonnegative values

Principal values specified as nonnegative values using a NINST-by-1 vector or NINST-by-1 cell array of notional principal amounts. When using a NINST-by-1 cell array, each

element is a `NumDates`-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: `double` | `cell`

### **Options** — (Optional) Structure containing derivatives pricing options

structure

Structure containing derivatives pricing options, specified using `derivset`.

Data Types: `struct`

### **EndMonthRule** — (Optional) End-of-month rule flag

1 (in effect) (default) | nonnegative integer [0,1]

End-of-month rule flag, specified as nonnegative integer [0,1] using a `NINST`-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: `double`

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`,`Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, ..., NameN, ValueN`.

Example: `Price =`

`optemfloatbyhw(HWTree,Spread,Settle,Maturity,OptSpec,Strike,ExerciseDates,'Ame`

### **'AmericanOpt'** — Option type

scalar | vector of positive integers[0,1]

Option type, specified as `NINST`-by-1 positive integer scalar flags with values:

- 0 — European/Bermuda
- 1 — American

Data Types: single | double

**'Reset' — Frequency of payments per year**

1 (default) | positive integer from the set [1, 2, 3, 4, 6, 12] | vector of positive integers from the set [1, 2, 3, 4, 6, 12]

Frequency of payments per year, specified as positive integers for the values [1, 2, 3, 4, 6, 12] in a NINST-by-1 vector.

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates cannot be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

Data Types: char

**'Basis' — Day-count basis of instrument**

0 (actual/actual) (default) | positive integers of the set [1 . . . 13] | vector of positive integers of the set [1 . . . 13]

Day-count basis of the instrument, specified as a positive integer using a NINST-by-1 vector. The **Basis** value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)

- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: char

### 'Principal' — (Optional) Principal values

100 (default) | vector of nonnegative values | cell array of nonnegative values

Principal values specified as nonnegative values using a NINST-by-1 vector or NINST-by-1 cell array of notional principal amounts. When using a NINST-by-1 cell array, each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: double | cell

### 'Options' — Structure containing derivatives pricing options

structure

Structure containing derivatives pricing options, specified using `derivset`.

Data Types: struct

### 'EndMonthRule' — End-of-month rule flag

1 (in effect) (default) | nonnegative integer [0, 1]

End-of-month rule flag, specified as a nonnegative integer[0, 1] using a NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: char

## Output Arguments

### **Price** — Expected prices of floating-rate note embedded option at time 0

scalar | vector

Expected prices of the floating-rate note embedded option at time 0, returned as a scalar or an NINST-by-1 vector.

### **PriceTree** — Structure of trees containing vectors of embedded option prices at each node

tree structure

Structure of trees containing vectors of instrument prices and accrued interest and a vector of observation times for each node, returned as:

- `PriceTree.PTree` contains embedded option prices.

## More About

- `basis`
- “Pricing Options Structure”

## See Also

`instoptemfloat` | `optembndbyhw` | `optemfloatbybdt` | `optemfloatbybk` | `optemfloatbyhjm`



# optfloatbybdt

Price options on floating-rate notes for BDT interest-rate tree

## Syntax

```
Price = optfloatbybdt(BDTree,OptSpec,Strike,ExerciseDates,
AmericanOpt,
Spread,Settle,Maturity)
Price = optfloatbybdt(BDTree,OptSpec,Strike,ExerciseDates,
AmericanOpt,
Spread,Settle,Maturity,Reset,Basis,Principal,Options,EndMonthRule)
[Price,PriceTree] = optfloatbybdt( ___ )
```

```
Price = optfloatbybdt(BDTree,OptSpec,Strike,ExerciseDates,
AmericanOpt,
Spread,Settle,Maturity)
Price = optfloatbybdt( ___, Name,Value)
[Price,PriceTree] = optfloatbybdt( ___ )
```

## Description

`Price = optfloatbybdt(BDTree,OptSpec,Strike,ExerciseDates, AmericanOpt, Spread,Settle,Maturity)` returns the option price of the instrument(s) at valuation date.

`Price = optfloatbybdt(BDTree,OptSpec,Strike,ExerciseDates, AmericanOpt, Spread,Settle,Maturity,Reset,Basis,Principal,Options,EndMonthRule)` returns the option price of the instrument(s) at valuation date using optional arguments.

`[Price,PriceTree] = optfloatbybdt( ___ )` returns the option price of the instrument(s) at valuation date and a structure of trees containing vectors of option prices at each node.

```
Price = optfloatbybdt(BDTree,OptSpec,Strike,ExerciseDates,
AmericanOpt,
```



Build the BDT tree and assume a volatility of 10%.

```
Sigma = 0.1;
BDTTimeSpec = bdttimespec(ValuationDate, EndDates);
BDTVolSpec = bdtvolspec(ValuationDate, EndDates, Sigma*ones(1, length(EndDates)));
BDTT = bdttree(BDTVolSpec, RateSpec, BDTTimeSpec)
```

BDTT =

```
    FinObj: 'BDTFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
      tObs: [0 1 2 3]
      dObs: [734869 735235 735600 735965]
      TFwd: {[4x1 double] [3x1 double] [2x1 double] [3]}
      CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4]}
      FwdTree: {1x4 cell}
```

The floater instrument has a spread of 10, a period of one year, and matures on Jan-1-2016.

```
Spread = 10;
Settle = 'Jan-1-2012';
Maturity = 'Jan-1-2016';
Period = 1;
```

Define the option for the floating-rate note.

```
OptSpec = {'call'; 'put'};
Strike = [100;101];
ExerciseDates = 'Jan-1-2015';
AmericanOpt = 1;
```

Compute the price of the call and put options.

```
Price= optfloatbybdt(BDTT, OptSpec, Strike, ExerciseDates,AmericanOpt, Spread,...
Settle, Maturity)
```

Price =

```
    0.3655
    0.8087
```

## Input Arguments

### **BDTTree** — Interest-rate tree structure

binomial tree structure

Interest-rate tree specified as a structure by using `bdttree`.

Data Types: `struct`

### **OptSpec** — Definition of option

string | cell array of strings

Definition of option as 'call' or 'put' specified as a NINST-by-1 cell array of strings for 'call' or 'put'.

Data Types: `cell` | `char`

### **Strike** — Option strike price values

nonnegative integer | vector of nonnegative integers

Option strike price values specified nonnegative integers using as NINST-by-NSTRIKES vector of strike price values.

Data Types: `single` | `double`

### **ExerciseDates** — Exercise date for option (European, Bermuda, or American)

nonnegative integer | vector of nonnegative integers

Exercise date for option (European, Bermuda, or American) specified as nonnegative integers using a NINST-by-NSTRIKES or NINST-by-2 vector of for the option exercise dates.

- If a European or Bermuda option, the `ExerciseDates` is a 1-by-1 (European) or 1-by-NSTRIKES (Bermuda) vector of exercise dates. For a European option, there is only one `ExerciseDate` on the option expiry date.
- If an American option, then `ExerciseDates` is a 1-by-2 vector of exercise date boundaries. The option exercises on any date between or including the pair of dates on that row. If there is only one non-NaN date, or if `ExerciseDates` is 1-by-1, the option exercises between the `Settle` date and the single listed `ExerciseDate`.

Data Types: `char` | `cell`

**AmericanOpt — Option type**

scalar | vector of positive integers[0, 1]

Option type specified as NINST-by-1 positive integer scalar flags with values:

- 0 — European/Bermuda
- 1 — American

Data Types: single | double

**Spread — Number of basis points over the reference rate**

nonnegative integer | vector of nonnegative integers

Number of basis points over the reference rate specified as a vector nonnegative integers for the number of instruments (NINST)-by-1).

Data Types: single | double

**Settle — Settlement dates of floating-rate note**

ValuationDate of HW Tree (default) | nonnegative integer | vector of nonnegative integers

Settlement dates of floating-rate note specified as nonnegative integers using a NINST-by-1 vector of dates.

---

**Note:** The **Settle** date for every floating-rate note is set to the **ValuationDate** of the HW Tree. The floating-rate note argument **Settle** is ignored.

---

Data Types: char

**Maturity — Floating-rate note maturity date**

nonnegative integer | vector of nonnegative integers

Floating-rate note maturity date specified as nonnegative integers using a NINST-by-1 vector of dates.

Data Types: char

**Reset — (Optional) Frequency of payments per year**

1 (default) | positive integer from the set [1, 2, 3, 4, 6, 12] | vector of positive integers from the set [1, 2, 3, 4, 6, 12]

Frequency of payments per year specified as positive integers for the values [ 1, 2, 3, 4, 6, 12 ] in a NINST-by-1 vector.

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates can not be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

Data Types: double

**Basis — (Optional) Day-count basis of the instrument**

0 (actual/actual) (default) | positive integers of the set [ 1 . . . 13 ] | vector of positive integers of the set [ 1 . . . 13 ]

Day-count basis of the instrument specified as a positive integer using a NINST-by-1 vector. The **Basis** value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: double

### **Principal — (Optional) Principal values**

100 (default) | vector of nonnegative values | cell array of nonnegative values

Principal values specified as nonnegative values using a NINST-by-1 vector or NINST-by-1 cell array of notional principal amounts. When using a NINST-by-1 cell array, each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: double | cell

### **Options — (Optional) Structure containing derivatives pricing options**

structure

Structure containing derivatives pricing options specified using `derivset`.

Data Types: struct

### **EndMonthRule — (Optional) End-of-month rule flag**

1 (in effect) (default) | nonnegative integer [0,1]

End-of-month rule flag is specified as nonnegative integer [0, 1] using a NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: double

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

Example: `Price=`

`optfloatbybdt(BDTree,OptSpec,Strike,ExerciseDates,AmericanOpt,Spread,Settle,M`

**'Reset' — Frequency of payments per year**

1 (default) | positive integer from the set [1,2,3,4,6,12] | vector of positive integers from the set [1,2,3,4,6,12]

Frequency of payments per year specified as positive integers for the values [1,2,3,4,6,12] in a NINST-by-1 vector.

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates can not be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

Data Types: char

**'Basis' — Day-count basis of the instrument**

0 (actual/actual) (default) | positive integers of the set [1...13] | vector of positive integers of the set [1...13]

Day-count basis of the instrument specified as a positive integer using a NINST-by-1 vector. The **Basis** value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)



- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: char

#### 'Principal' — (Optional) Principal values

100 (default) | vector of nonnegative values | cell array of nonnegative values

Principal values specified as nonnegative values using a NINST-by-1 vector or NINST-by-1 cell array of notional principal amounts. When using a NINST-by-1 cell array, each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: double | cell

#### 'Principal' — Principal values

100 (default) | nonnegative integer | vector of nonnegative integers

Principal values specified as a nonnegative integer using a NINST-by-1 vector of notional principal amounts.

Data Types: char

#### 'Options' — Structure containing derivatives pricing options

structure

Structure containing derivatives pricing options specified using `derivset`.

Data Types: struct

#### 'EndMonthRule' — End-of-month rule flag

1 (in effect) (default) | nonnegative integer [0,1]

End-of-month rule flag is specified as a nonnegative integer [0, 1] using a NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: char

## Output Arguments

### **Price** — Expected prices of the floating-rate note option at time 0

scalar | vector

Expected prices of the floating-rate note option at time 0 is returned as a scalar or an NINST-by-1 vector.

### **PriceTree** — Structure of trees containing vectors of option prices at each node

tree structure

Structure of trees containing vectors of instrument prices and accrued interest and a vector of observation times for each node returned as:

- `PriceTree.PTree` contains option prices.

## More About

- `basis`
- “Pricing Options Structure”

## See Also

`bdttree` | `bondbybdt` | `capbybdt` | `cfbybdt` | `floatbybdt` | `floorbybdt` | `instoptfloat` | `swapbybdt`

# optfloatbybk

Price options on floating-rate notes for BK interest-rate tree

## Syntax

```
Price = optfloatbybk(BKTree,OptSpec,Strike,ExerciseDates,
AmericanOpt,
Spread,Settle,Maturity)
Price = optfloatbybk(BKTree,OptSpec,Strike,ExerciseDates,
AmericanOpt,
Spread,Settle,Maturity,Reset,Basis,Principal,Options,EndMonthRule)
[Price,PriceTree] = optfloatbybk( ___ )
```

```
Price = optfloatbybk(BKTree,OptSpec,Strike,ExerciseDates,
AmericanOpt,
Spread,Settle,Maturity)
Price = optfloatbybk( ___ , Name,Value)
[Price,PriceTree] = optfloatbybk( ___ )
```

## Description

Price = optfloatbybk(BKTree,OptSpec,Strike,ExerciseDates, AmericanOpt, Spread,Settle,Maturity) returns the option price of the instrument(s) at valuation date.

Price = optfloatbybk(BKTree,OptSpec,Strike,ExerciseDates, AmericanOpt, Spread,Settle,Maturity,Reset,Basis,Principal,Options,EndMonthRule) returns the option price of the instrument(s) at valuation date using optional arguments.

[Price,PriceTree] = optfloatbybk( \_\_\_ ) returns the option price of the instrument(s) at valuation date and a structure of trees containing vectors of option prices at each node.

```
Price = optfloatbybk(BKTree,OptSpec,Strike,ExerciseDates,
AmericanOpt,
```

`Spread,Settle,Maturity)` returns the option price of the instrument(s) at valuation date.

`Price = optfloatbybk( ____, Name,Value)` returns the option price of the instrument(s) at valuation date using optional Name-Value pairs.

`[Price,PriceTree] = optfloatbybk( ____)` returns the option price of the instrument(s) at valuation date and a structure of trees containing vectors of option prices at each node using optional name-value pair arguments.

## Examples

### Compute the Price of American and European Call Options on a Floating-Rate Note

Define the interest-rate term structure.

```
Rates = [0.03;0.034;0.038;0.04];
ValuationDate = 'Jan-1-2012';
StartDates = ValuationDate;
EndDates = {'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'; 'Jan-1-2016'};
Compounding = 1;
```

Create the `RateSpec`.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

`RateSpec =`

```
    FinObj: 'RateSpec'
  Compounding: 1
        Disc: [4x1 double]
        Rates: [4x1 double]
    EndTimes: [4x1 double]
  StartTimes: [4x1 double]
    EndDates: [4x1 double]
  StartDates: 734869
ValuationDate: 734869
        Basis: 0
  EndMonthRule: 1
```

Build the BK tree.

```
VolDates = ['1-Jan-2013'; '1-Jan-2014'; '1-Jan-2015'; '1-Jan-2016'];
VolCurve = 0.01;
AlphaDates = '01-01-2016';
AlphaCurve = 0.1;

HWVolSpec = hwwolspec(RateSpec.ValuationDate, VolDates, VolCurve,...
                    AlphaDates, AlphaCurve);
HWTTimeSpec = hwtimespec(RateSpec.ValuationDate, VolDates, Compounding);
HWT = hwtree(HWVolSpec, RateSpec, HWTTimeSpec)
```

HWT =

```
    FinObj: 'HWFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
    tObs: [0 1 2 3]
    dObs: [734869 735235 735600 735965]
    CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4]}
    Probs: {[3x1 double] [3x3 double] [3x5 double]}
    Connect: {[2] [2 3 4] [2 2 3 4 4]}
    FwdTree: {[1.0300] [1.0553 1.0381 1.0211] [1x5 double] [1x5 double]}
```

The floater instrument has a spread of 10, a period of one year, and matures on Jan-1-2016.

```
Spread = 10;
Settle = 'Jan-1-2012';
Maturity = 'Jan-1-2016';
Period = 1;
```

Define the option for the floating-rate note.

```
OptSpec = {'call'};
Strike = 95;
ExerciseDates = 'Jan-1-2016';
AmericanOpt = [0;1];
```

Compute the price of the call options.

```
Price= optfloatbyhw(HWT, OptSpec, Strike, ExerciseDates,AmericanOpt,...
Spread, Settle, Maturity)
```

```
Price =  
  
    4.2740  
    5.3655
```

## Input Arguments

### **BKTree** — Interest-rate tree structure

binomial tree structure

Interest-rate tree specified as a structure by using `bktree`.

Data Types: `struct`

### **OptSpec** — Definition of option

string | cell array of strings

Definition of option as 'call' or 'put' specified as a NINST-by-1 cell array of strings for 'call' or 'put'.

Data Types: `cell` | `char`

### **Strike** — Option strike price values

nonnegative integer | vector of nonnegative integers

Option strike price values specified nonnegative integers using as NINST-by-NSTRIKES vector of strike price values.

Data Types: `single` | `double`

### **ExerciseDates** — Exercise date for option (European, Bermuda, or American)

nonnegative integer | vector of nonnegative integers

Exercise date for option (European, Bermuda, or American) specified as nonnegative integers using a NINST-by-NSTRIKES or NINST-by-2 vector of for the option exercise dates.

- If a European or Bermuda option, the `ExerciseDates` is a 1-by-1 (European) or 1-by-NSTRIKES (Bermuda) vector of exercise dates. For a European option, there is only one `ExerciseDate` on the option expiry date.

- If an American option, then `ExerciseDates` is a 1-by-2 vector of exercise date boundaries. The option exercises on any date between or including the pair of dates on that row. If there is only one non-NaN date, or if `ExerciseDates` is 1-by-1, the option exercises between the `Settle` date and the single listed `ExerciseDate`.

Data Types: char | cell

### **AmericanOpt** — Option type

scalar | vector of positive integers[0, 1]

Option type specified as NINST-by-1 positive integer scalar flags with values:

- 0 — European/Bermuda
- 1 — American

Data Types: single | double

### **Spread** — Number of basis points over the reference rate

nonnegative integer | vector of nonnegative integers

Number of basis points over the reference rate specified as a vector nonnegative integers for the number of instruments (NINST)-by-1).

Data Types: single | double

### **Settle** — Settlement dates of floating-rate note

ValuationDate of HW Tree (default) | nonnegative integer | vector of nonnegative integers

Settlement dates of floating-rate note specified as nonnegative integers using a NINST-by-1 vector of dates.

---

**Note:** The `Settle` date for every floating-rate note is set to the `ValuationDate` of the HW Tree. The floating-rate note argument `Settle` is ignored.

---

Data Types: char

### **Maturity** — Floating-rate note maturity date

nonnegative integer | vector of nonnegative integers

Floating-rate note maturity date specified as nonnegative integers using a NINST-by-1 vector of dates.

Data Types: char

**Reset — (Optional) Frequency of payments per year**

1 (default) | positive integer from the set [1, 2, 3, 4, 6, 12] | vector of positive integers from the set [1, 2, 3, 4, 6, 12]

Frequency of payments per year specified as positive integers for the values [1, 2, 3, 4, 6, 12] in a NINST-by-1 vector.

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates can not be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

Data Types: double

**Basis — (Optional) Day-count basis of the instrument**

0 (actual/actual) (default) | positive integers of the set [1 . . . 13] | vector of positive integers of the set [1 . . . 13]

Day-count basis of the instrument specified as a positive integer using a NINST-by-1 vector. The **Basis** value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)



- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: double

### **Principal — (Optional) Principal values**

100 (default) | vector of nonnegative values | cell array of nonnegative values

Principal values specified as nonnegative values using a NINST-by-1 vector or NINST-by-1 cell array of notional principal amounts. When using a NINST-by-1 cell array, each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: double | cell

### **Options — (Optional) Structure containing derivatives pricing options**

structure

Structure containing derivatives pricing options specified using `derivset`.

Data Types: struct

### **EndMonthRule — (Optional) End-of-month rule flag**

1 (in effect) (default) | nonnegative integer [0,1]

End-of-month rule flag is specified as nonnegative integer [0, 1] using a NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: double

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single

quotes ( ' ' ). You can specify several name and value pair arguments in any order as Name1, Value1, . . . , NameN, ValueN.

Example: Price=

optfloatbybk(BKTTree, OptSpec, Strike, ExerciseDates, AmericanOpt, Spread, Settle, Ma

**'Reset' — Frequency of payments per year**

1 (default) | positive integer from the set [1, 2, 3, 4, 6, 12] | vector of positive integers from the set [1, 2, 3, 4, 6, 12]

Frequency of payments per year specified as positive integers for the values 1, 2, 3, 4, 6, 12] in a NINST-by-1 vector.

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates can not be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

Data Types: char

**'Basis' — Day-count basis of the instrument**

0 (actual/actual) (default) | positive integers of the set [1 . . . 13] | vector of positive integers of the set [1 . . . 13]

Day-count basis of the instrument specified as a positive integer using a NINST-by-1 vector. The Basis value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)

- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: char

### 'Principal' — (Optional) Principal values

100 (default) | vector of nonnegative values | cell array of nonnegative values

Principal values specified as nonnegative values using a NINST-by-1 vector or NINST-by-1 cell array of notional principal amounts. When using a NINST-by-1 cell array, each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: double | cell

### 'Options' — Structure containing derivatives pricing options

structure

Structure containing derivatives pricing options specified using `derivset`.

Data Types: struct

### 'EndMonthRule' — End-of-month rule flag

1 (in effect) (default) | nonnegative integer [0,1]

End-of-month rule flag is specified as a nonnegative integer [0, 1] using a NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: char

## Output Arguments

### **Price** — Expected prices of the floating-rate note option at time 0

scalar | vector

Expected prices of the floating-rate note option at time 0 is returned as a scalar or an NINST-by-1 vector.

### **PriceTree** — Structure of trees containing vectors of option prices at each node

tree structure

Structure of trees containing vectors of instrument prices and accrued interest and a vector of observation times for each node returned as:

- `PriceTree.PTree` contains option prices.

## More About

- `basis`
- “Pricing Options Structure”

## See Also

`bktree` | `bondbybk` | `capbybk` | `cfbybk` | `floatbybk` | `floorbybk` | `instoptfloat`  
| `swapbybk`

# optfloatbyhjm

Price options on floating-rate notes for HJM interest-rate tree

## Syntax

```
Price = optfloatbyhjm(HJMTree,OptSpec,Strike,ExerciseDates,
AmericanOpt,
Spread,Settle,Maturity)
Price = optfloatbyhjm(HJMTree,OptSpec,Strike,ExerciseDates,
AmericanOpt,
Spread,Settle,Maturity,Reset,Basis,Principal,Options,EndMonthRule)
[Price,PriceTree] = optfloatbyhjm( ___ )
```

```
Price = optfloatbyhjm(HJMTree,OptSpec,Strike,ExerciseDates,
AmericanOpt,
Spread,Settle,Maturity)
Price = optfloatbyhjm( ___ , Name,Value)
[Price,PriceTree] = optfloatbyhjm( ___ )
```

## Description

`Price = optfloatbyhjm(HJMTree,OptSpec,Strike,ExerciseDates, AmericanOpt, Spread,Settle,Maturity)` returns the option price of the instrument(s) at valuation date.

`Price = optfloatbyhjm(HJMTree,OptSpec,Strike,ExerciseDates, AmericanOpt, Spread,Settle,Maturity,Reset,Basis,Principal,Options,EndMonthRule)` returns the option price of the instrument(s) at valuation date using optional arguments.

`[Price,PriceTree] = optfloatbyhjm( ___ )` returns the option price of the instrument(s) at valuation date and a structure of trees containing vectors of option prices at each node.

```
Price = optfloatbyhjm(HJMTree,OptSpec,Strike,ExerciseDates,
AmericanOpt,
```

`Spread,Settle,Maturity)` returns the option price of the instrument(s) at valuation date.

`Price = optfloatbyhjm( ____, Name, Value)` returns the option price of the instrument(s) at valuation date using optional Name-Value pairs.

`[Price,PriceTree] = optfloatbyhjm( ____, )` returns the option price of the instrument(s) at valuation date and a structure of trees containing vectors of option prices at each node using optional name-value pair arguments.

## Examples

### Compute the Price of American and European Call Options on a Floating-Rate Note

Define the interest-rate term structure.

```
Rates = [0.03;0.035;0.040;0.045];
ValuationDate = 'Jan-1-2012';
StartDates = {'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'};
EndDates = {'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'; 'Jan-1-2016'};
Compounding = 1;
```

Create the `RateSpec`.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
  Compounding: 1
        Disc: [4x1 double]
        Rates: [4x1 double]
    EndTimes: [4x1 double]
  StartTimes: [4x1 double]
    EndDates: [4x1 double]
  StartDates: [4x1 double]
ValuationDate: 734869
        Basis: 0
  EndMonthRule: 1
```

Build the HJM tree.

```
VolSpec = hjmvolspec('Constant', 0.01);
TimeSpec = hjmtimespec(RateSpec.ValuationDate, EndDates, Compounding);
HJMTree = hjmtree(VolSpec, RateSpec, TimeSpec)
```

HJMTree =

```
    FinObj: 'HJMFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
    tObs: [0 1 2 3]
    dObs: [734869 735235 735600 735965]
    TFwd: {[4x1 double] [3x1 double] [2x1 double] [3]}
    CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4]}
    FwdTree: {[4x1 double] [3x1x2 double] [2x2x2 double] [1x4x2 double]}
```

The floater instrument has a spread of 10, a period of one year, and matures on Jan-1-2015.

```
Spread = 10;
Settle = 'Jan-1-2012';
Maturity = 'Jan-1-2015';
Period = 1;
```

Define the option for the floating-rate note.

```
OptSpec = {'call'};
Strike = 95;
ExerciseDates = 'Jan-1-2015';
AmericanOpt = [0;1];
```

Compute the price of the call options.

```
Price= optfloatbyhjm(HJMTree, OptSpec, Strike, ExerciseDates,AmericanOpt,...
Spread, Settle, Maturity)
```

Price =

```
    4.5098
    5.2811
```

## Input Arguments

### **HJMTree** — Interest-rate tree structure

binomial tree structure

Interest-rate tree specified as a structure by using `hjmTree`.

Data Types: `struct`

### **OptSpec** — Definition of option

string | cell array of strings

Definition of option as 'call' or 'put' specified as a NINST-by-1 cell array of strings for 'call' or 'put'.

Data Types: `cell` | `char`

### **Strike** — Option strike price values

nonnegative integer | vector of nonnegative integers

Option strike price values specified nonnegative integers using as NINST-by-NSTRIKES vector of strike price values.

Data Types: `single` | `double`

### **ExerciseDates** — Exercise date for option (European, Bermuda, or American)

nonnegative integer | vector of nonnegative integers

Exercise date for option (European, Bermuda, or American) specified as nonnegative integers using a NINST-by-NSTRIKES or NINST-by-2 vector of for the option exercise dates.

- If a European or Bermuda option, the `ExerciseDates` is a 1-by-1 (European) or 1-by-NSTRIKES (Bermuda) vector of exercise dates. For a European option, there is only one `ExerciseDate` on the option expiry date.
- If an American option, then `ExerciseDates` is a 1-by-2 vector of exercise date boundaries. The option exercises on any date between or including the pair of dates on that row. If there is only one non-NaN date, or if `ExerciseDates` is 1-by-1, the option exercises between the `Settle` date and the single listed `ExerciseDate`.

Data Types: `char` | `cell`



**AmericanOpt — Option type**

scalar | vector of positive integers[0, 1]

Option type specified as NINST-by-1 positive integer scalar flags with values:

- 0 — European/Bermuda
- 1 — American

Data Types: single | double

**Spread — Number of basis points over the reference rate**

nonnegative integer | vector of nonnegative integers

Number of basis points over the reference rate specified as a vector nonnegative integers for the number of instruments (NINST)-by-1).

Data Types: single | double

**Settle — Settlement dates of floating-rate note**

ValuationDate of HW Tree (default) | nonnegative integer | vector of nonnegative integers

Settlement dates of floating-rate note specified as nonnegative integers using a NINST-by-1 vector of dates.

---

**Note:** The **Settle** date for every floating-rate note is set to the **ValuationDate** of the HW Tree. The floating-rate note argument **Settle** is ignored.

---

Data Types: char

**Maturity — Floating-rate note maturity date**

nonnegative integer | vector of nonnegative integers

Floating-rate note maturity date specified as nonnegative integers using a NINST-by-1 vector of dates.

Data Types: char

**Reset — (Optional) Frequency of payments per year**

1 (default) | positive integer from the set [1, 2, 3, 4, 6, 12] | vector of positive integers from the set [1, 2, 3, 4, 6, 12]

Frequency of payments per year specified as positive integers for the values [ 1, 2, 3, 4, 6, 12 ] in a NINST-by-1 vector.

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates can not be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

Data Types: double

**Basis — (Optional) Day-count basis of the instrument**

0 (actual/actual) (default) | positive integers of the set [ 1 . . . 13 ] | vector of positive integers of the set [ 1 . . . 13 ]

Day-count basis of the instrument specified as a positive integer using a NINST-by-1 vector. The **Basis** value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: `double`

### **Principal** — (Optional) Principal values

100 (default) | vector of nonnegative values | cell array of nonnegative values

Principal values specified as nonnegative values using a `NINST`-by-1 vector or `NINST`-by-1 cell array of notional principal amounts. When using a `NINST`-by-1 cell array, each element is a `NumDates`-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: `double` | `cell`

### **Options** — (Optional) Structure containing derivatives pricing options

structure

Structure containing derivatives pricing options specified using `derivset`.

Data Types: `struct`

### **EndMonthRule** — (Optional) End-of-month rule flag

1 (in effect) (default) | nonnegative integer [0,1]

End-of-month rule flag is specified as nonnegative integer [0, 1] using a `NINST`-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: `double`

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`,`Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, ..., NameN, ValueN`.

Example: `Price=`

`optfloatbyhjm(HJMTree,OptSpec,Strike,ExerciseDates,AmericanOpt,Spread,Settle,M`

**'Reset' — Frequency of payments per year**

1 (default) | positive integer from the set [1,2,3,4,6,12] | vector of positive integers from the set [1,2,3,4,6,12]

Frequency of payments per year specified as positive integers for the values [1,2,3,4,6,12] in a NINST-by-1 vector. .

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates can not be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

Data Types: char

**'Basis' — Day-count basis of the instrument**

0 (actual/actual) (default) | positive integers of the set [1...13] | vector of positive integers of the set [1...13]

Day-count basis of the instrument specified as a positive integer using a NINST-by-1 vector. The **Basis** value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)

- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: char

#### 'Principal' — (Optional) Principal values

100 (default) | vector of nonnegative values | cell array of nonnegative values

Principal values specified as nonnegative values using a NINST-by-1 vector or NINST-by-1 cell array of notional principal amounts. When using a NINST-by-1 cell array, each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: double | cell

#### 'Options' — Structure containing derivatives pricing options

structure

Structure containing derivatives pricing options specified using `derivset`.

Data Types: struct

#### 'EndMonthRule' — End-of-month rule flag

1 (in effect) (default) | nonnegative integer [0,1]

End-of-month rule flag is specified as a nonnegative integer [0, 1] using a NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: char

## Output Arguments

### Price — Expected prices of the floating-rate note option at time 0

scalar | vector

Expected prices of the floating-rate note option at time 0 is returned as a scalar or an NINST-by-1 vector.

### **PriceTree — Structure of trees containing vectors of option prices at each node**

tree structure

Structure of trees containing vectors of instrument prices and accrued interest and a vector of observation times for each node returned as:

- `PriceTree.PTree` contains option prices.

## **More About**

- **basis**
- “Pricing Options Structure”

## **See Also**

`bondbyhjm` | `capbyhjm` | `cfbyhjm` | `floatbyhjm` | `floorbyhw` | `hjmtree` | `instoptfloat` | `swapbyhjm`

# optfloatbyhw

Price options on floating-rate notes for HW interest-rate tree

## Syntax

```
Price = optfloatbyhw(HWTree,OptSpec,Strike,ExerciseDates,
AmericanOpt,
Spread,Settle,Maturity)
Price= optfloatbyhw(HWTree,OptSpec,Strike,ExerciseDates,AmericanOpt,
Spread,Settle,Maturity,Reset,Basis,Principal,Options,EndMonthRule)
[Price,PriceTree] = optfloatbyhw( ___ )
```

```
Price = optfloatbyhw(HWTree,OptSpec,Strike,ExerciseDates,
AmericanOpt,
Spread,Settle,Maturity)
Price = optfloatbyhw( ___ , Name,Value)
[Price,PriceTree] = optfloatbyhw( ___ )
```

## Description

Price = optfloatbyhw(HWTree,OptSpec,Strike,ExerciseDates, AmericanOpt, Spread,Settle,Maturity) returns the option price of the instrument(s) at valuation date.

Price= optfloatbyhw(HWTree,OptSpec,Strike,ExerciseDates,AmericanOpt, Spread,Settle,Maturity,Reset,Basis,Principal,Options,EndMonthRule) returns the option price of the instrument(s) at valuation date using optional arguments.

[Price,PriceTree] = optfloatbyhw( \_\_\_ ) returns the option price of the instrument(s) at valuation date and a structure of trees containing vectors of option prices at each node.

Price = optfloatbyhw(HWTree,OptSpec,Strike,ExerciseDates, AmericanOpt, Spread,Settle,Maturity) returns the option price of the instrument(s) at valuation date.

`Price = optfloatbyhw( ____, Name, Value)` returns the option price of the instrument(s) at valuation date using optional Name-Value pairs.

`[Price, PriceTree] = optfloatbyhw( ____, )` returns the option price of the instrument(s) at valuation date and a structure of trees containing vectors of option prices at each node using optional Name-Value pairs.

## Examples

### Compute the Price of American and European Call Options on a Floating-Rate Note

Define the interest-rate term structure.

```
Rates = [0.03;0.034;0.038;0.04];
ValuationDate = 'Jan-1-2012';
StartDates = ValuationDate;
EndDates = {'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'; 'Jan-1-2016'};
Compounding = 1;
```

Create the `RateSpec`.

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

`RateSpec =`

```
    FinObj: 'RateSpec'
  Compounding: 1
        Disc: [4x1 double]
        Rates: [4x1 double]
    EndTimes: [4x1 double]
  StartTimes: [4x1 double]
    EndDates: [4x1 double]
  StartDates: 734869
ValuationDate: 734869
        Basis: 0
  EndMonthRule: 1
```

Build the HW tree using the following:

```
VolDates = ['1-Jan-2013'; '1-Jan-2014'; '1-Jan-2015'; '1-Jan-2016'];
```



```

VolCurve = 0.01;
AlphaDates = '01-01-2016';
AlphaCurve = 0.1;

HWVolSpec = hwvolspec(RateSpec.ValuationDate, VolDates, VolCurve,...
    AlphaDates, AlphaCurve);
HWTTimeSpec = hwtimespec(RateSpec.ValuationDate, VolDates, Compounding);
HWT = hwtree(HWVolSpec, RateSpec, HWTTimeSpec)

```

HWT =

```

    FinObj: 'HWFwdTree'
    VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
    tObs: [0 1 2 3]
    dObs: [734869 735235 735600 735965]
    CFlowT: {[4x1 double] [3x1 double] [2x1 double] [4]}
    Probs: {[3x1 double] [3x3 double] [3x5 double]}
    Connect: {[2] [2 3 4] [2 2 3 4 4]}
    FwdTree: {[1.0300] [1.0553 1.0381 1.0211] [1x5 double] [1x5 double]}

```

The floater instrument has a spread of 10, a period of one year, and matures on Jan-1-2016.

```

Spread = 10;
Settle = 'Jan-1-2012';
Maturity = 'Jan-1-2016';
Period = 1;

```

Define the option for the floating-rate note.

```

OptSpec = {'call'};
Strike = 95;
ExerciseDates = 'Jan-1-2016';
AmericanOpt = [0;1];

```

Compute the price of the call options.

```

Price= optfloatbyhw(HWT, OptSpec, Strike, ExerciseDates,AmericanOpt,...
    Spread, Settle, Maturity)

```

Price =

4.2740

5.3655

## Input Arguments

### **HWTtree** — Interest-rate tree structure

binomial tree structure

Interest-rate tree specified as a structure by using `hwtree`.

Data Types: `struct`

### **OptSpec** — Definition of option

string | cell array of strings

Definition of option as 'call' or 'put' specified as a NINST-by-1 cell array of strings for 'call' or 'put'.

Data Types: `cell` | `char`

### **Strike** — Option strike price values

nonnegative integer | vector of nonnegative integers

Option strike price values specified nonnegative integers using as NINST-by-NSTRIKES vector of strike price values.

Data Types: `single` | `double`

### **ExerciseDates** — Exercise date for option (European, Bermuda, or American)

nonnegative integer | vector of nonnegative integers

Exercise date for option (European, Bermuda, or American) specified as nonnegative integers using a NINST-by-NSTRIKES or NINST-by-2 vector of for the option exercise dates.

- If a European or Bermuda option, the `ExerciseDates` is a 1-by-1 (European) or 1-by-NSTRIKES (Bermuda) vector of exercise dates. For a European option, there is only one `ExerciseDate` on the option expiry date.
- If an American option, then `ExerciseDates` is a 1-by-2 vector of exercise date boundaries. The option exercises on any date between or including the pair of dates on

that row. If there is only one non-NaN date, or if `ExerciseDates` is 1-by-1, the option exercises between the `Settle` date and the single listed `ExerciseDate`.

Data Types: char | cell

### **AmericanOpt — Option type**

scalar | vector of positive integers[0, 1]

Option type specified as NINST-by-1 positive integer scalar flags with values:

- 0 — European/Bermuda
- 1 — American

Data Types: single | double

### **Spread — Number of basis points over the reference rate**

nonnegative integer | vector of nonnegative integers

Number of basis points over the reference rate specified as a vector nonnegative integers for the number of instruments (NINST)-by-1).

Data Types: single | double

### **Settle — Settlement dates of floating-rate note**

ValuationDate of HW Tree (default) | nonnegative integer | vector of nonnegative integers

Settlement dates of floating-rate note specified as nonnegative integers using a NINST-by-1 vector of dates.

---

**Note:** The `Settle` date for every floating-rate note is set to the `ValuationDate` of the HW Tree. The floating-rate note argument `Settle` is ignored.

---

Data Types: char

### **Maturity — Floating-rate note maturity date**

nonnegative integer | vector of nonnegative integers

Floating-rate note maturity date specified as nonnegative integers using a NINST-by-1 vector of dates.

Data Types: char

**Reset — (Optional) Frequency of payments per year**

1 (default) | positive integer from the set [1, 2, 3, 4, 6, 12] | vector of positive integers from the set [1, 2, 3, 4, 6, 12]

Frequency of payments per year specified as positive integers for the values [1, 2, 3, 4, 6, 12] in a NINST-by-1 vector.

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates can not be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

Data Types: double

**Basis — (Optional) Day-count basis of the instrument**

0 (actual/actual) (default) | positive integers of the set [1 . . . 13] | vector of positive integers of the set [1 . . . 13]

Day-count basis of the instrument specified as a positive integer using a NINST-by-1 vector. The **Basis** value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)

- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: double

### **Principal — (Optional) Principal values**

100 (default) | vector of nonnegative values | cell array of nonnegative values

Principal values specified as nonnegative values using a NINST-by-1 vector or NINST-by-1 cell array of notional principal amounts. When using a NINST-by-1 cell array, each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: double | cell

### **Options — (Optional) Structure containing derivatives pricing options**

structure

Structure containing derivatives pricing options specified using `derivset`.

Data Types: struct

### **EndMonthRule — (Optional) End-of-month rule flag**

1 (in effect) (default) | nonnegative integer [0,1]

End-of-month rule flag is specified as nonnegative integer [0, 1] using a NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: double

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name, Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single

quotes ( ' ' ). You can specify several name and value pair arguments in any order as Name1, Value1, . . . , NameN, ValueN.

Example: Price=

```
optfloatbyhw(HWTree,OptSpec,Strike,ExerciseDates,AmericanOpt,Spread,Settle,Mat
```

**'Reset' — Frequency of payments per year**

1 (default) | positive integer from the set [1,2,3,4,6,12] | vector of positive integers from the set [1,2,3,4,6,12]

Frequency of payments per year specified as positive integers for the values [1,2,3,4,6,12] in a NINST-by-1 vector.

---

**Note:** Payments on floating-rate notes (FRNs) are determined by the effective interest-rate between reset dates. If the reset period for a FRN spans more than one tree level, calculating the payment becomes impossible due to the recombining nature of the tree. That is, the tree path connecting the two consecutive reset dates can not be uniquely determined because there will be more than one possible path for connecting the two payment dates.

---

Data Types: char

**'Basis' — Day-count basis of the instrument**

0 (actual/actual) (default) | positive integers of the set [1 . . . 13] | vector of positive integers of the set [1 . . . 13]

Day-count basis of the instrument specified as a positive integer using a NINST-by-1 vector. The **Basis** value represents the basis used when annualizing the input forward-rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)

- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: char

### 'Principal' — (Optional) Principal values

100 (default) | vector of nonnegative values | cell array of nonnegative values

Principal values specified as nonnegative values using a NINST-by-1 vector or NINST-by-1 cell array of notional principal amounts. When using a NINST-by-1 cell array, each element is a NumDates-by-2 cell array where the first column is dates and the second column is associated principal amount. The date indicates the last day that the principal value is valid.

Data Types: double | cell

### 'Options' — Structure containing derivatives pricing options

structure

Structure containing derivatives pricing options specified using `derivset`.

Data Types: struct

### 'EndMonthRule' — End-of-month rule flag

1 (in effect) (default) | nonnegative integer [0,1]

End-of-month rule flag is specified as a nonnegative integer [0, 1] using a NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

Data Types: char

## Output Arguments

### **Price** — Expected prices of the floating-rate note option at time 0

scalar | vector

Expected prices of the floating-rate note option at time 0 is returned as a scalar or an NINST-by-1 vector.

### **PriceTree** — Structure of trees containing vectors of option prices at each node

tree structure

Structure of trees containing vectors of instrument prices and accrued interest and a vector of observation times for each node returned as:

- `PriceTree.PTree` contains option prices.

## More About

- `basis`
- “Pricing Options Structure”

## See Also

`bondbyhw` | `capbyhw` | `cfbyhw` | `floatbyhw` | `floorbyhw` | `hwtree` | `instoptfloat`  
| `swapbyhw`



# optsensbysabr

Calculate option sensitivities using SABR model

## Syntax

```
Sens = optsensbysabr(ZeroCurve,Alpha,Beta,Rho,Nu,Settle,  
ExerciseDate,  
ForwardValue,Strike,OptSpec)  
Sens = optsensbysabr( ____,Name,Value)
```

## Description

`Sens = optsensbysabr(ZeroCurve,Alpha,Beta,Rho,Nu,Settle,ExerciseDate,ForwardValue,Strike,OptSpec)` returns the sensitivities of an option value by using the SABR stochastic volatility model.

`Sens = optsensbysabr( ____,Name,Value)` returns the sensitivities of an option value by using the SABR stochastic volatility model and optional name-value pair arguments.

## Examples

### Calculate the Sensitivity Values for an Interest-Rate Swaption

Define the interest rate and the model parameters.

```
ForwardRate = 0.0357;  
Strike = 0.03;  
Alpha = 0.036;  
Beta = 0.5;  
Rho = -0.25;  
Nu = 0.35;  
Rates = 0.05;
```

Define the `Settle`, `ExerciseDate`, and `OptSpec` for an interest-rate swaption.

```
Settle = datenum('15-Sep-2013');
```

```
ExerciseDate = datenum('15-Sep-2015');  
OptSpec = 'call';
```

Define the `RateSpec` for the interest-rate curve.

```
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...  
    'EndDates', ExerciseDate, 'Rates', Rates, 'Compounding', -1, 'Basis', 1)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'  
    Compounding: -1  
        Disc: 0.9048  
        Rates: 0.0500  
    EndTimes: 2  
    StartTimes: 0  
    EndDates: 736222  
    StartDates: 735492  
    ValuationDate: 735492  
        Basis: 1  
    EndMonthRule: 1
```

Calculate the `Delta` and `Vega` sensitivity values for the interest-rate swaption.

```
[SABRDelta, SABRVega] = optsensbysabr(RateSpec, Alpha, Beta, Rho, Nu, Settle, ...  
    ExerciseDate, ForwardRate, Strike, OptSpec, 'OutSpec', {'Delta', 'Vega'})
```

```
SABRDelta =
```

```
    0.7025
```

```
SABRVega =
```

```
    0.0772
```

## Input Arguments

**ZeroCurve** — Annualized interest-rate term structure for zero-coupon bonds structure

---

Annualized interest-rate term structure for zero-coupon bonds, specified by using the `RateSpec` obtained from `intenvset` or an `IRDataCurve` with multiple rates using the `IRDataCurve` constructor.

Data Types: `struct`

**Alpha — Current SABR volatility**

scalar

Current SABR volatility, specified as a scalar.

Data Types: `double`

**Beta — SABR constant elasticity of variance (CEV) exponent**

scalar

SABR CEV exponent, specified as a scalar.

Data Types: `double`

**Rho — Correlation between forward value and volatility**

scalar

Correlation between forward value and volatility, specified as a scalar.

Data Types: `double`

**Nu — Volatility of volatility**

scalar

Volatility of volatility, specified as a scalar.

Data Types: `double`

**Settle — Settlement date**

scalar for serial nonnegative date number | scalar for date string

Settlement date, specified as a scalar using a serial nonnegative date number or date string.

Data Types: `double` | `char`

**ExerciseDate — Option exercise date**

scalar for serial nonnegative date number | scalar for date string

Option exercise date, specified as a scalar using a serial nonnegative date number or date string.

Data Types: double | char

### **ForwardValue** — Current forward value of underlying asset

scalar | vector

Current forward value of the underlying asset, specified as a scalar or vector of size NINST-by-1.

Data Types: double

### **Strike** — Option strike price values

scalar | vector

Option strike price values, specified as a scalar value or a vector of size NINST-by-1.

Data Types: double

### **OptSpec** — Definition of option

string with value 'call' or 'put'

Definition of option, specified as 'call' or 'put' using a string.

Data Types: char

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

Example: `ModifiedSABRDelta =  
optsensbysabr(RateSpec,Alpha,Beta,Rho,Nu,Settle,ExerciseDate,ForwardValue,Stri`

### **'OutSpec'** — Sensitivity outputs

'Delta' (default) | string with values 'Delta', 'Vega', 'ModifiedDelta',  
'ModifiedVega', 'dSigmaF', 'dSigmaAlpha' | cell array of strings with  
values 'Delta', 'Vega', 'ModifiedDelta', 'ModifiedVega', 'dSigmaF',  
'dSigmaAlpha'

Sensitivity outputs, specified by a NOUT- by-1 or 1-by-NOUT cell array of strings with possible values of 'Delta', 'Vega', 'ModifiedDelta', 'ModifiedVega', 'dSigmaF', and 'dSigmaAlpha' where:

- 'Delta' is SABR Delta by Hagan et al. (2002).
- 'Vega' is SABR Vega by Hagan et al. (2002).
- 'ModifiedDelta' SABR Delta modified by Bartlett (2006).
- 'ModifiedVega' SABR Vega modified by Bartlett (2006).
- 'dSigmaF' is the sensitivity of implied Black volatility with respect to the underlying current forward value,  $F$ .
- 'dSigmaAlpha' is the sensitivity of implied Black volatility with respect to the Alpha parameter.

Example: OutSpec =

```
{'Delta', 'Vega', 'ModifiedDelta', 'ModifiedVega', 'dSigmaF', 'dSigmaAlpha'}
```

Data Types: char | cell

## Output Arguments

### Sens — Sensitivity values

array

Sensitivity values, returned as an NINST-by-1 array as defined by OutSpec.

## More About

### Algorithms

In the SABR model, an option with value  $V$  is given by the modified Black formula  $B$ , where  $\sigma_B$  is the SABR implied Black volatility.

$$V = B(F, K, T, \sigma_B(\alpha, \beta, \rho, \nu, F, K, T))$$

The Delta and Vega sensitivities under the SABR model are expressed in terms of partial derivatives in the original paper by Hagan (2002).

$$\text{SABR Delta} = \frac{\partial V}{\partial F} = \frac{\partial B}{\partial F} + \frac{\partial B}{\partial \sigma_B} \frac{\partial \sigma_B}{\partial F}$$

$$\text{SABR Vega} = \frac{\partial V}{\partial \alpha} = \frac{\partial B}{\partial \sigma_B} \frac{\partial \sigma_B}{\partial \alpha}$$

Later, Bartlett (2006) made better use of the model dynamics by incorporating the correlated changes between  $F$  and  $\alpha$

$$\text{Modified SABR Delta} = \frac{\partial B}{\partial F} + \frac{\partial B}{\partial \sigma_B} \left( \frac{\partial \sigma_B}{\partial F} + \frac{\partial \sigma_B}{\partial \alpha} \frac{\rho \nu}{F^\beta} \right)$$

$$\text{Modified SABR Vega} = \frac{\partial B}{\partial \sigma_B} \left( \frac{\partial \sigma_B}{\partial \alpha} + \frac{\partial \sigma_B}{\partial F} \frac{\rho F^\beta}{\nu} \right)$$

where  $\frac{\partial B}{\partial F}$  is the classic Black **Delta** and  $\frac{\partial B}{\partial \sigma_B}$  is the classic Black **Vega**. The Black implied volatility  $\sigma_B$  is computed internally by calling `blackvolbysabr`, while its

partial derivatives  $\frac{\partial \sigma_B}{\partial F}$  and  $\frac{\partial \sigma_B}{\partial \alpha}$  are computed using closed-form expressions by `optsensbysabr`.

## References

Hagan, P. S., D. Kumar, A. S. Lesniewski, and D. E. Woodward, *Managing Smile Risk*, Wilmott Magazine, 2002.

Bartlett, B., *Hedging under SABR Model*, Wilmott Magazine, 2006.

## See Also

`blackvolbysabr` | `intenvset` | `IRDataCurve` | `toRateSpec`

# optstockbybjs

Price American options using Bjerksund-Stensland 2002 option pricing model

## Syntax

Price = optstockbybjs(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike)

## Arguments

RateSpec	The annualized continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.

## Description

Price = optstockbybjs(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike) computes American option prices with continuous dividend yield using the Bjerksund-Stensland 2002 option pricing model.

Price is a NINST-by-1 vector of expected option prices.

---

**Note:** optstockbybjs computes prices of American options with continuous dividend yield using the Bjerksund-Stensland option pricing model.

---

## Examples

### Compute the American Option Prices With Continuous Dividend Yield Using the Bjerksund-Stensland 2002 Option Pricing Model

This example shows how to compute the American option prices with continuous dividend yield using the Bjerksund-Stensland 2002 option pricing model. Consider two American stock options (a call and a put) with an exercise price of \$100. The options expire on April 1, 2008. Assume the underlying stock pays a continuous dividend yield of 4% as of January 1, 2008. The stock has a volatility of 20% per annum and the annualized continuously compounded risk-free rate is 8% per annum. Using this data, calculate the price of the American call and put, assuming the following current prices of the stock: \$90 (for the call) and \$120 (for the put).

```
Settle = 'Jan-1-2008';
Maturity = 'April-1-2008';
Strike = 100;
AssetPrice = [90;120];
DivYield = 0.04;
Rate = 0.08;
Sigma = 0.20;

% define the RateSpec and StockSpec
StockSpec = stockspec(Sigma, AssetPrice, {'continuous'}, DivYield);

RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
    'EndDates', Maturity, 'Rates', Rate, 'Compounding', -1);

% define the option type
OptSpec = {'call'; 'put'};

Price = optstockbybjs(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike)

Price =
    0.8420
    0.1108
```



The first element of the **Price** vector represents the price of the call (\$0.84); the second element represents the price of the put option (\$0.11).

## References

Bjerk Sund, P. and G. Stensland, *Closed-Form Approximation of American Options*, Scandinavian Journal of Management, 1993, Vol. 9, Suppl., pp. S88-S99.

Bjerk Sund, P. and G. Stensland, *Closed Form Valuation of American Options*, Discussion paper 2002 ([http://brage.bibsys.no/nhh/bitstream/URN:NBN:no-bibsys\\_brage\\_22301/1/bjerk\\_sund%20petter%200902.pdf](http://brage.bibsys.no/nhh/bitstream/URN:NBN:no-bibsys_brage_22301/1/bjerk_sund%20petter%200902.pdf))

## See Also

impvbybjs | intenvset | optstocksensbybjs | stockspec

## optstockbyblk

Price options on futures and forwards using Black option pricing model

### Syntax

```
Price = optstockbyblk(RateSpec, StockSpec, Settle, Maturity,
  OptSpec, Strike)
```

```
Price = optstockbyblk(RateSpec, StockSpec, Settle, Maturity,
  OptSpec, Strike, ForwardMaturity)
```

### Arguments

RateSpec	The annualized continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates for the option.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.
<b>Note:</b> Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes ( ' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.	
ForwardMaturity	(Optional) NINST-by-1 maturity date or delivery date of the forward contract. The default is equal to the Maturity of the option.

### Description

```
Price = optstockbyblk(RateSpec, StockSpec, Settle, Maturity,
```

OptSpec, Strike) computes option prices on futures using the Black option pricing model.

Price = optstockbyblk(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike, ForwardMaturity) computes option prices on forwards using the Black option pricing model.

Price is a NINST-by-1 vector of expected option prices.

---

**Note:** optstockbyblk calculates option prices on futures and forwards. If ForwardMaturity is not passed, the function calculates prices of future options. If ForwardMaturity is passed, the function computes prices of forward options. This function handles several types of underlying assets, for example, stocks and commodities. For more information on the underlying asset specification, see `stockspec`.

---

## Examples

### Compute Option Prices on Futures Using the Black Option Pricing Model

This example shows how to compute option prices on futures using the Black option pricing model. Consider two European call options on a futures contract with exercise prices of \$20 and \$25 that expire on September 1, 2008. Assume that on May 1, 2008 the contract is trading at \$20, and has a volatility of 35% per annum. The risk-free rate is 4% per annum. Using this data, calculate the price of the call futures options using the Black model.

```
Strike = [20; 25];
AssetPrice = 20;
Sigma = .35;
Rates = 0.04;
Settle = 'May-01-08';
Maturity = 'Sep-01-08';

% define the RateSpec and StockSpec
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
    'EndDates', Maturity, 'Rates', Rates, 'Compounding', -1);

StockSpec = stockspec(Sigma, AssetPrice);

% define the call options
```

```
OptSpec = {'call'};

Price = optstockbyblk(RateSpec, StockSpec, Settle, Maturity,...
OptSpec, Strike)

Price =

    1.5903
    0.3037
```

### Compute Option Prices on a Forward

This example shows how to compute option prices on forwards using the Black pricing model. Consider two European options, a call and put on the Brent Blend forward contract that expires on January 1, 2015. The options expire on October 1, 2014 with an exercise price of \$200 and \$98 respectively. Assume that on January 1, 2014 the forward price is at \$107, the annualized continuously compounded risk-free rate is 3% per annum and volatility is 28% per annum. Using this data, compute the price of the options.

Define the RateSpec.

```
ValuationDate = 'Jan-1-2014';
EndDates = 'Jan-1-2015';
Rates = 0.03;
Compounding = -1;
Basis = 1;
RateSpec = intenvset('ValuationDate', ValuationDate, ...
'StartDates', ValuationDate, 'EndDates', EndDates, 'Rates', Rates, ....
'Compounding', Compounding, 'Basis', Basis)
```

```
RateSpec =

    FinObj: 'RateSpec'
    Compounding: -1
    Disc: 0.9704
    Rates: 0.0300
    EndTimes: 1
    StartTimes: 0
    EndDates: 735965
    StartDates: 735600
    ValuationDate: 735600
```

```
Basis: 1
EndMonthRule: 1
```

Define the StockSpec.

```
AssetPrice = 107;
Sigma = 0.28;
StockSpec = stockspec(Sigma, AssetPrice);
```

Define the options.

```
Settle = 'Jan-1-2014';
Maturity = 'Oct-1-2014'; %Options maturity
Strike = [200;90];
OptSpec = {'call'; 'put'};
```

Price the forward call and put options.

```
ForwardMaturity = 'Jan-1-2015'; % Forward contract maturity
Price = optstockbyblk(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike,...
'ForwardMaturity', ForwardMaturity)
```

Price =

```
0.0535
3.2111
```

### Compute the Option Price on a Future

Consider a call European option on the Crude Oil Brent futures. The option expires on December 1, 2014 with an exercise price of \$120. Assume that on April 1, 2014 futures price is at \$105, the annualized continuously compounded risk-free rate is 3.5% per annum and volatility is 22% per annum. Using this data, compute the price of the option.

Define the RateSpec.

```
ValuationDate = 'January-1-2014';
EndDates = 'January-1-2015';
Rates = 0.035;
Compounding = -1;
Basis = 1;
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', ValuationDate,...
```

```
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding, 'Basis', Basis')
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'  
    Compounding: -1  
        Disc: 0.9656  
        Rates: 0.0350  
    EndTimes: 1  
    StartTimes: 0  
    EndDates: 735965  
    StartDates: 735600  
    ValuationDate: 735600  
        Basis: 1  
    EndMonthRule: 1
```

Define the StockSpec.

```
AssetPrice = 105;  
Sigma = 0.22;  
StockSpec = stockspec(Sigma, AssetPrice)
```

```
StockSpec =
```

```
    FinObj: 'StockSpec'  
        Sigma: 0.2200  
    AssetPrice: 105  
    DividendType: []  
    DividendAmounts: 0  
    ExDividendDates: []
```

Define the option.

```
Settle = 'April-1-2014';  
Maturity = 'Dec-1-2014';  
Strike = 120;  
OptSpec = {'call'};
```

Price the futures call option.

```
Price = optstockbyblk(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike)
```

Price =

2.5847

## More About

- “Forwards Option”
- “Futures Option”

## See Also

[impvbyblk](#) | [intenvset](#) | [optstocksensbyblk](#) | [stockspec](#)

## optstockbybls

Price options using Black-Scholes option pricing model

### Syntax

```
Price = optstockbybls(RateSpec, StockSpec, Settle, Maturity,  
OptSpec, Strike)
```

### Arguments

RateSpec	The annualized continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.

### Description

```
Price = optstockbybls(RateSpec, StockSpec, Settle, Maturity,  
OptSpec, Strike)
```

Price is a NINST-by-1 vector of expected option prices.

---

**Note:** When using `StockSpec` with `optstockbybls`, you can modify `StockSpec` to handle other types of underliers when pricing instruments that use the Black-Scholes model.

When pricing Futures (Black model), enter the following in `StockSpec`:



```
DivType = 'Continuous';
DivAmount = RateSpec.Rates;
```

When pricing Foreign Currencies (Garman-Kohlhagen model), enter the following in StockSpec:

```
DivType = 'Continuous';
DivAmount = ForeignRate;
```

where ForeignRate is the continuously compounded, annualized risk free interest rate in the foreign country.

---

## Examples

### Compute Option Prices Using the Black-Scholes Option Pricing Model

This example shows how to compute option prices using the Black-Scholes option pricing model. Consider two European options, a call and a put, with an exercise price of \$29 on January 1, 2008. The options expire on May 1, 2008. Assume that the underlying stock for the call option provides a cash dividend of \$0.50 on February 15, 2008. The underlying stock for the put option provides a continuous dividend yield of 4.5% per annum. The stocks are trading at \$30 and have a volatility of 25% per annum. The annualized continuously compounded risk-free rate is 5% per annum. Using this data, compute the price of the options using the Black-Scholes model.

```
Strike = 29;
AssetPrice = 30;
Sigma = .25;
Rates = 0.05;
Settle = 'Jan-01-2008';
Maturity = 'May-01-2008';

% define the RateSpec and StockSpec
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, 'EndDates',...
Maturity, 'Rates', Rates, 'Compounding', -1);

DividendType = {'cash'; 'continuous'};
DividendAmounts = [0.50; 0.045];
ExDividendDates = {'Feb-15-2008'; NaN};

StockSpec = stockspec(Sigma, AssetPrice, DividendType, DividendAmounts,...
ExDividendDates);
```

```
OptSpec = {'call'; 'put'};
```

```
Price = optstockbybls(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike)
```

```
Price =
```

```
    2.2030
```

```
    1.2025
```

### See Also

`impvbybls` | `intenvset` | `optstocksensbybls` | `stockspec`

# optstockbycrr

Price stock option from Cox-Ross-Rubinstein tree

## Syntax

```
[Price, PriceTree] = optstockbycrr(CRRTree, OptSpec, Strike,
Settle, ExerciseDates, AmericanOpt)
```

## Arguments

<b>CRRTree</b>	Stock tree structure created by <code>crrtree</code> .
<b>OptSpec</b>	Number of instruments (NINST)-by-1 cell array of strings 'call' or 'put'.
<p><b>Note</b> The interpretation of the <b>Strike</b> and <b>ExerciseDates</b> arguments depends upon the setting of the <b>AmericanOpt</b> argument. If <b>AmericanOpt</b> = 0, NaN, or is unspecified, the option is a European or Bermuda option. If <b>AmericanOpt</b> = 1, the option is an American option.</p>	
<b>Strike</b>	<p>European option: NINST-by-1 vector of strike price values.</p> <p>Bermuda option: NINST by number of strikes (NSTRIKES) matrix of strike price values.</p> <p>Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.</p> <p>American option: NINST-by-1 vector of strike price values for each option.</p>
<b>Settle</b>	NINST-by-1 vector of settlement or trade dates.
<b>ExerciseDates</b>	<p>NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option:</p>

NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if `ExerciseDates` is NINST-by-1, the option can be exercised between the `ValuationDate` of the stock tree and the single listed `ExerciseDate`.

Data arguments are NINST-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument. The others may be omitted or passed as empty matrices [ ].

## Description

`[Price, PriceTree] = optstockbycrr(CRRTree, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt)` computes the price of a European, Bermuda, or American stock option.

`Price` is a NINST-by-1 vector of expected option prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

## Examples

### Price an American Stock Option Using a CRR Binomial Tree

This example shows how to price an American stock option using a CRR binomial tree by loading the file `deriv.mat`, which provides `CRRTree`. The `CRRTree` structure contains the stock specification and time information needed to price the American option.

```
load deriv.mat;
```

```
OptSpec = 'Call';  
Strike = 105;  
Settle = '01-Jan-2003';  
ExerciseDates = '01-Jan-2005';  
AmericanOpt = 1;
```

```
Price = optstockbycrr(CRRTree, OptSpec, Strike, Settle, ...  
ExerciseDates, AmericanOpt)
```

```
Price =  
      8.2863
```

### Price a Bermudan Stock Option Using a CRR Binomial Tree

Load the file `deriv.mat`, which provides `CRRTree`. The `CRRTree` structure contains the stock specification and time information needed to price the Bermudan option.

```
load deriv.mat;  
  
% Option  
OptSpec = 'Call';  
Strike = 105;  
Settle = '01-Jan-2003';  
ExerciseDatesBerm={'01-Jan-2004', '01-Jul-2004', '01-Jan-2005', '01-Jul-2005'};
```

Price the Bermudan option.

```
Price = optstockbycrr(CRRTree, OptSpec, Strike, Settle, ExerciseDatesBerm)
```

Warning: Some ExerciseDates are not aligned with tree nodes. Result will be approximated.

```
Price =  
      9.6381
```

### See Also

`crrtree` | `instoptstock`

## optstockbyeqp

Price stock option from Equal Probabilities binomial tree

### Syntax

```
[Price, PriceTree] = optstockbyeqp(EQPTree, OptSpec, Strike,
Settle, ExerciseDates, AmericanOpt)
```

### Arguments

EQPTree	Stock tree structure created by <code>eqptree</code> .
OptSpec	Number of instruments (NINST)-by-1 cell array of strings 'call' or 'put'.
<p><b>Note</b> The interpretation of the <code>Strike</code> and <code>ExerciseDates</code> arguments depends upon the setting of the <code>AmericanOpt</code> argument. If <code>AmericanOpt</code> = 0, NaN, or is unspecified, the option is a European or Bermuda option. If <code>AmericanOpt</code> = 1, the option is an American option.</p>	
Strike	<p>European option: NINST-by-1 vector of strike price values.</p> <p>Bermuda option: NINST by number of strikes (NSTRIKES) matrix of strike price values.</p> <p>Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.</p> <p>American option: NINST-by-1 vector of strike price values for each option.</p>
Settle	NINST-by-1 vector of settlement or trade dates.
ExerciseDates	<p>NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p> <p>For an American option:</p>

	NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <code>ExerciseDates</code> is NINST-by-1, the option can be exercised between the <code>ValuationDate</code> of the stock tree and the single listed <code>ExerciseDate</code> .
--	---

Data arguments are NINST-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument. The others may be omitted or passed as empty matrices [ ].

## Description

`[Price, PriceTree] = optstockbyeqp(EQPTree, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt)` computes the price of a European/Bermuda or American stock option.

`Price` is a NINST-by-1 vector of expected option prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

## Examples

### Price an American Stock Option Using an EQP Equity Tree

This example shows how to price an American stock option using an EQP equity tree by loading the file `deriv.mat`, which provides `EQPTree`. The `EQPTree` structure contains the stock specification and time information needed to price the American option.

```
load deriv.mat
```

```
OptSpec = 'Call';
Strike = 105;
Settle = '01-Jan-2003';
ExerciseDates = '01-Jan-2006';
AmericanOpt = 1;
```

```
Price = optstockbyeqp(EQPTree, OptSpec, Strike, Settle, ...
ExerciseDates, AmericanOpt)
```

```
Price =  
  
    12.2632
```

### Price a Bermudan Stock Option Using a EQP Equity Tree

Load the file `deriv.mat`, which provides `EQPTree`. The `EQPTree` structure contains the stock specification and time information needed to price the Bermudan option.

```
load deriv.mat;  
  
% Option  
OptSpec = 'Call';  
Strike = 105;  
Settle = '01-Jan-2003';  
ExerciseDatesBerm={'15-Jan-2004', '15-Jul-2004', '15-Jan-2005', '15-Jul-2005'};
```

Price the Bermudan option.

```
Price= optstockbyeqp(EQPTree, OptSpec, Strike, Settle, ExerciseDatesBerm)
```

```
Warning: Some ExerciseDates are not aligned with tree nodes. Result will be approximated.
```

```
Price =  
  
    12.0255
```

### See Also

`eqptree` | `instoptstock`



# optstockbyitt

Price options on stocks using implied trinomial tree (ITT)

## Syntax

```
[Price, PriceTree] = optstockbyitt(ITTree, OptSpec, Strike,
Settle, ExerciseDates, AmericanOpt)
```

## Arguments

ITTree	Stock tree structure created by <code>itttree</code> .
OptSpec	Number of instruments (NINST)-by-1 cell array of strings 'call' or 'put'.
<p><b>Note</b> The interpretation of the <code>Strike</code> and <code>ExerciseDates</code> arguments depends on the setting of the <code>AmericanOpt</code> argument. If <code>AmericanOpt</code> = 0, NaN, or is unspecified, the option is a European or Bermuda option. If <code>AmericanOpt</code> = 1, the option is an American option.</p>	
Strike	<p>European option: NINST-by-1 vector of strike price values.</p> <p>Bermuda option: NINST by number of strikes (NSTRIKES) matrix of strike price values.</p> <p>Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.</p> <p>American option: NINST-by-1 vector of strike price values for each option.</p>
Settle	NINST-by-1 vector of settlement or trade dates.
ExerciseDates	<p>For a European or Bermuda option:</p> <p>NINST-by-1 (European option) or NINST-by-NSTRIKES (Bermuda option) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one exercise date, the option expiry date.</p>

	For an American option:  NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any tree date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <code>ExerciseDates</code> is NINST-by-1, the option can be exercised between the <code>ValuationDate</code> of the stock tree and the single listed <code>ExerciseDate</code> .
<code>AmericanOpt</code>	(Optional) If <code>AmericanOpt</code> = 0, NaN, or is unspecified, the option is a European or Bermuda option. If <code>AmericanOpt</code> = 1, the option is an American option.

---

**Note:** Data arguments for `optstockbyitt` are NINST-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument; the others may be omitted or passed as empty matrices [ ].

---

## Description

`[Price, PriceTree] = optstockbyitt(ITTTree, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt)` computes the price of a European/Bermuda or American stock option.

`Price` is a NINST-by-1 vector of expected option prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

---

**Note:** The `Settle` date for every option is set to the `ValuationDate` of the stock tree. The option argument, `Settle`, is ignored.

---

## Examples

### Price an American Stock Option Using an ITT Equity Tree

This example shows how to price an American stock option using an ITT equity tree by loading the file `deriv.mat`, which provides the `ITTTree`. The `ITTTree` structure

contains the stock specification and time information needed to price the American option.

```
load deriv.mat

OptSpec = 'Put';
Strike = 30;
Settle = '01-Jan-2006';
ExerciseDates = ' 01-Jan-2010 ';
AmericanOpt = 1;

Price = optstockbyitt(ITTree, OptSpec, Strike, Settle,ExerciseDates, AmericanOpt)

Price =

    0.1271
```

### Price a Bermudan Stock Option Using an ITT Equity Tree

Load the file `deriv.mat`, which provides an `ITTree`. The `ITTree` structure contains the stock specification and time information needed to price the Bermudan option.

```
load deriv.mat;

% Option
OptSpec = 'Put';
Strike = 30;
Settle = '01-Jan-2006';
ExerciseDatesBerm={'1-Jan-2007', '1-Jul-2007', '1-Jan-2008', '1-Jul-2008'};
```

Price the Bermudan option.

```
Price = optstockbyitt(ITTree, OptSpec, Strike, Settle, ExerciseDatesBerm)

Warning: Some ExerciseDates are not aligned with tree nodes. Result will be approximated.
> In procoptions at 171
   In optstockbystocktree at 22
   In optstockbyitt at 68

Price =

    0.0664
```

## References

Chriss, Neil A., E. Derman, and I. Kani, “Implied trinomial trees of the volatility smile,” *Journal of Derivatives*, 1996.

**See Also**

instoptstock | ittree | stockoptspec

# optstockbylr

Price options on stocks using Leisen-Reimer binomial tree model

## Syntax

```
[Price, PriceTree] = optstockbylr(LRTree, OptSpec, Strike,
Settle, ExerciseDates)
[Price, PriceTree] = optstockbylr(LRTree, OptSpec, Strike,
Settle, ExerciseDates, Name, Value)
```

## Description

[Price, PriceTree] = optstockbylr(LRTree, OptSpec, Strike, Settle, ExerciseDates) computes option prices on stocks using the Leisen-Reimer binomial tree model.

[Price, PriceTree] = optstockbylr(LRTree, OptSpec, Strike, Settle, ExerciseDates, Name, Value) computes option prices on stocks using the Leisen-Reimer binomial tree model with additional options specified by one or more Name, Value pair arguments.

## Input Arguments

### LRTree

Stock tree structure created by lrtree.

### OptSpec

NINST-by-1 cell array of strings 'call' or 'put'.

### Strike

NINST-by-1 (European/American) or NINST-by-NSTRIKES (Bermuda) matrix of strike price values. Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.

## Settle

NINST-by-1 matrix of settlement or trade dates.

---

**Note:** The settle date for every option is set to the `ValuationDate` of the stock tree. The option argument, `Settle`, is ignored.

---

## ExerciseDates

NINST-by-1 (European/American) or NINST-by-NSTRIKEDATES (Bermuda) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one `ExerciseDate` on the option expiry date. For the American type, the option can be exercised on any tree data between the `ValuationDate` and tree maturity. The last element of each row must be the same as the maturity of the tree.

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes ( ' '). You can specify several name and value pair arguments in any order as `Name1,Value1, . . . ,NameN,ValueN`.

### 'AmericanOpt'

NINST-by-1 flags with a value of 0 (European/Bermuda) or 1 (American).

**Default:** 0

## Output Arguments

### Price

NINST-by-1 expected prices at time 0.

### PriceTree

Tree structure with a vector of instrument prices at each node.

## Examples

### Price Options on Stocks Using the Leisen-Reimer Binomial Tree Model

This example shows how to price options on stocks using the Leisen-Reimer binomial tree model. Consider European call and put options with an exercise price of \$95 that expire on July 1, 2010. The underlying stock is trading at \$100 on January 1, 2010, provides a continuous dividend yield of 3% per annum and has a volatility of 20% per annum. The annualized continuously compounded risk-free rate is 8% per annum. Using this data, compute the price of the options using the Leisen-Reimer model with a tree of 15 and 55 time steps.

```

AssetPrice = 100;
Strike = 95;

ValuationDate = 'Jan-1-2010';
Maturity = 'July-1-2010';

% define StockSpec
Sigma = 0.2;
DividendType = 'continuous';
DividendAmounts = 0.03;

StockSpec = stockspec(Sigma, AssetPrice, DividendType, DividendAmounts);

% define RateSpec
Rates = 0.08;
Settle = ValuationDate;
Basis = 1;
Compounding = -1;

RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', Settle, ...
'EndDates', Maturity, 'Rates', Rates, 'Compounding', Compounding, 'Basis', Basis);

% build the Leisen-Reimer (LR) tree with 15 and 55 time steps
LRTimeSpec15 = lrtimespec(ValuationDate, Maturity, 15);
LRTimeSpec55 = lrtimespec(ValuationDate, Maturity, 55);

% use the PP2 method
LRMethod = 'PP2';

LRTree15 = lrtree(StockSpec, RateSpec, LRTimeSpec15, Strike, 'method', LRMethod);
LRTree55 = lrtree(StockSpec, RateSpec, LRTimeSpec55, Strike, 'method', LRMethod);

```

```
% price the call and the put options using the LR model:
OptSpec = {'call'; 'put'};

PriceLR15 = optstockbylr(LRTree15, OptSpec, Strike, Settle, Maturity);
PriceLR55 = optstockbylr(LRTree55, OptSpec, Strike, Settle, Maturity);

% calculate price using the Black-Scholes model (BLS) to compare values with
% the LR model:
PriceBLS = optstockbybbs(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike);

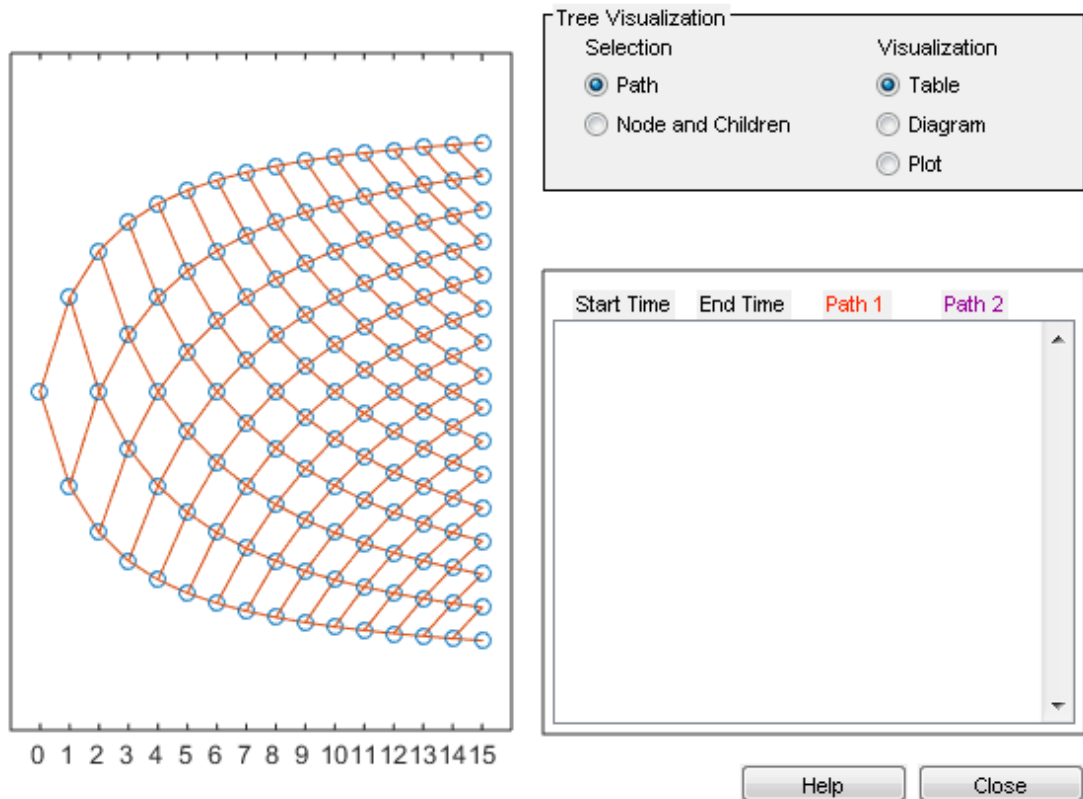
% compare values of BLS and LR
[PriceBLS PriceLR15 PriceLR55]

% use treeviewer to display LRTree of 15 time steps
treeviewer(LRTree15)

ans =

    9.7258    9.7252    9.7257
    2.4896    2.4890    2.4895
```





## References

Leisen D.P., M. Reimer, “Binomial Models for Option Valuation – Examining and Improving Convergence,” *Applied Mathematical Finance*, Number 3, 1996, pp. 319-346.

## See Also

| instoptstock | lrtree | optstocksensbylr

## optstockbyls

Price European, Bermudan, or American vanilla options using Longstaff-Schwartz model

### Syntax

```
Price = optstockbyls(RateSpec,StockSpec,OptSpec,StrikeSettle,  
ExerciseDates)
```

```
Price = optstockbyls( ____,Name,Value)
```

```
[Price,Path,Times,Z] = optstockbyls(RateSpec,StockSpec,OptSpec,  
StrikeSettle,  
ExerciseDates)
```

```
[Price,Path,Times,Z] = optstockbyls( ____,Name,Value)
```

### Description

`Price = optstockbyls(RateSpec,StockSpec,OptSpec,StrikeSettle,ExerciseDates)` returns vanilla option prices using the Longstaff-Schwartz model. `optstockbyls` computes prices of European, Bermudan, and American vanilla options. For American and Bermudan options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium.

`Price = optstockbyls( ____,Name,Value)` returns vanilla option prices using the Longstaff-Schwartz model using optional name-value pair arguments. `optstockbyls` computes prices of European, Bermudan, and American vanilla options. For American and Bermudan options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium.

```
[Price,Path,Times,Z] = optstockbyls(RateSpec,StockSpec,OptSpec,  
StrikeSettle,  
ExerciseDates)
```

returns vanilla option prices using the Longstaff-Schwartz model. `optstockbyls` computes prices of European, Bermudan, and American vanilla options. For American and Bermudan options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium.

```
[Price,Path,Times,Z] = optstockbyls( ____,Name,Value)
```

returns vanilla option prices using the Longstaff-Schwartz model using optional name-value pair

arguments. `optstockbyls` computes prices of European, Bermudan, and American vanilla options. For American and Bermudan options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium.

## Examples

### Compute the Price of a Vanilla Option

Define the `RateSpec`.

```
StartDates = 'Jan-1-2013';
EndDates = 'Jan-1-2015';
Rates = 0.05;
RateSpec = intenvset('ValuationDate', StartDates, 'StartDates', StartDates, ...
    'EndDates', EndDates, 'Rates', Rates)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
    Compounding: 2
        Disc: 0.9060
        Rates: 0.0500
    EndTimes: 4
    StartTimes: 0
    EndDates: 735965
    StartDates: 735235
    ValuationDate: 735235
        Basis: 0
    EndMonthRule: 1
```

Define the `StockSpec` for the asset.

```
AssetPrice = 100;
Sigma = 0.1;
StockSpec = stockspec(Sigma, AssetPrice)
```

```
StockSpec =
```

```
    FinObj: 'StockSpec'
    Sigma: 0.1000
```

```
AssetPrice: 100
DividendType: []
DividendAmounts: 0
ExDividendDates: []
```

Define the vanilla option.

```
OptSpec = 'put';
Settle = 'Jan-1-2013';
ExerciseDates = 'Jan-1-2015';
Strike = 105;
```

Compute the vanilla option price using the Longstaff-Schwartz model.

```
Antithetic = true;
Price = optstockbyls(RateSpec, StockSpec, OptSpec, Strike, Settle, ...
ExerciseDates, 'Antithetic', Antithetic)
```

```
Price =
    3.2292
```

## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

Interest-rate term structure (annualized and continuously compounded), specified by the `RateSpec` obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: `struct`

### **StockSpec** — Stock specification for underlying asset

structure

Stock specification for underlying asset, specified using `StockSpec` obtained from `stockspec`. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, stocks, stock indices, and commodities.

Data Types: struct

### **OptSpec** — Definition of option

string with value 'call' or 'put'

Definition of option, specified as 'call' or 'put' using a string.

Data Types: char

### **Strike** — Option strike price values

nonnegative scalar integer

Option strike price value, specified with nonnegative scalar integer:

- For a European option, use a scalar of strike price.
- For a Bermuda option, use a 1-by-NSTRIKES vector of strike prices.
- For an American option, use a scalar of strike price.

Data Types: single | double

### **Settle** — Settlement date or trade date

date string | nonnegative scalar integer

Settlement date or trade date for the vanilla option, specified as a date string or nonnegative scalar integer.

Data Types: char

### **ExerciseDates** — Option exercise dates

date string | nonnegative integer

Option exercise dates, specified as a date string or nonnegative scalar integer:

- For a European option, use a 1-by-1 vector of dates. For a European option, there is only one **ExerciseDates** on the option expiry date.
- For a Bermuda option, use a 1-by-NSTRIKES vector of dates.
- For an American option, use a 1-by-2 vector of exercise date boundaries. The option can be exercised on any date between or including the pair of dates on that row. If only one non-NaN date is listed, or if **ExerciseDates** is a 1-by-1 vector of serial date numbers or cell array of strings, the option can be exercised between **Settle** and the single listed **ExerciseDates**.

Data Types: char

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes ( ' '). You can specify several name and value pair arguments in any order as `Name1`, `Value1`, . . . , `NameN`, `ValueN`.

Example: `Price = optstockbyls(RateSpec, StockSpec, OptSpec, Strike, Settle, ExerciseDates, 'AmericanOpt`

### 'AmericanOpt' — Option type

0 European or Bermuda (default) | scalar with values [0, 1]

Option type, specified as positive integer scalar flags with values:

- 0 — European or Bermuda
- 1 — American

Data Types: `single` | `double`

### 'NumTrials' — Simulation trials

1000 (default) | scalar

Simulation trials, specified as a scalar number of independent sample paths.

Data Types: `double`

### 'NumPeriods' — Simulation periods per trial

100 (default) | scalar

Simulation periods per trial, specified as a scalar number. `NumPeriods` is considered only when pricing European vanilla options. For American and Bermuda vanilla options, `NumPeriod` is equal to the number of `Exercise` days during the life of the option.

Data Types: `double`

### 'Z' — Dependent random variates

TBD (default) | scalar | nonnegative integer

Dependent random variates used to generate the Brownian motion vector (i.e., Wiener processes) that drive the simulation, specified as a `NumPeriods`-by-2-by-`NumTrials` 3-D time series array.

Data Types: `single` | `double`

**'Antithetic' — Indicator for antithetic sampling**

false (default) | logical flag with value of true or false

Indicator for antithetic sampling, specified with a value of true or false.

Data Types: logical

## Output Arguments

**Price — Expected price of vanilla option**

scalar

Expected price of the vanilla option, returned as a 1-by-1 scalar.

**Path — Simulated paths of correlated state variables**

vector

Simulated paths of correlated state variables, returned as a  $(\text{NumPeriods} + 1)$ -by-2-by- $\text{NumTrials}$  3-D time series array. Each row of **Paths** is the transpose of the state vector  $X(t)$  at time  $t$  for a given trial.

**Times — Observation times associated with simulated paths**

vector

Observation times associated with simulated paths, returned as a  $(\text{NumPeriods} + 1)$ -by-1 column vector of observation times associated with the simulated paths. Each element of **Times** is associated with the corresponding row of **Paths**.

**Z — Dependent random variates**

vector

Dependent random variates, if **Z** is specified as an optional input argument, the same value is returned. Otherwise, **Z** contains the random variates generated internally.

## More About

- “Vanilla Option”

## See Also

optstocksensbyls

## optstocksensbyls

Calculate European, Bermudan, or American vanilla option prices and sensitivities using Longstaff-Schwartz model

### Syntax

```
PriceSens = optstocksensbyls(RateSpec, StockSpec, OptSpec, Strike  
Settle,  
ExerciseDates)  
PriceSens = optstocksensbyls( ____, Name, Value)
```

```
[PriceSens, Path, Times, Z] = optstocksensbyls(RateSpec, StockSpec,  
OptSpec, StrikeSettle,  
ExerciseDates)  
[PriceSens, Path, Times, Z] = optstocksensbyls( ____, Name, Value)
```

### Description

`PriceSens = optstocksensbyls(RateSpec, StockSpec, OptSpec, StrikeSettle, ExerciseDates)` returns vanilla option prices and sensitivities using the Longstaff-Schwartz model. `optstockbyls` computes prices of European, Bermudan, and American vanilla options. For American and Bermudan options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium.

`PriceSens = optstocksensbyls( ____, Name, Value)` returns vanilla option prices using the Longstaff-Schwartz model and using optional name-value pair arguments. `optstockbyls` computes prices and sensitivities of European, Bermudan, and American vanilla options. For American and Bermudan options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium.

`[PriceSens, Path, Times, Z] = optstocksensbyls(RateSpec, StockSpec, OptSpec, StrikeSettle, ExerciseDates)` returns vanilla option prices and sensitivities using the Longstaff-Schwartz model. `optstockbyls` computes prices of European, Bermudan, and American vanilla options. For American and Bermudan options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium.



[PriceSens,Path,Times,Z] = optstocksensbyls( \_\_\_\_,Name,Value) returns vanilla option prices and sensitivities using the Longstaff-Schwartz model and using optional name-value pair arguments. optstockbyls computes prices of European, Bermudan, and American vanilla options. For American and Bermudan options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium.

## Examples

### Compute the Price and Sensitivities of a Vanilla Option

Define the RateSpec.

```
StartDates = 'Jan-1-2013';
EndDates = 'Jan-1-2015';
Rates = 0.05;
RateSpec = intenvset('ValuationDate', StartDates, 'StartDates', StartDates, ...
    'EndDates', EndDates, 'Rates', Rates)
```

RateSpec =

```
    FinObj: 'RateSpec'
  Compounding: 2
        Disc: 0.9060
        Rates: 0.0500
    EndTimes: 4
  StartTimes: 0
    EndDates: 735965
  StartDates: 735235
ValuationDate: 735235
        Basis: 0
  EndMonthRule: 1
```

Define the StockSpec for the asset.

```
AssetPrice = 100;
Sigma = 0.1;
DivType = 'continuous';
DivAmounts = 0.04;
StockSpec = stockspec(Sigma, AssetPrice, DivType, DivAmounts)
```

```
StockSpec =  
    FinObj: 'StockSpec'  
    Sigma: 0.1000  
    AssetPrice: 100  
    DividendType: {'continuous'}  
    DividendAmounts: 0.0400  
    ExDividendDates: []
```

Define the vanilla option.

```
OptSpec = 'call';  
Settle = 'jan-1-2013';  
ExerciseDates = 'jan-1-2015';  
Strike = 105;
```

Compute the Delta sensitivity for the vanilla option using the Longstaff-Schwartz model.

```
Antithetic = true;  
OutSpec = {'Delta'};  
PriceSens = optstocksensbyls(RateSpec, StockSpec, OptSpec, Strike, ...  
    Settle, ExerciseDates, 'Antithetic', Antithetic, 'OutSpec', OutSpec)
```

```
PriceSens =  
    0.3945
```

## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

Interest-rate term structure (annualized and continuously compounded), specified by the RateSpec obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: `struct`

### **StockSpec** — Stock specification for underlying asset

structure

Stock specification for underlying asset, specified using `StockSpec` obtained from `stockspec`. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, stocks, stock indices, and commodities.

Data Types: `struct`

### **OptSpec** — Definition of option

string values 'call' or 'put'

Definition of option, specified as 'call' or 'put' using a string.

Data Types: `char`

### **Strike** — Option strike price value

nonnegative scalar integer

Option strike price value, specified with a nonnegative scalar integer:

- For a European option, use a scalar of strike price.
- For a Bermuda option, use a 1-by-NSTRIKES vector of strike price.
- For an American option, use a scalar of strike price.

Data Types: `single` | `double`

### **Settle** — Settlement date or trade date

date string | nonnegative scalar integer

Settlement date or trade date for the vanilla option, specified as a date string or a nonnegative integer.

Data Types: `char`

### **ExerciseDates** — Option exercise date

date string | nonnegative scalar integer

Option exercise date, specified as a date string or nonnegative scalar integer:

- For a European option, use a 1-by-1 vector of dates. For a European option, there is only one `ExerciseDates` on the option expiry date.
- For a Bermuda option, use a 1-by-NSTRIKES vector of dates.

- For an American option, use a 1-by-2 vector of exercise date boundaries. The option can be exercised on any date between or including the pair of dates on that row. If only one non-NaN date is listed, or if `ExerciseDates` is a 1-by-1 vector of serial date numbers or cell array of strings, the option can be exercised between `Settle` and the single listed `ExerciseDates`.

Data Types: char

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes ( ' '). You can specify several name and value pair arguments in any order as `Name1`, `Value1`, ..., `NameN`, `ValueN`.

```
Example: Price = optstocksensbyls(RateSpec, StockSpec,
OptSpec, Strike, Settle, ExerciseDates, 'AmericanOpt', '1', 'NumTrials', '2000', 'OutS
{'All'})
```

### 'AmericanOpt' — Option type

0 European or Bermuda (default) | scalar with values [0,1]

Option type, specified as a positive integer scalar flag with values:

- 0 — European or Bermuda
- 1 — American

Data Types: single | double

### 'NumTrials' — Simulation trials

1000 (default) | scalar

Simulation trials, specified as a scalar number of independent sample paths.

Data Types: double

### 'NumPeriods' — Simulation periods per trial

100 (default) | scalar

Simulation periods per trial, specified as a scalar number. `NumPeriods` is considered only when pricing European vanilla options. For American and Bermuda vanilla options, `NumPeriod` is equal to the number of `Exercise` days during the life of the option.

Data Types: double

### 'Z' — Dependent random variates

scalar | nonnegative integer

Dependent random variates used to generate the Brownian motion vector (i.e., Wiener processes) that drive the simulation, specified as a NumPeriods-by-2-by-NumTrials 3-D time series array.

Data Types: single | double

### 'Antithetic' — Indicator for antithetic sampling

false (default) | logical flag with value of true or false

Indicator for antithetic sampling, specified with a value of true or false.

Data Types: logical

### 'OutSpec' — Define outputs

{'Price'} (default) | string with values 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All' | cell array of strings with values: 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'

Define outputs specifying NOUT- by-1 or 1-by-NOUT cell array of strings with possible values of 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta' and 'All'.

OutSpec = {'All'} specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying OutSpec to include each sensitivity:

Example: OutSpec =  
{'delta', 'gamma', 'vega', 'lambda', 'rho', 'theta', 'price'}

Data Types: char | cell

## Output Arguments

### PriceSens — Expected price and sensitivities of vanilla option

vector

Expected price and sensitivities of the vanilla option, returned as a NINST-by-1 vector.

**Path — Simulated paths of correlated state variables**

vector

Simulated paths of correlated state variables, returned as a  $(\text{NumPeriods} + 1)$ -by-2-by- $\text{NumTrials}$  3-D time series array. Each row of **Paths** is the transpose of the state vector  $X(t)$  at time  $t$  for a given trial.

**Times — Observation times associated with simulated paths**

vector

Observation times associated with simulated paths, returned as a  $(\text{NumPeriods} + 1)$ -by-1 column vector of observation times associated with the simulated paths. Each element of **Times** is associated with the corresponding row of **Paths**.

**Z — Dependent random variates**

vector

Dependent random variates, if **Z** is specified as an optional input argument, the same value is returned. Otherwise, **Z** contains the random variates generated internally.

## More About

- “Vanilla Option”

## See Also

optstockbyls

# optstockbyrgw

Determine American call option prices using Roll-Geske-Whaley option pricing model

## Syntax

Price = optstockbyrgw(RateSpec, StockSpec, Settle, Maturity, Strike)

## Arguments

RateSpec	The annualized continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
Strike	NINST-by-1 vector of strike price values.

## Description

Price = optstockbyrgw(RateSpec, StockSpec, Settle, Maturity, Strike) computes the American call option prices using the Roll-Geske-Whaley option pricing model.

Price is a NINST-by-1 vector of expected call option prices.

---

**Note:** optstockbyrgw computes prices of American calls with a single cash dividend using the Roll-Geske-Whaley option pricing model.

---

## Examples

### Determine American Call Option Prices Using Roll-Geske-Whaley Option Pricing Model

This example shows how to determine American call option prices using Roll-Geske-Whaley option pricing model. Consider an American call option with an exercise price of \$22 that expires on February 1, 2009. The underlying stock is trading at \$20 on June 1, 2008 and has a volatility of 20% per annum. The annualized continuously compounded risk-free rate is 6.77% per annum. The stock pays a single dividend of \$2 on September 1, 2008. Using this data, compute price of the American call option using the Roll-Geske-Whaley option pricing model.

```
Settle = 'Jun-01-2008';
Maturity = 'Feb-01-2009';
AssetPrice = 20;
Strike = 22;
Sigma = 0.2;
Rate = 0.0677;
DivAmount = 2;
DivDate = 'Sep-01-2008';

% define the RateSpec and StockSpec
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, 'EndDates',...
Maturity, 'Rates', Rate, 'Compounding', -1, 'Basis', 0);

StockSpec = stockspec(Sigma, AssetPrice, {'cash'}, DivAmount, DivDate);

Price = optstockbyrgw(RateSpec, StockSpec, Settle, Maturity, Strike)

Price =

    0.3359
```

### See Also

`impvbyrgw` | `intenvset` | `optstocksensbyrgw` | `stockspec`



# optstocksensbybjs

Determine American option prices and sensitivities using Bjerksund-Stensland 2002 option pricing model

## Syntax

```
PriceSens = optstocksensbybjs(RateSpec, StockSpec, Settle,
Maturity, OptSpec, Strike, 'Name1', Value1...)
```

## Arguments

RateSpec	The annualized continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.
OutSpec	(Optional) All optional inputs are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. Parameter name/value pairs may be specified in any order; names are case-insensitive and partial string matches are allowed provided no ambiguities exist. Valid parameter names are: <ul style="list-style-type: none"> <li>• NOUT-by-1 or 1-by-NOUT cell array of strings indicating the nature and order of the outputs for the function. Possible values are: 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', or 'All'.</li> </ul>

For example, `OutSpec = {'Price'; 'Lambda'; 'Rho'}` specifies that the output should be Price, Lambda, and Rho, in that order.

To invoke from a function: `[Price, Lambda, Rho] = optstocksensbybjs(..., 'OutSpec', {'Price', 'Lambda', 'Rho'})`

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec = {'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', 'Price'}`;

- Default is `OutSpec = {'Price'}`.

## Description

`PriceSens = optstocksensbybjs(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike, 'Name1', Value1...)` computes American option prices and sensitivities using the Bjerksund-Stensland 2002 option pricing model.

`optstocksensbybjs` can be used to compute six sensitivities for the Bjerksund-Stensland 2002 model: `delta`, `gamma`, `vega`, `lambda`, `rho`, and `theta`. This function is also capable of returning the price of the option. The selection of output parameters and their order is determined by the optional input parameter `OutSpec`. This parameter is a cell array of strings, each one specifying a desired output parameter. The order in which these output parameters are returned by the function is the same as the order of the strings contained in `OutSpec`.

`PriceSens` is a NINST-by-1 vector of expected prices or sensitivities values.

---

**Note:** `optstocksensbybjs` computes prices of American options with continuous dividend yield using the Bjerksund-Stensland option pricing model. All sensitivities are evaluated by computing a discrete approximation of the partial derivative. This means that the option is revalued with a fractional change for each relevant parameter, and the change in the option value divided by the increment, is the approximated sensitivity value.

---

## Examples

### Compute American Option Prices and Sensitivities Using the Bjerksund-Stensland 2002 Option Pricing Model

This example shows how to compute American option prices and sensitivities using the Bjerksund-Stensland 2002 option pricing model. Consider four American put options with an exercise price of \$100. The options expire on October 1, 2008. Assume the underlying stock pays a continuous dividend yield of 4% and has a volatility of 40% per annum. The annualized continuously compounded risk-free rate is 8% per annum. Using this data, calculate the **delta**, **gamma**, and **price** of the American put options, assuming the following current prices of the stock on July 1, 2008: \$90, \$100, \$110 and \$120.

```
Settle = 'July-1-2008';
Maturity = 'October-1-2008';
Strike = 100;
AssetPrice = [90;100;110;120];
Rate = 0.08;
Sigma = 0.40;
DivYield = 0.04;

% define the RateSpec and StockSpec
StockSpec = stockspec(Sigma, AssetPrice, {'continuous'}, DivYield);

RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
'EndDates', Maturity, 'Rates', Rate, 'Compounding', -1);

% define the option type
OptSpec = {'put'};

OutSpec = {'Delta', 'Gamma', 'Price'};

[Delta, Gamma, Price] = optstocksensbybjs(RateSpec, StockSpec, Settle, Maturity,...
OptSpec, Strike, 'OutSpec', OutSpec)

Delta =

    -0.6572
    -0.4434
    -0.2660
    -0.1442
```

Gamma =

0.0217  
0.0202  
0.0150  
0.0095

Price =

12.9467  
7.4571  
3.9539  
1.9495

## References

Bjerksund, P. and G. Stensland, *Closed-Form Approximation of American Options*, Scandinavian Journal of Management, 1993, Vol. 9, Suppl., pp. S88-S99.

Bjerksund, P. and G. Stensland, *Closed Form Valuation of American Options*, Discussion paper 2002 ([http://brage.bibsys.no/nhh/bitstream/URN:NBN:no-bibsys\\_brage\\_22301/1/bjerksund%20petter%200902.pdf](http://brage.bibsys.no/nhh/bitstream/URN:NBN:no-bibsys_brage_22301/1/bjerksund%20petter%200902.pdf))

## See Also

[impvbybjs](#) | [intenvset](#) | [optstockbybjs](#) | [stockspec](#)

# optstocksensbyblk

Determine option prices and sensitivities on futures and forwards using Black pricing model

## Syntax

```
PriceSens = optstocksensbyblk(RateSpec, StockSpec, Settle,
Maturity, OptSpec, Strike, 'Name1', Value1...)
```

## Arguments

RateSpec	The annualized continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.
<p><b>Note:</b> Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.</p>	
ForwardMaturity	(Optional) NINST-by-1 maturity date or delivery date of the forward contract. The default is equal to the Maturity of the option.
OutSpec	(Optional) NOUT-by-1 or 1-by-NOUT cell array of strings indicating the nature and order of the outputs for the function. Possible values are: <ul style="list-style-type: none"> <li>'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', or 'All'.</li> </ul>

For example, `OutSpec = {'Price'; 'Lambda'; 'Rho'}` specifies that the output should be Price, Lambda, and Rho, in that order.

To invoke from a function: `[Price, Lambda, Rho] = optstocksensbyblk(..., 'OutSpec', {'Price', 'Lambda', 'Rho'})`

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec = {'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', 'Price'}`;

- Default is `OutSpec = {'Price'}`.

## Description

`PriceSens = optstocksensbyblk(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike, 'Name1', Value1...)` computes option prices and sensitivities on futures and forwards using the Black pricing model.

`PriceSens` is a NINST-by-1 vector of expected future prices or sensitivities values.

---

**Note:** `optstocksensbyblk` calculates option prices and sensitivities on futures and forwards. If `ForwardMaturity` is not passed, the function calculates prices and sensitivities of future options. If `ForwardMaturity` is passed, the function computes prices and sensitivities of forward options. This function handles several types of underlying assets, for example, stocks and commodities. For more information on the underlying asset specification, see `stockspec`.

---

## Examples

### Compute Option Prices and Sensitivities on Futures Using the Black Pricing Model

This example shows how to compute option prices and sensitivities on futures using the Black pricing model. Consider a European put option on a futures contract with an

exercise price of \$60 that expires on June 30, 2008. On April 1, 2008 the underlying stock is trading at \$58 and has a volatility of 9.5% per annum. The annualized continuously compounded risk-free rate is 5% per annum. Using this data, compute **delta**, **gamma**, and the **price** of the put option.

```
AssetPrice = 58;
Strike = 60;
Sigma = .095;
Rates = 0.05;
Settle = 'April-01-08';
Maturity = 'June-30-08';

% define the RateSpec and StockSpec
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, 'EndDates',...
Maturity, 'Rates', Rates, 'Compounding', -1, 'Basis', 1);

StockSpec = stockspec(Sigma, AssetPrice);

% define the options
OptSpec = {'put'};

OutSpec = {'Delta', 'Gamma', 'Price'};
[Delta, Gamma, Price] = optstocksensbyblk(RateSpec, StockSpec, Settle,...
Maturity, OptSpec, Strike, 'OutSpec', OutSpec)

Delta =

    -0.7469

Gamma =

    0.1130

Price =

    2.3569
```

### Compute Forward Option Prices and Delta Sensitivities

This example shows how to compute option prices and sensitivities on forwards using the Black pricing model. Consider two European call options on the Brent Blend forward contract that expires on January 1, 2015. The options expire on October 1, 2014 and Dec 1, 2014 with an exercise price % of \$120 and \$150 respectively. Assume that on January 1, 2014 the forward price is at \$107, the annualized continuously compounded risk-free rate is 3% per annum and volatility is 28% per annum. Using this data, compute the price and delta of the options.

Define the RateSpec.

```
ValuationDate = 'Jan-1-2014';
EndDates = 'Jan-1-2015';
Rates = 0.03;
Compounding = -1;
Basis = 1;
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', ...
ValuationDate, 'EndDates', EndDates, 'Rates', Rates, ...
'Compounding', Compounding, 'Basis', Basis');
```

Define the StockSpec.

```
AssetPrice = 107;
Sigma = 0.28;
StockSpec = stockspec(Sigma, AssetPrice);
```

Define the options.

```
Settle = 'Jan-1-2014';
Maturity = {'Oct-1-2014'; 'Dec-1-2014'}; %Options maturity
Strike = [120;150];
OptSpec = {'call'; 'call'};
```

Price the forward call options and return the Delta sensitivities.

```
ForwardMaturity = 'Jan-1-2015'; % Forward contract maturity
OutSpec = {'Delta'; 'Price'};
[Delta, Price] = optstocksensbyblk(RateSpec, StockSpec, Settle, Maturity, OptSpec, ...
Strike, 'ForwardMaturity', ForwardMaturity, 'OutSpec', OutSpec)
```

```
Delta =
```



0.3518  
0.1262

Price =

5.4808  
1.6224

## More About

- “Forwards Option”
- “Futures Option”

## See Also

[impvbyblk](#) | [intenvset](#) | [optstockbyblk](#) | [stockspec](#)

## optstocksensbybls

Determine option prices and sensitivities using Black-Scholes option pricing model

### Syntax

```
PriceSens = optstocksensbybls(RateSpec, StockSpec, Settle,
Maturity, OptSpec, Strike, 'Name1', Value1...)
```

### Arguments

RateSpec	The annualized continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.
OutSpec	<p>(Optional) All optional inputs are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. Parameter name/value pairs may be specified in any order; names are case-insensitive and partial string matches are allowed provided no ambiguities exist. Valid parameter names are:</p> <ul style="list-style-type: none"> <li>• NOUT-by-1 or 1-by-NOUT cell array of strings indicating the nature and order of the outputs for the function. Possible values are: 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', or 'All'.</li> </ul> <p>For example, <code>OutSpec = {'Price'; 'Lambda'; 'Rho'}</code> specifies that the output should be Price, Lambda, and Rho, in that order.</p>

To invoke from a function: `[Price, Lambda, Rho] = optstocksensbybls(..., 'OutSpec', {'Price', 'Lambda', 'Rho'})`

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec` as `OutSpec = {'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', 'Price'}`;

- Default is `OutSpec = {'Price'}`.

## Description

`PriceSens = optstocksensbybls(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike, 'Name1', Value1...)` computes option prices and sensitivities using the Black-Scholes option pricing model.

`PriceSens` is a NINST-by-1 vector of expected prices or sensitivities values.

---

**Note:** When using `StockSpec` with `optstocksensbybls`, you can modify `StockSpec` to handle other types of underliers when pricing instruments that use the Black-Scholes model.

When pricing Futures (Black model), enter the following in `StockSpec`:

```
DivType = 'Continuous';
DivAmount = RateSpec.Rates;
```

When pricing Foreign Currencies (Garman-Kohlhagen model), enter the following in `StockSpec`:

```
DivType = 'Continuous';
DivAmount = ForeignRate;
```

where `ForeignRate` is the continuously compounded, annualized risk free interest rate in the foreign country.

---

## Examples

### Compute Option Prices and Sensitivities Using the Black-Scholes Option Pricing Model

This example shows how to compute option prices and sensitivities using the Black-Scholes option pricing model. Consider a European call and put options with an exercise price of \$30 that expires on June 1, 2008. The underlying stock is trading at \$30 on January 1, 2008 and has a volatility of 30% per annum. The annualized continuously compounded risk-free rate is 5% per annum. Using this data, compute the `delta`, `gamma`, and `price` of the options using the Black-Scholes model.

```
AssetPrice = 30;
Strike = 30;
Sigma = .30;
Rates = 0.05;
Settle = 'January-01-2008';
Maturity = 'June -01-2008';

% define the RateSpec and StockSpec
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, 'EndDates',...
Maturity, 'Rates', Rates, 'Compounding', -1, 'Basis', 1);

StockSpec = stockspec(Sigma, AssetPrice);

% define the options
OptSpec = {'call', 'put'};

OutSpec = {'Delta', 'Gamma', 'Price'};
[Delta, Gamma, Price] = optstocksensbybls(RateSpec, StockSpec, Settle,...
Maturity, OptSpec, Strike, 'OutSpec', OutSpec)

Delta =

    0.5810
   -0.4190

Gamma =

    0.0673
    0.0673
```

Price =

2.6126

1.9941

## **See Also**

[impvbybls](#) | [intenvset](#) | [optstockbybls](#) | [stockspec](#)

## optstocksensbylr

Determine option prices and sensitivities using Leisen-Reimer binomial tree model

### Syntax

```
PriceSens = optstocksensbylr(LRTree, OptSpec, Strike, Settle,  
ExerciseDates)  
PriceSens = optstocksensbylr(LRTree, OptSpec, Strike, Settle,  
ExerciseDates, Name, Value)
```

### Description

`PriceSens = optstocksensbylr(LRTree, OptSpec, Strike, Settle, ExerciseDates)` calculates option prices and sensitivities using a Leisen-Reimer binomial tree model.

`PriceSens = optstocksensbylr(LRTree, OptSpec, Strike, Settle, ExerciseDates, Name, Value)` constructs a Leisen-Reimer stock tree with additional options specified by one or more `Name, Value` pair arguments.

### Input Arguments

#### LRTree

Stock tree structure created by `lrtree`.

#### OptSpec

NINST-by-1 cell array of strings 'call' or 'put'.

#### Strike

NINST-by-1 (European/American) or NINST-by-NSTRIKES (Bermuda) matrix of strike price values. Each row is the schedule for one option. If an option has fewer than NSTRIKES exercise opportunities, the end of the row is padded with NaNs.

## Settle

NINST-by-1 matrix of settlement or trade dates.

## ExerciseDates

NINST-by-1 (European/American) or NINST-by-NSTRIKEDATES (Bermuda) matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one `ExerciseDate` on the option expiry date. For the American type, the option can be exercised on any tree data between the `ValuationDate` and tree maturity. The last element of each row must be the same as the maturity of the tree.

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name, Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

### 'AmericanOpt'

NINST-by-1 flags with values of 0 (European/Bermuda) or 1 (American).

**Default:** 0

### 'OutSpec'

NOUT-by-1 or 1-by-NOUT cell array of strings indicating the nature and order of the outputs for the function. Possible values are `Price`, `Delta`, `Gamma`, `Vega`, `Lambda`, `Rho`, and `All`.

**Default:** `Price`

## Output Arguments

### PriceSens

NINST-by-1 expected prices or sensitivities values.

## Examples

### Compute Option Prices and Sensitivities Using a Leisen-Reimer Binomial Tree Model

This example shows how to compute option prices and sensitivities using a Leisen-Reimer binomial tree model. Consider European call and put options with an exercise price of \$100 that expire on December 1, 2010. The underlying stock is trading at \$100 on June 1, 2010 and has a volatility of 30% per annum. The annualized continuously compounded risk-free rate is 7% per annum. Using this data, compute the price, delta and gamma of the options using the Leisen-Reimer model with a tree of 25 time steps and the PP2 method.

```
AssetPrice = 100;
Strike = 100;

ValuationDate = 'June-1-2010';
Maturity = 'December-1-2010';

% define StockSpec
Sigma = 0.3;

StockSpec = stockspec(Sigma, AssetPrice);

% define RateSpec
Rates = 0.07;
Settle = ValuationDate;
Basis = 1;
Compounding = -1;

RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', Settle, ...
    'EndDates', Maturity, 'Rates', Rates, 'Compounding', Compounding, 'Basis', Basis);

% build the Leisen-Reimer (LR) tree with 25 time steps
LRTimeSpec = lrtimespec(ValuationDate, Maturity, 25);

% use the PP2 method
LRMethod = 'PP2';

TreeLR = lrtree(StockSpec, RateSpec, LRTimeSpec, Strike, 'method', LRMethod);

% compute prices and sensitivities using the LR model:
OptSpec = {'call'; 'put'};
OutSpec = {'Price', 'Delta', 'Gamma'};
```



```
[Price, Delta, Gamma] = optstocksensbylr(TreeLR, OptSpec, Strike, Settle, ...  
Maturity, 'OutSpec', OutSpec)
```

```
Price =
```

```
    10.1332  
     6.6937
```

```
Delta =
```

```
    0.6056  
   -0.3944
```

```
Gamma =
```

```
    0.0185  
    0.0185
```

## References

Leisen D.P., M. Reimer, “Binomial Models for Option Valuation – Examining and Improving Convergence,” *Applied Mathematical Finance*, Number 3, 1996, pp. 319-346.

## See Also

| optstockbylr | lrtree

## optstocksensbyrgw

Determine American call option prices and sensitivities using Roll-Geske-Whaley option pricing model

### Syntax

```
PriceSens = optstocksensbyrgw(RateSpec, StockSpec, Settle,
Maturity, OptSpec, Strike, 'Name1', Value1...)
```

### Arguments

RateSpec	The annualized continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
Strike	NINST-by-1 vector of strike price values.
OutSpec	<p>(Optional) All optional inputs are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. Parameter name/value pairs may be specified in any order; names are case-insensitive and partial string matches are allowed provided no ambiguities exist. Valid parameter names are:</p> <ul style="list-style-type: none"> <li>• NOUT-by-1 or 1-by-NOUT cell array of strings indicating the nature and order of the outputs for the function. Possible values are: 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', or 'All'.</li> </ul>

For example, `OutSpec = {'Price'; 'Lambda'; 'Rho'}` specifies that the output should be Price, Lambda, and Rho, in that order.

To invoke from a function: `[Price, Lambda, Rho] = optstocksensbyrgw(..., 'OutSpec', {'Price', 'Lambda', 'Rho'})`

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec = {'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', 'Price'}`;

- Default is `OutSpec = {'Price'}`.

## Description

`PriceSens = optstocksensbyrgw(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike, 'Name1', Value1...)` computes American call option prices and sensitivities using the Roll-Geske-Whaley option pricing model.

`PriceSens` is a NINST-by-1 vector of expected prices or sensitivities values.

---

**Note:** `optstocksensbyrgw` computes prices of American calls with a single cash dividend using the Roll-Geske-Whaley option pricing model. All sensitivities are evaluated by computing a discrete approximation of the partial derivative. This means that the option is revalued with a fractional change for each relevant parameter, and the change in the option value divided by the increment, is the approximated sensitivity value.

---

## Examples

### Compute American Call Option Prices and Sensitivities Using the Roll-Geske-Whaley Option Pricing Model

This example shows how to compute American call option prices and sensitivities using the Roll-Geske-Whaley option pricing model. Consider an American stock option with

an exercise price of \$82 on January 1, 2008 that expires on May 1, 2008. Assume the underlying stock pays dividends of \$4 on April 1, 2008. The stock is trading at \$80 and has a volatility of 30% per annum. The risk-free rate is 6% per annum. Using this data, calculate the price and the value of  $\delta$  and  $\gamma$  of the American call using the Roll-Geske-Whaley option pricing model.

```
AssetPrice = 80;
Settle = 'Jan-01-2008';
Maturity = 'May-01-2008';
Strike = 82;
Rate = 0.06;
Sigma = 0.3;
DivAmount = 4;
DivDate = 'Apr-01-2008';

% define the RateSpec and StockSpec
StockSpec = stockspec(Sigma, AssetPrice, {'cash'}, DivAmount, DivDate);

RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
'EndDates', Maturity, 'Rates', Rate, 'Compounding', -1, 'Basis', 1);

% define the OutSpec
OutSpec = {'Price', 'Delta', 'Gamma'};

[Price, Delta, Gamma] = optstocksensbyrgw(RateSpec, StockSpec, Settle,...
Maturity, Strike, 'OutSpec', OutSpec)

Price =

    4.3860

Delta =

    0.5022

Gamma =

    0.0336
```

## **See Also**

impvbyrgw | intenvset | optstockbyrgw | stockspec

## optpricebysim

Price option given simulated underlying values

### Syntax

```
Price = optpricebysim(RateSpec, SimulatedPrices, Times, OptSpec,  
Strike, ExerciseTimes)  
Price = optpricebysim( ____, Name, Value)
```

### Description

`Price = optpricebysim(RateSpec, SimulatedPrices, Times, OptSpec, Strike, ExerciseTimes)` calculates the price of European, American, and Bermudan call/put options based on risk-neutral simulation of the underlying asset. For American and Bermudan options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium.

`Price = optpricebysim( ____, Name, Value)` calculates the price of European, American, and Bermudan call/put options based on risk-neutral simulation of the underlying asset using optional name-value pair arguments. For American options, the Longstaff-Schwartz least squares method calculates the early exercise premium.

### Examples

#### Compute the Price of an American Option Using Monte Carlo Simulation Based on Geometric Brownian Motion

Define the option.

```
S0 = 100; % Initial price of underlying asset  
Sigma = .2; % Volatility of underlying asset  
Strike = 110; % Strike  
OptSpec = 'call'; % Call option  
Settle = '1-Jan-2013'; % Settlement date of option  
Maturity = '1-Jan-2014'; % Maturity date of option  
r = .05; % Risk-free rate (annual, continuous compounding)  
Compounding = -1; % Continuous compounding
```

```
Basis = 0; % Act/Act day count convention
T = yearfrac(Settle, Maturity, Basis); % Time to expiration in years
```

Set up the `gbm` object and run the Monte Carlo simulation based on Geometric Brownian Motion (GBM) using the `simBySolution` method from Financial Toolbox™.

```
NTRIALS = 1000;
NPERIODS = daysact(Settle, Maturity);
dt = T/NPERIODS;
OptionGBM = gbm(r, Sigma, 'StartState', S0);
[Paths, Times, Z] = OptionGBM.simBySolution(NPERIODS, ...
'NTRIALS', NTRIALS, 'DeltaTime', dt, 'Antithetic', true);
```

Create the interest-rate term structure to define `RateSpec`.

```
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
'EndDates', Maturity, 'Rate', r, 'Compounding', Compounding, ...
'Basis', Basis)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
  Compounding: -1
        Disc: 0.9512
        Rates: 0.0500
   EndTimes: 1
  StartTimes: 0
   EndDates: 735600
  StartDates: 735235
ValuationDate: 735235
        Basis: 0
  EndMonthRule: 1
```

Price an American option.

```
SimulatedPrices = squeeze(Paths);
OptPrice = optpricebysim(RateSpec, SimulatedPrices, Times, OptSpec, ...
    Strike, T, 'AmericanOpt', 1)
```

```
OptPrice =
```

```
    6.2028
```

**Compute the Price of an American Asian Option Using Monte Carlo Simulation Based on Geometric Brownian Motion**

Define the option.

```
S0 = 100; % Initial price of underlying asset
Sigma = .2; % Volatility of underlying asset
Strike = 110; % Strike
OptSpec = 'call'; % Call option
Settle = '1-Jan-2013'; % Settlement date of option
Maturity = '1-Jan-2014'; % Maturity date of option
r = .05; % Risk-free rate (annual, continuous compounding)
Compounding = -1; % Continuous compounding
Basis = 0; % Act/Act day count convention
T = yearfrac(Settle, Maturity, Basis); % Time to expiration in years
```

Set up the `gbm` object and run the Monte Carlo simulation based on Geometric Brownian Motion (GBM) using the `simBySolution` method from Financial Toolbox™.

```
NTRIALS = 1000;
NPERIODS = daysact(Settle, Maturity);
dt = T/NPERIODS;
OptionGBM = gbm(r, Sigma, 'StartState', S0);
[Paths, Times, Z] = OptionGBM.simBySolution(NPERIODS, ...
'NTRIALS', NTRIALS, 'DeltaTime', dt, 'Antithetic', true);
```

Create the interest-rate term structure to define `RateSpec`.

```
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
'EndDates', Maturity, 'Rate', r, 'Compounding', Compounding, ...
'Basis', Basis)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
  Compounding: -1
        Disc: 0.9512
        Rates: 0.0500
   EndTimes: 1
  StartTimes: 0
   EndDates: 735600
  StartDates: 735235
ValuationDate: 735235
```



```
Basis: 0
EndMonthRule: 1
```

Price an American Asian option (arithmetic mean) by finding the average price over periods.

```
AvgPrices = zeros(NPERIODS+1, NTRIALS);
for i = 1:NPERIODS+1
    AvgPrices(i,:) = mean(squeeze(Paths(1:i,:,:)));
end
AsianPrice = optpricebysim(RateSpec, AvgPrices, Times, OptSpec, ...
    Strike, T, 'AmericanOpt', 1)
```

```
AsianPrice =
```

```
1.8540
```

### Compute the Price of an American Lookback Option Using Monte Carlo Simulation Based on Geometric Brownian Motion

Define the option.

```
S0 = 100; % Initial price of underlying asset
Sigma = .2; % Volatility of underlying asset
Strike = 110; % Strike
OptSpec = 'call'; % Call option
Settle = '1-Jan-2013'; % Settlement date of option
Maturity = '1-Jan-2014'; % Maturity date of option
r = .05; % Risk-free rate (annual, continuous compounding)
Compounding = -1; % Continuous compounding
Basis = 0; % Act/Act day count convention
T = yearfrac(Settle, Maturity, Basis); % Time to expiration in years
```

Set up the `gbm` object and run the Monte Carlo simulation based on Geometric Brownian Motion (GBM) using the `simBySolution` method from Financial Toolbox™.

```
NTRIALS = 1000;
NPERIODS = daysact(Settle, Maturity);
dt = T/NPERIODS;
OptionGBM = gbm(r, Sigma, 'StartState', S0);
[Paths, Times, Z] = OptionGBM.simBySolution(NPERIODS, ...
    'NTRIALS', NTRIALS, 'DeltaTime', dt, 'Antithetic', true);
```

Create the interest-rate term structure to define RateSpec.

```
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...  
    'EndDates', Maturity, 'Rate', r, 'Compounding', Compounding, ...  
    'Basis', Basis)
```

```
RateSpec =  
  
    FinObj: 'RateSpec'  
    Compounding: -1  
        Disc: 0.9512  
        Rates: 0.0500  
    EndTimes: 1  
    StartTimes: 0  
    EndDates: 735600  
    StartDates: 735235  
    ValuationDate: 735235  
        Basis: 0  
    EndMonthRule: 1
```

Price an American lookback option by finding the maximum price over periods.

```
MaxPrices = zeros(NPERIODS+1, NTRIALS);  
LastPrice = squeeze(Paths(1, :, :))';  
for i = 1:NPERIODS+1;  
    MaxPrices(i, :) = max([LastPrice; Paths(i, :)]);  
    LastPrice = MaxPrices(i, :);  
end  
LookbackPrice = optpricebysim(RateSpec, MaxPrices, Times, OptSpec, ...  
    Strike, T, 'AmericanOpt', 1)
```

```
LookbackPrice =  
  
    10.4084
```

### Compute the Price of a Bermudan Option Using Monte Carlo Simulation Based on Geometric Brownian Motion

Define the option.

```
S0 = 80; % Initial price of underlying asset
```

```

Sigma = .3; % Volatility of underlying asset
Strike = 75; % Strike
OptSpec = 'put'; % Put option
Settle = '1-Jan-2013'; % Settlement date of option
Maturity = '1-Jan-2014'; % Maturity date of option
ExerciseDates = {'1-Jun-2013', '1-Jan-2014'}; % Exercise dates of option
r = .05; % Risk-free rate (annual, continuous compounding)
Compounding = -1; % Continuous compounding
Basis = 0; % Act/Act day count convention
T = yearfrac(Settle, Maturity, Basis); % Time to expiration in years
ExerciseTimes = yearfrac(Settle, ExerciseDates, Basis)'; % Exercise times

```

Set up the `gbm` object and run the Monte Carlo simulation based on Geometric Brownian Motion (GBM) using the `simBySolution` method from Financial Toolbox™.

```

NTRIALS = 1000;
NPERIODS = daysact(Settle, Maturity);
dt = T/NPERIODS;
OptionGBM = gbm(r, Sigma, 'StartState', S0);
[Paths, Times, Z] = OptionGBM.simBySolution(NPERIODS, ...
'NTRIALS', NTRIALS, 'DeltaTime', dt, 'Antithetic', true);

```

Create the interest-rate term structure to define `RateSpec`.

```

RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
'EndDates', Maturity, 'Rate', r, 'Compounding', Compounding, ...
'Basis', Basis)

```

```
RateSpec =
```

```

    FinObj: 'RateSpec'
  Compounding: -1
        Disc: 0.9512
        Rates: 0.0500
    EndTimes: 1
   StartTimes: 0
    EndDates: 735600
   StartDates: 735235
ValuationDate: 735235
        Basis: 0
EndMonthRule: 1

```

Price the Bermudan option.

```
SimulatedPrices = squeeze(Paths);
BermudanPrice = optpricebysim(RateSpec, SimulatedPrices, Times, ...
OptSpec, Strike, ExerciseTimes)
```

```
BermudanPrice =
    5.3950
```

### Compute the Price of an American Spread Option Using Monte Carlo Simulation Based on Geometric Brownian Motion

Define the option.

```
S1 = 110; % Price of first underlying asset
S2 = 100; % Price of second underlying asset
Sigma1 = .1; % Volatility of first underlying asset
Sigma2 = .15; % Volatility of second underlying asset
Strike = 15; % Strike
Rho = .3; % Correlation between underlyings
OptSpec = 'put'; % Put option
Settle = '1-Jan-2013'; % Settlement date of option
Maturity = '1-Jan-2014'; % Maturity date of option
r = .05; % Risk-free rate (annual, continuous compounding)
Compounding = -1; % Continuous compounding
Basis = 0; % Act/Act day count convention
T = yearfrac(Settle, Maturity, Basis); % Time to expiration in years
```

Set up the `gbm` object and run the Monte Carlo simulation based on Geometric Brownian Motion (GBM) using the `simBySolution` method from Financial Toolbox™.

```
NTRIALS = 1000;
NPERIODS = daysact(Settle, Maturity);
dt = T/NPERIODS;
SpreadGBM = gbm(r*eye(2), diag([Sigma1;Sigma2]), 'Correlation', ...
[1 Rho;Rho 1], 'StartState', [S1;S2]);
[Paths, Times, Z] = SpreadGBM.simBySolution(NPERIODS, 'NTRIALS', NTRIALS, ...
'DeltaTime', dt, 'Antithetic', true);
```

Create the interest-rate term structure to define `RateSpec`.

```
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
'EndDates', Maturity, 'Rate', r, 'Compounding', Compounding, ...
'Basis', Basis)
```

```
RateSpec =
    FinObj: 'RateSpec'
    Compounding: -1
    Disc: 0.9512
    Rates: 0.0500
    EndTimes: 1
    StartTimes: 0
    EndDates: 735600
    StartDates: 735235
    ValuationDate: 735235
    Basis: 0
    EndMonthRule: 1
```

Price the American spread option.

```
Spread = squeeze(Paths(:,1,:) - Paths(:,2,:));
SpreadPrice = optpricebysim(RateSpec, Spread, Times, OptSpec, Strike, ...
T, 'AmericanOpt', 1)
```

```
SpreadPrice =
    9.0007
```

## Input Arguments

**RateSpec** — Interest-rate term structure of risk-free rates  
structure

Interest-rate term structure of risk-free rates (annualized and continuously compounded), specified by the `RateSpec` obtained from `intenvset`. The valuation date must be at the settlement date of the option, and the day-count basis and end-of-month rule must be the same as those used to calculate the `Times` input. For information on the interest-rate specification, see `intenvset`.

Data Types: struct

**SimulatedPrices** — Simulated prices  
matrix

Simulated prices, specified using a `(NumPeriods + 1)`-by-`NumTrials` matrix of risk-neutral simulated prices. The first element of `SimulatedPrices` is the initial value at time 0.

Data Types: `single` | `double`

### **Times** — Annual time factors associated with simulated prices

vector

Annual time factors associated with simulated prices, specified using a `(NumPeriods + 1)`-by-`1` column vector. Each element of `Times` is associated with the corresponding row of `SimulatedPrices`. The first element of `Times` must be 0 (current time).

Data Types: `single` | `double`

### **OptSpec** — Definition of option

string with values `'call'` or `'put'`

Definition of option as `'call'` or `'put'`, specified as a string.

Data Types: `char`

### **Strike** — Option strike price values

scalar | function handle

Option strike price values, specified as a scalar value Strike price. Strike for Bermudan options can be specified as a `1`-by-`NSTRIKES` vector or a function handle that returns the value of the strike given the time of the strike.

Data Types: `single` | `double` | `function_handle`

### **ExerciseTimes** — Exercise time for option

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Exercise time for the option, specified as a date string or a nonnegative integer as follows:

- For a European or Bermudan option, `ExerciseTimes` is a `1`-by-`1` (European) or `1`-by-`NSTRIKES` (Bermudan) vector of exercise times. For a European option, there is only one `ExerciseTimes` on the option expiry date.
- For an American option, `ExerciseTimes` is a `1`-by-`2` vector of exercise time boundaries. The option exercises on any date between, or including, the pair of times

on that row. If `ExerciseTimes` is 1-by-1, the option exercises between time 0 and the single listed `ExerciseTimes`.

Data Types: char | cell

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name`,`Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

Example: `Price =`

```
optpricebysim(RateSpec,Prices,Times,OptSpec,Settle,Strike,ExerciseTimes,'Ameri
```

### 'AmericanOpt' — Option type

0 European or Bermudan (default) | scalar flag with value [0,1]

Option type, specified as an integer scalar flag with these values:

- 0 — European or Bermudan
- 1 — American

For American options, the Longstaff-Schwartz least squares method calculates the early exercise premium.

Data Types: single | double

## Output Arguments

### Price — Price of option

scalar

Price of the option, returned as a scalar value.

## More About

- “Creating Geometric Brownian Motion (GBM) Models”

**See Also**

gbm | intenvset | simBySolution



# rangefloatbybdt

Price range floating note using Black-Derman-Toy tree

## Syntax

```
Price = rangefloatbybdt(BDTree,Spread,Settle,Maturity,  
RateSched)  
[Price,PriceTree] = rangefloatbybdt(BDTree,Spread,Settle,  
Maturity, RateSched, Name,Value)
```

## Description

`Price = rangefloatbybdt(BDTree,Spread,Settle,Maturity,RateSched)` calculates the price of the range note instrument at the valuation date using a BDT model.

`[Price,PriceTree] = rangefloatbybdt(BDTree,Spread,Settle,Maturity, RateSched, Name,Value)` calculates the price of the range note instrument at the valuation date and the price evolution for one or more range instruments using a BDT model with additional options specified by one or more `Name,Value` pair arguments.

## Input Arguments

### **BDTree**

Interest-rate tree structure created by `bdttree`.

### **Spread**

NINST-by-1 vector of the number of basis points over the reference rate.

### **Settle**

NINST-by-1 vector of dates representing the settle date of the range floating note.

---

**Note:** The `Settle` date for every range floating instrument is set to the `ValuationDate` of the BDT tree. The range floating note argument `Settle` is ignored.

---

### **Maturity**

NINST-by-1 vector of dates representing the maturity date of the floating-rate note.

### **RateSched**

NINST-by-1 vector of structures representing the range of rates within which cash flows are nonzero. Each element of the structure array contains two fields:

- `RateSched.Dates` — NDates-by-1 cell array of dates corresponding to the range schedule.
- `RateSched.Rates` — NDates-by-2 array with the first column containing the lower bound of the range and the second column containing the upper bound of the range. Cash flow for date `RateSched.Dates(n)` is nonzero for rates in the range `RateSched.Rates(n,1) < Rate < RateSched.Rate (n,2)`.

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes ( ' '). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

### **'Basis'**

NINST-by-1 vector representing the day-count basis used when annualizing the input forward rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)

- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

#### **'EndMonthRule'**

NINST-by-1 vector for end-of-month rule. Values are 1 (in effect) and 0 (not in effect).

**Default:** 1 (in effect)

#### **'Options'**

Structure created with `derivset` containing derivatives pricing options.

**Default:** None

#### **'Principal'**

NINST-by-1 vector of the notional principal amount.

**Default:** 100

#### **'Reset'**

NINST-by-1 vector representing the frequency of payments per year.

**Default:** 1

## **Output Arguments**

### **Price**

NINST-by-1 vector for expected prices at time 0.

## PriceTree

Structure containing trees of vectors of instrument prices and accrued interest, and a vector of observation times for each node. Values are:

- `PriceTree.PTree` contains the clean prices.
- `PriceTree.AITree` contains the accrued interest.
- `PriceTree.tObs` contains the observation times.

## Examples

### Compute the Price of a Range Note Using a Black-Derman-Toy Tree

This example shows how to compute the price of a range note using a Black-Derman-Toy tree with the following interest-rate term structure data.

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2011';
StartDates = ValuationDate;
EndDates = {'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'};
Compounding = 1;

% define RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% range note instrument matures in Jan-1-2014 and has the following RateSchedule:
Spread = 100;
Settle = 'Jan-1-2011';
Maturity = 'Jan-1-2014';
RateSched(1).Dates = {'Jan-1-2012'; 'Jan-1-2013' ; 'Jan-1-2014'};
RateSched(1).Rates = [0.045 0.055 ; 0.0525 0.0675; 0.06 0.08];

% data to build the tree is as follows:
% assume the volatility is 10%.
Sigma = 0.1;
BDTTS = bdttimespec(ValuationDate, EndDates, Compounding);
BDTVS = bdtvolspec(ValuationDate, EndDates, Sigma*ones(1, length(EndDates)));
BDTT = bdttree(BDTV, RS, BDTTS);

% price the instrument
Price = rangefloatbybdt(BDTT, Spread, Settle, Maturity, RateSched)
```

Price =  
97.5267

## More About

### Range Note Instrument

A range note is a structured (market-linked) security whose coupon rate is equal to the reference rate as long as the reference rate is within a certain range. If the reference rate is outside of the range, the coupon rate is 0 for that period. This type of instrument entitles the holder to cash flows that depend on the level of some reference interest rate and are floored to be positive. The note holder gets direct exposure to the reference rate. In return for the drawback that no interest will be paid for the time the range is left, they offer higher coupon rates than comparable standard products, like vanilla floating notes.

- “Pricing Options Structure”

## References

Jarrow, Robert, *Modelling Fixed Income Securities and Interest Rate Options*, Stanford Economics and Finance, 2nd edition, 2002.

### See Also

bdttree | bondbybdt | cfbybdt | fixedbybdt | floatbybdt | floorbybdt |  
instrangefloat | rangefloatbybk | rangefloatbyhjm | rangefloatbyhw |  
swapbybdt

## rangefloatbybk

Price range floating note using Black-Karasinski tree

### Syntax

```
Price = rangefloatbybk(BKTree,Spread,Settle,Maturity,
RateSched)
[Price,PriceTree] = rangefloatbybk(BKTree,Spread,Settle,
Maturity, RateSched, Name,Value)
```

### Description

`Price = rangefloatbybk(BKTree,Spread,Settle,Maturity,RateSched)` calculates the price of the range note instrument at the valuation date using a BK model.

`[Price,PriceTree] = rangefloatbybk(BKTree,Spread,Settle,Maturity, RateSched, Name,Value)` calculates the price of the range note instrument at the valuation date and the price evolution for one or more range instruments using a BK model with additional options specified by one or more `Name,Value` pair arguments.

### Input Arguments

#### **BKTree**

Interest-rate tree structure created by `bktree`.

#### **Spread**

NINST-by-1 vector of the number of basis points over the reference rate.

#### **Settle**

NINST-by-1 vector of dates representing the settle date of the range floating note.

---

**Note:** The **Settle** date for every range floating instrument is set to the **ValuationDate** of the BK tree. The range floating note argument **Settle** is ignored.

---

### **Maturity**

NINST-by-1 vector of dates representing the maturity date of the floating-rate note.

### **RateSched**

NINST-by-1 vector of structures representing the range of rates within which cash flows are nonzero. Each element of the structure array contains two fields:

- **RateSched.Dates** — NDates-by-1 cell array of dates corresponding to the range schedule.
- **RateSched.Rates** — NDates-by-2 array with the first column containing the lower bound of the range and the second column containing the upper bound of the range. Cash flow for date **RateSched.Dates**(*n*) is nonzero for rates in the range **RateSched.Rates**(*n*,1) < **Rate** < **RateSched.Rate** (*n*,2).

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of **Name**,**Value** arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as **Name1**,**Value1**, . . . ,**NameN**,**ValueN**.

### **'Basis'**

NINST-by-1 vector representing the day-count basis used when annualizing the input forward rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)

- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

**'EndMonthRule'**

NINST-by-1 vector for end-of-month rule. Values are 1 (in effect) and 0 (not in effect).

**Default:** 1 (in effect)

**'Options'**

Structure created with `derivset` containing derivatives pricing options.

**Default:** None

**'Principal'**

NINST-by-1 vector of the notional principal amount.

**Default:** 100

**'Reset'**

NINST-by-1 vector representing the frequency of payments per year.

**Default:** 1

## Output Arguments

**Price**

NINST-by-1 vector for expected prices at time 0.



## PriceTree

Structure containing trees of vectors of instrument prices and accrued interest, and a vector of observation times for each node. Values are:

- `PriceTree.PTree` contains the clean prices.
- `PriceTree.AITree` contains the accrued interest.
- `PriceTree.tObs` contains the observation times.

## Examples

### Compute the Price of a Range Note Using a Black-Karasinski Tree

This example shows how to compute the price of a range note using a Black-Karasinski tree with the following interest-rate term structure data.

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2011';
StartDates = ValuationDate;
EndDates = {'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'};
Compounding = 1;

% define RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% range note instrument matures in Jan-1-2014 and has the following RateSchedule:
Spread = 100;
Settle = 'Jan-1-2011';
Maturity = 'Jan-1-2014';
RateSched(1).Dates = {'Jan-1-2012'; 'Jan-1-2013' ; 'Jan-1-2014'};
RateSched(1).Rates = [0.045 0.055 ; 0.0525 0.0675; 0.06 0.08];

% data to build the tree is as follows:
VolDates = ['1-Jan-2012'; '1-Jan-2013'; '1-Jan-2014'; '1-Jan-2015'];
VolCurve = 0.01;
AlphaDates = '01-01-2015';
AlphaCurve = 0.1;

BKVS = bkvolspec(RS.ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);
BKTS = bktimespec(RS.ValuationDate, VolDates, Compounding);
```

```
BKT = bktree(BKVS, RS, BKTS);  
  
% price the instrument  
Price = rangefloatbybk(BKT, Spread, Settle, Maturity, RateSched)  
  
Price =  
  
    102.7574
```

## More About

### Range Note Instrument

A range note is a structured (market-linked) security whose coupon rate is equal to the reference rate as long as the reference rate is within a certain range. If the reference rate is outside of the range, the coupon rate is 0 for that period. This type of instrument entitles the holder to cash flows that depend on the level of some reference interest rate and are floored to be positive. The note holder gets direct exposure to the reference rate. In return for the drawback that no interest will be paid for the time the range is left, they offer higher coupon rates than comparable standard products, like vanilla floating notes.

- “Pricing Options Structure”

## References

Jarrow, Robert, *Modelling Fixed Income Securities and Interest Rate Options*, Stanford Economics and Finance, 2nd edition, 2002.

### See Also

bktree | bondbybk | capbybk | cfbybk | fixedbybk | floorbybk |  
instrangefloat | rangefloatbybdt | rangefloatbyhjm | rangefloatbyhw |  
swapbybk

# rangefloatbyhjm

Price range floating note using Heath-Jarrow-Morton tree

## Syntax

```
Price = rangefloatbyhjm(HJMTree,Spread,Settle,Maturity,  
RateSched)  
[Price,PriceTree] = rangefloatbyhjm(HJMTree,Spread,Settle,  
Maturity, RateSched, Name,Value)
```

## Description

Price = rangefloatbyhjm(HJMTree,Spread,Settle,Maturity,RateSched) calculates the price of the range note instrument at the valuation date using an HJM model.

[Price,PriceTree] = rangefloatbyhjm(HJMTree,Spread,Settle,Maturity, RateSched, Name,Value) calculates the price of the range note instrument at the valuation date and the price evolution for one or more range instruments using an HJM model with additional options specified by one or more Name,Value pair arguments.

## Input Arguments

### HJMTree

Interest-rate tree structure created by `hjmtree`.

### Spread

NINST-by-1 vector of the number of basis points over the reference rate.

### Settle

NINST-by-1 vector of dates representing the settle date of the range floating note.

---

**Note:** The `Settle` date for every range floating instrument is set to the `ValuationDate` of the HJM tree. The range floating note argument `Settle` is ignored.

---

### **Maturity**

NINST-by-1 vector of dates representing the maturity date of the floating-rate note.

### **RateSched**

NINST-by-1 vector of structures representing the range of rates within which cash flows are nonzero. Each element of the structure array contains two fields:

- `RateSched.Dates` — NDates-by-1 cell array of dates corresponding to the range schedule.
- `RateSched.Rates` — NDates-by-2 array with the first column containing the lower bound of the range and the second column containing the upper bound of the range. Cash flow for date `RateSched.Dates(n)` is nonzero for rates in the range `RateSched.Rates(n,1) < Rate < RateSched.Rate (n,2)`.

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

### **'Basis'**

NINST-by-1 vector representing the day-count basis used when annualizing the input forward rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)

- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

#### **'EndMonthRule'**

NINST-by-1 vector for end-of-month rule. Values are 1 (in effect) and 0 (not in effect).

**Default:** 1 (in effect)

#### **'Options'**

Structure created with `derivset` containing derivatives pricing options.

**Default:** None

#### **'Principal'**

NINST-by-1 vector of the notional principal amount.

**Default:** 100

#### **'Reset'**

NINST-by-1 vector representing the frequency of payments per year.

**Default:** 1

## **Output Arguments**

### **Price**

NINST-by-1 vector for expected prices at time 0.

## PriceTree

Structure containing trees of vectors of instrument prices and accrued interest, and a vector of observation times for each node. Values are:

- `PriceTree.PTree` contains the clean prices.
- `PriceTree.AITree` contains the accrued interest.
- `PriceTree.tObs` contains the observation times.

## Examples

### Compute the Price of a Range Note Using a Heath-Jarrow-Morton Tree

This example shows how to compute the price of a range note using a Heath-Jarrow-Morton tree with the following interest-rate term structure data.

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2011';
StartDates = ValuationDate;
EndDates = {'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'};
Compounding = 1;

% define RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% range note instrument matures in Jan-1-2014 and has the following RateSchedule:
Spread = 100;
Settle = 'Jan-1-2011';
Maturity = 'Jan-1-2014';
RateSched(1).Dates = {'Jan-1-2012'; 'Jan-1-2013' ; 'Jan-1-2014'};
RateSched(1).Rates = [0.045 0.055 ; 0.0525 0.0675; 0.06 0.08];

% data to build the tree is as follows:
Volatility = [.2; .19; .18; .17];
CurveTerm = [ 1; 2; 3; 4];
MaTree = {'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'};
HJMTree = hjmtimespec(ValuationDate, MaTree);
HJMVS = hjmvolspec('Proportional', Volatility, CurveTerm, 1e6);
HJMT = hjmtree(HJMVS, RS, HJMTree);

% price the instrument
```

Price = rangefloatbyhjm(HJMT, Spread, Settle, Maturity, RateSched)

Price =

90.2348

## More About

### Range Note Instrument

A range note is a structured (market-linked) security whose coupon rate is equal to the reference rate as long as the reference rate is within a certain range. If the reference rate is outside of the range, the coupon rate is 0 for that period. This type of instrument entitles the holder to cash flows that depend on the level of some reference interest rate and are floored to be positive. The note holder gets direct exposure to the reference rate. In return for the drawback that no interest will be paid for the time the range is left, they offer higher coupon rates than comparable standard products, like vanilla floating notes.

- “Pricing Options Structure”

## References

Jarrow, Robert, *Modelling Fixed Income Securities and Interest Rate Options*, Stanford Economics and Finance, 2nd edition, 2002.

### See Also

bondbyhjm | cfbyhjm | fixedbyhjm | floatbyhjm | floorbyhjm | hjmtree | instrangefloat | rangefloatbybdt | rangefloatbybk | rangefloatbyhw | swapbyhjm

## rangefloatbyhw

Price range floating note using Hull-White tree

### Syntax

```
Price = rangefloatbyhw(HWTree,Spread,Settle,Maturity,
RateSched)
[Price,PriceTree] = rangefloatbyhw(HWTree,Spread,Settle,
Maturity, RateSched, Name,Value)
```

### Description

Price = rangefloatbyhw(HWTree,Spread,Settle,Maturity, RateSched) calculates the price of the range note instrument at the valuation date using an HW model.

[Price,PriceTree] = rangefloatbyhw(HWTree,Spread,Settle, Maturity, RateSched, Name,Value) calculates the price of the range note instrument at the valuation date and the price evolution for one or more range instruments using an HW model with additional options specified by one or more Name,Value pair arguments.

### Input Arguments

#### **HWTree**

Interest-rate tree structure created by `hwtree`.

#### **Spread**

NINST-by-1 vector of the number of basis points over the reference rate.

#### **Settle**

NINST-by-1 vector of dates representing the settle date of the range floating note.



---

**Note:** The **Settle** date for every range floating instrument is set to the **ValuationDate** of the HW tree. The range floating note argument **Settle** is ignored.

---

### **Maturity**

NINST-by-1 vector of dates representing the maturity date of the floating-rate note.

### **RateSched**

NINST-by-1 vector of structures representing the range of rates within which cash flows are nonzero. Each element of the structure array contains two fields:

- **RateSched.Dates** — NDates-by-1 cell array of dates corresponding to the range schedule.
- **RateSched.Rates** — NDates-by-2 array with the first column containing the lower bound of the range and the second column containing the upper bound of the range. Cash flow for date **RateSched.Dates**(*n*) is nonzero for rates in the range **RateSched.Rates**(*n*,1) < **Rate** < **RateSched.Rate** (*n*,2).

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of **Name**,**Value** arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as **Name1**,**Value1**, . . . ,**NameN**,**ValueN**.

### **'Basis'**

NINST-by-1 vector representing the day-count basis used when annualizing the input forward rate tree.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)

- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### 'EndMonthRule'

NINST-by-1 vector for end-of-month rule. Values are 1 (in effect) and 0 (not in effect).

**Default:** 1 (in effect)

### 'Options'

Structure created with `derivset` containing derivatives pricing options.

**Default:** None

### 'Principal'

NINST-by-1 vector of the notional principal amount.

**Default:** 100

### 'Reset'

NINST-by-1 vector representing the frequency of payments per year.

**Default:** 1

## Output Arguments

### Price

NINST-by-1 vector for expected prices at time 0.

## PriceTree

Structure containing trees of vectors of instrument prices and accrued interest, and a vector of observation times for each node. Values are:

- `PriceTree.PTree` contains the clean prices.
- `PriceTree.AITree` contains the accrued interest.
- `PriceTree.tObs` contains the observation times.

## Examples

### Compute the Price of a Range Note Using a Hull-White Tree

This example shows how to compute the price of a range note using a Hull-White tree with the following interest-rate term structure data.

```
Rates = [0.035; 0.042147; 0.047345; 0.052707];
ValuationDate = 'Jan-1-2011';
StartDates = ValuationDate;
EndDates = {'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'};
Compounding = 1;

% define RateSpec
RS = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates,...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);

% range note instrument matures in Jan-1-2014 and has the following RateSchedule:
Spread = 100;
Settle = 'Jan-1-2011';
Maturity = 'Jan-1-2014';
RateSched(1).Dates = {'Jan-1-2012'; 'Jan-1-2013' ; 'Jan-1-2014'};
RateSched(1).Rates = [0.045 0.055 ; 0.0525 0.0675; 0.06 0.08];

% data to build the tree is as follows:
VolDates = ['1-Jan-2012'; '1-Jan-2013'; '1-Jan-2014'; '1-Jan-2015'];
VolCurve = 0.01;
AlphaDates = '01-01-2015';
AlphaCurve = 0.1;

HWVS = hwvolspec(RS.ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);
HWTS = hwtimespec(RS.ValuationDate, VolDates, Compounding);
```

```
HWT = hwtree(HWVS, RS, HWTS);  
  
% price the instrument  
Price = rangefloatbyhw(HWT, Spread, Settle, Maturity, RateSched)  
  
Price =  
  
    96.6501
```

## More About

### Range Note Instrument

A range note is a structured (market-linked) security whose coupon rate is equal to the reference rate as long as the reference rate is within a certain range. If the reference rate is outside of the range, the coupon rate is 0 for that period. This type of instrument entitles the holder to cash flows that depend on the level of some reference interest rate and are floored to be positive. The note holder gets direct exposure to the reference rate. In return for the drawback that no interest will be paid for the time the range is left, they offer higher coupon rates than comparable standard products, like vanilla floating notes.

- “Pricing Options Structure”

## References

Jarrow, Robert, *Modelling Fixed Income Securities and Interest Rate Options*, Stanford Economics and Finance, 2nd edition, 2002.

### See Also

bondbyhw | capbyhw | cfbyhw | fixedbyhw | floorbyhw | hwtree |  
instrangefloat | rangefloatbybdt | rangefloatbybk | rangefloatbyhjm |  
swapbyhw

# rate2disc

Discount factors from interest rates

## Syntax

**Usage 1:** Interval points are input as times in periodic units.

```
Disc = rate2disc(Compounding, Rates, EndTimes)
```

```
Disc = rate2disc(Compounding, Rates, EndTimes, StartTimes)
```

**Usage 2:** ValuationDate is passed and interval points are input as dates.

```
[Disc, EndTimes, StartTimes] = rate2disc(Compounding, Rates,  
EndDates, StartDates, ValuationDate)
```

```
[Disc, EndTimes, StartTimes] = rate2disc(Compounding, Rates,  
EndDates, StartDates, ValuationDate, Basis, EndMonthRule)
```

## Arguments

Compounding	<p>Scalar value representing the rate at which the input zero rates were compounded when annualized. This argument determines the formula for the discount factors:</p> <p>Compounding = 1, 2, 3, 4, 6, 12</p> <p><math>Disc = (1 + Z/F)^{-T}</math>, where F is the compounding frequency, Z is the zero rate, and T is the time in periodic units; for example, T = F is 1 year.</p> <p>Compounding = 365</p> <p><math>Disc = (1 + Z/F)^{-T}</math>, where F is the number of days in the basis year and T is a number of days elapsed computed by basis.</p> <p>Compounding = -1</p> <p><math>Disc = \exp(-T*Z)</math>, where T is time in years.</p>
-------------	--

Rates	Number of points (NPOINTS) by number of curves (NCURVES) matrix of rates in decimal form. For example, 5% is 0.05 in Rates. Rates are the yields over investment intervals from StartTimes, when the cash flow is valued, to EndTimes, when the cash flow is received.
EndTimes	<p>NPOINTS-by-1 vector or scalar of times in periodic units ending the interval to discount over.</p> <hr/> <p><b>Note:</b> When ValuationDate is not passed, the third and fourth arguments (EndTimes and StartTimes) are interpreted as times.</p>
StartTimes	(Optional) NPOINTS-by-1 vector or scalar of times in periodic units starting the interval to discount over. Default = 0.
EndDates	<p>NPOINTS-by-1 vector or scalar of serial maturity dates ending the interval to discount over.</p> <hr/> <p><b>Note:</b> : When ValuationDate is passed, the third and fourth arguments (EndDates and StartDates) are interpreted as dates. The date ValuationDate is used as the zero point for computing the times.</p>
StartDates	<p>(Optional) NPOINTS-by-1 vector or scalar of serial dates starting the interval to discount over. StartDates must be earlier than EndDates.</p> <p>Default = ValuationDate.</p>
ValuationDate	Scalar value in serial date number form representing the observation date of the investment horizons entered in StartDates and EndDates. Required in Usage 2. Omitted or passed as an empty matrix to invoke Usage 1.

<b>Basis</b>	<p>(Optional) Day-count basis of the instrument when using <b>Usage 2</b>. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<b>EndMonthRule</b>	<p>(Optional) End-of-month rule when using <b>Usage 2</b>. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.</p>

## Description

**Usage 1:** `Disc = rate2disc(Compounding, Rates, EndTimes)` or `Disc = rate2disc(Compounding, Rates, EndTimes, StartTimes)` where interval points are input as times in periodic units.

**Usage 2:** `[Disc, EndTimes, StartTimes] = rate2disc(Compounding, Rates, EndDates, StartDates, ValuationDate)` or `[Disc, EndTimes, StartTimes] = rate2disc(Compounding, Rates, EndDates, StartDates, ValuationDate, Basis, EndMonthRule)` where `ValuationDate` is passed and interval points are input as dates.

`rate2disc` computes the discounts over a series of `NPOINTS` time intervals given the annualized yield over those intervals. `NCURVES` different rate curves can be translated at once if they have the same time structure. The time intervals can represent a zero curve or a forward curve.

The output `Disc` is an `NPOINTS`-by-`NCURVES` column vector of discount factors in decimal form representing the value at time `StartTime` of a unit cash flow received at time `EndTime`.

You can specify the investment intervals either with input times (**Usage 1**) or with input dates (**Usage 2**). Entering `ValuationDate` invokes the date interpretation; omitting `ValuationDate` invokes the default time interpretations.

For **Usage 1**:

- `StartTimes` is an `NPOINTS`-by-1 column vector of times starting the interval to discount over, measured in periodic units.
- `EndTimes` is an `NPOINTS`-by-1 column vector of times ending the interval to discount over, measured in periodic units.

For **Usage 2**:

- `StartDates` is an `NPOINTS`-by-1 column vector of serial dates starting the interval to discount over, measured in days.
- `EndDates` is an `NPOINTS`-by-1 column vector of serial dates ending the interval to discount over, measured in days.

If `Compounding = 365` (daily), `StartDates` and `EndDates` are measured in days as in **Usage 2**. Otherwise, in **Usage 1**, the arguments contain values, `T`, computed from SIA semiannual time factors, `Tsemi`, by the formula  $T = T_{\text{semi}}/2 * F$ , where `F` is the compounding frequency.



## Examples

**Example 1** demonstrates **Usage 1**. Compute discounts from a zero curve at 6 months, 12 months, and 24 months. The times to the cash flows are 1, 2, and 4. You are computing the present value (at time 0) of the cash flows.

```
Compounding = 2;
Rates = [0.05; 0.06; 0.065];
EndTimes = [1; 2; 4];
Disc = rate2disc(Compounding, Rates, EndTimes)
```

```
Disc =
    0.9756
    0.9426
    0.8799
```

**Example 2** demonstrates **Usage 2**. Compute discounts from a zero curve at 6 months, 12 months, and 24 months. Use dates to specify the ending time horizon.

```
Compounding = 2;
Rates = [0.05; 0.06; 0.065];
EndDates = ['10/15/97'; '04/15/98'; '04/15/99'];
ValuationDate = '4/15/97';
Disc = rate2disc(Compounding, Rates, EndDates, [], ValuationDate)
```

```
Disc =
    0.9756
    0.9426
    0.8799
```

**Example 3** demonstrates **Usage 1**. Compute discounts from the 1-year forward rates beginning now, in 6 months, and in 12 months. Use monthly compounding. The times to the cash flows are 12, 18, 24, and the forward times are 0, 6, 12.

```
Compounding = 12;
Rates = [0.05; 0.04; 0.06];
EndTimes = [12; 18; 24];
StartTimes = [0; 6; 12];
Disc = rate2disc(Compounding, Rates, EndTimes, StartTimes)
```

```
Disc =
    0.9513
    0.9609
    0.9419
```

**See Also**

disc2rate | ratetimes

## ratetimes

Change time intervals defining interest-rate environment

### Syntax

Usage 1: ValuationDate not passed; third through sixth arguments are interpreted as times.

```
[Rates, EndTimes, StartTimes] = ratetimes(Compounding,
RefRates, RefEndTimes, RefStartTimes, EndTimes, StartTimes)
```

Usage 2: ValuationDate passed and interval points input as dates.

```
[Rates, EndTimes, StartTimes] = ratetimes(Compounding,
RefRates, RefEndDates, RefStartDates, EndDates, StartDates,
ValuationDate)
```

### Arguments

Compounding	<p>Scalar value representing the rate at which the input zero rates were compounded when annualized. This argument determines the formula for the discount factors:</p> <p>Compounding = 1, 2, 3, 4, 6, 12</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the compounding frequency, Z is the zero rate, and T is the time in periodic units; for example, T = F is 1 year.</p> <p>Compounding = 365</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the number of days in the basis year and T is a number of days elapsed computed by basis.</p> <p>Compounding = -1</p> <p>Disc = <math>\exp(-T*Z)</math>, where T is time in years.</p>
-------------	--

RefRates	NREFPTS-by-NCURVES matrix of reference rates in decimal form. RefRates are the yields over investment intervals from RefStartTimes, when the cash flow is valued, to RefEndTimes, when the cash flow is received.
RefEndTimes	NREFPTS-by-1 vector or scalar of times in periodic units ending the intervals corresponding to RefRates.
RefStartTimes	(Optional) NREFPTS-by-1 vector or scalar of times in periodic units starting the intervals corresponding to RefRates. Default = 0.
EndTimes	NPOINTS-by-1 vector or scalar of times in periodic units ending the interval to discount over.
StartTimes	(Optional) NPOINTS-by-1 vector or scalar of times in periodic units starting the interval to discount over. Default = 0.
RefEndDates	NREFPTS-by-1 vector or scalar of serial dates ending the intervals corresponding to RefRates.
RefStartDates	(Optional) NREFPTS-by-1 vector or scalar of serial dates starting the intervals corresponding to RefRates. Default = ValuationDate.
EndDates	NPOINTS-by-1 vector or scalar of serial maturity dates ending the interval to discount over.
StartDates	(Optional) NPOINTS-by-1 vector or scalar of serial dates starting the interval to discount over. StartDates must be earlier than EndDates.  Default = ValuationDate.
ValuationDate	Scalar value in serial date number form representing the observation date of the investment horizons entered in StartDates and EndDates. Required in Usage 2. Omitted or passed as an empty matrix to invoke Usage 1.

## Description

[Rates, EndTimes, StartTimes] = ratetimes(Compounding, RefRates, RefEndTimes, RefStartTimes, EndTimes, StartTimes) and [Rates, EndTimes, StartTimes] = ratetimes(Compounding, RefRates,

RefEndDates, RefStartDates, EndDates, StartDates, ValuationDate) change time intervals defining an interest-rate environment.

ratetimes takes an interest-rate environment defined by yields over one collection of time intervals and computes the yields over another set of time intervals. The zero rate is assumed to be piece-wise linear in time.

Rates is an NPOINTS-by-NCURVES matrix of rates implied by the reference interest-rate structure and sampled at new intervals.

StartTimes is an NPOINTS-by-1 column vector of times starting the new intervals where rates are desired, measured in periodic units.

EndTimes is an NPOINTS-by-1 column vector of times ending the new intervals, measured in periodic units.

If Compounding = 365 (daily), StartTimes and EndTimes are measured in days. The arguments otherwise contain values, T, computed from SIA semiannual time factors, Tsemi, by the formula  $T = T_{\text{semi}}/2 * F$ , where F is the compounding frequency.

You can specify the investment intervals either with input times (Usage 1) or with input dates (Usage 2). Entering the argument ValuationDate invokes the date interpretation; omitting ValuationDate invokes the default time interpretations.

## Examples

**Example 1.** The reference environment is a collection of zero rates at 6, 12, and 24 months. Create a collection of 1-year forward rates beginning at 0, 6, and 12 months.

```
RefRates = [0.05; 0.06; 0.065];
RefEndTimes = [1; 2; 4];
StartTimes = [0; 1; 2];
EndTimes = [2; 3; 4];
Rates = ratetimes(2, RefRates, RefEndTimes, 0, EndTimes,...
StartTimes)
```

```
Rates =
0.0600
0.0688
0.0700
```

**Example 2.** Interpolate a zero yield curve to different dates. Zero curves start at the default date of ValuationDate.

```
RefRates = [0.04; 0.05; 0.052];
RefDates = [729756; 729907; 730121];
Dates    = [730241; 730486];
ValuationDate = 729391;
Rates = ratetimes(2, RefRates, RefDates, [], Dates, [],...
ValuationDate)
```

```
Rates =
    0.0520
    0.0520
```

### See Also

[disc2rate](#) | [rate2disc](#)

# spreadbykirk

Price European spread options using Kirk pricing model

## Syntax

Price = spreadbykirk(RateSpec,StockSpec1,StockSpec2,Settle,Maturity,OptSpec,Strike,Corr)

## Description

Price = spreadbykirk(RateSpec,StockSpec1,StockSpec2,Settle,Maturity,OptSpec,Strike,Corr) returns the price for a European spread option using the Kirk pricing model.

## Examples

### Compute the Price of a Spread Option Using the Kirk Model

Define the spread option dates.

```
Settle = '01-Jan-2012';
Maturity = '01-April-2012';
```

Define asset 1. Price and volatility of RBOB gasoline

```
Price1gallon = 2.85;           % $/gallon
Price1 = Price1gallon * 42;    % $/barrel
Vol1 = 0.29;
```

Define asset 2. Price and volatility of WTI crude oil

```
Price2 = 93.20;               % $/barrel
Vol2 = 0.36;
```

Define the correlation between the underlying asset prices of asset 1 and asset 2.

```
Corr = 0.42;
```

Define the spread option.

```
OptSpec = 'call';  
Strike = 20;
```

Define the RateSpec.

```
rates = 0.05;  
Compounding = -1;  
Basis = 1;  
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...  
    'EndDates', Maturity, 'Rates', rates, ...  
    'Compounding', Compounding, 'Basis', Basis)
```

RateSpec =

```
    FinObj: 'RateSpec'  
    Compounding: -1  
        Disc: 0.9876  
        Rates: 0.0500  
    EndTimes: 0.2500  
    StartTimes: 0  
    EndDates: 734960  
    StartDates: 734869  
    ValuationDate: 734869  
        Basis: 1  
    EndMonthRule: 1
```

Define the StockSpec for the two assets.

```
StockSpec1 = stockspec(Vol1, Price1)  
StockSpec2 = stockspec(Vol2, Price2)
```

StockSpec1 =

```
    FinObj: 'StockSpec'  
    Sigma: 0.2900  
    AssetPrice: 119.7000  
    DividendType: []  
    DividendAmounts: 0  
    ExDividendDates: []
```

StockSpec2 =



```

        FinObj: 'StockSpec'
        Sigma: 0.3600
    AssetPrice: 93.2000
    DividendType: []
    DividendAmounts: 0
    ExDividendDates: []

```

Compute the European spread option price based on the Kirk model.

```

Price = spreadbykirk(RateSpec, StockSpec1, StockSpec2, Settle, ...
Maturity, OptSpec, Strike, Corr)

```

```

Price =
    11.1904

```

- “Pricing European and American Spread Options”
- “Hedging Strategies Using Spread Options”

## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

Interest-rate term structure (annualized and continuously compounded), specified by the **RateSpec** obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: `struct`

### **StockSpec1** — Stock specification for underlying asset 1

structure

Stock specification for underlying asset 1. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is

represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: `struct`

### **StockSpec2 — Stock specification for underlying asset 2**

structure

Stock specification for underlying asset 2. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: `struct`

### **Settle — Settlement dates for spread option**

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Settlement dates for the spread option, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: `char` | `cell`

### **Maturity — Maturity date for spread option**

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Maturity date for spread option, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: `char` | `cell`

### **OptSpec — Definition of option**

string with values 'call' or 'put' | cell array of strings

Definition of option as 'call' or 'put', specified as a NINST-by-1 cell array of strings.

Data Types: `cell` | `char`

### **Strike — Option strike price values**

integer | vector of integers

Option strike price values, specified as an integer using a NINST-by-1 vector of strike price values.

If **Strike** is equal to 0, the function computes the price of an exchange option.

Data Types: single | double

### **Corr — Correlation between underlying asset prices**

integer | vector of integers

Correlation between underlying asset prices, specified as an integer using a NINST-by-1 vector.

Data Types: single | double

## **Output Arguments**

### **Price — Expected prices of spread option**

vector

Expected prices of the spread option, returned as a NINST-by-1 vector.

## **More About**

- “Spread Option”

## **References**

Carmona, R., Durrleman, V., “Pricing and Hedging Spread Options,” *SIAM Review*, Vol. 45, No. 4, pp. 627–685, Society for Industrial and Applied Mathematics, 2003.

## **See Also**

spreadbybjs | spreadbyfd | spreadbyls | spreadsensbykirk

## spreadbybjs

Price European spread options using Bjerksund-Stensland pricing model

### Syntax

```
Price = spreadbybjs(RateSpec,StockSpec1,StockSpec2,Settle,Maturity,  
OptSpec,Strike,Corr)
```

### Description

Price = spreadbybjs(RateSpec,StockSpec1,StockSpec2,Settle,Maturity,OptSpec,Strike,Corr) returns the price for a European spread option using the Bjerksund-Stensland pricing model.

### Examples

#### Compute the Price of a Spread Option Using the Bjerksund-Stensland Model

Define the spread option dates.

```
Settle = '01-Jan-2012';  
Maturity = '01-April-2012';
```

Define asset 1. Price and volatility of RBOB gasoline

```
Price1gallon = 2.85;           % $/gallon  
Price1 = Price1gallon * 42;   % $/barrel  
Vol1 = 0.29;
```

Define asset 2. Price and volatility of WTI crude oil

```
Price2 = 93.20;              % $/barrel  
Vol2 = 0.36;
```

Define the correlation between the underlying asset prices of asset 1 and asset 2.

```
Corr = 0.42;
```

Define the spread option.

```
OptSpec = 'call';  
Strike = 20;
```

Define the RateSpec.

```
rates = 0.05;  
Compounding = -1;  
Basis = 1;  
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...  
    'EndDates', Maturity, 'Rates', rates, ...  
    'Compounding', Compounding, 'Basis', Basis)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'  
    Compounding: -1  
        Disc: 0.9876  
        Rates: 0.0500  
    EndTimes: 0.2500  
    StartTimes: 0  
    EndDates: 734960  
    StartDates: 734869  
    ValuationDate: 734869  
        Basis: 1  
    EndMonthRule: 1
```

Define the StockSpec for the two assets.

```
StockSpec1 = stockspec(Vol1, Price1)  
StockSpec2 = stockspec(Vol2, Price2)
```

```
StockSpec1 =
```

```
    FinObj: 'StockSpec'  
    Sigma: 0.2900  
    AssetPrice: 119.7000  
    DividendType: []  
    DividendAmounts: 0  
    ExDividendDates: []
```

```
StockSpec2 =
```

```
        FinObj: 'StockSpec'  
        Sigma: 0.3600  
    AssetPrice: 93.2000  
    DividendType: []  
    DividendAmounts: 0  
    ExDividendDates: []
```

Compute the European spread option price based on the Bjerksund-Stensland model.

```
Price = spreadbybjs(RateSpec, StockSpec1, StockSpec2, Settle, ...  
Maturity, OptSpec, Strike, Corr)
```

```
Price =  
    11.2000
```

- “Pricing European and American Spread Options”
- “Hedging Strategies Using Spread Options”

## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

Interest-rate term structure (annualized and continuously compounded), specified by the **RateSpec** obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: `struct`

### **StockSpec1** — Stock specification for underlying asset 1

structure

Stock specification for underlying asset 1. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is

represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: struct

### **StockSpec2 — Stock specification for underlying asset 2**

structure

Stock specification for underlying asset 2. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: struct

### **Settle — Settlement dates for spread option**

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Settlement dates for the spread option, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: char | cell

### **Maturity — Maturity date for spread option**

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Maturity date for spread option, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: char | cell

### **OptSpec — Definition of option**

string with values 'call' or 'put' | cell array of strings

Definition of option as 'call' or 'put', specified as a NINST-by-1 cell array of strings.

Data Types: char | cell

### **Strike — Option strike price values**

integer | vector of integers

Option strike price values, specified as an integer using a NINST-by-1 vector of strike price values.

If **Strike** is equal to zero the function computes the price of an exchange option.

Data Types: `single` | `double`

### **Corr — Correlation between underlying asset prices**

`integer` | `vector of integers`

Correlation between underlying asset prices, specified as an integer using a NINST-by-1 vector.

Data Types: `single` | `double`

## **Output Arguments**

### **Price — Expected prices of spread option**

`vector`

Expected prices of the spread option, returned as a NINST-by-1 vector.

## **More About**

- “Spread Option”

## **References**

Carmona, R., Durrleman, V., “Pricing and Hedging Spread Options,” *SIAM Review*, Vol. 45, No. 4, pp. 627–685, Society for Industrial and Applied Mathematics, 2003.

Bjerksund, Petter, Stensland, Gunnar, “Closed form spread option valuation,” Department of Finance, NHH, 2006.

## **See Also**

`spreadbybjs` | `spreadbyfd` | `spreadbyls` | `spreadsensbykirk`



# spreadbyfd

Price European or American spread options using finite difference method

## Syntax

```
Price = spreadbyfd(RateSpec,StockSpec1,StockSpec2,Settle,Maturity,
OptSpec,Strike,Corr)
Price = spreadbyfd( ____,Name,Value)
```

```
[Price,PriceGrid,AssetPrice1,AssetPrice2,Times] = spreadbyfd(
RateSpec,StockSpec1,StockSpec2,Settle,Maturity,
OptSpec,Strike,Corr)
[Price,PriceGrid,AssetPrice1,AssetPrice2,Times] = spreadbyfd( ____,
Name,Value)
```

## Description

`Price = spreadbyfd(RateSpec,StockSpec1,StockSpec2,Settle,Maturity,OptSpec,Strike,Corr)` returns the price of European or American call or put spread options using the Alternate Direction Implicit (ADI) finite difference method. The spread is between the asset defined in `StockSpec1` minus the asset defined in `StockSpec2`.

`Price = spreadbyfd( ____,Name,Value)` returns the price of European or American call or put spread options using the Alternate Direction Implicit (ADI) finite difference method using optional name-value pair arguments. The spread is between the asset defined in `StockSpec1` minus the asset defined in `StockSpec2`.

`[Price,PriceGrid,AssetPrice1,AssetPrice2,Times] = spreadbyfd(RateSpec,StockSpec1,StockSpec2,Settle,Maturity,OptSpec,Strike,Corr)` returns the `Price`, `PriceGrid`, `AssetPrice1`, `AssetPrice2`, and `Times` for a European or American call or put spread options using the Alternate Direction Implicit (ADI) finite difference method. The spread is between the asset defined in `StockSpec1` minus the asset defined in `StockSpec2`.

`[Price,PriceGrid,AssetPrice1,AssetPrice2,Times] = spreadbyfd( ____,Name,Value)` returns the `Price`, `PriceGrid`, `AssetPrice1`, `AssetPrice2`, and `Times` for a European or American call or put spread options using the Alternate Direction

Implicit (ADI) finite difference method using optional name-value pair arguments. The spread is between the asset defined in StockSpec1 minus the asset defined in StockSpec2.

## Examples

### Compute the Price of a Spread Option Using the Alternate Direction Implicit (ADI) Finite Difference Method

Define the spread option dates.

```
Settle = '01-Jan-2012';  
Maturity = '01-April-2012';
```

Define asset 1. Price and volatility of RBOB gasoline

```
Price1gallon = 2.85;           % $/gallon  
Price1 = Price1gallon * 42;    % $/barrel  
Vol1 = 0.29;
```

Define asset 2. Price and volatility of WTI crude oil

```
Price2 = 93.20;               % $/barrel  
Vol2 = 0.36;
```

Define the correlation between the underlying asset prices of asset 1 and asset 2.

```
Corr = 0.42;
```

Define the spread option.

```
OptSpec = 'call';  
Strike = 20;
```

Define the RateSpec.

```
rates = 0.05;  
Compounding = -1;  
Basis = 1;  
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...  
    'EndDates', Maturity, 'Rates', rates, ...  
    'Compounding', Compounding, 'Basis', Basis)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
```

```

Compounding: -1
  Disc: 0.9876
  Rates: 0.0500
  EndTimes: 0.2500
  StartTimes: 0
  EndDates: 734960
  StartDates: 734869
ValuationDate: 734869
  Basis: 1
  EndMonthRule: 1

```

Define the `StockSpec` for the two assets.

```

StockSpec1 = stockspec(Vol1, Price1)
StockSpec2 = stockspec(Vol2, Price2)

```

```

StockSpec1 =

```

```

  FinObj: 'StockSpec'
  Sigma: 0.2900
  AssetPrice: 119.7000
  DividendType: []
  DividendAmounts: 0
  ExDividendDates: []

```

```

StockSpec2 =

```

```

  FinObj: 'StockSpec'
  Sigma: 0.3600
  AssetPrice: 93.2000
  DividendType: []
  DividendAmounts: 0
  ExDividendDates: []

```

Compute the spread option price based on the Alternate Direction Implicit (ADI) finite difference method.

```

[Price, PriceGrid, AssetPrice1, AssetPrice2, Times] = ...
spreadbyfd(RateSpec, StockSpec1, StockSpec2, Settle, ...
Maturity, OptSpec, Strike, Corr);

```

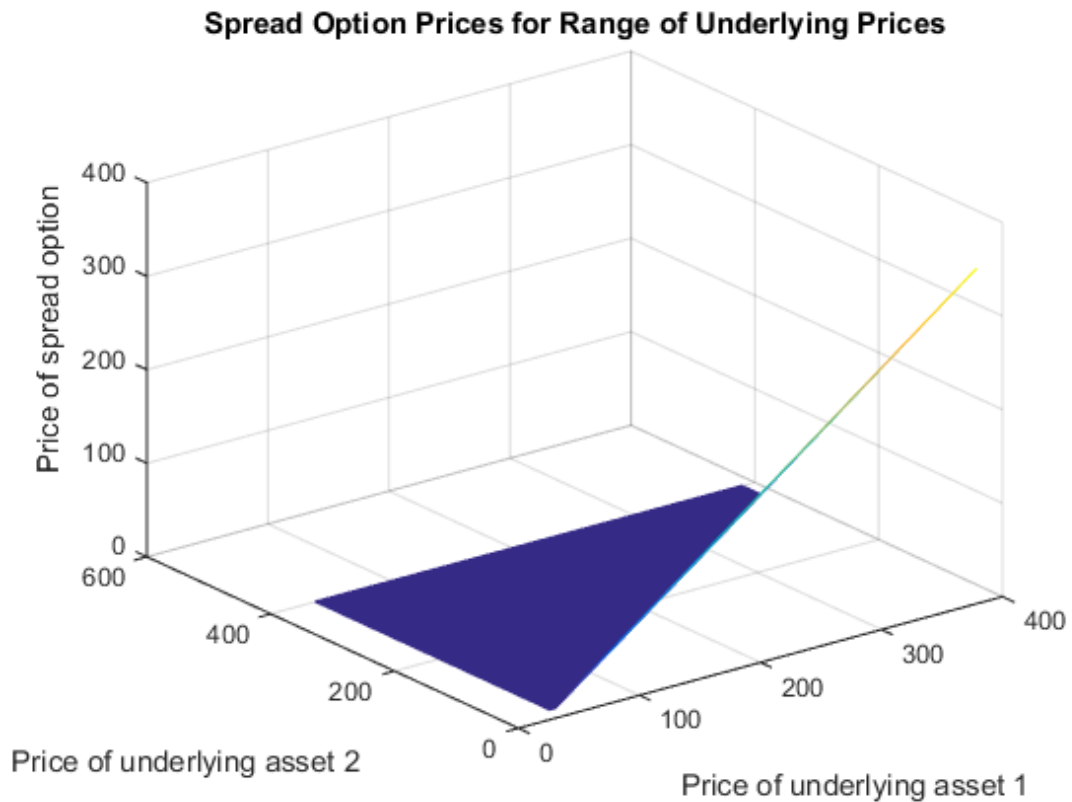
Display the price.

Price

```
Price =  
    11.1998
```

Plot the finite difference grid.

```
mesh(AssetPrice1, AssetPrice2, PriceGrid(:, :, 1));  
    title('Spread Option Prices for Range of Underlying Prices');  
    xlabel('Price of underlying asset 1');  
    ylabel('Price of underlying asset 2');  
    zlabel('Price of spread option');
```



- “Pricing European and American Spread Options”
- “Hedging Strategies Using Spread Options”

## Input Arguments

**RateSpec** — Interest-rate term structure  
structure

Interest-rate term structure (annualized and continuously compounded), specified by the `RateSpec` obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: struct

### **StockSpec1 — Stock specification for underlying asset 1**

structure

Stock specification for underlying asset 1. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: struct

### **StockSpec2 — Stock specification for underlying asset 2**

structure

Stock specification for underlying asset 2. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: struct

### **Settle — Settlement dates for spread option**

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Settlement dates for the spread option, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: char | cell

### **Maturity — Maturity date for spread option**

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Maturity date for spread option, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: char | cell

### **OptSpec — Definition of option**

string with values 'call' or 'put' | cell array of strings

Definition of option as 'call' or 'put', specified as a NINST-by-1 cell array of strings.

Data Types: char | cell

### **Strike — Option strike price values**

integer | vector of integers

Option strike price values, specified as an integer using a NINST-by-1 vector of strike price values.

Data Types: single | double

### **Corr — Correlation between underlying asset prices**

integer | vector of integers

Correlation between underlying asset prices, specified as an integer using a NINST-by-1 vector.

Data Types: single | double

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name,Value arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

Example: [Price,PriceGrid,AssetPrice1,AssetPrice2,Times] = spreadbyfd(RateSpec,StockSpec1,StockSpec2,Settle,Maturity,OptSpec,Strike,Corr,

### **'AssetPriceMin' — Minimum price for price grid boundary**

if unspecified, StockSpec values are calculated based on asset distributions at maturity (default) | array

Minimum price for price grid boundary, specified by a 1-by-2 array. The first entry in the array corresponds to the first asset defined by StockSpec1 and the second entry corresponds to the second asset defined by StockSpec2.

For the finite difference method, the composition of the grid affects the quality of the output as well as the execution time. It is highly recommended to use the optional arguments `AssetPriceMin`, `AssetPriceMax`, `PriceGridSize`, and `TimeGridSize` to control the composition of the grid to ensure the quality of the output and a reasonable execution time.

Data Types: `single` | `double`

**'AssetPriceMax' — Maximum price for price grid boundary**

if unspecified, `StockSpec` values are calculated based on asset distributions at maturity (default) | array

Maximum price for price grid boundary, specified by a 1-by-2 array. The first entry in the array corresponds to the first asset defined by `StockSpec1` and the second entry corresponds to the second asset defined by `StockSpec2`.

For the finite difference method, the composition of the grid affects the quality of the output as well as the execution time. It is highly recommended to use the optional arguments `AssetPriceMin`, `AssetPriceMax`, `PriceGridSize`, and `TimeGridSize` to control the composition of the grid to ensure the quality of the output and a reasonable execution time.

Data Types: `single` | `double`

**'PriceGridSize' — Size for finite difference grid**

[300,300] (default) | array

Size for finite difference grid, specified by a 1-by-2 array. The first entry corresponds to the first asset defined by `StockSpec1` and the second entry corresponds to the second asset defined by `StockSpec2`.

For the finite difference method, the composition of the grid affects the quality of the output as well as the execution time. It is highly recommended to use the optional arguments `AssetPriceMax`, `PriceGridSize`, and `TimeGridSize` to control the composition of the grid to ensure the quality of the output and a reasonable execution time.

Data Types: `single` | `double`

**'TimeGridSize' — Size of the time grid for finite difference grid**

100 (default) | scalar | nonnegative integer

Size of the time grid for finite difference grid, specified as a nonnegative integer.



For the finite difference method, the composition of the grid affects the quality of the output as well as the execution time. It is highly recommended to use the optional arguments `AssetPriceMax`, `PriceGridSize`, and `TimeGridSize` to control the composition of the grid to ensure the quality of the output and a reasonable execution time.

Data Types: `single` | `double`

#### 'AmericanOpt' — Option type

0 European (default) | scalar | vector of positive integers[0, 1]

Option type, specified as NINST-by-1 positive integer scalar flags with values:

- 0 — European
- 1 — American

Data Types: `single` | `double`

## Output Arguments

### Price — Expected prices of spread option

vector

Expected prices of the spread option, returned as a NINST-by-1 vector.

### PriceGrid — Grid containing prices calculated by finite difference method

array

Grid containing prices calculated by finite difference method, returned as a 3-D grid with a size of `PriceGridSize(1) * PriceGridSize(2) * TimeGridSize`. The price for  $t = 0$  is contained in `PriceGrid(:, :, 1)`.

### AssetPrice1 — Prices for first asset defined by StockSpec1

vector

Prices for first asset defined by `StockSpec1`, corresponding to the first dimension of `PriceGrid`, returned as a vector.

### AssetPrice2 — Prices for second asset defined by StockSpec2

vector

Prices for second asset defined by `StockSpec2`, corresponding to the second dimension of `PriceGrid`, returned as a vector.

**Times** — Times corresponding to third dimension of `PriceGrid`  
vector

Times corresponding to third dimension of `PriceGrid`, returned as a vector.

## More About

- “Spread Option”

## References

Carmona, R., Durrleman, V., “Pricing and Hedging Spread Options,” *SIAM Review*, Vol. 45, No. 4, pp. 627–685, Society for Industrial and Applied Mathematics, 2003.

Villeneuve, S., Zanette, A., “Parabolic ADI Methods for Pricing American Options on Two Stocks,” *Mathematics of Operations Research*, Vol. 27, No. 1, pp. 121–149, INFORMS, 2002.

Ikonen, S., Toivanen, J., *Efficient Numerical Methods for Pricing American Options Under Stochastic Volatility*, Wiley InterScience, 2007.

## See Also

`spreadbybjs` | `spreadbykirk` | `spreadbyls` | `spreadsensbyfd`

# spreadbyls

Price European or American spread options using Monte Carlo simulations

## Syntax

```
Price = spreadbyls(RateSpec,StockSpec1,StockSpec2,Settle,Maturity,
OptSpec,Strike,Corr)
```

```
Price = spreadbyls( ____,Name,Value)
```

```
[Price,Paths,Times,Z] = spreadbyls(RateSpec,StockSpec1,StockSpec2,
Settle,Maturity,
OptSpec,Strike,Corr)
```

```
[Price,Paths,Times,Z] = spreadbyls( ____,Name,Value)
```

## Description

`Price = spreadbyls(RateSpec,StockSpec1,StockSpec2,Settle,Maturity,OptSpec,Strike,Corr)` returns the price of a European or American call or put spread option using Monte Carlo simulations.

`Price = spreadbyls( ____,Name,Value)` returns the price of a European or American call or put spread option using Monte Carlo simulations using optional name-value pair arguments.

`[Price,Paths,Times,Z] = spreadbyls(RateSpec,StockSpec1,StockSpec2,Settle,Maturity,OptSpec,Strike,Corr)` returns the `Price`, `Paths`, `Times`, and `Z` of a European or American call or put spread option using Monte Carlo simulations.

`[Price,Paths,Times,Z] = spreadbyls( ____,Name,Value)` returns the `Price`, `Paths`, `Times`, and `Z` of a European or American call or put spread option using Monte Carlo simulations using optional name-value pair arguments.

## Examples

### Compute the Price of a Spread Option Using Monte Carlo Simulation

Define the spread option dates.

```
Settle = '01-Jan-2012';  
Maturity = '01-April-2012';
```

Define asset 1. Price and volatility of RBOB gasoline

```
Price1gallon = 2.85;           % $/gallon  
Price1 = Price1gallon * 42;    % $/barrel  
Vol1 = 0.29;
```

Define asset 2. Price and volatility of WTI crude oil

```
Price2 = 93.20;               % $/barrel  
Vol2 = 0.36;
```

Define the correlation between the underlying asset prices of asset 1 and asset 2.

```
Corr = 0.42;
```

Define the spread option.

```
OptSpec = 'call';  
Strike = 20;
```

Define the RateSpec.

```
rates = 0.05;  
Compounding = -1;  
Basis = 1;  
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...  
    'EndDates', Maturity, 'Rates', rates, ...  
    'Compounding', Compounding, 'Basis', Basis)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'  
    Compounding: -1  
    Disc: 0.9876
```

```

        Rates: 0.0500
        EndTimes: 0.2500
        StartTimes: 0
        EndDates: 734960
        StartDates: 734869
        ValuationDate: 734869
        Basis: 1
        EndMonthRule: 1

```

Define the `StockSpec` for the two assets.

```

StockSpec1 = stockspec(Vol1, Price1)
StockSpec2 = stockspec(Vol2, Price2)

```

```

StockSpec1 =

```

```

        FinObj: 'StockSpec'
        Sigma: 0.2900
        AssetPrice: 119.7000
        DividendType: []
        DividendAmounts: 0
        ExDividendDates: []

```

```

StockSpec2 =

```

```

        FinObj: 'StockSpec'
        Sigma: 0.3600
        AssetPrice: 93.2000
        DividendType: []
        DividendAmounts: 0
        ExDividendDates: []

```

Compute the spread option price using Monte Carlo simulation based on the Longstaff-Schwartz model.

```

Price = spreadbyls(RateSpec, StockSpec1, StockSpec2, Settle, ...
Maturity, OptSpec, Strike, Corr)

```

```

Price =

```

11.0799

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## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

Interest-rate term structure (annualized and continuously compounded), specified by the `RateSpec` obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: `struct`

### **StockSpec1** — Stock specification for underlying asset 1

structure

Stock specification for underlying asset 1. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: `struct`

### **StockSpec2** — Stock specification for underlying asset 2

structure

Stock specification for underlying asset 2. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: struct

**Settle — Settlement date for spread option**

date string | nonnegative scalar integer

Settlement date for the spread option specified, as a date string or nonnegative scalar integer.

Data Types: char

**Maturity — Maturity date for spread option**

date string | nonnegative scalar integer

Maturity date for spread option, specified as a date string or a nonnegative scalar integer.

Data Types: char

**OptSpec — Definition of option**

string with values 'call' or 'put'

Definition of option as 'call' or 'put', specified as a string.

Data Types: char

**Strike — Option strike price value**

nonnegative scalar integer

Option strike price value, specified, as a nonnegative scalar integer.

Data Types: single | double

**Corr — Correlation between underlying asset prices**

scalar integer

Correlation between underlying asset prices, specified as an scalar integer.

Data Types: single | double

**Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single

quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, ..., NameN, ValueN`.

Example: `Price = spreadbyls(RateSpec, StockSpec1, StockSpec2, Settle, Maturity, OptSpec, Strike, Corr,`

**'AmericanOpt' — Option type**

0 European (default) | scalar with value [0,1]

Option type, specified as an integer scalar flag with value:

- 0 — European
- 1 — American

For American options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium.

Data Types: `single` | `double`

**'NumTrials' — Scalar number of independent sample paths**

1000 (default) | nonnegative scalar integer

Scalar number of independent sample paths (simulation trials), specified as a nonnegative integer.

Data Types: `single` | `double`

**'NumPeriods' — Scalar number of simulation periods per trial**

100 (default) | nonnegative scalar integer

Scalar number of simulation periods per trial, specified as a nonnegative integer. `NumPeriods` is considered only when pricing European basket options. For American spread options, `NumPeriod` is equal to the number of exercise days during the life of the option.

Data Types: `single` | `double`

**'Z' — Time series array of dependent random variates**

vector

Time series array of dependent random variates specified as a `NumPeriods`-by-2-by-`NumTrials` 3-D array. The `Z` value generates the Brownian motion vector (i.e., Wiener processes) that drives the simulation.



Data Types: `single` | `double`

**'Antithetic'** — Indicator for antithetic sampling

`false` (default) | scalar logical flag with value of `true` or `false`

Indicator for antithetic sampling, specified with a value of `true` or `false`.

Data Types: `logical`

## Output Arguments

**Price** — Expected price of spread option

scalar

Expected price of the spread option, returned as a 1-by-1 scalar.

**Paths** — Simulated paths of correlated state variables

vector

Simulated paths of correlated state variables, returned as a `NumPeriods + 1`-by-2-by-`NumTrials` 3-D time series array. Each row of `Paths` is the transpose of the state vector  $X(t)$  at time  $t$  for a given trial.

**Times** — Observation times associated with simulated paths

vector

Observation times associated with simulated paths, returned as a `NumPeriods + 1`-by-1 column vector of observation times associated with the simulated paths. Each element of `Times` is associated with the corresponding row of `Paths`.

**Z** — Time series array of dependent random variates

vector

Time series array of dependent random variates, returned as a `NumPeriods`-by-2-by-`NumTrials` 3-D array when `Z` is specified as an input argument. If the `Z` input argument is not specified, then the `Z` output argument contains the random variates generated internally.

## More About

- “Spread Option”

## References

Carmona, R., Durrleman, V., “Pricing and Hedging Spread Options,” *SIAM Review*, Vol. 45, No. 4, pp. 627–685, Society for Industrial and Applied Mathematics, 2003.

## See Also

spreadbybjs | spreadbyfd | spreadbykirk | spreadsensbyls

# spreadsensbykirk

Calculate European spread option prices and sensitivities using Kirk pricing model

## Syntax

```
PriceSens = spreadbykirk(RateSpec,StockSpec1,StockSpec2,Settle,
Maturity,
OptSpec,Strike,Corr)
PriceSens = spreadsensbykirk( ____,Name,Value)
```

## Description

PriceSens = spreadbykirk(RateSpec,StockSpec1,StockSpec2,Settle, Maturity, OptSpec,Strike,Corr) returns the European spread option prices and sensitivities using the Kirk pricing model.

PriceSens = spreadsensbykirk( \_\_\_\_,Name,Value) returns the European spread option prices and sensitivities using the Kirk pricing model with optional name-value pair arguments.

## Examples

### Compute the Price and Sensitivities of a Spread Option Using the Kirk Model

Define the spread option dates.

```
Settle = '01-Jun-2012';
Maturity = '01-Sep-2012';
```

Define asset 1. Price and volatility of RBOB gasoline

```
Price1gallon = 2.85;           % $/gallon
Price1 = Price1gallon * 42;    % $/barrel
Vol1 = 0.29;
```

Define asset 2. Price and volatility of WTI crude oil

```
Price2 = 93.20;           % $/barrel
Vol2 = 0.36;
```

Define the correlation between the underlying asset prices of asset 1 and asset 2.

```
Corr = 0.42;
```

Define the spread option.

```
OptSpec = 'call';
Strike = 20;
```

Define the RateSpec.

```
rates = 0.05;
Compounding = -1;
Basis = 1;
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
    'EndDates', Maturity, 'Rates', rates, ...
    'Compounding', Compounding, 'Basis', Basis)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
    Compounding: -1
        Disc: 0.9876
        Rates: 0.0500
    EndTimes: 0.2500
    StartTimes: 0
        EndDates: 735113
        StartDates: 735021
    ValuationDate: 735021
        Basis: 1
    EndMonthRule: 1
```

Define the StockSpec for the two assets.

```
StockSpec1 = stockspec(Vol1, Price1)
StockSpec2 = stockspec(Vol2, Price2)
```

```

StockSpec1 =
    FinObj: 'StockSpec'
    Sigma: 0.2900
    AssetPrice: 119.7000
    DividendType: []
    DividendAmounts: 0
    ExDividendDates: []

```

```

StockSpec2 =
    FinObj: 'StockSpec'
    Sigma: 0.3600
    AssetPrice: 93.2000
    DividendType: []
    DividendAmounts: 0
    ExDividendDates: []

```

Compute the spread option price and sensitivities based on the Kirk model.

```

OutSpec = {'Price', 'Delta', 'Gamma'};
[Price, Delta, Gamma] = spreadsensbykirk(RateSpec, StockSpec1, StockSpec2, Settle, ...
Maturity, OptSpec, Strike, Corr, 'OutSpec', OutSpec)

```

```

Price =
    11.1904

```

```

Delta =
    0.6722   -0.6067

```

```

Gamma =
    0.0191   0.0217

```

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## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

Interest-rate term structure (annualized and continuously compounded), specified by the `RateSpec` obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: `struct`

### **StockSpec1** — Stock specification for underlying asset 1

structure

Stock specification for underlying asset 1. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: `struct`

### **StockSpec2** — Stock specification for underlying asset 2

structure

Stock specification for underlying asset 2. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: `struct`

### **Settle** — Settlement dates for spread option

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Settlement dates for the spread option, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: char | cell

### **Maturity** — Maturity date for spread option

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Maturity date for spread option, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: char | cell

### **OptSpec** — Definition of option

string with values 'call' or 'put' | cell array of strings

Definition of option as 'call' or 'put', specified as a NINST-by-1 cell array of strings.

Data Types: char | cell

### **Strike** — Option strike price values

integer | vector of integers

Option strike price values, specified as an integer using as NINST-by-1 vector of strike price values.

If **Strike** is equal to zero, this function computes the price and sensitivities of an exchange option.

Data Types: single | double

### **Corr** — Correlation between underlying asset prices

integer | vector of integers

Correlation between underlying asset prices, specified as an integer using as NINST-by-1 vector.

Data Types: single | double

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name,Value arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

```
Example: PriceSens =  
spreadsensbykirk(RateSpec, StockSpec1, StockSpec2, Settle, Maturity, OptSpec, Strike,  
{ 'All' })
```

### 'OutSpec' — Define outputs

{ 'Price' } (default) | string with values 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All' | cell array of strings with values 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'

Define outputs specifying NOUT- by-1 or 1-by-NOUT cell array of strings with possible values of 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'.

OutSpec = { 'All' } specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying OutSpec to include each sensitivity:

```
Example: OutSpec =  
{ 'delta', 'gamma', 'vega', 'lambda', 'rho', 'theta', 'price' }
```

Data Types: char | cell

## Output Arguments

### PriceSens — Expected price or sensitivities values of spread option

vector

Expected price or sensitivities values of the spread option, returned as a NINST-by-1 or NINST-by-2 vector.

## More About

- “Spread Option”

## References

Carmona, R., Durrleman, V., “Pricing and Hedging Spread Options,” *SIAM Review*, Vol. 45, No. 4, pp. 627–685, Society for Industrial and Applied Mathematics, 2003.



## **See Also**

spreadbybjs | spreadbyfd | spreadbykirk | spreadbyls

## spreadsensbybjs

Calculate European spread option prices and sensitivities using Bjerksund-Stensland pricing model

### Syntax

```
PriceSens = spreadbybjs(RateSpec,StockSpec1,StockSpec2,Settle,  
Maturity,  
OptSpec,Strike,Corr)  
PriceSens = spreadsensbybjs( ____,Name,Value)
```

### Description

`PriceSens = spreadbybjs(RateSpec,StockSpec1,StockSpec2,Settle, Maturity, OptSpec,Strike,Corr)` returns the European spread option prices and sensitivities using the Bjerksund-Stensland pricing model.

`PriceSens = spreadsensbybjs( ____,Name,Value)` returns the European spread option prices and sensitivities using the Bjerksund-Stensland pricing model with optional name-value pair arguments.

### Examples

#### Compute the Price and Sensitivities of a Spread Option Using the Bjerksund-Stensland Model

Define the spread option dates.

```
Settle = '01-Jun-2012';  
Maturity = '01-Sep-2012';
```

Define asset 1. Price and volatility of RBOB gasoline

```
Price1gallon = 2.85;           % $/gallon  
Price1 = Price1gallon * 42;   % $/barrel
```

```
Vol1 = 0.29;
```

Define asset 2. Price and volatility of WTI crude oil

```
Price2 = 93.20;           % $/barrel
Vol2 = 0.36;
```

Define the correlation between the underlying asset prices of asset 1 and asset 2.

```
Corr = 0.42;
```

Define the spread option.

```
OptSpec = 'call';
Strike = 20;
```

Define the RateSpec.

```
rates = 0.05;
Compounding = -1;
Basis = 1;
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...
'EndDates', Maturity, 'Rates', rates, ...
'Compounding', Compounding, 'Basis', Basis)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
  Compounding: -1
        Disc: 0.9876
        Rates: 0.0500
   EndTimes: 0.2500
  StartTimes: 0
   EndDates: 735113
  StartDates: 735021
ValuationDate: 735021
        Basis: 1
  EndMonthRule: 1
```

Define the StockSpec for the two assets.

```
StockSpec1 = stockspec(Vol1, Price1)
StockSpec2 = stockspec(Vol2, Price2)
```

```

StockSpec1 =
    FinObj: 'StockSpec'
    Sigma: 0.2900
    AssetPrice: 119.7000
    DividendType: []
    DividendAmounts: 0
    ExDividendDates: []

```

```

StockSpec2 =
    FinObj: 'StockSpec'
    Sigma: 0.3600
    AssetPrice: 93.2000
    DividendType: []
    DividendAmounts: 0
    ExDividendDates: []

```

Compute the spread option price and sensitivities based on the Kirk model.

```

OutSpec = {'Price', 'Delta', 'Gamma'};
[Price, Delta, Gamma] = spreadsensbybjs(RateSpec, StockSpec1, StockSpec2, Settle, ...
Maturity, OptSpec, Strike, Corr, 'OutSpec', OutSpec)

```

```

Price =
    11.2000

```

```

Delta =
    0.6737   -0.6082

```

```

Gamma =
    0.0190   0.0216

```

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## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

Interest-rate term structure (annualized and continuously compounded), specified by the `RateSpec` obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: `struct`

### **StockSpec1** — Stock specification for underlying asset 1

structure

Stock specification for underlying asset 1. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: `struct`

### **StockSpec2** — Stock specification for underlying asset 2

structure

Stock specification for underlying asset 2. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: `struct`

### **Settle** — Settlement dates for spread option

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Settlement dates for the spread option, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: `char` | `cell`

### **Maturity** — Maturity date for spread option

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Maturity date for spread option, specified as a date string or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: `char` | `cell`

### **OptSpec** — Definition of option

string with values 'call' or 'put' | cell array of strings

Definition of option as 'call' or 'put', specified as a NINST-by-1 cell array of strings.

Data Types: `char` | `cell`

### **Strike** — Option strike price values

integer | vector of integers

Option strike price values, specified as an integer using a NINST-by-1 vector of strike price values.

If **Strike** is equal to zero the function computes the price and sensitivities of an exchange option.

Data Types: `single` | `double`

### **Corr** — Correlation between underlying asset prices

integer | vector of integers

Correlation between underlying asset prices, specified as an integer using a NINST-by-1 vector.

Data Types: `single` | `double`

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of **Name**,**Value** arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as **Name1**,**Value1**, . . . ,**NameN**,**ValueN**.

Example: `PriceSens = spreadsensbykirk(RateSpec, StockSpec1, StockSpec2, Settle, Maturity, OptSpec, Strike, {'All'})`

### 'OutSpec' — Define outputs

{'Price'} (default) | string with values 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All' | cell array of strings with values 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'

Define outputs specifying NOUT- by-1 or 1-by-NOUT cell array of strings with possible values of 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'.

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec` to include each sensitivity:

Example: `OutSpec = {'delta', 'gamma', 'vega', 'lambda', 'rho', 'theta', 'price'}`

Data Types: char | cell

## Output Arguments

### PriceSens — Expected prices or sensitivities values of spread option

vector

Expected prices or sensitivities values of the spread option, returned as a NINST-by-1 or NINST-by-2 vector.

## More About

- “Spread Option”

## References

Carmona, R., Durrleman, V., “Pricing and Hedging Spread Options,” *SIAM Review*, Vol. 45, No. 4, pp. 627–685, Society for Industrial and Applied Mathematics, 2003.

Bjerk Sund, Petter, Stensland, Gunnar, “Closed form spread option valuation,”  
Department of Finance, NHH, 2006.

**See Also**

spreadbybjs | spreadbyfd | spreadbykirk | spreadbyls



## spreadsensbyls

Calculate price and sensitivities for European or American spread options using Monte Carlo simulations

### Syntax

```
PriceSens = spreadsensbyls(RateSpec,StockSpec1,StockSpec2,Settle,
Maturity,
OptSpec,Strike,Corr)
PriceSens = spreadsensbyls( ____,Name,Value)
```

```
[PriceSens,Paths,Times,Z] = spreadsensbyls(RateSpec,StockSpec1,
StockSpec2,Settle,Maturity,
OptSpec,Strike,Corr)
[PriceSens,Paths,Times,Z] = spreadsensbyls( ____,Name,Value)
```

### Description

`PriceSens = spreadsensbyls(RateSpec,StockSpec1,StockSpec2,Settle, Maturity, OptSpec,Strike,Corr)` returns the price of a European or American call or put spread option using Monte Carlo simulations.

`PriceSens = spreadsensbyls( ____,Name,Value)` returns the price of a European or American call or put spread option using Monte Carlo simulations with optional name-value pair arguments.

`[PriceSens,Paths,Times,Z] = spreadsensbyls(RateSpec,StockSpec1, StockSpec2,Settle,Maturity, OptSpec,Strike,Corr)` returns the `PriceSens`, `Paths`, `Times`, and `Z` of a European or American call or put spread option using Monte Carlo simulations.

`[PriceSens,Paths,Times,Z] = spreadsensbyls( ____,Name,Value)` returns the `PriceSens`, `Paths`, `Times`, and `Z` of a European or American call or put spread option using Monte Carlo simulations with optional name-value pair arguments.

## Examples

### Compute the Price and Sensitivities of a Spread Option Using Monte Carlo Simulation

Define the spread option dates.

```
Settle = '01-Jun-2012';  
Maturity = '01-Sep-2012';
```

Define asset 1. Price and volatility of RBOB gasoline

```
Price1gallon = 2.85;           % $/gallon  
Price1 = Price1gallon * 42;    % $/barrel  
Vol1 = 0.29;
```

Define asset 2. Price and volatility of WTI crude oil

```
Price2 = 93.20;               % $/barrel  
Vol2 = 0.36;
```

Define the correlation between the underlying asset prices of asset 1 and asset 2.

```
Corr = 0.42;
```

Define the spread option.

```
OptSpec = 'call';  
Strike = 20;
```

Define the RateSpec.

```
rates = 0.05;  
Compounding = -1;  
Basis = 1;  
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...  
    'EndDates', Maturity, 'Rates', rates, ...  
    'Compounding', Compounding, 'Basis', Basis)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'  
    Compounding: -1  
           Disc: 0.9876  
           Rates: 0.0500
```

```

        EndTimes: 0.2500
    StartTimes: 0
        EndDates: 735113
    StartDates: 735021
ValuationDate: 735021
        Basis: 1
    EndMonthRule: 1

```

Define the **StockSpec** for the two assets.

```

StockSpec1 = stockspec(Vol1, Price1)
StockSpec2 = stockspec(Vol2, Price2)

```

```

StockSpec1 =

```

```

        FinObj: 'StockSpec'
        Sigma: 0.2900
    AssetPrice: 119.7000
    DividendType: []
    DividendAmounts: 0
    ExDividendDates: []

```

```

StockSpec2 =

```

```

        FinObj: 'StockSpec'
        Sigma: 0.3600
    AssetPrice: 93.2000
    DividendType: []
    DividendAmounts: 0
    ExDividendDates: []

```

Compute the spread option price and sensitivities using Monte Carlo simulation based on the Longstaff-Schwartz model.

```

OutSpec = {'Price', 'Delta', 'Gamma'};
[Price, Delta, Gamma] = spreadsensbyls(RateSpec, StockSpec1, StockSpec2, ...
Settle, Maturity, OptSpec, Strike, Corr, 'OutSpec', OutSpec)

```

```

Price =

```

11.0799

Delta =

0.6626    -0.5972

Gamma =

0.0209    0.0240

- “Pricing European and American Spread Options”
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## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

Interest-rate term structure (annualized and continuously compounded), specified by the `RateSpec` obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: struct

### **StockSpec1** — Stock specification for underlying asset 1

structure

Stock specification for underlying asset 1. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: struct

### **StockSpec2** — Stock specification for underlying asset 2

structure

Stock specification for underlying asset 2. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: `struct`

#### **Settle** — Settlement date for spread option

date string | nonnegative scalar integer

Settlement date for the spread option, specified as a date string or as a nonnegative scalar integer.

Data Types: `char`

#### **Maturity** — Maturity date for spread option

date string | nonnegative scalar integer

Maturity date for spread option, specified as a date string or as a nonnegative scalar integer.

Data Types: `char`

#### **OptSpec** — Definition of option

string with values 'call' or 'put'

Definition of option as 'call' or 'put', specified as a string.

Data Types: `char`

#### **Strike** — Option strike price value

nonnegative scalar integer

Option strike price value, specified as a scalar integer.

Data Types: `single` | `double`

#### **Corr** — Correlation between underlying asset prices

scalar integer

Correlation between underlying asset prices, specified as a scalar integer.

Data Types: `single` | `double`

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name`,`Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

Example: `PriceSens =`

`spreadbyls(RateSpec,StockSpec1,StockSpec2,Settle,Maturity,OptSpec,Strike,Corr,`

### '**AmericanOpt**' — Option type

0 European (default) | scalar with values [0,1]

Option type, specified as a scalar integer flag with values:

- 0 — European
- 1 — American

For American options, the Longstaff-Schwartz least squares method is used to calculate the early exercise premium.

Data Types: `single` | `double`

### '**NumTrials**' — Number of independent sample paths

1000 (default) | nonnegative scalar integer

Number of independent sample paths (simulation trials) specified as a nonnegative scalar integer.

Data Types: `single` | `double`

### '**NumPeriods**' — Number of simulation periods per trial

100 (default) | nonnegative scalar integer

Number of simulation periods per trial, specified as a nonnegative scalar integer. `NumPeriods` is considered only when pricing European basket options. For American spread options, `NumPeriods` is equal to the number of exercise days during the life of the option.

Data Types: `single` | `double`

**'Z' — Time series array of dependent random variates**

vector

Time series array of dependent random variates, specified as a NumPeriods-by-2-by-NumTrials 3-D array. The Z value generates the Brownian motion vector (i.e., Wiener processes) that drives the simulation.

Data Types: single | double

**'Antithetic' — Indicator for antithetic sampling**

false (default) | logical flag with value of true or false

Indicator for antithetic sampling, specified with value of true or false.

Data Types: logical

**'OutSpec' — Define outputs**

{'Price'} (default) | string with values 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All' | cell array of strings with values 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'

Define outputs specifying NOUT- by-1 or 1-by-NOUT cell array of strings with possible values of 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'.

OutSpec = {'All'} specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying OutSpec to include each sensitivity:

Example: OutSpec =  
{'delta', 'gamma', 'vega', 'lambda', 'rho', 'theta', 'price'}

Data Types: char | cell

## Output Arguments

**PriceSens — Expected price and sensitivities of spread option**

vector

Expected price and sensitivities of the spread option, returned as a NINST-by-1 vector.

**Paths — Simulated paths of correlated state variables**

vector

Simulated paths of correlated state variables, returned as a `NumPeriods + 1`-by-2-by-`NumTrials` 3-D time series array. Each row of `Paths` is the transpose of the state vector  $X(t)$  at time  $t$  for a given trial.

**Times** — Observation times associated with simulated paths

vector

Observation times associated with simulated paths, returned as a `NumPeriods + 1`-by-1 column vector of observation times associated with the simulated paths. Each element of `Times` is associated with the corresponding row of `Paths`.

**Z** — Time series array of dependent random variates

vector

Time series array of dependent random variates, returned as a `NumPeriods`-by-2-by-`NumTrials` 3-D array when `Z` is specified as an input argument. If the `Z` input argument is not specified, then the `Z` output argument contains the random variates generated internally.

## More About

- “Spread Option”

## References

Carmona, R., Durrleman, V., “Pricing and Hedging Spread Options,” *SIAM Review*, Vol. 45, No. 4, pp. 627–685, Society for Industrial and Applied Mathematics, 2003.

## See Also

`spreadbybjs` | `spreadbyfd` | `spreadbykirk` | `spreadbyls`



# spreadsensbyfd

Calculate price and sensitivities of European or American spread options using finite difference method

## Syntax

```
PriceSens = spreadbyfd(RateSpec,StockSpec1,StockSpec2,Settle,
Maturity,
OptSpec,Strike,Corr)
PriceSens = spreadbyfd( ____,Name,Value)
```

```
[PriceSens,PriceGrid,AssetPrice1,AssetPrice2,Times] = spreadbyfd(
RateSpec,StockSpec1,StockSpec2,Settle,Maturity,
OptSpec,Strike,Corr)
[PriceSens,PriceGrid,AssetPrice1,AssetPrice2,Times] =
spreadbyfd( ____,Name,Value)
```

## Description

`PriceSens = spreadbyfd(RateSpec,StockSpec1,StockSpec2,Settle, Maturity, OptSpec,Strike,Corr)` returns the price and sensitivities of European or American call or put spread options using the Alternate Direction Implicit (ADI) finite difference method. The spread is between the asset defined in `StockSpec1` minus the asset defined in `StockSpec2`.

`PriceSens = spreadbyfd( ____,Name,Value)` returns the price and sensitivities of European or American call or put spread options using the Alternate Direction Implicit (ADI) finite difference method using optional name-value pair arguments. The spread is between the asset defined in `StockSpec1` minus the asset defined in `StockSpec2`.

`[PriceSens,PriceGrid,AssetPrice1,AssetPrice2,Times] = spreadbyfd(RateSpec,StockSpec1,StockSpec2,Settle,Maturity, OptSpec,Strike,Corr)` returns the `PriceSens`, `PriceGrid`, `AssetPrice1`, `AssetPrice2`, and `Times` for European or American call or put spread options using the Alternate Direction Implicit (ADI) finite difference method. The spread is between the asset defined in `StockSpec1` minus the asset defined in `StockSpec2`.

[PriceSens, PriceGrid, AssetPrice1, AssetPrice2, Times] = spreadbyfd( \_\_\_\_, Name, Value) returns the PriceSens, PriceGrid, AssetPrice1, AssetPrice2, and Times for European or American call or put spread options using the Alternate Direction Implicit (ADI) finite difference method using optional name-value pair arguments. The spread is between the asset defined in StockSpec1 minus the asset defined in StockSpec2.

## Examples

### Compute the Price of a Spread Option Using the Alternate Direction Implicit (ADI) Finite Difference Method

Define the spread option dates.

```
Settle = '01-Jun-2012';  
Maturity = '01-Sep-2012';
```

Define asset 1. Price and volatility of RBOB gasoline

```
Price1gallon = 2.85;           % $/gallon  
Price1 = Price1gallon * 42;    % $/barrel  
Vol1 = 0.29;
```

Define asset 2. Price and volatility of WTI crude oil

```
Price2 = 93.20;               % $/barrel  
Vol2 = 0.36;
```

Define the correlation between the underlying asset prices of asset 1 and asset 2.

```
Corr = 0.42;
```

Define the spread option.

```
OptSpec = 'call';  
Strike = 20;
```

Define the RateSpec.

```
rates = 0.05;  
Compounding = -1;  
Basis = 1;
```

```
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle, ...  
'EndDates', Maturity, 'Rates', rates, ...  
'Compounding', Compounding, 'Basis', Basis)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'  
    Compounding: -1  
        Disc: 0.9876  
        Rates: 0.0500  
    EndTimes: 0.2500  
    StartTimes: 0  
        EndDates: 735113  
        StartDates: 735021  
ValuationDate: 735021  
        Basis: 1  
    EndMonthRule: 1
```

Define the **StockSpec** for the two assets.

```
StockSpec1 = stockspec(Vol1, Price1)  
StockSpec2 = stockspec(Vol2, Price2)
```

```
StockSpec1 =
```

```
    FinObj: 'StockSpec'  
        Sigma: 0.2900  
    AssetPrice: 119.7000  
    DividendType: []  
    DividendAmounts: 0  
    ExDividendDates: []
```

```
StockSpec2 =
```

```
    FinObj: 'StockSpec'  
        Sigma: 0.3600  
    AssetPrice: 93.2000  
    DividendType: []  
    DividendAmounts: 0  
    ExDividendDates: []
```

Compute the spread option price and sensitivities based on the Alternate Direction Implicit (ADI) finite difference method.

```
OutSpec = {'Price', 'Delta', 'Gamma'};
[Price, Delta, Gamma, PriceGrid, AssetPrice1, AssetPrice2, Times] = ...
spreadsensbyfd(RateSpec, StockSpec1, StockSpec2, Settle, ...
Maturity, OptSpec, Strike, Corr, 'OutSpec', OutSpec);
```

Display the price and sensitivities.

```
Price
Delta
Gamma
```

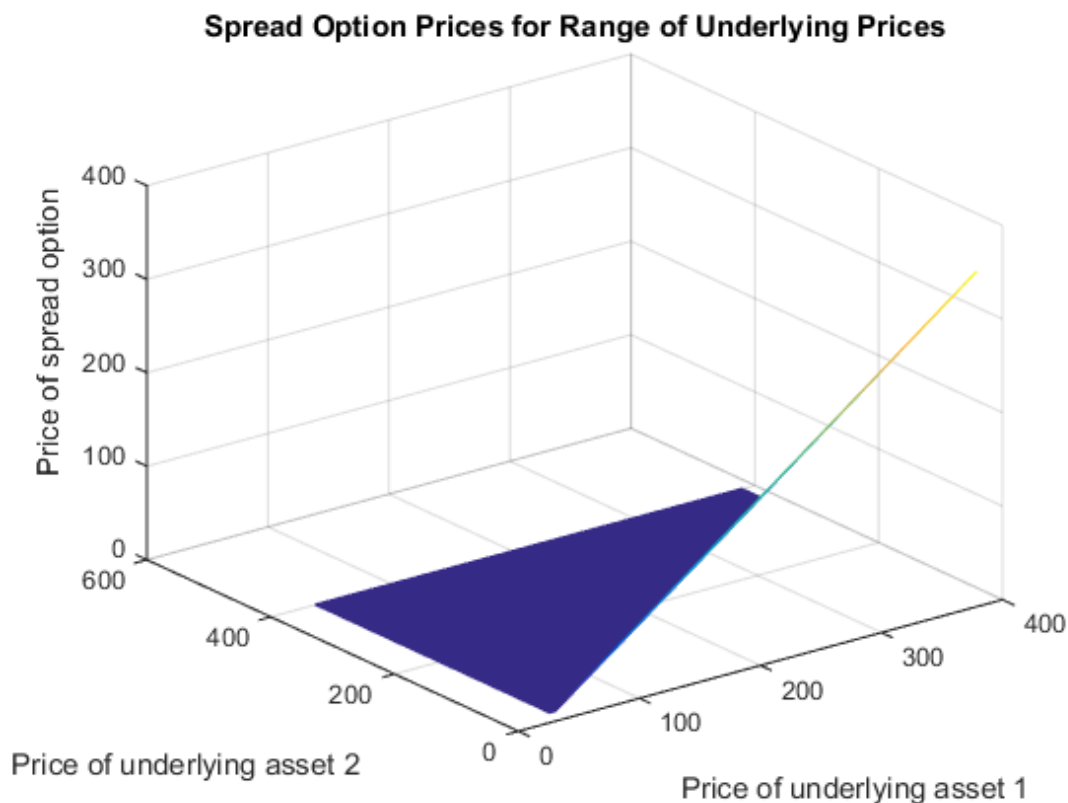
```
Price =
    11.1998
```

```
Delta =
    0.6736   -0.6082
```

```
Gamma =
    0.0190    0.0214
```

Plot the finite difference grid.

```
mesh(AssetPrice1, AssetPrice2, PriceGrid(:, :, 1));
title('Spread Option Prices for Range of Underlying Prices');
xlabel('Price of underlying asset 1');
ylabel('Price of underlying asset 2');
zlabel('Price of spread option');
```



- “Pricing European and American Spread Options”
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## Input Arguments

### **RateSpec** — Interest-rate term structure

structure

Interest-rate term structure (annualized and continuously compounded), specified by the `RateSpec` obtained from `intenvset`. For information on the interest-rate specification, see `intenvset`.

Data Types: struct

### **StockSpec1 — Stock specification for underlying asset 1**

structure

Stock specification for underlying asset 1. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: struct

### **StockSpec2 — Stock specification for underlying asset 2**

structure

Stock specification for underlying asset 2. For information on the stock specification, see `stockspec`.

`stockspec` can handle other types of underlying assets. For example, for physical commodities the price is represented by `StockSpec.Asset`, the volatility is represented by `StockSpec.Sigma`, and the convenience yield is represented by `StockSpec.DividendAmounts`.

Data Types: struct

### **Settle — Settlement dates for spread option**

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Settlement dates for the spread option, specified as date strings or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: char | cell

### **Maturity — Maturity date for spread option**

nonnegative integer | vector of nonnegative integers | date string | cell array of date strings

Maturity date for spread option, specified as date strings or as nonnegative integers using a NINST-by-1 vector or cell array of dates.

Data Types: char | cell

**OptSpec — Definition of option**

string with values 'call' or 'put' | cell array of strings

Definition of option as 'call' or 'put', specified as a NINST-by-1 cell array of strings.

Data Types: char | cell

**Strike — Option strike price values**

integer | vector of integers

Option strike price values, specified as an integer using a NINST-by-1 vector of strike price values.

Data Types: single | double

**Corr — Correlation between underlying asset prices**

integer | vector of integers

Correlation between underlying asset prices, specified as an integer using a NINST-by-1 vector.

Data Types: single | double

**Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

```
Example: [PriceSens,PriceGrid,AssetPrice1,AssetPrice2,Times] =
spreadbyfd(RateSpec,StockSpec1,StockSpec2,Settle,Maturity,OptSpec,Strike,Corr,
'AssetPriceMin','AssetPriceMax','PriceGridSize','TimeGridSize','AmericanOpt',0
{'All'})
```

**'OutSpec' — Define outputs**

{'Price'} (default) | string with values 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All' | cell array of strings with values 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'

Define outputs specifying NOUT- by-1 or 1-by-NOUT cell array of strings with possible values of 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', and 'All'.

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec` to include each sensitivity:

```
Example: OutSpec =  
{'delta', 'gamma', 'vega', 'lambda', 'rho', 'theta', 'price'}
```

Data Types: `char` | `cell`

#### **'AssetPriceMin' — Minimum price for price grid boundary**

if unspecified, `StockSpec` values are calculated based on asset distributions at maturity (default) | array

Minimum price for price grid boundary, specified by a 1-by-2 array. The first entry in the array corresponds to the first asset defined by `StockSpec1` and the second entry corresponds to the second asset defined by `StockSpec2`.

For the finite difference method, the composition of the grid affects the quality of the output as well as the execution time. It is highly recommended to use the optional arguments `AssetPriceMin`, `AssetPriceMax`, `PriceGridSize`, and `TimeGridSize` to control the composition of the grid to ensure the quality of the output and a reasonable execution time.

Data Types: `single` | `double`

#### **'AssetPriceMax' — Maximum price for price grid boundary**

if unspecified, `StockSpec` values are calculated based on asset distributions at maturity (default) | array

Maximum price for price grid boundary, specified by a 1-by-2 array. The first entry in the array corresponds to the first asset defined by `StockSpec1` and the second entry corresponds to the second asset defined by `StockSpec2`.

For the finite difference method, the composition of the grid affects the quality of the output as well as the execution time. It is highly recommended to use the optional arguments `AssetPriceMin`, `AssetPriceMax`, `PriceGridSize`, and `TimeGridSize` to control the composition of the grid to ensure the quality of the output and a reasonable execution time.

Data Types: `single` | `double`

#### **'PriceGridSize' — Size for finite difference grid**

[300,300] (default) | array



Size for finite difference grid, specified by a 1-by-2 array. The first entry corresponds to the first asset defined by `StockSpec1` and the second entry corresponds to the second asset defined by `StockSpec2`.

For the finite difference method, the composition of the grid affects the quality of the output as well as the execution time. It is highly recommended to use the optional arguments `AssetPriceMax`, `PriceGridSize`, and `TimeGridSize` to control the composition of the grid to ensure the quality of the output and a reasonable execution time.

Data Types: `single` | `double`

#### **'TimeGridSize' — Size of time grid for finite difference grid**

100 (default) | `scalar` | `nonnegative integer`

Size of time grid for finite difference grid, specified as a nonnegative integer.

For the finite difference method, the composition of the grid affects the quality of the output as well as the execution time. It is highly recommended to use the optional arguments `AssetPriceMax`, `PriceGridSize`, and `TimeGridSize` to control the composition of the grid to ensure the quality of the output and a reasonable execution time.

Data Types: `single` | `double`

#### **'AmericanOpt' — Option type**

0 European (default) | `scalar` | `vector of positive integers[0, 1]`

Option type, specified as NINST-by-1 positive integer scalar flags with values:

- 0 — European
- 1 — American

Data Types: `single` | `double`

## Output Arguments

#### **PriceSens — Expected prices and sensitivities of spread option**

`vector`

Expected prices and sensitivities of the spread option, returned as an NINST-by-1 vector.

**PriceGrid** — Grid containing prices calculated by finite difference method

array

Grid containing prices calculated by finite difference method, returned as a 3-D grid with a size of `PriceGridSize(1) * PriceGridSize(2) * TimeGridSize`. The price for  $t = 0$  is contained in `PriceGrid(:, :, 1)`.

**AssetPrice1** — Prices for first asset defined by `StockSpec1`

vector

Prices for first asset defined by `StockSpec1`, corresponding to the first dimension of `PriceGrid`, returned as a vector.

**AssetPrice2** — Prices for second asset defined by `StockSpec2`

vector

Prices for second asset defined by `StockSpec2`, corresponding to the second dimension of `PriceGrid`, returned as a vector.

**Times** — Times corresponding to third dimension of `PriceGrid`

vector

Times corresponding to third dimension of `PriceGrid`, returned as a vector.

## More About

- “Spread Option”

## References

Carmona, R., Durrleman, V., “Pricing and Hedging Spread Options,” *SIAM Review*, Vol. 45, No. 4, pp. 627–685, Society for Industrial and Applied Mathematics, 2003.

Villeneuve, S., Zannette, A., “Parabolic ADI Methods for Pricing American Options on Two Stocks,” *Mathematics of Operations Research*, Vol. 27, No. 1, pp. 121–149, INFORMS, 2002.

Ikonen, S., Toivanen, J., *Efficient Numerical Methods for Pricing American Options Under Stochastic Volatility*, Wiley InterScience, 2007.

**See Also**

spreadbybjs | spreadbykirk | spreadbyls | spreadsensbyfd

## stockoptspec

Specify European stock option structure

### Syntax

```
[StockOptSpec] = stockoptspec(OptPrice, Strike, Settle,
Maturity, OptSpec, InterpMethod)
```

### Arguments

OptPrice	NINST-by-1 vector of European option prices.
Strike	NINST-by-1 vector of strike prices.
Settle	Scalar date marking the settlement date.
Maturity	NINST-by-1 vector of maturity dates.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'.
InterpMethod	(Optional) Method of interpolation to use for option prices. InterpMethod is [{'price'}   'vol']. The default is 'price'. By specifying 'vol', implied volatilities will be used for interpolation purposes. The interpolated values will then be used to calculate the implicit interpolated prices.

### Description

[StockOptSpec] = stockoptspec(OptPrice, Strike, Settle, Maturity, OptSpec, InterpMethod) creates a structure encapsulating the properties of a stock option structure.

### Examples

#### Specify a European Stock Option Structure

This example shows how to specify a European stock option structure using the following data quoted from liquid options in the market with varying strikes and maturity.

```
Settle = '01/01/06';

Maturity = ['07/01/06';
            '07/01/06';
            '07/01/06';
            '01/01/07';
            '01/01/07';
            '01/01/07';
            '01/01/07';
            '07/01/07';
            '07/01/07';
            '07/01/07';
            '07/01/07';
            '01/01/08';
            '01/01/08';
            '01/01/08';
            '01/01/08'];

Strike = [113;
          101;
          100;
          88;
          128;
          112;
          100;
          78;
          144;
          112;
          100;
          69;
          162;
          112;
          100;
          61];

OptPrice = [0;
            4.807905472659144;
            1.306321897011867;
            0.048039195057173;
            0;
            2.310953054191461;
            1.421950392866235;
            0.020414826276740;
```

```
0;  
5.091986935627730;  
1.346534812295291;  
0.005101325584140;  
0;  
8.047628153217246;  
1.219653432150932;  
0.001041436654748];
```

```
OptSpec = { 'call';  
            'call';  
            'put';  
            'put';  
            'call';  
            'call';  
            'put';  
            'put';  
            'call';  
            'call';  
            'put';  
            'put';  
            'call';  
            'call';  
            'put';  
            'put'};
```

```
StockOptSpec = stockoptspec(OptPrice, Strike, Settle, Maturity, OptSpec)
```

```
StockOptSpec =
```

```
    FinObj: 'StockOptSpec'  
    OptPrice: [16x1 double]  
    Strike: [16x1 double]  
    Settle: 732678  
    Maturity: [16x1 double]  
    OptSpec: {16x1 cell}  
    InterpMethod: 'price'
```

## See Also

[ittprice](#) | [itttree](#) | [stockspec](#)

# stockspec

Create stock structure

## Syntax

StockSpec = stockspec(Sigma, AssetPrice, DividendType, DividendAmounts, ExDividendDates)

## Arguments

Sigma	NINST-by-1 decimal annual price volatility of underlying security.
AssetPrice	NINST-by-1 vector of underlying asset price values at time 0.
DividendType	<p>(Optional) NINST-by-1 cell array of strings specifying each stock's dividend type. Dividend type must be either <b>cash</b> for actual dollar dividends, <b>constant</b> for constant dividend yield, or <b>continuous</b> for continuous dividend yield. This function does not handle stock option dividends.</p> <hr/> <p><b>Note</b> Dividends are assumed to be paid in cash. Noncash dividends (stock) are not allowed. When combining two or more type of dividends, shorter rows should be padded with the value NaN.</p>
DividendAmounts	(Optional) NINST-by-NDIV matrix of cash dividends or NINST-by-1 vector representing a constant or continuous annualized dividend yield.
ExDividendDates	(Optional) NINST-by-NDIV matrix of ex-dividend dates for cash type or NINST-by-1 vector of ex-dividend dates for constant dividend type. For continuous dividend type, this argument should be ignored.

## Description

`StockSpec = stockspec(Sigma, AssetPrice, DividendType, DividendAmounts, ExDividendDates)` creates a MATLAB structure containing the properties of a stock.

---

**Note:** `StockSpec` handles other types of underliers when pricing instruments other than equities.

---

## Examples

### Create a StockSpec for Stocks With Cash Dividends

Consider a stock that provides four cash dividends of \$0.50 on January 3, 2008, April 1, 2008, July 5, 2008 and October 1, 2008. The stock is trading at \$50, and has a volatility of 20% per annum. Using this data, create the structure `StockSpec`:

```
AssetPrice = 50;  
Sigma = 0.20;
```

```
DividendType = {'cash'};  
DividendAmounts = [0.50, 0.50, 0.50, 0.50];  
ExDividendDates = {'03-Jan-2008', '01-Apr-2008', '05-July-2008', '01-Oct-2008'};
```

```
StockSpec = stockspec(Sigma, AssetPrice, DividendType, DividendAmounts, ExDividendDates)
```

```
StockSpec =
```

```
    FinObj: 'StockSpec'  
    Sigma: 0.2000  
    AssetPrice: 50  
    DividendType: {'cash'}  
    DividendAmounts: [0.5000 0.5000 0.5000 0.5000]  
    ExDividendDates: [733410 733499 733594 733682]
```

Examine the `StockSpec` structure.

```
datedisp(StockSpec.ExDividendDates)
```



```
StockSpec.DividendType
```

```
03-Jan-2008    01-Apr-2008    05-Jul-2008    01-Oct-2008
```

```
ans =
```

```
    'cash'
```

The `StockSpec` structure encapsulates the information of the stock and its four cash dividends.

### Create a `StockSpec` for Stocks With Cash and Continuous Dividends

Consider two stocks that are trading at \$40 and \$35. The first one provides two cash dividends of \$0.25 on March 1, 2008 and June 1, 2008. The second stock provides a continuous dividend yield of 3%. The stocks have a volatility of 30% per annum. Using this data, create the structure `StockSpec`:

```
AssetPrice = [40; 35];
Sigma = .30;
```

```
DividendType = {'cash'; 'continuous'};
DividendAmount = [0.25, 0.25 ; 0.03 NaN];
```

```
DividendDate1 = 'March-01-2008';
DividendDate2 = 'Jun-01-2008';
```

```
StockSpec = stockspec(Sigma, AssetPrice, DividendType, DividendAmount,...
{ DividendDate1, DividendDate2 ; NaN NaN})
```

```
StockSpec =
```

```
    FinObj: 'StockSpec'
    Sigma: [2x1 double]
    AssetPrice: [2x1 double]
    DividendType: {2x1 cell}
    DividendAmounts: [2x2 double]
    ExDividendDates: [2x2 double]
```

Examine the `StockSpec` structure.

```
datedisp(StockSpec.ExDividendDates)
```

`StockSpec.DividendType`

```
01-Mar-2008    01-Jun-2008
      NaN          NaN
```

```
ans =
```

```
    'cash'
    'continuous'
```

The `StockSpec` structure encapsulates the information of the two stocks and their dividends.

## See Also

`crrprice` | `crrtree` | `intenvset` | `optstockbybjs` | `optstockbyblk` |  
`optstockbyls` | `optstockbypls` | `spreadbykirk` | `spreadbybjs` | `spreadbyfd` |  
`spreadbyls` | `optstockbyrgw`

# supersharebybls

Calculate price of supershare digital options using Black-Scholes model

## Syntax

Price = supersharebybls(RateSpec, StockSpec, Settle, Maturity, OptSpec, StrikeLow, StrikeHigh)

## Arguments

RateSpec	The annualized, continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
StrikeLow	NINST-by-1 vector of low strike price values.
StrikeHigh	NINST-by-1 vector of high strike price values.

## Description

Price = supersharebybls(RateSpec, StockSpec, Settle, Maturity, OptSpec, StrikeLow, StrikeHigh) computes supershare digital option prices using the Black-Scholes model.

Price is a NINST-by-1 vector of expected option prices.

## Examples

### Compute the Price of Supershare Digital Options Using Black-Scholes Model

This example shows how to compute the price of supershare digital options using Black-Scholes model. Consider a supershare based on a portfolio of nondividend paying stocks

with a lower strike of 350 and an upper strike of 450. The value of the portfolio on November 1, 2008 is 400. The risk-free rate is 4.5% and the volatility is 18%. Using this data, calculate the price of the supershare option on February 1, 2009.

```
Settle = 'Nov-1-2008';
Maturity = 'Feb-1-2009';
Rates = 0.045;
Basis = 1;
Compounding = -1;

% create the RateSpec
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
'EndDates', Maturity, 'Rates', Rates, 'Compounding', Compounding, 'Basis', Basis);

% define the StockSpec
AssetPrice = 400;
Sigma = .18;
StockSpec = stockspec(Sigma, AssetPrice);

% define the high and low strike points
StrikeLow = 350;
StrikeHigh = 450;

% calculate the price
Pssh = supersharebybls(RateSpec, StockSpec, Settle, Maturity,...
StrikeLow, StrikeHigh)

Pssh =

    0.9411
```

## See Also

assetbybls | cashbybls | gapbybls | supersharesensbybls

# supersharesensbybls

Calculate price and sensitivities of supershare digital options using Black-Scholes model

## Syntax

```
PriceSens = supersharesensbybls(RateSpec, StockSpec, Settle,
Maturity, StrikeLow, StrikeHigh)
PriceSens = supersharesensbybls(RateSpec, StockSpec, Settle,
Maturity, StrikeLow, StrikeHigh, OutSpec)
```

## Arguments

RateSpec	The annualized, continuously compounded rate term structure. For information on the interest rate specification, see <code>intenvset</code> .
StockSpec	Stock specification. See <code>stockspec</code> .
Settle	NINST-by-1 vector of settlement or trade dates.
Maturity	NINST-by-1 vector of maturity dates.
StrikeLow	NINST-by-1 vector of low strike price values.
StrikeHigh	NINST-by-1 vector of high strike price values.
OutSpec	<p>(Optional) All optional inputs are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. You can specify parameter name/value pairs in any order. Names are case-insensitive and partial string matches are allowed provided no ambiguities exist. Valid parameter names are:</p> <ul style="list-style-type: none"> <li>NOUT-by-1 or 1-by-NOUT cell array of strings indicating the nature and order of the outputs for the function. Possible values are 'Price', 'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', or 'All'.</li> </ul>

For example, `OutSpec = {'Price'; 'Lambda'; 'Rho'}` specifies that the output should be Price, Lambda, and Rho, in that order.

To invoke from a function: `[Price, Lambda, Rho] = supersharesensbybls(..., 'OutSpec', {'Price', 'Lambda', 'Rho'})`

`OutSpec = {'All'}` specifies that the output should be Delta, Gamma, Vega, Lambda, Rho, Theta, and Price, in that order. This is the same as specifying `OutSpec = {'Delta', 'Gamma', 'Vega', 'Lambda', 'Rho', 'Theta', 'Price'}`;

- Default is `OutSpec = {'Price'}`.

## Description

`PriceSens = supersharesensbybls(RateSpec, StockSpec, Settle, Maturity, StrikeLow, StrikeHigh)` computes supershare option prices using the Black-Scholes option pricing model.

`PriceSens = supersharesensbybls(RateSpec, StockSpec, Settle, Maturity, StrikeLow, StrikeHigh, OutSpec)` includes an `OutSpec` argument defined as parameter/value pairs, and computes supershare option prices and sensitivities using the Black-Scholes option pricing model.

`PriceSens` is a NINST-by-1 vector of expected option prices and sensitivities.

## Examples

### Compute Price and Sensitivities of Supershare Digital Options Using Black-Scholes Model

This example shows how to compute price and sensitivities of supershare digital options using a Black-Scholes model. Consider a supershare based on a portfolio of nondividend paying stocks with a lower strike of 350 and an upper strike of 450. The value of the portfolio on November 1, 2008 is 400. The risk-free rate is 4.5% and the volatility is 18%.

Using this data, calculate the price and sensitivity of the supershare option on February 1, 2009.

```

Settle = 'Nov-1-2008';
Maturity = 'Feb-1-2009';
Rates = 0.045;
Basis = 1;
Compounding = -1;

% define the RateSpec
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
'EndDates', Maturity, 'Rates', Rates, 'Compounding', Compounding, 'Basis', Basis);

% define the StockSpec
AssetPrice = 400;
Sigma = .18;
StockSpec = stockspec(Sigma, AssetPrice);

% define the high and low strike points
StrikeLow = 350;
StrikeHigh = 450;

% calculate the price
Pssh = supersharebybls(RateSpec, StockSpec, Settle, Maturity,...
StrikeLow, StrikeHigh)

% compute the delta and theta of the supershare option
OutSpec = { 'delta'; 'theta' };
[Delta, Theta]= supersharesensbybls(RateSpec, StockSpec, Settle,...
Maturity, StrikeLow, StrikeHigh, 'OutSpec', OutSpec)

Pssh =

    0.9411

Delta =

   -0.0010

Theta =

   -1.0102

```

**See Also**

supersharebyb1s



# swapbybdt

Price swap instrument from Black-Derman-Toy interest-rate tree

## Syntax

```
[Price, PriceTree, CFTree, SwapRate] = swapbybdt(BDTree,
LegRate, Settle, Maturity)
[Price, PriceTree, CFTree, SwapRate] = swapbybdt(BDTree,
LegRate, Settle, Maturity, LegReset, Basis, Principal,
LegType, EndMonthRule)
[Price, PriceTree, CFTree, SwapRate] = swapbybdt(BDTree,
LegRate, Settle, Maturity, Name, Value)
```

## Input Arguments

<b>BDTree</b>	Interest-rate tree structure created by <code>bdttree</code> .
<b>LegRate</b>	Number of instruments (NINST)-by-2 matrix, with each row defined as:  [CouponRate Spread] or [Spread CouponRate]  CouponRate is the decimal annual rate. Spread is the number of basis points over the reference rate. The first column represents the receiving leg, while the second column represents the paying leg.
<b>Settle</b>	Settlement date. NINST-by-1 vector of serial date numbers or date strings representing the settlement date for each swap. Settle must be earlier than Maturity.
<b>Maturity</b>	Maturity date. NINST-by-1 vector of dates representing the maturity date for each swap.

The **Settle** date for every swap is set to the **ValuationDate** of the BDT tree. The swap argument **Settle** is ignored.

This function also calculates the **SwapRate** (fixed rate) so that the value of the swap is initially 0. To do this, enter **CouponRate** as **NaN**.

## Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

### LegReset

NINST-by-2 matrix representing the reset frequency per year for each swap. NINST-by-1 vector representing the frequency of payments per year.

**Default:** [1 1]

### Basis

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### Principal

NINST-by-1 vector or NINST-by-1 cell array of the notional principal amounts or principal value schedules. For the latter case, each element of the cell array is a NumDates-by-2

call array where the first column is dates and the second column is its associated notional principal value. The date indicates the last day that the principal value is valid.

**Default:** 100

### **LegType**

NINST-by-2 matrix. Each row represents an instrument. Each column indicates if the corresponding leg is fixed (1) or floating (0). This matrix defines the interpretation of the values entered in `LegRate`.

**Default:** [1 0] for each instrument

### **Options**

Derivatives pricing options structure created with `derivset`.

**Default:**

### **EndMonthRule**

End-of-month rule. NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

### **AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** false

### **BusinessDayConvention**

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

### **Holidays**

Holidays used for business day convention. NHOLIDAYS-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, `holidays.m` is used.

### **StartDate**

NINST-by-1 vector of dates when the swap actually starts. Use this argument to price forward swaps, i.e., swaps that start in a future date

**Default:** Settle date

## **Description**

`[Price, PriceTree, CFTree, SwapRate] = swapbybdt(BDTree, LegRate, Settle, Maturity)` computes the price of a swap instrument from a BDT interest-rate tree.

`[Price, PriceTree, CFTree, SwapRate] = swapbybdt(BDTree, LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType, EndMonthRule)` computes the price of a swap instrument from a BDT interest-rate tree using optional input arguments.

`[Price, PriceTree, CFTree, SwapRate] = swapbybdt(BDTree, LegRate, Settle, Maturity, Name, Value)` computes the price of a swap instrument from a BDT interest-rate tree with additional options specified by one or more Name, Value pair arguments.

`Price` is number of instruments (NINST)-by-1 expected prices of the swap at time 0.

`PriceTree` is a tree structure with a vector of the swap values at each node.

`CFTree` is a tree structure with a vector of the swap cash flows at each node. This structure contains only NaNs because with binomial recombining trees, cash flows cannot be computed accurately at each node of a tree.

`SwapRate` is a NINST-by-1 vector of rates applicable to the fixed leg such that the swaps' values are zero at time 0. This rate is used in calculating the swaps' prices when the rate specified for the fixed leg in `LegRate` is NaN. `SwapRate` is padded with NaN for those instruments in which `CouponRate` is not set to NaN.

## Examples

### Price an Interest-Rate Swap

Price an interest-rate swap with a fixed receiving leg and a floating paying leg. Payments are made once a year, and the notional principal amount is \$100. The values for the remaining arguments are:

- Coupon rate for fixed leg: 0.15 (15%)
- Spread for floating leg: 10 basis points
- Swap settlement date: Jan. 01, 2000
- Swap maturity date: Jan. 01, 2003

Based on the information above, set the required arguments and build the `LegRate`, `LegType`, and `LegReset` matrices:

```
Settle = '01-Jan-2000';
Maturity = '01-Jan-2003';
Basis = 0;
Principal = 100;
LegRate = [0.15 10]; % [CouponRate Spread]
```

```
LegType = [1 0]; % [Fixed Float]
LegReset = [1 1]; % Payments once per year
```

Price the swap using the `BDTTree` included in the MAT-file `deriv.mat`. `BDTTree` contains the time and forward-rate information needed to price the instrument.

```
load deriv.mat;
```

Use `swapbybdt` to compute the price of the swap.

```
Price = swapbybdt(BDTTree, LegRate, Settle, Maturity,...
LegReset, Basis, Principal, LegType)
```

```
Price =
    7.4222
```

Using the previous data, calculate the swap rate, the coupon rate for the fixed leg, such that the swap price at time = 0 is zero.

```
LegRate = [NaN 20];
```

```
[Price, PriceTree, CFTree, SwapRate] = swapbybdt(BDTTree,...
LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType)
```

```
Price =
   -1.4211e-14
```

```
PriceTree =
    FinObj: 'BDTPriceTree'
      tObs: [0 1 2 3 4]
      PTree: {1x5 cell}
```

```
CFTree =
    FinObj: 'BDTCFTree'
      tObs: [0 1 2 3 4]
    CFTree: {[NaN] [NaN NaN] [NaN NaN NaN] [NaN NaN NaN NaN] [1x4 double]}
```

```
SwapRate =
    0.1205
```

### Price an Amortizing Swap

Price an amortizing swap using the `Principal` input argument to define the amortization schedule.

Create the `RateSpec`.

```
Rates = 0.035;
ValuationDate = '1-Jan-2011';
StartDates = ValuationDate;
EndDates = '1-Jan-2017';
Compounding = 1;
```

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
    FinObj: 'RateSpec'
    Compounding: 1
    Disc: 0.8135
    Rates: 0.0350
    EndTimes: 6
    StartTimes: 0
    EndDates: 736696
    StartDates: 734504
    ValuationDate: 734504
    Basis: 0
    EndMonthRule: 1
```

Create the swap instrument using the following data:

```
Settle = '1-Jan-2011';
Maturity = '1-Jan-2017';
Period = 1;
LegRate = [0.04 10];
```





```

    EndTimes: 6
    StartTimes: 0
    EndDates: 737061
    StartDates: 734869
    ValuationDate: 734869
    Basis: 0
    EndMonthRule: 1

```

Build the tree with a volatility of 10%.

```

MatDates = {'1-Jan-2013'; '1-Jan-2014'; '1-Jan-2015'; '1-Jan-2016'; '1-Jan-2017'; '1-Jan-2018'};
BDTTimeSpec = bdttimespec(ValuationDate, MatDates);
Volatility = 0.10;
BDTVolSpec = bdtvolspec(ValuationDate, MatDates, Volatility*ones(1,length(MatDates)));
BDTT = bdttree(BDTVolSpec, RateSpec, BDTTimeSpec);

```

Compute the price of a forward swap that starts in two years (Jan 1, 2014) and matures in three years with a forward swap rate of 3.85%.

```

Settle = '1-Jan-2012';
Maturity = '1-Jan-2017';
StartDate = '1-Jan-2014';
LegRate = [0.0385 10];

```

```

Price = swapbybdt(BDTT, LegRate, Settle, Maturity, 'StartDate', StartDate)

```

```

Price =
    1.3203

```

Using the previous data, compute the forward swap rate, the coupon rate for the fixed leg, such that the forward swap price at time = 0 is zero.

```

LegRate = [NaN 10];
[Price, ~,~, SwapRate] = swapbybdt(BDTT, LegRate, Settle, Maturity, 'StartDate', StartDate)

```

```

Price =
    -4.5191e-12

```

```
SwapRate =  
    0.0335
```

## More About

### Amortizing Swap

In an amortizing swap, the notional principal decreases periodically because it is tied to an underlying financial instrument with a declining (amortizing) principal balance, such as a mortgage.

### Forward Swap

Agreement to enter into an interest-rate swap arrangement on a fixed date in the future.

- “Pricing Options Structure”

### See Also

bdttree | capbybdt | cfbybdt | floorbybdt

# swapbybk

Price swap instrument from Black-Karasinski interest-rate tree

## Syntax

```
[Price, PriceTree, SwapRate] = swapbybk(BKTree,
LegRate, Settle, Maturity)
[Price, PriceTree, SwapRate] = swapbybk(BKTree,
LegRate, Settle, Maturity, LegReset, Basis, Principal,
LegType, EndMonthRule)
[Price, PriceTree, SwapRate] = swapbybk(BKTree,
LegRate, Settle, Maturity, Name, Value)
```

## Input Arguments

<b>BKTree</b>	Interest-rate tree structure created by <code>bktree</code> .
<b>LegRate</b>	Number of instruments (NINST)-by-2 matrix, with each row defined as:  [CouponRate Spread] or [Spread CouponRate]  CouponRate is the decimal annual rate. Spread is the number of basis points over the reference rate. The first column represents the receiving leg, while the second column represents the paying leg.
<b>Settle</b>	Settlement date. NINST-by-1 vector of serial date numbers or date strings representing the settlement date for each swap. Settle must be earlier than Maturity.
<b>Maturity</b>	Maturity date. NINST-by-1 vector of dates representing the maturity date for each swap.

The **Settle** date for every swap is set to the **ValuationDate** of the BK tree. The swap argument **Settle** is ignored.

This function also calculates the **SwapRate** (fixed rate) so that the value of the swap is initially zero. To do this, enter **CouponRate** as **NaN**.

swapbybk computes prices of vanilla swaps, amortizing swaps and forward swaps.

## Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

### LegReset

NINST-by-2 matrix representing the reset frequency per year for each swap. NINST-by-1 vector representing the frequency of payments per year.

**Default:** [1 1]

### Basis

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

**Principal**

NINST-by-1 vector or NINST-by-1 cell array of the notional principal amounts or principal value schedules. For the latter case, each element of the cell array is a NumDates-by-2 cell array where the first column is dates and the second column is its associated notional principal value. The date indicates the last day that the principal value is valid.

**Default:** 100

**LegType**

NINST-by-2 matrix. Each row represents an instrument. Each column indicates if the corresponding leg is fixed (1) or floating (0). This matrix defines the interpretation of the values entered in LegRate.

**Default:** [1 0] for each instrument

**Options**

Derivatives pricing options structure created with `derivset`.

**Default:**

**EndMonthRule**

End-of-month rule. A NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

**StartDate**

NINST-by-1 vector of dates when the swap actually starts. Use this argument to price forward swaps, i.e., swaps that start in a future date

**Default:** Settle date

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

### **AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. `NINST-by-1` of logicals.

**Default:** `false`

### **BusinessDayConvention**

Require payment dates to be business dates. `NINST-by-1` cell array with possible choices of business day convention:

- `actual`
- `follow`
- `modifiedfollow`
- `previous`
- `modifiedprevious`

**Default:** `actual`

### **Holidays**

Holidays used for business day convention. `NHOLIDAYS-by-1` of MATLAB date numbers.

**Default:** If no dates are specified, `holidays.m` is used.

## Description

`[Price, PriceTree, SwapRate] = swapbybk(BKTree, LegRate, Settle, Maturity)` computes the price of a swap instrument from a Black-Karasinski interest-rate tree.

`[Price, PriceTree, SwapRate] = swapbybk(BKTree,`

`LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType, EndMonthRule)` computes the price of a swap instrument from a Black-Karasinski interest-rate tree using optional input arguments.

`[Price, PriceTree, SwapRate] = swapbybk(BKTree, LegRate, Settle, Maturity, Name, Value)` computes the price of a swap instrument from a Black-Karasinski interest-rate tree with additional options specified by one or more `Name, Value` pair arguments.

`Price` is the number of instruments (NINST)-by-1 expected prices of the swap at time 0.

`PriceTree` is the tree structure with a vector of the swap values at each node:

- `PriceTree.PTree` contains swap values.
- `PriceTree.tObs` contains the observation times.
- `PriceTree.Connect` contains the connectivity vectors. Each element in the cell array describes how nodes in that level connect to the next. For a given tree level, there are `NumNodes` elements in the vector, and they contain the index of the node at the next level that the middle branch connects to. Subtracting 1 from that value indicates where the up-branch connects to, and adding 1 indicates where the down branch connects to.
- `PriceTree.Probs` contains the probability arrays. Each element of the cell array contains the up, middle, and down transition probabilities for each node of the level.

`SwapRate` is a NINST-by-1 vector of rates applicable to the fixed leg such that the swaps' values are zero at time 0. This rate is used in calculating the swaps' prices when the rate specified for the fixed leg in `LegRate` is NaN. The `SwapRate` output is padded with NaN for those instruments in which `CouponRate` is not set to NaN.

## Examples

### Price an Interest-Rate Swap

Price an interest-rate swap with a fixed receiving leg and a floating paying leg. Payments are made once a year, and the notional principal amount is \$100. The values for the remaining arguments are:

- Coupon rate for fixed leg: 0.06 (6%)
- Spread for floating leg: 20 basis points

- Swap settlement date: Jan. 01, 2004
- Swap maturity date: Jan. 01, 2006

Based on the information above, set the required arguments and build the `LegRate`, `LegType`, and `LegReset` matrices:

```
Settle = '01-Jan-2004';  
Maturity = '01-Jan-2006';  
Basis = 0;  
Principal = 100;  
LegRate = [0.06 20]; % [CouponRate Spread]  
LegType = [1 0]; % [Fixed Float]  
LegReset = [1 1]; % Payments once per year
```

Price the swap using the `BKTree` included in the MAT-file `deriv.mat`. `BKTree` contains the time and forward-rate information needed to price the instrument.

```
load deriv.mat;
```

Use `swapbybk` to price of the swap.

```
Price = swapbybk(BKTree, LegRate,...  
Settle, Maturity, LegReset, Basis, Principal, LegType)
```

```
Price =  
  
5.0425
```

Using the previous data, calculate the swap rate, which is the coupon rate for the fixed leg, such that the swap price at time = 0 is zero.

```
LegRate = [NaN 20];
```

```
[Price, PriceTree, SwapRate] = swapbybk(BKTree, LegRate,...  
Settle, Maturity, LegReset, Basis, Principal, LegType)
```

```
Price =  
  
-2.8422e-14
```



```
PriceTree =
```

```
    FinObj: 'BKPriceTree'
    PTree: {1x5 cell}
    tObs: [0 1 2 3 4]
    Connect: {[2] [2 3 4] [2 2 3 4 4]}
    Probs: {[3x1 double] [3x3 double] [3x5 double]}
```

```
SwapRate =
```

```
0.0336
```

### Price an Amortizing Swap

Price an amortizing swap using the `Principal` input argument to define the amortization schedule.

Create the `RateSpec`.

```
Rates = 0.035;
ValuationDate = '1-Jan-2011';
StartDates = ValuationDate;
EndDates = '1-Jan-2017';
Compounding = 1;
```

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
    Compounding: 1
    Disc: 0.8135
    Rates: 0.0350
    EndTimes: 6
    StartTimes: 0
    EndDates: 736696
    StartDates: 734504
    ValuationDate: 734504
    Basis: 0
    EndMonthRule: 1
```

Create the swap instrument using the following data:

```
Settle = '1-Jan-2011';  
Maturity = '1-Jan-2017';  
Period = 1;  
LegRate = [0.04 10];
```

Define the swap amortizing schedule.

```
Principal = {'1-Jan-2013' 100; '1-Jan-2014' 80; '1-Jan-2015' 60; '1-Jan-2016' 40; '1-Jan-2017' 0};
```

Build the BK tree and assume volatility is 10%.

```
MatDates = {'1-Jan-2012'; '1-Jan-2013'; '1-Jan-2014'; '1-Jan-2015'; '1-Jan-2016'; '1-Jan-2017'};  
BKTimeSpec = bktimespec(ValuationDate, MatDates);  
Volatility = 0.10;  
AlphaDates = '01-01-2017';  
AlphaCurve = 0.1;  
BKVolSpec = bkvolspec(ValuationDate, MatDates, Volatility*ones(1,length(MatDates))',...  
AlphaDates, AlphaCurve);  
BKT = bktree(BKVolSpec, RateSpec, BKTimeSpec);
```

Compute the price of the amortizing swap.

```
Price = swapybybk(BKT, LegRate, Settle, Maturity, 'Principal' , Principal)
```

```
Price =
```

```
1.4574
```

### Price a Forward Swap

Price a forward swap using the `StartDate` input argument to define the future starting date of the swap.

Create the `RateSpec`.

```
Rates = 0.0374;  
ValuationDate = '1-Jan-2012';  
StartDates = ValuationDate;  
EndDates = '1-Jan-2018';  
Compounding = 1;
```

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'
  Compounding: 1
        Disc: 0.8023
        Rates: 0.0374
    EndTimes: 6
  StartTimes: 0
    EndDates: 737061
  StartDates: 734869
ValuationDate: 734869
        Basis: 0
  EndMonthRule: 1
```

Build a BK tree.

```
VolDates = {'1-Jan-2013'; '1-Jan-2014'; '1-Jan-2015'; '1-Jan-2016'; '1-Jan-2017'; '1-Jan-2018'};
VolCurve = 0.1;
AlphaDates = '01-01-2018';
AlphaCurve = 0.1;
```

```
BKVolSpec = bkvolspec(RateSpec.ValuationDate, VolDates, VolCurve, ...
AlphaDates, AlphaCurve);
BKTimeSpec = bktimespec(RateSpec.ValuationDate, VolDates, Compounding);
BKT = bktree(BKVolSpec, RateSpec, BKTimeSpec);
```

Compute the price of a forward swap that starts in a year (Jan 1, 2013) and matures in four years with a forward swap rate of 4.25%.

```
Settle = '1-Jan-2012';
Maturity = '1-Jan-2017';
StartDate = '1-Jan-2013';
LegRate = [0.0425 10];
```

```
Price = swapbybk(BKT, LegRate, Settle, Maturity, 'StartDate', StartDate)
```

```
Price =
```

```
1.4434
```

Using the previous data, compute the forward swap rate, the coupon rate for the fixed leg, such that the forward swap price at time = 0 is zero.

```
LegRate = [NaN 10];  
[Price, ~, SwapRate] = swapbybk(BKT, LegRate, Settle, Maturity, 'StartDate', StartDate)
```

```
Price =
```

```
2.8422e-14
```

```
SwapRate =
```

```
0.0384
```

## More About

### Amortizing Swap

In an amortizing swap, the notional principal decreases periodically because it is tied to an underlying financial instrument with a declining (amortizing) principal balance, such as a mortgage.

### Forward Swap

Agreement to enter into an interest-rate swap arrangement on a fixed date in the future.

- “Pricing Options Structure”

### See Also

bktree | bondbybk | capbybk | fixedbybk | floorbybk

# swapbyhjm

Price swap instrument from Heath-Jarrow-Morton interest-rate tree

## Syntax

```
[Price, PriceTree, CFTree, SwapRate] = swapbyhjm(HJMTree,
LegRate, Settle, Maturity)
[Price, PriceTree, CFTree, SwapRate] = swapbyhjm(HJMTree,
LegRate, Settle, Maturity, LegReset, Basis, Principal,
LegType, EndMonthRule)
[Price, PriceTree, CFTree, SwapRate] = swapbyhjm(HJMTree,
LegRate, Settle, Maturity, Name, Value)
```

## Input Arguments

HJMTree	Forward-rate tree structure created by <code>hjmtree</code> .
LegRate	Number of instruments (NINST)-by-2 matrix, with each row defined as:  [CouponRate Spread] or [Spread CouponRate]  CouponRate is the decimal annual rate. Spread is the number of basis points over the reference rate. The first column represents the receiving leg, while the second column represents the paying leg.
Settle	Settlement date. NINST-by-1 vector of serial date numbers or date strings representing the settlement date for each swap. Settle must be earlier than Maturity.
Maturity	Maturity date. NINST-by-1 vector of dates representing the maturity date for each swap.

The **Settle** date for every swap is set to the **ValuationDate** of the HJM tree. The swap argument **Settle** is ignored.

This function also calculates the **SwapRate** (fixed rate) so that the value of the swap is initially zero. To do this, enter **CouponRate** as **NaN**.

## Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

### LegReset

NINST-by-2 matrix representing the reset frequency per year for each swap. NINST-by-1 vector representing the frequency of payments per year.

**Default:** [1 1]

### Basis

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### Principal

NINST-by-1 vector or NINST-by-1 cell array of the notional principal amounts or principal value schedules. For the latter case, each element of the cell array is a NumDates-by-2

call array where the first column is dates and the second column is its associated notional principal value. The date indicates the last day that the principal value is valid.

**Default:** 100

### **LegType**

NINST-by-2 matrix. Each row represents an instrument. Each column indicates if the corresponding leg is fixed (1) or floating (0). This matrix defines the interpretation of the values entered in `LegRate`.

**Default:** [1 0] for each instrument

### **Options**

Derivatives pricing options structure created with `derivset`.

**Default:**

### **EndMonthRule**

End-of-month rule. A NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

### **AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** false

### **BusinessDayConvention**

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

### **Holidays**

Holidays used for business day convention. NHOLIDAYS-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, `holidays.m` is used.

### **StartDate**

NINST-by-1 vector of dates when the swap actually starts. Use this argument to price forward swaps, i.e., swaps that start in a future date

**Default:** Settle date

## **Description**

`[Price, PriceTree, CFTree, SwapRate] = swapbyhjm(HJMTree, LegRate, Settle, Maturity)` computes the price of a swap instrument from an HJM interest-rate tree.

`[Price, PriceTree, CFTree, SwapRate] = swapbyhjm(HJMTree, LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType, EndMonthRule)` computes the price of a swap instrument from an HJM interest-rate tree with optional input arguments.



`[Price, PriceTree, CFTree, SwapRate] = swapbyhjm(HJMTree, LegRate, Settle, Maturity, Name, Value)` computes the price of a swap instrument from an HJM interest-rate tree with additional options specified by one or more Name, Value pair arguments.

Price is the number of instruments (NINST-by-1) expected prices of the swap at time 0.

PriceTree is the tree structure with a vector of the swap values at each node.

CFTree is the tree structure with a vector of the swap cash flows at each node.

SwapRate is a NINST-by-1 vector of rates applicable to the fixed leg such that the swaps' values are zero at time 0. This rate is used in calculating the swaps' prices when the rate specified for the fixed leg in LegRate is NaN. The SwapRate output is padded with NaN for those instruments in which CouponRate is not set to NaN.

## Examples

### Price an Interest-Rate Swap

Price an interest-rate swap with a fixed receiving leg and a floating paying leg. Payments are made once a year, and the notional principal amount is \$100. The values for the remaining arguments are:

- Coupon rate for fixed leg: 0.06 (6%)
- Spread for floating leg: 20 basis points
- Swap settlement date: Jan. 01, 2000
- Swap maturity date: Jan. 01, 2003

Based on the information above, set the required arguments and build the LegRate, LegType, and LegReset matrices:

```
Settle = '01-Jan-2000';
Maturity = '01-Jan-2003';
Basis = 0;
Principal = 100;
LegRate = [0.06 20]; % [CouponRate Spread]
LegType = [1 0]; % [Fixed Float]
```

```
LegReset = [1 1]; % Payments once per year
```

Price the swap using the `HJMTree` included in the MAT-file `deriv.mat`. The `HJMTree` structure contains the time and forward-rate information needed to price the instrument.

```
load deriv.mat;
```

Use `swapbyhjm` to compute the price of the swap.

```
[Price, PriceTree, CFTree] = swapbyhjm(HJMTree, LegRate,...  
Settle, Maturity, LegReset, Basis, Principal, LegType)
```

```
Price =
```

```
3.6923
```

```
PriceTree =
```

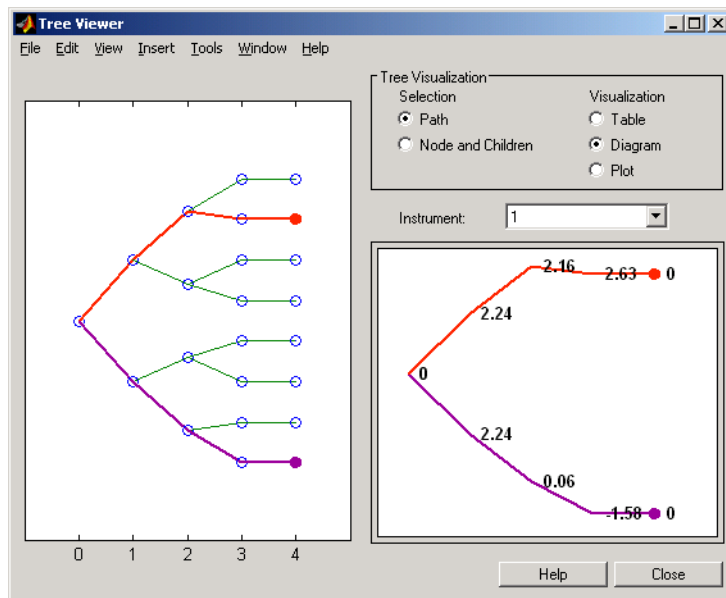
```
FinObj: 'HJMPriceTree'  
tObs: [0 1 2 3 4]  
PBush: {1x5 cell}
```

```
CFTree =
```

```
FinObj: 'HJMCFTree'  
tObs: [0 1 2 3 4]  
CFBush: {[0] [1x1x2 double] [1x2x2 double] ... [1x8 double]}
```

Use `treeview` to examine `CFTree` graphically and see the cash flows from the swap along both the up and the down branches. A positive cash flow indicates an inflow (income - payments > 0), while a negative cash flow indicates an outflow (income - payments < 0).

```
treeview(CFTree)
```



In this example, you have sold a swap (receive fixed rate and pay floating rate). At time  $t = 3$ , if interest rates go down, your cash flow is positive (\$2.63), meaning that you will receive this amount. But if interest rates go up, your cash flow is negative (-\$1.58), meaning that you owe this amount.

treeviewer price tree diagrams follow the convention that increasing prices appear on the upper branch of a tree and, consequently, decreasing prices appear on the lower branch. Conversely, for interest-rate displays, *decreasing* interest rates appear on the upper branch (prices are rising) and *increasing* interest rates on the lower branch (prices are falling).

Using the previous data, calculate the swap rate, which is the coupon rate for the fixed leg, such that the swap price at time = 0 is zero.

```
LegRate = [NaN 20];
```

```
[Price, PriceTree, CFTree, SwapRate] = swapbyhjm(HJMTTree, ...
LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType)
```

```
Price =
```

```
0
```

```
PriceTree =  
  
FinObj: 'HJMPriceTree'  
  tObs: [0 1 2 3 4]  
  PBush:{[0] [1x1x2 double] [1x2x2 double] ... [1x8 double]}
```

```
CFTree =  
  
FinObj: 'HJMCFTree'  
  tObs: [0 1 2 3 4]  
  CFBush:{[0] [1x1x2 double] [1x2x2 double] ... [1x8 double]}
```

```
SwapRate =  
  
    0.0466
```

### Price an Amortizing Swap

Price an amortizing swap using the `Principal` input argument to define the amortization schedule.

Create the `RateSpec`.

```
Rates = 0.035;  
ValuationDate = '1-Jan-2011';  
StartDates = ValuationDate;  
EndDates = '1-Jan-2017';  
Compounding = 1;
```

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...  
  'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =  
  
    FinObj: 'RateSpec'  
    Compounding: 1  
    Disc: 0.8135  
    Rates: 0.0350  
    EndTimes: 6  
    StartTimes: 0  
    EndDates: 736696  
    StartDates: 734504  
    ValuationDate: 734504
```

```
Basis: 0
EndMonthRule: 1
```

Create the swap instrument using the following data:

```
Settle = '1-Jan-2011';
Maturity = '1-Jan-2017';
Period = 1;
LegRate = [0.04 10];
```

Define the swap amortizing schedule.

```
Principal = {'1-Jan-2013' 100; '1-Jan-2014' 80; '1-Jan-2015' 60; '1-Jan-2016' 40; '1-Jan-2017' 20};
```

Build the HJM tree using the following data:

```
MatDates = {'1-Jan-2012'; '1-Jan-2013'; '1-Jan-2014'; '1-Jan-2015'; '1-Jan-2016'; '1-Jan-2017'};
HJMTimeSpec = hjmtimespec(RateSpec.ValuationDate, MatDates);
Volatility = [.10; .08; .06; .04];
CurveTerm = [ 1; 2; 3; 4];
HJMVolSpec = hjmvolspec('Proportional', Volatility, CurveTerm, 1e6);
HJMT = hjmtree(HJMVolSpec, RateSpec, HJMTimeSpec);
```

Compute the price of the amortizing swap.

```
Price = swapbyhjm(HJMT, LegRate, Settle, Maturity, 'Principal', Principal)
```

```
Price =
    1.4574
```

### Price a Forward Swap

Price a forward swap using the `StartDate` input argument to define the future starting date of the swap.

Create the `RateSpec`.

```
Rates = 0.0374;
ValuationDate = '1-Jan-2012';
StartDates = ValuationDate;
EndDates = '1-Jan-2018';
```

```
Compounding = 1;  
  
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...  
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =  
    FinObj: 'RateSpec'  
    Compounding: 1  
    Disc: 0.8023  
    Rates: 0.0374  
    EndTimes: 6  
    StartTimes: 0  
    EndDates: 737061  
    StartDates: 734869  
    ValuationDate: 734869  
    Basis: 0  
    EndMonthRule: 1
```

Build an HJM tree.

```
MatDates = {'1-Jan-2013'; '1-Jan-2014'; '1-Jan-2015'; '1-Jan-2016'; '1-Jan-2017'; '1-Jan-2018'};  
HJMTimeSpec = hjmtimespec(RateSpec.ValuationDate, MatDates);  
Volatility = [.10; .08; .06; .04];  
CurveTerm = [ 1; 2; 3; 4];  
HJMVolSpec = hjmvolspec('Proportional', Volatility, CurveTerm, 1e6);  
HJMT = hjmtree(HJMVolSpec, RateSpec, HJMTimeSpec);
```

Compute the price of a forward swap that starts in a year (Jan 1, 2013) and matures in four years with a forward swap rate of 4.25%.

```
Settle = '1-Jan-2012';  
Maturity = '1-Jan-2017';  
StartDate = '1-Jan-2013';  
LegRate = [0.0425 10];
```

```
Price = swapbyhjm(HJMT, LegRate, Settle, Maturity, 'StartDate', StartDate)
```

```
Price =  
    1.4434
```

Using the previous data, compute the forward swap rate, the coupon rate for the fixed leg, such that the forward swap price at time = 0 is zero.

```
LegRate = [NaN 10];  
[Price, ~,~, SwapRate] = swapbyhjm(HJMT, LegRate, Settle, Maturity, 'StartDate', StartDate)
```

```
Price =
```

```
0
```

```
SwapRate =
```

```
0.0384
```

## More About

### Amortizing Swap

In an amortizing swap, the notional principal decreases periodically because it is tied to an underlying financial instrument with a declining (amortizing) principal balance, such as a mortgage.

### Forward Swap

Agreement to enter into an interest-rate swap arrangement on a fixed date in the future.

- “Pricing Options Structure”

### See Also

capbyhjm | cfbyhjm | floorbyhjm | hjmtree | treeviewer

## swapbyhw

Price swap instrument from Hull-White interest-rate tree

### Syntax

```
[Price, PriceTree, SwapRate] = swapbyhw(HWTree,
LegRate, Settle, Maturity)
[Price, PriceTree, SwapRate] = swapbyhw(HWTree,
LegRate, Settle, Maturity, LegReset, Basis,
Principal, LegType, Options, EndMonthRule)
[Price, PriceTree, SwapRate] = swapbyhw(HWTree,
LegRate, Settle, Maturity, Name, Value)
```

### Input Arguments

<b>HWTree</b>	Forward-rate tree structure created by <code>hwtree</code> .
<b>LegRate</b>	Number of instruments (NINST)-by-2 matrix, with each row defined as:  [CouponRate Spread] or [Spread CouponRate]  CouponRate is the decimal annual rate. Spread is the number of basis points over the reference rate. The first column represents the receiving leg, while the second column represents the paying leg.
<b>Settle</b>	Settlement date. NINST-by-1 vector of serial date numbers or date strings representing the settlement date for each swap. Settle must be earlier than Maturity.
<b>Maturity</b>	Maturity date. NINST-by-1 vector of dates representing the maturity date for each swap.

The **Settle** date for every swap is set to the **ValuationDate** of the HW tree. The swap argument **Settle** is ignored.

This function also calculates the **SwapRate** (fixed rate) so that the value of the swap is initially zero. To do this, enter **CouponRate** as **NaN**.



## Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

### LegReset

NINST-by-2 matrix representing the reset frequency per year for each swap. NINST-by-1 vector representing the frequency of payments per year.

**Default:** [1 1]

### Basis

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### Principal

NINST-by-1 vector or NINST-by-1 cell array of the notional principal amounts or principal value schedules. For the latter case, each element of the cell array is a NumDates-by-2

call array where the first column is dates and the second column is its associated notional principal value. The date indicates the last day that the principal value is valid.

**Default:** 100

### **LegType**

NINST-by-2 matrix. Each row represents an instrument. Each column indicates if the corresponding leg is fixed (1) or floating (0). This matrix defines the interpretation of the values entered in `LegRate`.

**Default:** [1 0] for each instrument

### **Options**

Derivatives pricing options structure created with `derivset`.

**Default:**

### **EndMonthRule**

End-of-month rule. NINST-by-1 vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

### **AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** false

### **BusinessDayConvention**

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

### **Holidays**

Holidays used for business day convention. NHOLIDAYS-by-1 of MATLAB date numbers.

**Default:** If no dates are specified, `holidays.m` is used.

### **StartDate**

NINST-by-1 vector of dates when the swap actually starts. Use this argument to price forward swaps, i.e., swaps that start in a future date

**Default:** Settle date

## **Description**

`[Price, PriceTree, SwapRate] = swapbyhw(HWTree, LegRate, Settle, Maturity)` computes the price of a swap instrument from a Hull-White interest-rate tree.

`[Price, PriceTree, SwapRate] = swapbyhw(HWTree, LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType, Options, EndMonthRule)` computes the price of a swap instrument from a Hull-White interest-rate tree with optional input arguments.

`[Price, PriceTree, SwapRate] = swapbyhw(HWTree,`

`LegRate, Settle, Maturity, Name, Value`) computes the price of a swap instrument from a Hull-White interest-rate tree with additional options specified by one or more `Name, Value` pair arguments.

`Price` is number of instruments (NINST)-by-1 expected prices of the swap at time 0.

`PriceTree` is the tree structure with a vector of the swap values at each node.

`SwapRate` is a NINST-by-1 vector of rates applicable to the fixed leg such that the swaps' values are zero at time 0. This rate is used in calculating the swaps' prices when the rate specified for the fixed leg in `LegRate` is NaN. The `SwapRate` output is padded with NaNs for those instruments in which `CouponRate` is not set to NaN.

## Examples

### Price an Interest-Rate Swap

Price an interest-rate swap with a fixed receiving leg and a floating paying leg. Payments are made once a year, and the notional principal amount is \$100. The values for the remaining arguments are:

- Coupon rate for fixed leg: 0.06 (6%)
- Spread for floating leg: 20 basis points
- Swap settlement date: Jan. 01, 2005
- Swap maturity date: Jan. 01, 2008

Based on the information above, set the required arguments and build the `LegRate`, `LegType`, and `LegReset` matrices:

```
Settle = '01-Jan-2005';  
Maturity = '01-Jan-2008';  
Basis = 0;  
Principal = 100;  
LegRate = [0.06 20]; % [CouponRate Spread]  
LegType = [1 0]; % [Fixed Float]  
LegReset = [1 1]; % Payments once per year
```

Price the swap using the `HWTtree` included in the MAT-file `deriv.mat`. The `HWTtree` structure contains the time and forward-rate information needed to price the instrument.

```
load deriv.mat;
```

Use `swapbyhw` to compute the price of the swap.

```
[Price, PriceTree, SwapRate] = swapbyhw(HWTree, LegRate, ...
Settle, Maturity, LegReset, Basis, Principal, LegType)
```

Warning: Swaps are valued at Tree ValuationDate rather than Settle

```
Price =
```

```
    5.9109
```

```
PriceTree =
```

```
    FinObj: 'HWPriceTree'
    PTree: {1x5 cell}
    tObs: [0 1 2 3 4]
    Connect: {[2] [2 3 4] [2 2 3 4 4]}
    Probs: {[3x1 double] [3x3 double] [3x5 double]}
```

```
SwapRate =
```

```
    NaN
```

Using the previous data, calculate the swap rate, which is the coupon rate for the fixed leg, such that the swap price at time = 0 is zero.

```
LegRate = [NaN 20];
```

```
[Price, PriceTree, SwapRate] = swapbyhw(HWTree, LegRate, ...
Settle, Maturity, LegReset, Basis, Principal, LegType)
```

Warning: Swaps are valued at Tree ValuationDate rather than Settle

```
Price =
```

```
    1.4211e-14
```

```
PriceTree =
```

```
FinObj: 'HWPriceTree'  
PTree: {1x5 cell}  
tObs: [0 1 2 3 4]  
Connect: {[2] [2 3 4] [2 2 3 4 4]}  
Probs: {[3x1 double] [3x3 double] [3x5 double]}
```

```
SwapRate =
```

```
0.0438
```

### Price an Amortizing Swap

Price an amortizing swap using the `Principal` input argument to define the amortization schedule.

Create the `RateSpec`.

```
Rates = 0.035;  
ValuationDate = '1-Jan-2011';  
StartDates = ValuationDate;  
EndDates = '1-Jan-2017';  
Compounding = 1;
```

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...  
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'  
    Compounding: 1  
        Disc: 0.8135  
        Rates: 0.0350  
    EndTimes: 6  
    StartTimes: 0  
    EndDates: 736696  
    StartDates: 734504  
    ValuationDate: 734504  
        Basis: 0  
    EndMonthRule: 1
```

Create the swap instrument using the following data:

```
Settle = '1-Jan-2011';
Maturity = '1-Jan-2017';
Period = 1;
LegRate = [0.04 10];
```

Define the swap amortizing schedule.

```
Principal = {'1-Jan-2013' 100; '1-Jan-2014' 80; '1-Jan-2015' 60; '1-Jan-2016' 40; '1-Jan-2017' 0};
```

Build the HW tree using the following data:

```
VolDates = ['1-Jan-2012'; '1-Jan-2013'; '1-Jan-2014'; '1-Jan-2015'; '1-Jan-2016'; '1-Jan-2017'];
VolCurve = 0.1;
AlphaDates = '01-01-2017';
AlphaCurve = 0.1;
```

```
HWVolSpec = hwwolspec(RateSpec.ValuationDate, VolDates, VolCurve, ...
AlphaDates, AlphaCurve);
HWTimeSpec = hwtimespec(RateSpec.ValuationDate, VolDates, Compounding);
HWT = hwtree(HWVolSpec, RateSpec, HWTimeSpec);
```

Compute the price of the amortizing swap.

```
Price = swapbyhw(HWT, LegRate, Settle, Maturity, 'Principal', Principal)
```

```
Price =
    1.4574
```

### Price a Forward Swap

Price a forward swap using the `StartDate` input argument to define the future starting date of the swap.

Create the `RateSpec`.

```
Rates = 0.0374;
ValuationDate = '1-Jan-2012';
StartDates = ValuationDate;
EndDates = '1-Jan-2018';
Compounding = 1;
```

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
```

```
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =
```

```
    FinObj: 'RateSpec'  
    Compounding: 1  
        Disc: 0.8023  
        Rates: 0.0374  
    EndTimes: 6  
    StartTimes: 0  
    EndDates: 737061  
    StartDates: 734869  
    ValuationDate: 734869  
        Basis: 0  
    EndMonthRule: 1
```

Build an HW tree.

```
VolDates = {'1-Jan-2013'; '1-Jan-2014'; '1-Jan-2015'; '1-Jan-2016'; '1-Jan-2017'; '1-Jan-2018'};  
VolCurve = 0.1;  
AlphaDates = '01-01-2018';  
AlphaCurve = 0.1;
```

```
HWVolSpec = hwvolspec(RateSpec.ValuationDate, VolDates, VolCurve, ...  
AlphaDates, AlphaCurve);  
HWTimeSpec = hwtimespec(RateSpec.ValuationDate, VolDates, Compounding);  
HWT = hwtree(HWVolSpec, RateSpec, HWTimeSpec);
```

Compute the price of a forward swap that starts in a year (Jan 1, 2013) and matures in four years with a forward swap rate of 4.25%.

```
Settle = '1-Jan-2012';  
Maturity = '1-Jan-2017';  
StartDate = '1-Jan-2013';  
LegRate = [0.0425 10];
```

```
Price = swapbyhw(HWT, LegRate, Settle, Maturity, 'StartDate', StartDate)
```

```
Price =
```

```
    1.4434
```



Using the previous data, compute the forward swap rate, the coupon rate for the fixed leg, such that the forward swap price at time = 0 is zero.

```
LegRate = [NaN 10];  
[Price, ~, SwapRate] = swapbyhw(HWT, LegRate, Settle, Maturity, 'StartDate', StartDate)
```

```
Price =
```

```
0
```

```
SwapRate =
```

```
0.0384
```

## More About

### Amortizing Swap

In an amortizing swap, the notional principal decreases periodically because it is tied to an underlying financial instrument with a declining (amortizing) principal balance, such as a mortgage.

### Forward Swap

Agreement to enter into an interest-rate swap arrangement on a fixed date in the future.

- “Pricing Options Structure”

### See Also

bondbyhw | capbyhw | cfbyhw | fixedbyhw | floorbyhw | hwtree

## swapbyzero

Price swap instrument from set of zero curves

### Syntax

```
[Price, SwapRate AI, RecCF, RecCFDates, PayCF, PayCFDates] =  
swapbyzero(RateSpec, LegRate, Settle, Maturity)  
[Price, SwapRate AI, RecCF, RecCFDates, PayCF, PayCFDates] =  
swapbyzero(RateSpec, LegRate, Settle, Maturity,  
LegReset, Basis, Principal, LegType, EndMonthRule)  
[Price, SwapRate, AI, RecCF, RecCFDates, PayCF, PayCFDates] =  
swapbyzero(RateSpec, LegRate, Settle, Maturity,  
Name, Value)
```

### Description

[Price, SwapRate AI, RecCF, RecCFDates, PayCF, PayCFDates] = swapbyzero(RateSpec, LegRate, Settle, Maturity) prices a swap instrument from a set of zero coupon bond rates. You can use swapbyzero to compute prices of vanilla swaps, amortizing swaps, and forward swaps. All inputs are either scalars or NINST-by-1 vectors unless otherwise specified. Any date can be a serial date number or date string. An optional argument can be passed as an empty matrix [ ].

[Price, SwapRate AI, RecCF, RecCFDates, PayCF, PayCFDates] = swapbyzero(RateSpec, LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType, EndMonthRule) prices a swap instrument from a set of zero coupon bond rates with optional input arguments. You can use swapbyzero to compute prices of vanilla swaps, amortizing swaps, and forward swaps. All inputs are either scalars or NINST-by-1 vectors unless otherwise specified. Any date can be a serial date number or date string. An optional argument can be passed as an empty matrix [ ].

[Price, SwapRate, AI, RecCF, RecCFDates, PayCF, PayCFDates] = swapbyzero(RateSpec, LegRate, Settle, Maturity, Name, Value) prices a swap instrument from a set of zero coupon bond rates with additional options specified by one or more Name, Value pair arguments. You can use swapbyzero to compute prices of vanilla swaps, amortizing swaps, and forward swaps.

## Input Arguments

### RateSpec

Structure containing the properties of an interest-rate structure. See `intenvset` for information on creating `RateSpec`.

`RateSpec` can also be a 1-by-2 input variable of `RateSpecs`, with the second `RateSpec` structure containing the discount curve(s) for the paying leg. If only one `RateSpec` structure is specified, then this `RateSpec` is used to discount both legs.

### LegRate

Number of instruments (NINST)-by-2 matrix, with each row defined as:

[CouponRate Spread] or [Spread CouponRate]

`CouponRate` is the decimal annual rate. `Spread` is the number of basis points over the reference rate. The first column represents the receiving leg, while the second column represents the paying leg.

### Settle

Settlement date. `Settle` must be either a scalar or NINST-by-1 vector of serial date numbers or date strings of the same value which represent the settlement date for each swap. `Settle` must be earlier than `Maturity`.

### Maturity

Maturity date. NINST-by-1 vector of dates representing the maturity date for each swap.

## Ordered Input or Name-Value Pair Arguments

Enter the following optional inputs using an ordered syntax or as name-value pair arguments. You cannot mix ordered syntax with name-value pair arguments.

### LegReset

NINST-by-2 matrix representing the reset frequency per year for each swap. NINST-by-1 vector representing the frequency of payments per year.

**Default:** [1 1]

**Basis**

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

**Principal**

NINST-by-1 vector or NINST-by-1 cell array of the notional principal amounts or principal value schedules. For the latter case, each element of the cell array is a NumDates-by-2 call array where the first column is dates and the second column is its associated notional principal value. The date indicates the last day that the principal value is valid.

**Default:** 100

**LegType**

NINST-by-2 matrix. Each row represents an instrument. Each column indicates if the corresponding leg is fixed (1) or floating (0). This matrix defines the interpretation of the values entered in LegRate.

**Default:** [1 0] for each instrument

### **EndMonthRule**

End-of-month rule. NINST-by-1 vector. This rule applies only when **Maturity** is an end-of-month date for a month having 30 or fewer days.

- 0 = Ignore rule, meaning that a bond coupon payment date is always the same numerical day of the month.
- 1 = Set rule on, meaning that a bond coupon payment date is always the last actual day of the month.

**Default:** 1

### **Name-Value Pair Arguments**

Specify optional comma-separated pairs of **Name**,**Value** arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as **Name1**,**Value1**, . . . ,**NameN**,**ValueN**.

### **AdjustCashFlowsBasis**

Adjust the cash flows based on the actual period day count. NINST-by-1 of logicals.

**Default:** false

### **BusinessDayConvention**

Require payment dates to be business dates. NINST-by-1 cell array with possible choices of business day convention:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

**Holidays**

Holidays used for business day convention. `NHOLIDAYS-by-1` of MATLAB date numbers.

**Default:** If none specified, `holidays.m` is used.

**LatestFloatingRate**

Rate for the next floating payment, set at the last reset date. `NINST-by-1` of scalars.

**Default:** If not specified, then the `RateSpec` must contain this information.

**ProjectionCurve**

The rate curve to be used in generating cash flows for the floating leg of the swap. This structure must be created using `intenvset`.

**Default:** If `ProjectionCurve` is not specified, then the `RateSpec` is used both for discounting and generating cash flows for the floating leg.

**StartDate**

`NINST-by-1` vector of dates when the swap actually starts. Use this argument to price forward swaps, i.e., swaps that start in a future date

**Default:** `Settle` date

## Output Arguments

**Price**

Number of instruments (`NINST`) by number of curves (`NUMCURVES`) matrix of swap prices. Each column arises from one of the zero curves. `Price` output is the dirty price. To compute the clean price, subtract the accrued interest (`AI`) from the dirty price.

**SwapRate**

`NINST-by-NUMCURVES` matrix of rates applicable to the fixed leg such that the swap's values are zero at time 0. This rate is used in calculating the swaps' prices when the rate specified for the fixed leg in `LegRate` is `NaN`. The `SwapRate` output is padded with `NaN` for those instruments in which `CouponRate` is not set to `NaN`.

Output cash flows, cash flow dates, and accrued interest.

**AI**

NINST-by-NUMCURVES matrix of accrued interest.

**RecCF**

NINST-by-NUMCURVES matrix of cash flows for the receiving leg.

---

**Note:** If there is more than one curve specified in the `RateSpec` input, then the first `NCURVES` row corresponds to the first swap, the second `NCURVES` row correspond to the second swap, and so on.

---

**RecCFDates**

NINST-by-NUMCURVES matrix of payment dates for the receiving leg.

**PayCF**

NINST-by-NUMCURVES matrix of cash flows for the paying leg.

**PayCFDates**

NINST-by-NUMCURVES matrix of payment dates for the paying leg.

## Examples

**Price an Interest-Rate Swap**

Price an interest-rate swap with a fixed receiving leg and a floating paying leg. Payments are made once a year, and the notional principal amount is \$100. The values for the remaining arguments are:

- Coupon rate for fixed leg: 0.06 (6%)
- Spread for floating leg: 20 basis points
- Swap settlement date: Jan. 01, 2000

- Swap maturity date: Jan. 01, 2003

Based on the information above, set the required arguments and build the `LegRate`, `LegType`, and `LegReset` matrices:

```
Settle = '01-Jan-2000';
Maturity = '01-Jan-2003';
Basis = 0;
Principal = 100;
LegRate = [0.06 20]; % [CouponRate Spread]
LegType = [1 0]; % [Fixed Float]
LegReset = [1 1]; % Payments once per year
```

Load the file `deriv.mat`, which provides `ZeroRateSpec`, the interest-rate term structure needed to price the bond.

```
load deriv.mat;
```

Use `swapbyzero` to compute the price of the swap.

```
Price = swapbyzero(ZeroRateSpec, LegRate, Settle, Maturity, ...
LegReset, Basis, Principal, LegType)
```

```
Price =
    3.6923
```

Using the previous data, calculate the swap rate, which is the coupon rate for the fixed leg, such that the swap price at time = 0 is zero.

```
LegRate = [NaN 20];
```

```
[Price, SwapRate] = swapbyzero(ZeroRateSpec, LegRate, Settle, ...
Maturity, LegReset, Basis, Principal, LegType)
```

```
Price =
    0
```

```
SwapRate =
```



0.0466

Use `swapbyzero` with name-value pair arguments for `LegRate`, `LegType`, `LatestFloatingRate`, `AdjustCashFlowsBasis`, and `BusinessDayConvention` to calculate output for `Price`, `SwapRate`, `AI`, `RecCF`, `RecCFDates`, `PayCF`, and `PayCFDates`:

```
Settle = datenum('08-Jun-2010');
RateSpec = intenvset('Rates', [.005 .0075 .01 .014 .02 .025 .03]',...
'StartDates',Settle, 'EndDates',{ '08-Dec-2010', '08-Jun-2011',...
'08-Jun-2012', '08-Jun-2013', '08-Jun-2015', '08-Jun-2017', '08-Jun-2020' });
Maturity = datenum('15-Sep-2020');
LegRate = [.025 50];
LegType = [1 0]; % fixed/floating
LatestFloatingRate = .005;
```

```
[Price, SwapRate, AI, RecCF, RecCFDates, PayCF, PayCFDates] = ...
swapbyzero(RateSpec, LegRate, Settle, Maturity, 'LegType', LegType, ...
'LatestFloatingRate', LatestFloatingRate, 'AdjustCashFlowsBasis', true, ...
'BusinessDayConvention', 'modifiedfollow')
```

Price =

-6.7259

SwapRate =

NaN

AI =

1.4575

RecCF =

Columns 1 through 7

-1.8219    2.5000    2.5000    2.5137    2.4932    2.4932    2.5000

Columns 8 through 12

2.5000 2.5000 2.5137 2.4932 102.4932

RecCFDates =

Columns 1 through 6

734297 734396 734761 735129 735493 735857

Columns 7 through 12

736222 736588 736953 737320 737684 738049

PayCF =

Columns 1 through 7

-0.3644 0.5000 1.4048 1.9961 2.8379 3.2760 3.8218

Columns 8 through 12

4.1733 4.5164 4.4920 4.7950 104.6608

PayCFDates =

Columns 1 through 6

734297 734396 734761 735129 735493 735857

Columns 7 through 12

736222 736588 736953 737320 737684 738049

### Price Swaps By Specifying Multiple Term Structures Using RateSpec

Price three swaps using two interest-rate curves. First, define the data for the interest-rate term structure:

```
StartDates = '01-May-2012';
EndDates = {'01-May-2013'; '01-May-2014'; '01-May-2015'; '01-May-2016'};
```

```
Rates = [[0.0356;0.041185;0.04489;0.047741],[0.0366;0.04218;0.04589;0.04974]];
```

Create the RateSpec using intenvset.

```
RateSpec = intenvset('Rates', Rates, 'StartDates', StartDates, ...
    'EndDates', EndDates, 'Compounding', 1)
```

```
RateSpec =
```

```

    FinObj: 'RateSpec'
  Compounding: 1
        Disc: [4x2 double]
        Rates: [4x2 double]
    EndTimes: [4x1 double]
    StartTimes: [4x1 double]
    EndDates: [4x1 double]
    StartDates: 734990
ValuationDate: 734990
        Basis: 0
    EndMonthRule: 1
```

Look at the Rates for the two interest-rate curves.

```
RateSpec.Rates
```

```
ans =
```

```

    0.0356    0.0366
    0.0412    0.0422
    0.0449    0.0459
    0.0477    0.0497
```

Define the swap instruments.

```
Settle = '01-May-2012';
Maturity = '01-May-2015';
LegRate = [0.06 10];
Principal = [100;50;100]; % Three notional amounts
```

Price three swaps using two curves.

```
Price = swapbyzero(RateSpec, LegRate, Settle, Maturity, 'Principal', Principal)
```

```
Price =  
  
    3.9688    3.6869  
    1.9844    1.8434  
    3.9688    3.6869
```

### Price Swap By Specifying Multiple Term Structures Using a 1-by-2 RateSpec

Price a swap using two interest-rate curves. First, define data for the two interest-rate term structures:

```
StartDates = '01-May-2012';  
EndDates = {'01-May-2013'; '01-May-2014'; '01-May-2015'; '01-May-2016'};  
Rates1 = [0.0356;0.041185;0.04489;0.047741];  
Rates2 = [0.0366;0.04218;0.04589;0.04974];
```

Create the RateSpec using `intenvset`.

```
RateSpecReceiving = intenvset('Rates', Rates1, 'StartDates', StartDates, ...  
    'EndDates', EndDates, 'Compounding', 1);  
RateSpecPaying = intenvset('Rates', Rates2, 'StartDates', StartDates, ...  
    'EndDates', EndDates, 'Compounding', 1);  
RateSpec = [RateSpecReceiving RateSpecPaying]
```

```
RateSpec =
```

```
1x2 struct array with fields:
```

```
    FinObj  
    Compounding  
    Disc  
    Rates  
    EndTimes  
    StartTimes  
    EndDates  
    StartDates  
    ValuationDate  
    Basis  
    EndMonthRule
```

Define the swap instruments.

```
Settle = '01-May-2012';
Maturity = '01-May-2015';
LegRate = [0.06 10];
Principal = [100;50;100];
```

Price three swaps using the two curves.

```
Price = swapbyzero(RateSpec, LegRate, Settle, Maturity, 'Principal', Principal)
```

```
Price =
    3.9693
    1.9846
    3.9693
```

### Price an Amortizing Swap

Price an amortizing swap using the `Principal` input argument to define the amortization schedule.

Create the `RateSpec`.

```
Rates = 0.035;
ValuationDate = '1-Jan-2011';
StartDates = ValuationDate;
EndDates = '1-Jan-2017';
Compounding = 1;
```

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding);
```

Create the swap instrument using the following data:

```
Settle = '1-Jan-2011';
Maturity = '1-Jan-2017';
Period = 1;
LegRate = [0.04 10];
```

Define the swap amortizing schedule.

```
Principal = {'1-Jan-2013' 100; '1-Jan-2014' 80; '1-Jan-2015' 60; '1-Jan-2016' 40; '1-Jan-2017' 0};
```

Compute the price of the amortizing swap.

```
Price = swapyzero(RateSpec, LegRate, Settle, Maturity, 'Principal' , Principal)
```

```
Price =  
    1.4574
```

### Price a Forward Swap

Price a forward swap using the `StartDate` input argument to define the future starting date of the swap.

Create the `RateSpec`.

```
Rates = 0.0325;  
ValuationDate = '1-Jan-2012';  
StartDates = ValuationDate;  
EndDates = '1-Jan-2018';  
Compounding = 1;
```

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', StartDates, ...  
    'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding)
```

```
RateSpec =  
    FinObj: 'RateSpec'  
    Compounding: 1  
    Disc: 0.8254  
    Rates: 0.0325  
    EndTimes: 6  
    StartTimes: 0  
    EndDates: 737061  
    StartDates: 734869  
    ValuationDate: 734869  
    Basis: 0  
    EndMonthRule: 1
```

Compute the price of a forward swap that starts in a year (Jan 1, 2013) and matures in three years with a forward swap rate of 4.27%.

```
Settle = '1-Jan-2012';  
StartDate = '1-Jan-2013';
```

```

Maturity = '1-Jan-2016';
LegRate = [0.0427 10];

Price = swapbyzero(RateSpec, LegRate, Settle, Maturity, 'StartDate' , StartDate)

Price =

    2.5083

```

Using the previous data, compute the forward swap rate, the coupon rate for the fixed leg, such that the forward swap price at time = 0 is zero.

```

LegRate = [NaN 10];
[Price, SwapRate] = swapbyzero(RateSpec, LegRate, Settle, Maturity,...
'StartDate' , StartDate)

Price =

    0

SwapRate =

    0.0335

```

### **Specify the Rate at the Instrument's Starting Date When it Cannot be Obtained From the RateSpec**

If `Settle` is not on a reset date of a floating-rate note, `swapbyzero` attempts to obtain the latest floating rate before `Settle` from `RateSpec` or the `LatestFloatingRate` parameter. When the reset date for this rate is out of the range of `RateSpec` (and `LatestFloatingRate` is not specified), `swapbyzero` fails to obtain the rate for that date and generates an error. This example shows how to use the `LatestFloatingRate` input parameter to avoid the error.

Create the error condition when a swap instrument's `StartDate` cannot be determined from the `RateSpec`.

```

Settle = '01-Jan-2000';
Maturity = '01-Dec-2003';

```

```

Basis = 0;
Principal = 100;
LegRate = [0.06 20]; % [CouponRate Spread]
LegType = [1 0]; % [Fixed Float]
LegReset = [1 1]; % Payments once per year

load deriv.mat;

Price = swapbyzero(ZeroRateSpec, LegRate, Settle, Maturity,...
'LegReset', LegReset, 'Basis', Basis, 'Principal', Principal, ...
'LegType', LegType)

Error using floatbyzero (line 256)
The rate at the instrument starting date cannot be obtained from RateSpec.
Its reset date (01-Dec-1999) is out of the range of dates contained in RateSpec.
This rate is required to calculate cash flows at the instrument starting date.
Consider specifying this rate with the 'LatestFloatingRate' input parameter.

Error in swapbyzero (line 289)
[FloatFullPrice, FloatPrice,FloatCF,FloatCFDates] = floatbyzero(FloatRateSpec, Spreads, Settle,...

```

Here, the reset date for the rate at `Settle` was 01-Dec-1999, which was earlier than the valuation date of `ZeroRateSpec` (01-Jan-2000). This error can be avoided by specifying the rate at the swap instrument's starting date using the `LatestFloatingRate` input parameter.

Define `LatestFloatingRate` and calculate the floating-rate price.

```

Price = swapbyzero(ZeroRateSpec, LegRate, Settle, Maturity,...
'LegReset', LegReset, 'Basis', Basis, 'Principal', Principal, ...
'LegType', LegType, 'LatestFloatingRate', 0.03)

```

```
Price =
```

```
4.7594
```

### Price a Swap Using a Different Curve to Generate the Cash Flows of the Floating Leg

Define the OIS and Libor rates.

```

Settle = datenum('15-Mar-2013');
CurveDates = daysadd(Settle,360*[1/12 2/12 3/12 6/12 1 2 3 4 5 7 10],1);
OISRates = [.0018 .0019 .0021 .0023 .0031 .006 .011 .017 .021 .026 .03]';
LiborRates = [.0045 .0047 .005 .0055 .0075 .011 .016 .022 .026 .030 .0348]';

```

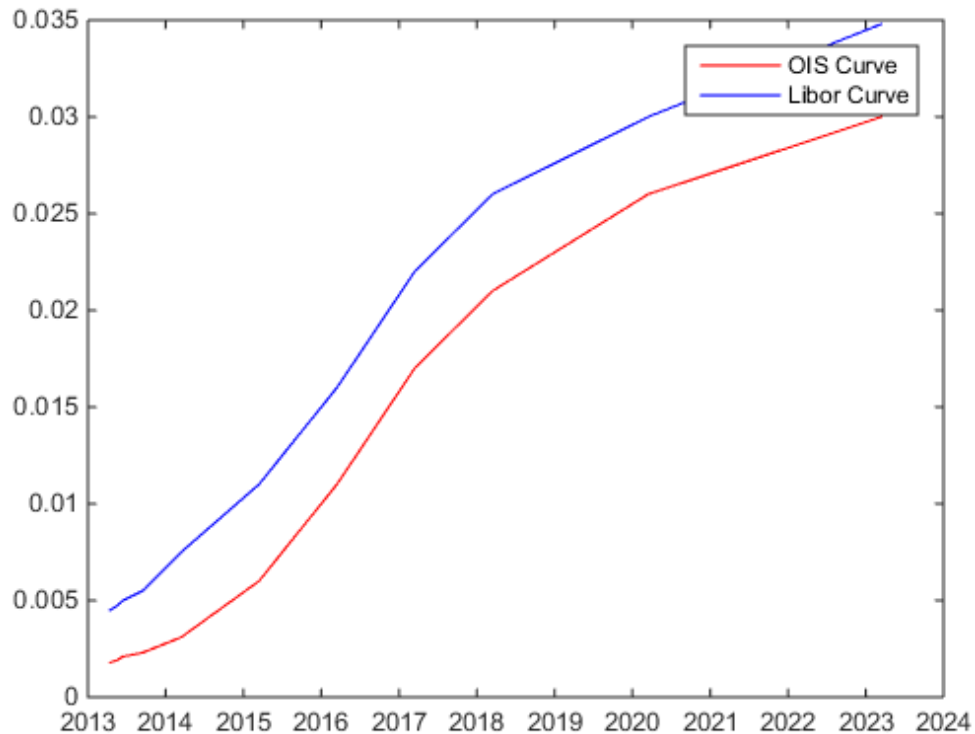
Plot the dual curves.

```

figure,plot(CurveDates,OISRates,'r');hold on;plot(CurveDates,LiborRates,'b')
datetick
legend({'OIS Curve', 'Libor Curve'})

```





Create an associated RateSpec for the OIS and Libor curves.

```
OISCurve = intenvset('Rates',OISRates,'StartDate',Settle,'EndDates',CurveDates);
LiborCurve = intenvset('Rates',LiborRates,'StartDate',Settle,'EndDates',CurveDates);
```

Define the swap.

```
Maturity = datenum('15-Mar-2018'); % Five year swap
FloatSpread = 0;
FixedRate = .025;
LegRate = [FixedRate FloatSpread];
```

Compute the price of the swap instrument. The LiborCurve term structure will be used to generate the cash flows of the floating leg. The OISCurve term structure will be used for discounting the cash flows.

```
Price = swapbyzero(OISCurve, LegRate, Settle,...  
Maturity, 'ProjectionCurve', LiborCurve)
```

```
Price =  
-0.3697
```

Compare results when the term structure `OISCurve` is used both for discounting and also generating the cash flows of the floating leg.

```
PriceSwap = swapbyzero(OISCurve, LegRate, Settle, Maturity)
```

```
PriceSwap =  
2.0517
```

## More About

### Amortizing Swap

In an amortizing swap, the notional principal decreases periodically because it is tied to an underlying financial instrument with a declining (amortizing) principal balance, such as a mortgage.

### Forward Swap

Agreement to enter into an interest-rate swap arrangement on a fixed date in future.

### See Also

| `bondbyzero` | `intenvset` | `cfbyzero` | `fixedbyzero` | `floatbyzero`

# swaptionbybdt

Price swaption from Black-Derman-Toy interest-rate tree

## Syntax

```
[Price, PriceTree] = swaptionbybdt(BDTree, OptSpec, Strike,
ExerciseDates, Spread, Settle, Maturity,
'Name1', Value1, 'Name2', Value2)
```

## Arguments

<b>BDTree</b>	Interest-rate tree structure created by <code>bdttree</code> .
<b>OptSpec</b>	NINST-by-1 cell array of strings 'call' or 'put'. A 'call' swaption or Payer swaption allows the option buyer to enter into an interest-rate swap in which the buyer of the option pays the fixed rate and receives the floating rate. A 'put' swaption or Receiver swaption allows the option buyer to enter into an interest-rate swap in which the buyer of the option receives the fixed rate and pays the floating rate.
<b>Strike</b>	NINST-by-1 vector for strike swap rate values.
<b>ExerciseDates</b>	For a European option: NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one <code>ExerciseDate</code> on the option expiry date.  For an American option: NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non- <code>NaN</code> date is listed, or if <code>ExerciseDates</code> is NINST-by-1, the option can be exercised between the <code>ValuationDate</code> of the tree and the single listed <code>ExerciseDate</code> .
<b>Spread</b>	NINST-by-1 vector representing the number of basis points over the reference rate.

Settle	NINST-by-1 vector of dates representing the settle date for each swap.
Maturity	NINST-by-1 vector of dates representing the maturity date for the underlying swap for each swap.
<p><b>Note:</b> All optional inputs that follow are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. Parameter name/value pairs may be specified in any order; names are case-insensitive and partial string matches are allowed provided no ambiguities exist.</p>	
AmericanOpt	(Optional) NINST-by-1 flags options: <ul style="list-style-type: none"> <li>• 0 for European options</li> <li>• 1 for American options</li> </ul>
SwapReset	(Optional) NINST-by-1 vector representing the reset frequency per year for the underlying swap. Default is 1.

Basis	<p>(Optional) Day-count basis of the instrument. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Principal	(Optional) NINST-by-1 vector of the notional principal amounts. Default is 100.
Options	(Optional) Derivatives pricing options structure created with <b>derivset</b> .

## Description

[Price, PriceTree] = swaptionbybdt(BDTree, OptSpec, Strike, ExerciseDates, Spread, Settle, Maturity, 'Name1', Value1, 'Name2', Value2) computes the price of a swaption from a BDT interest-rate tree. The swaption may be a call swaption or a put swaption.

---

**Note:** The `Settle` date for every swaption is set to the `ValuationDate` of the BDT tree. The swap argument `Settle` is ignored. The underlying swap starts at the maturity of the swaption.

---

A call swaption or payer swaption allows the option buyer to enter into an interest rate swap in which the buyer of the option pays the fixed rate and receives the floating rate.

A put swaption or receiver swaption allows the option buyer to enter into an interest rate swap in which the buyer of the option receives the fixed rate and pays the floating rate.

`Price` is a NINST-by-1 vector of expected swaption prices at time 0.

`PriceTree` is a MATLAB structure of trees containing vectors of swaption instrument prices and a vector of observation times for each node. Within `PriceTree`:

- `PriceTree.PTree` contains the clean prices.
- `PriceTree.tObs` contains the observation times.

## Examples

### Price a 5-Year Call Swaption Using a BDT Interest-Rate Tree

This example shows how to price a 5-year call swaption using a BDT interest-rate tree. Assume that interest rate and volatility are fixed at 6% and 20% annually between the valuation date of the tree until its maturity. Build a tree with the following data.

```
Rates = 0.06 * ones (10,1);
StartDates = ['jan-1-2007'; 'jan-1-2008'; 'jan-1-2009'; 'jan-1-2010'; 'jan-1-2011'; ...
'jan-1-2012'; 'jan-1-2013'; 'jan-1-2014'; 'jan-1-2015'; 'jan-1-2016'];

EndDates = ['jan-1-2008'; 'jan-1-2009'; 'jan-1-2010'; 'jan-1-2011'; 'jan-1-2012'; ...
'jan-1-2013'; 'jan-1-2014'; 'jan-1-2015'; 'jan-1-2016'; 'jan-1-2017'];
ValuationDate = 'jan-1-2007';
Compounding = 1;

% define the RateSpec
RateSpec = intenvset('Rates', Rates, 'StartDates', StartDates, 'EndDates', EndDates, .
'Compounding', Compounding);

% use VolSpec to compute interest-rate volatility
Volatility = 0.20 * ones (10,1); VolSpec = bdtvolspec(ValuationDate,...
```

```

EndDates, Volatility);

% use TimeSpec to specify the structure of the time layout for a BDT tree
TimeSpec = bdttimespec(ValuationDate, EndDates, Compounding);

% build the BDT tree
BDTTree = bdttree(VolSpec, RateSpec, TimeSpec);

% use the following swaption arguments
ExerciseDates = 'jan-1-2012';
SwapSettlement = ExerciseDates;
SwapMaturity   = 'jan-1-2015';
Spread = 0;
SwapReset = 1;
Principal = 100;
OptSpec = 'call';
Strike=.062;
Basis=1;

% price the swaption
[Price, PriceTree] = swaptionbybdt(BDTTree, OptSpec, Strike, ExerciseDates, ...
Spread, SwapSettlement, SwapMaturity, 'SwapReset', SwapReset, ...
'Basis', Basis, 'Principal', Principal)

Price =

    2.0592

PriceTree =

    FinObj: 'BDTPriceTree'
      tObs: [0 1 2 3 4 5 6 7 8 9 10]
      PTree: {1x11 cell}

```

## More About

- “Pricing Options Structure”

## See Also

bdttree | instswaption | swapybybdt

## swaptionbybk

Price swaption from Black-Karasinski interest-rate tree

### Syntax

```
[Price, PriceTree] = swaptionbybk(BKTree, OptSpec, Strike,
ExerciseDates, Spread, Settle, Maturity,
'Name1', Value1, 'Name2', Value2)
```

### Arguments

BKTree	Interest-rate tree structure created by <code>bktree</code> .
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'. A 'call' swaption or Payer swaption allows the option buyer to enter into an interest-rate swap in which the buyer of the option pays the fixed rate and receives the floating rate. A 'put' swaption or Receiver swaption allows the option buyer to enter into an interest-rate swap in which the buyer of the option receives the fixed rate and pays the floating rate.
Strike	NINST-by-1 vector for strike swap rate values.
ExerciseDates	For a European option: NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one <code>ExerciseDate</code> on the option expiry date.  For an American option: NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <code>ExerciseDates</code> is NINST-by-1, the option can be exercised between the <code>ValuationDate</code> of the tree and the single listed <code>ExerciseDate</code> .
Spread	NINST-by-1 vector representing the number of basis points over the reference rate.



Settle	NINST-by-1 vector of dates representing the settle date for each swap.
Maturity	NINST-by-1 vector of dates representing the maturity date for the underlying swap for each swap.
<p><b>Note:</b> All optional inputs that follow are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. Parameter name/value pairs may be specified in any order; names are case-insensitive and partial string matches are allowed provided no ambiguities exist.</p>	
AmericanOpt	(Optional) NINST-by-1 flags options: <ul style="list-style-type: none"> <li>• 0 for European options</li> <li>• 1 for American options</li> </ul>
SwapReset	(Optional) NINST-by-1 vector representing the reset frequency per year for the underlying swap. Default is 1.

Basis	<p>(Optional) Day-count basis of the instrument. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Principal	<p>(Optional) NINST-by-1 vector of the notional principal amounts. Default is 100.</p>
Options	<p>(Optional) Derivatives pricing options structure created with <code>derivset</code>.</p>

## Description

[Price, PriceTree] = `swaptionbybk`(BKTree, OptSpec, Strike, ExerciseDates, Spread, Settle, Maturity, 'Name1', Value1, 'Name2', Value2) computes the price of a swaption from a BK interest-rate tree.

---

**Note:** The `Settle` date for every swaption is set to the `ValuationDate` of the BK tree. The swap argument `Settle` is ignored. The underlying swap starts at the maturity of the swaption.

---

The swaption may be a call swaption or a put swaption.

A call swaption or payer swaption allows the option buyer to enter into an interest rate swap in which the buyer of the option pays the fixed rate and receives the floating rate.

A put swaption or receiver swaption allows the option buyer to enter into an interest rate swap in which the buyer of the option receives the fixed rate and pays the floating rate.

`Price` is a NINST-by-1 vector of expected swaption prices at time 0.

`PriceTree` is a MATLAB structure of trees containing vectors of swaption instrument prices and a vector of observation times for each node. Within `PriceTree`:

- `PriceTree.PTree` contains the clean prices.
- `PriceTree.tObs` contains the observation times.

## Examples

### Price a 4-Year Call and Put Swaption Using a BK Interest-Rate Tree

This example shows how to price a 4-year call and put swaption using a BK interest-rate tree, assuming the interest rate is fixed at 7% annually.

```
Rates = 0.07 * ones (10,1);
Compounding = 2;
StartDates = ['jan-1-2007'; 'jul-1-2007'; 'jan-1-2008'; 'jul-1-2008'; 'jan-1-2009'; ...
'jul-1-2009'; 'jan-1-2010'; 'jul-1-2010'; 'jan-1-2011'; 'jul-1-2011'];
EndDates = ['jul-1-2007'; 'jan-1-2008'; 'jul-1-2008'; 'jan-1-2009'; 'jul-1-2009'; ...
'jan-1-2010'; 'jul-1-2010'; 'jan-1-2011'; 'jul-1-2011'; 'jan-1-2012'];
ValuationDate = 'jan-1-2007';

% define the RateSpec

RateSpec = intenvset('Rates', Rates, 'StartDates', StartDates, 'EndDates', EndDates,..
'Compounding', Compounding);
```

```
% use BKVolSpec to compute the interest-rate volatility
Volatility = 0.10*ones(10,1);
AlphaCurve = 0.05*ones(10,1);
AlphaDates = EndDates;
BKVolSpec = bkvolspec(ValuationDate, EndDates, Volatility, AlphaDates, AlphaCurve);

% use BKTimeSpec to specify the structure of the time layout for the BK interest-rate
BKTimeSpec = bktimespec(ValuationDate, EndDates, Compounding);

% build the BK tree
BKTree = bktree(BKVolSpec, RateSpec, BKTimeSpec);

% use the following arguments for a 1-year swap and 4-year swaption
ExerciseDates = 'jan-1-2011';
SwapSettlement = ExerciseDates;
SwapMaturity = 'jan-1-2012';
Spread = 0;
SwapReset = 2 ;
Principal = 100;
OptSpec = {'call' ;'put'};
Strike= [ 0.07 ; 0.0725];
Basis=1;

% price the swaption
PriceSwaption = swaptionbybk(BKTree, OptSpec, Strike, ExerciseDates, ...
Spread, SwapSettlement, SwapMaturity, 'SwapReset', SwapReset, 'Basis', Basis, ...
'Principal', Principal)

PriceSwaption =

    0.3593
    0.4756
```

## More About

- “Pricing Options Structure”

## See Also

bktree | instswaption | swapbybk

# swaptionbyblk

Price European swaption instrument using Black model

## Syntax

```
Price = swaptionbyblk(RateSpec, OptSpec, Strike,  
Settle, ExerciseDates, Maturity, Volatility)  
Price = swaptionbyblk(RateSpec, OptSpec, Strike, Settle,  
ExerciseDates, Maturity, Volatility, Name, Value)
```

## Description

Price = swaptionbyblk(RateSpec, OptSpec, Strike, Settle, ExerciseDates, Maturity, Volatility) prices swaptions using the Black option pricing model.

Price = swaptionbyblk(RateSpec, OptSpec, Strike, Settle, ExerciseDates, Maturity, Volatility, Name, Value) prices swaptions using the Black option pricing model with additional options specified by one or more Name,Value pair arguments.

---

**Note:** When pricing swaptions using the Black model, the underlying is not a regular swap, but a forward on a swap.

---

## Input Arguments

### RateSpec

Structure containing the properties of an interest-rate structure. See `intenvset` for information on creating `RateSpec`.

`RateSpec` can be a NINST-by-2 input variable of `RateSpecs`, with the second input being the discount curve for the paying leg if different than the receiving leg. If only one curve is specified, then it is used to discount both legs.

**OptSpec**

NINST-by-1 cell array of strings 'call' or 'put'.

A 'call' swaption or Payer swaption allows the option buyer to enter into an interest-rate swap in which the buyer of the option pays the fixed rate and receives the floating rate.

A 'put' swaption or Receiver swaption allows the option buyer to enter into an interest-rate swap in which the buyer of the option receives the fixed rate and pays the floating rate.

**Strike**

NINST-by-1 vector of strike swap rate values.

**Settle**

Settlement date. NINST-by-1 vector of serial date numbers or date strings representing the settlement date for each swaption. **Settle** must not be later than **ExerciseDate**.

The **Settle** date input for `swaptionbyblk` is the valuation date on which the swaption (an option to enter into a swap) is priced. The swaption buyer pays this price on this date to hold the swaption.

**ExerciseDate**

For a European option: NINST-by-1 vector of exercise dates. Each row is the schedule for one option. When using an European option, there is only one **ExerciseDate** on the option expiry date.

The **ExerciseDate** is the date on which the swaption expires and the underlying swap starts. The swaption holder can choose to enter into the swap on this date if the situation is favorable.

**Maturity**

Maturity date. NINST-by-1 vector of dates representing the maturity date for the underlying swap for each swaption.

**Volatility**

Volatilities values. NINST-by-1 vector of volatilities.

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

### **Basis**

Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### **Principal**

NINST-by-1 vector of the notional principal amount.

**Default:** 100

### SwapReset

NINST-by-1 vector representing the reset frequency per year for the underlying forward swap.

**Default:** 1

### ProjectionCurve

The rate curve to be used in generating the future forward rates. This structure must be created using `intenvset`. Use this optional input if the forward curve is different from the discount curve.

**Default:** If `ProjectionCurve` is not specified, then `RateSpec` is used both for discounting cash flows and projecting future forward rates.

## Output Arguments

### Price

NINST-by-1 vector of prices for the swaptions at time 0.

## Examples

### Price a European Swaption Using the Black Model Where the Yield Curve is Flat at 6%

Price a European swaption that gives the holder the right to enter in five years into a three-year paying swap where a fixed-rate of 6.2% is paid and floating is received. Assume that the yield curve is flat at 6% per annum with continuous compounding, the volatility of the swap rate is 20%, the principal is \$100, and payments are exchanged semiannually.

Create the `RateSpec`.

```
Rate = 0.06;  
Compounding = -1;  
ValuationDate = 'Jan-1-2010';  
EndDates = 'Jan-1-2020';  
Basis = 1;
```



```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', ValuationDate, ...
'EndDates', EndDates, 'Rates', Rate, 'Compounding', Compounding, 'Basis', Basis);
```

Price the swaption using the Black model.

```
Settle = 'Jan-1-2011';
ExerciseDates = 'Jan-1-2016';
Maturity = 'Jan-1-2019';
Reset = 2;
Principal = 100;
Strike = 0.062;
Volatility = 0.2;
OptSpec = 'call';
```

```
Price= swaptionbyblk(RateSpec, OptSpec, Strike, Settle, ExerciseDates, Maturity, ...
Volatility, 'Reset', Reset, 'Principal', Principal, 'Basis', Basis)
```

```
Price =
    2.0710
```

### Price a European Swaption Using the Black Model Where the Yield Curve Is Incrementally Increasing

Price a European swaption that gives the holder the right to enter into a 5-year receiving swap in a year, where a fixed rate of 3% is received and floating is paid. Assume that the 1-year, 2-year, 3-year, 4-year and 5-year zero rates are 3%, 3.4%, 3.7%, 3.9% and 4% with continuous compounding. The swap rate volatility is 21%, the principal is \$1000, and payments are exchanged semiannually.

Create the RateSpec.

```
ValuationDate = 'Jan-1-2010';
EndDates = {'Jan-1-2011'; 'Jan-1-2012'; 'Jan-1-2013'; 'Jan-1-2014'; 'Jan-1-2015'};
Rates = [0.03; 0.034 ; 0.037; 0.039; 0.04];
Compounding = -1;
Basis = 1;
```

```
RateSpec = intenvset('ValuationDate', ValuationDate, 'StartDates', ValuationDate, ...
'EndDates', EndDates, 'Rates', Rates, 'Compounding', Compounding, 'Basis', Basis)
```

```
RateSpec =  
  
    FinObj: 'RateSpec'  
    Compounding: -1  
        Disc: [5x1 double]  
        Rates: [5x1 double]  
        EndTimes: [5x1 double]  
        StartTimes: [5x1 double]  
        EndDates: [5x1 double]  
        StartDates: 734139  
    ValuationDate: 734139  
        Basis: 1  
    EndMonthRule: 1
```

Price the swaption using the Black model.

```
Settle = 'Jan-1-2011';  
ExerciseDates = 'Jan-1-2012';  
Maturity = 'Jan-1-2017';  
Strike = 0.03;  
Volatility = 0.21;  
Principal = 1000;  
Reset = 2;  
OptSpec = 'put';
```

```
Price = swaptionbyblk(RateSpec, OptSpec, Strike, Settle, ExerciseDates, ...  
Maturity, Volatility, 'Basis', Basis, 'Reset', Reset, 'Principal', Principal)
```

```
Price =  
  
    0.5771
```

### Price a Swaption Using a Different Curve to Generate the Future Forward Rates

Define the OIS and Libor curves.

```
Settle = datenum('15-Mar-2013');  
CurveDates = daysadd(Settle, 360*[1/12 2/12 3/12 6/12 1 2 3 4 5 7 10], 1);  
OISRates = [.0018 .0019 .0021 .0023 .0031 .006 .011 .017 .021 .026 .03]';  
LiborRates = [.0045 .0047 .005 .0055 .0075 .0109 .0162 .0216 .0262 .0309 .0348]';
```

Create an associated `RateSpec` for the OIS and Libor curves.

```
OISCurve = intenvset('Rates',OISRates,'StartDate',Settle,'EndDates',CurveDates,'Compound',1)
LiborCurve = intenvset('Rates',LiborRates,'StartDate',Settle,'EndDates',CurveDates,'Compound',1)
```

Define the swaption instruments.

```
ExerciseDate = '15-Mar-2018';
Maturity = {'15-Mar-2020';'15-Mar-2023'};
OptSpec = 'call';
Strike = 0.04;
BlackVol = 0.2;
```

Price the swaption instruments using the term structure `OISCurve` both for discounting the cash flows and generating the future forward rates.

```
Price = swaptionbyblk(OISCurve, OptSpec, Strike, Settle, ExerciseDate, Maturity, BlackVol)
```

```
Price =
```

```
1.0956
2.6944
```

Price the swaption instruments using the term structure `LiborCurve` to generate the future forward rates. The term structure `OISCurve` is used for discounting the cash flows.

```
PriceLC = swaptionbyblk(OISCurve, OptSpec, Strike, Settle, ExerciseDate, Maturity, BlackVol, LiborCurve)
```

```
PriceLC =
```

```
1.5346
3.8142
```

- “Price a Swaption Using the SABR Model”

## More About

### Forward Swap

A forward swap is a swap that starts at a future date.

**See Also**

blackvolbysabr | bondbyzero | cfbyzero | fixedbyzero | floatbyzero |  
intenvset

# swaptionbyhjm

Price swaption from Heath-Jarrow-Morton interest-rate tree

## Syntax

```
[Price, PriceTree] = swaptionbyhjm(HJMTree, OptSpec, Strike,
ExerciseDates, Spread, Settle, Maturity,
'Name1', Value1, 'Name2', Value2)
```

## Arguments

HJMTree	Interest-rate tree structure created by hjmtree.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'. A 'call' swaption or Payer swaption allows the option buyer to enter into an interest-rate swap in which the buyer of the option pays the fixed rate and receives the floating rate. A 'put' swaption or Receiver swaption allows the option buyer to enter into an interest-rate swap in which the buyer of the option receives the fixed rate and pays the floating rate.
Strike	NINST-by-1 vector of strike swap rate values.
ExerciseDates	For a European option: NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one <b>ExerciseDate</b> on the option expiry date.  For an American option: NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <b>ExerciseDates</b> is NINST-by-1, the option can be exercised between the <b>ValuationDate</b> of the tree and the single listed <b>ExerciseDate</b> .
Spread	NINST-by-1 vector representing the number of basis points over the reference rate.

Settle	NINST-by-1 vector of dates representing the settle date for each swap.
Maturity	NINST-by-1 vector of dates representing the maturity date for the underlying swap for each swap.
<b>Note:</b> All optional inputs that follow are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. Parameter name/value pairs may be specified in any order; names are case-insensitive and partial string matches are allowed provided no ambiguities exist.	
AmericanOpt	(Optional) NINST-by-1 flags options: <ul style="list-style-type: none"><li>• 0 for European options</li><li>• 1 for American options</li></ul>
SwapReset	(Optional) NINST-by-1 vector representing the reset frequency per year for the underlying swap. Default is 1.

Basis	<p>(Optional) Day-count basis of the instrument. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Principal	<p>(Optional) NINST-by-1 vector of the notional principal amounts. Default is 100.</p>
Options	<p>(Optional) Derivatives pricing options structure created with <b>derivset</b>.</p>

## Description

[Price, PriceTree] = swaptionbyhjm(HJMTree, OptSpec, Strike, ExerciseDates, Spread, Settle, Maturity, 'Name1', Value1, 'Name2', Value2) computes the price of a swaption from a HJM interest-rate tree.

---

**Note:** The `Settle` date for every swaption is set to the `ValuationDate` of the HJM tree. The swap argument `Settle` is ignored. The underlying swap starts at the maturity of the swaption.

---

The swaption may be a call swaption or a put swaption.

A call swaption or payer swaption allows the option buyer to enter into an interest rate swap in which the buyer of the option pays the fixed rate and receives the floating rate.

A put swaption or receiver swaption allows the option buyer to enter into an interest rate swap in which the buyer of the option receives the fixed rate and pays the floating rate.

`Price` is a (NINST-by-1 vector of expected swaption prices at time 0.

`PriceTree` is a MATLAB structure of trees containing vectors of swaption instrument prices and a vector of observation times for each node. Within `PriceTree`:

- `PriceTree.PTree` contains the clean prices.
- `PriceTree.tObs` contains the observation times.

## Examples

### Price a 1-Year Call Swaption Using an HJM Interest-Rate Tree

This example shows how to price a 1-year call swaption using an HJM interest-rate tree. Assume that interest rate is fixed at 5% annually between the valuation date of the tree until its maturity. Build a tree with the following data.

```
Rates = [ 0.05;0.05;0.05;0.05];
StartDates = 'jan-1-2007';
EndDates =['jan-1-2008';'jan-1-2009';'jan-1-2010';'jan-1-2011'];
ValuationDate = StartDates;
Compounding = 1;

% define the RateSpec
RateSpec = intenvset('Rates', Rates, 'StartDates', StartDates, 'EndDates',...
EndDates, 'Compounding', Compounding);

% use VolSpec to compute the interest-rate volatility
VolSpec=hjmvolspec('Constant',0.01);
```



```

% use TimeSpec to specify the structure of the time layout for the HJM interest-rate t
TimeSpec = hjmtimespec(ValuationDate, EndDates, Compounding);

% build the HJM tree
HJMTree = hjmtree(VolSpec, RateSpec, TimeSpec);

% use the following swaption arguments
ExerciseDates = '01-Jan-2008';
SwapSettlement = ExerciseDates;
SwapMaturity = 'jan-1-2010';
Spread = [0];
SwapReset = 1;
Basis = 1;
Principal = 100;
OptSpec = 'call';
Strike=0.05;

% price the swaption

[Price, PriceTree] = swaptionbyhjm(HJMTree, OptSpec, Strike, ExerciseDates, ...
Spread, SwapSettlement, SwapMaturity, 'SwapReset', SwapReset, ...
'Basis', Basis, 'Principal', Principal)

Price =

    0.9296

PriceTree =

    FinObj: 'HJMPriceTree'
           tObs: [5x1 double]
           PBush: {1x5 cell}

```

## More About

- “Pricing Options Structure”

## See Also

hjmtree | instswaption | swapbyhjm

## swaptionbyhw

Price swaption from Hull-White interest-rate tree

### Syntax

```
[Price, PriceTree] = swaptionbyhw(HWTree, OptSpec, Strike,
ExerciseDates, Spread, Settle, Maturity,
'Name1', Value1, 'Name2', Value2)
```

### Arguments

HWTree	Interest-rate tree structure created by hwtree.
OptSpec	NINST-by-1 cell array of strings 'call' or 'put'. A 'call' swaption or Payer swaption allows the option buyer to enter into an interest-rate swap in which the buyer of the option pays the fixed rate and receives the floating rate. A 'put' swaption or Receiver swaption allows the option buyer to enter into an interest-rate swap in which the buyer of the option receives the fixed rate and pays the floating rate.
Strike	NINST-by-1 vector for strike swap rate values.
ExerciseDates	For a European option: NINST-by-1 vector of exercise dates. Each row is the schedule for one option. For a European option, there is only one <b>ExerciseDate</b> on the option expiry date.  For an American option: NINST-by-2 vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-NaN date is listed, or if <b>ExerciseDates</b> is NINST-by-1, the option can be exercised between the <b>ValuationDate</b> of the tree and the single listed <b>ExerciseDate</b> .
Spread	NINST-by-1 vector representing the number of basis points over the reference rate.

Settle	NINST-by-1 vector of dates representing the settle date for each swap.
Maturity	NINST-by-1 vector of dates representing the maturity date for the underlying swap for each swap.
<p><b>Note:</b> All optional inputs that follow are specified as matching parameter name/value pairs. The parameter name is specified as a character string, followed by the corresponding parameter value. Parameter name/value pairs may be specified in any order; names are case-insensitive and partial string matches are allowed provided no ambiguities exist.</p>	
AmericanOpt	(Optional) NINST-by-1 flags options: <ul style="list-style-type: none"> <li>• 0 for European options</li> <li>• 1 for American options</li> </ul>
SwapReset	(Optional) NINST-by-1 vector representing the reset frequency per year for the underlying swap. Default is 1.

Basis	<p>(Optional) Day-count basis of the instrument. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
Principal	<p>(Optional) NINST-by-1 vector of the notional principal amounts. Default is 100.</p>
Options	<p>(Optional) Derivatives pricing options structure created with <code>derivset</code>.</p>

## Description

[Price, PriceTree] = `swaptionbyhw`(HWTTree, OptSpec, Strike, ExerciseDates, Spread, Settle, Maturity, 'Name1', Value1, 'Name2', Value2) computes the price of a swaption from a HW interest-rate tree.

---

**Note:** The `Settle` date for every swaption is set to the `ValuationDate` of the HW tree. The swap argument `Settle` is ignored. The underlying swap starts at the maturity of the swaption.

---

The swaption may be a call swaption or a put swaption.

A call swaption or payer swaption allows the option buyer to enter into an interest rate swap in which the buyer of the option pays the fixed rate and receives the floating rate.

A put swaption or receiver swaption allows the option buyer to enter into an interest rate swap in which the buyer of the option receives the fixed rate and pays the floating rate.

`Price` is a NINST-by-1 vector of expected swaption prices at time 0.

`PriceTree` is a MATLAB structure of trees containing vectors of swaption instrument prices and a vector of observation times for each node. Within `PriceTree`:

- `PriceTree.PTree` contains the clean prices.
- `PriceTree.tObs` contains the observation times.

## Examples

### Price a 3-Year Put Swaption Using an HW Interest-Rate Tree

This example shows how to price a 3-year put swaption using an HW interest-rate tree with the following data.

```
Rates = 0.075 * ones (10,1);
Compounding = 2;
StartDates = ['jan-1-2007'; 'jul-1-2007'; 'jan-1-2008'; 'jul-1-2008'; 'jan-1-2009'; ...
'jul-1-2009'; 'jan-1-2010'; 'jul-1-2010'; 'jan-1-2011'; 'jul-1-2011'];
EndDates = ['jul-1-2007'; 'jan-1-2008'; 'jul-1-2008'; 'jan-1-2009'; 'jul-1-2009'; ...
'jan-1-2010'; 'jul-1-2010'; 'jan-1-2011'; 'jul-1-2011'; 'jan-1-2012'];
ValuationDate = 'jan-1-2007';

% define the RatesSpec
RateSpec = intenvset('Rates', Rates, 'StartDates', StartDates, 'EndDates', ...
EndDates, 'Compounding', Compounding);

% use HWVolSpec to compute the interest-rate volatility
```

```
Volatility = 0.05*ones(10,1);
AlphaCurve = 0.01*ones(10,1);
AlphaDates = EndDates;
HWVolSpec = hwwolspec(ValuationDate, EndDates, Volatility, AlphaDates, AlphaCurve);

% use HWTTimeSpec to specify the structure of the time layout for an HW interest-rate tree
HWTTimeSpec = hwtimespec(ValuationDate, EndDates, Compounding);

% build the HW tree
HWTTree = hwtree(HWVolSpec, RateSpec, HWTTimeSpec);

% use the following arguments for a 1-year swap and 3-year swaption
ExerciseDates = 'jan-1-2010';
SwapSettlement = ExerciseDates;
SwapMaturity = 'jan-1-2012';
Spread = 0;
SwapReset = 2 ;
Principal = 100;
OptSpec = 'put';
Strike= 0.04;
Basis=1;

% price the swaption
PriceSwaption = swaptionbyhw(HWTTree, OptSpec, Strike, ExerciseDates, ...
Spread, SwapSettlement, SwapMaturity, 'SwapReset', SwapReset, ...
'Basis', Basis, 'Principal', Principal)

PriceSwaption =

    2.9081
```

## More About

- “Pricing Options Structure”

## See Also

[hwtree](#) | [instswaption](#) | [swapbyhw](#)

# swaptionbylg2f

Price European swaption using Linear Gaussian two-factor model

## Syntax

```
Price = swaptionbylg2f(ZeroCurve,a,b,sigma,eta,rho,
Strike,ExerciseDate,Maturity)
Price = swaptionbylg2f( ____, Name,Value)
```

## Description

Price = swaptionbylg2f(ZeroCurve,a,b,sigma,eta,rho, Strike,ExerciseDate,Maturity) returns the European swaption price for a two-factor additive Gaussian interest-rate model.

Price = swaptionbylg2f( \_\_\_\_, Name,Value) returns the European swaption price for two-factor additive Gaussian interest-rate model using optional name-value pairs.

## Examples

### Price a European Swaption Using a Linear Gaussian Two-Factor Model

Define the ZeroCurve, a, b, sigma, eta, and rho parameters to compute the price of the swaption.

```
Settle = datenum('15-Dec-2007');

ZeroTimes = [3/12 6/12 1 5 7 10 20 30]';
ZeroRates = [0.033 0.034 0.035 0.040 0.042 0.044 0.048 0.0475]';
CurveDates = daysadd(Settle,360*ZeroTimes,1);

irdc = IRDataCurve('Zero',Settle,CurveDates,ZeroRates);

a = .07;
b = .5;
sigma = .01;
eta = .006;
```

```
rho = -.7;

Reset = 1;
ExerciseDate = daysadd(Settle,360*5,1);
Maturity = daysadd(ExerciseDate,360*[3;4],1);
Strike = .05;

Price = swaptionbylg2f(irdc,a,b,sigma,eta,rho,Strike,ExerciseDate,Maturity, 'Reset',Rese

Price =

    1.1870
    1.5633
```

- “Price Swaptions With Interest-Rate Models Using Simulation”

## Input Arguments

### **ZeroCurve** — Zero-curve for Linear Gaussian two-factor model

structure

Zero-curve for the Linear Gaussian two-factor model, specified using `IRDataCurve` or `RateSpec`.

Data Types: `struct`

### **a** — Mean reversion for first factor for Linear Gaussian two-factor model

scalar

Mean reversion for first factor for the Linear Gaussian two-factor model, specified as a scalar.

Data Types: `single` | `double`

### **b** — Mean reversion for second factor for Linear Gaussian two-factor model

scalar

Mean reversion for second factor for the Linear Gaussian two-factor model, specified as a scalar.

Data Types: `single` | `double`



**sigma — Volatility for first factor for Linear Gaussian two-factor model**

scalar

Volatility for first factor for the Linear Gaussian two-factor model, specified as a scalar.

Data Types: `single` | `double`

**eta — Volatility for second factor for Linear Gaussian two-factor model**

scalar

Volatility for second factor for the Linear Gaussian two-factor model, specified as a scalar.

Data Types: `single` | `double`

**rho — Scalar correlation of the factors**

scalar

Scalar correlation of the factors, specified as a scalar.

Data Types: `single` | `double`

**Strike — Swaption strike price**

nonnegative integer | vector of nonnegative integers

Swaption strike price, specified as a nonnegative integer using a `NumSwaptions-by-1` vector.

Data Types: `single` | `double`

**ExerciseDate — Swaption exercise dates**

nonnegative integer | vector of nonnegative integers

Swaption exercise dates, specified as a `NumSwaptions-by-1` vector of serial date numbers or date strings.

Data Types: `single` | `double`

**Maturity — Underlying swap maturity date**

nonnegative integer | vector of nonnegative integers | string of dates

Underlying swap maturity date, specified using a `NumSwaptions-by-1` vector of serial date numbers or date strings.

Data Types: `single` | `double` | `cell`

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes ( `' '` ). You can specify several name and value pair arguments in any order as `Name1, Value1, . . . , NameN, ValueN`.

Example: `Price = swaptionbylg2f(irdc, a, b, sigma, eta, rho, Strike, ExerciseDate, Maturity, 'Reset', 1, 'Reset', 1, 'Notional', 100, 'OptSpec', 'call')`

### 'Reset' — Frequency of swaption payments per year

2 (default) | positive integer from the set [ 1, 2, 3, 4, 6, 12 ] | vector of positive integers from the set [ 1, 2, 3, 4, 6, 12 ]

Frequency of swaption payments per year, specified as positive integers for the values 1, 2, 4, 6, 12] in a `NumSwaptions-by-1` vector.

Data Types: `single` | `double`

### 'Notional' — Notional value of swaption

100 (default) | nonnegative integer | vector of nonnegative integers

Notional value of swaption, specified as a nonnegative integer using a `NumSwaptions-by-1` vector of notional amounts.

Data Types: `single` | `double`

### 'OptSpec' — Option specification for the swaption

'call' (default) | string with value of 'call' or 'put' | cell array of string with values of 'call' or 'put'

Option specification for the swaption, specified as a string or a `NumSwaptions-by-1` cell array of strings with a value of 'call' or 'put'.

A 'call' swaption or Payer swaption allows the option buyer to enter into an interest-rate swap in which the buyer of the option pays the fixed rate and receives the floating rate.

A 'put' swaption or Receiver swaption allows the option buyer to enter into an interest-rate swap in which the buyer of the option receives the fixed rate and pays the floating rate.

Data Types: `char` | `cell`

## Output Arguments

### Price — Swaption price

scalar | vector

Swaption price, returned as a scalar or an NumSwaptions-by-1 vector.

## More About

### Algorithms

The following defines the swaption price for a two-factor additive Gaussian interest-rate model, given the ZeroCurve, a, b, sigma, eta, and rho parameters:

$$r(t) = x(t) + y(t) + \phi(t)$$

$$dx(t) = -ax(t)dt + \sigma dW_1(t), \quad x(0) = 0$$

$$dy(t) = -by(t)dt + \eta dW_2(t), \quad y(0) = 0$$

where  $dW_1(t)dW_2(t) = \rho dt$  is a two-dimensional Brownian motion with correlation  $\rho$  and  $\phi$  is a function chosen to match the initial zero curve.

## References

- [1] Brigo, D. and F. Mercurio, *Interest Rate Models - Theory and Practice*, Springer Finance, 2006.

## See Also

LinearGaussian2F | capbylg2f | floorbylg2f

## time2date

Dates from time and frequency

### Syntax

Dates = time2date(Settle, Times, Compounding, Basis, EndMonthRule)

### Arguments

Settle	Settlement date. A vector of serial date numbers or date strings.
Times	Vector of times corresponding to the compounding value. <b>Times</b> must be equal to or greater than 0.
Compounding	<p>(Optional) Scalar value representing the rate at which the input zero rates were compounded when annualized. Default = 2. This argument determines the formula for the discount factors:</p> <p>Compounding = 1, 2, 3, 4, 6, 12 = F</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the compounding frequency, Z is the zero rate, and T is the time in periodic units; for example, T = F is 1 year.</p> <p>Compounding = 365</p> <p>Disc = <math>(1 + Z/F)^{-T}</math>, where F is the number of days in the basis year and T is a number of days elapsed computed by basis.</p> <p>Compounding = -1</p> <p>Disc = <math>\exp(-T*Z)</math>, where T is time in years.</p>
Basis	<p>(Optional) Day-count basis of the instrument. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> </ul>

	<ul style="list-style-type: none"> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
EndMonthRule	<p>(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.</p>

## Description

Dates = time2date(Settle, Times, Compounding, Basis, EndMonthRule) computes dates corresponding to compounded rate quotes between Settle and time factors.

**Note** To obtain accurate results from this function, the **Basis** and **Dates** arguments must be consistent. If the **Dates** argument contains months that have 31 days, **Basis** must be one of the values that allow months to contain more than 30 days; for example, **Basis** = 0, 3, or 7.

The `time2date` function is the inverse of `date2time`.

## Examples

Show that `date2time` and `time2date` are the inverse of each other. First compute the time factors using `date2time`.

```
Settle = '1-Sep-2002';
Dates = datenum(['31-Aug-2005'; '28-Feb-2006'; '15-Jun-2006';
                '31-Dec-2006']);
Compounding = 2;
Basis = 0;
EndMonthRule = 1;
Times = date2time(Settle, Dates, Compounding, Basis,...
                  EndMonthRule)
```

```
Times =
```

```
    5.9945
    6.9945
    7.5738
    8.6576
```

Now use the calculated `Times` in `time2date` and compare the calculated dates with the original set.

```
Dates_calc = time2date(Settle, Times, Compounding, Basis,...
                       EndMonthRule)
```

```
Dates_calc =
```

```
    732555
    732736
    732843
    733042
```

```
datestr(Dates_calc)
```

```
ans =
```

```
31-Aug-2005
28-Feb-2006
15-Jun-2006
31-Dec-2006
```

## See Also

`cftimes` | `date2time` | `cfamounts` | `disc2rate` | `rate2disc`

## treepath

Entries from node of recombining binomial tree

### Syntax

Values = treepath(Tree, BranchList)

### Arguments

Tree	Recombining binomial tree.
BranchList	Number of paths (NUMPATHS) by path length (PATHLENGTH) matrix containing the sequence of branchings.

### Description

Values = treepath(Tree, BranchList) extracts entries of a node of a recombining binomial tree. The node path is described by the sequence of branchings taken, starting at the root. The top branch is number one, the second-to-top is two, and so on. Set the branch sequence to zero to obtain the entries at the root node.

Values is a number of values (NUMVALS)-by-NUMPATHS matrix containing the retrieved entries of a recombining tree.

### Examples

Create a BDT tree by loading the example file.

```
load deriv.mat;
```

Then

```
FwdRates = treepath(BDTree.FwdTree, [1 2 1])
```

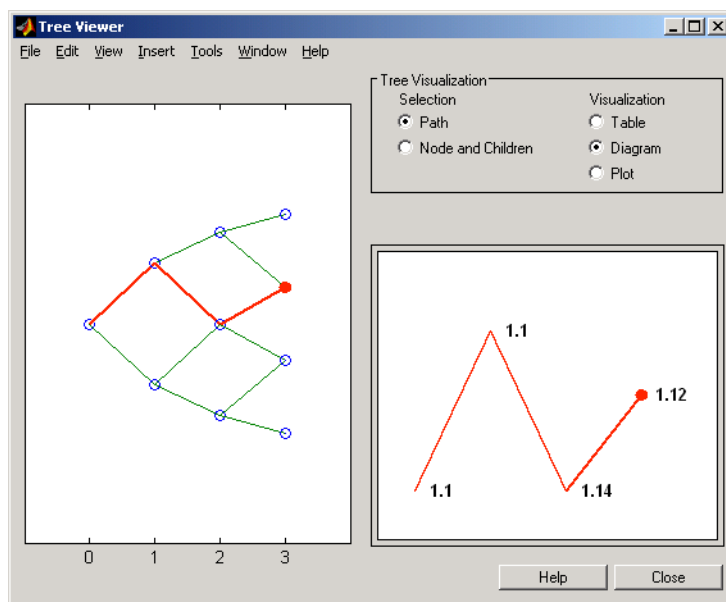
returns the rates at the tree nodes located by taking the up branch, then the down branch, and finally the up branch again.

```
FwdRates =
```

```
1.1000  
1.0979  
1.1377  
1.1183
```

You can visualize this with the `treeviewer` function.

```
treeviewer(BDTTree)
```



## See Also

`mktree` | `treeshape`



# treeshape

Shape of recombining binomial tree

## Syntax

```
[NumLevels, NumPos, IsPriceTree] = treeshape(Tree)
```

## Arguments

Tree	Recombining binomial tree.
------	----------------------------

## Description

`[NumLevels, NumPos, IsPriceTree] = treeshape(Tree)` returns information on a recombining binomial tree's shape.

`NumLevels` is the number of time levels of the tree.

`NumPos` is a 1-by-`NUMLEVELS` vector containing the length of the state vectors in each level.

`IsPriceTree` is a Boolean determining if a final horizontal branch is present in the tree.

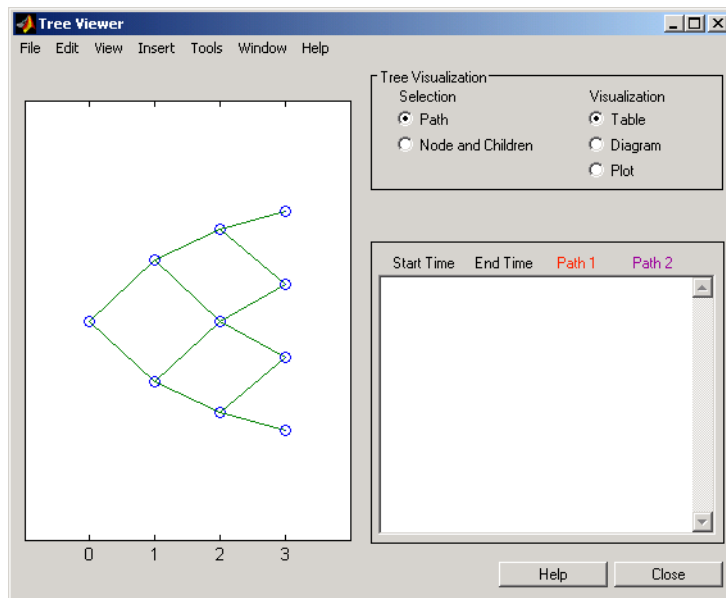
## Examples

Create a BDT tree by loading the example file.

```
load deriv.mat;
```

With `treeviewer` you can see the general shape of the BDT interest-rate tree.

```
treeviewer(BDTree)
```



With this tree

```
[NumLevels, NumPos, IsPriceTree] = treeshape(BDTree.FwdTree)
```

returns

```
NumLevels =
    4
```

```
NumPos =
    1    1    1    1
```

```
IsPriceTree =
    0
```

## See Also

[mktree](#) | [treepath](#)

# treeviewer

Tree information

## Syntax

```
treeviewer(Tree)
treeviewer(PriceTree, InstSet)
treeviewer(CFTree, InstSet)
```

## Arguments

Tree	<p>Tree can be any of the following types of trees.</p> <p><i>Interest-rate trees:</i></p> <ul style="list-style-type: none"> <li>• Black-Derman-Toy (BDTTree)</li> <li>• Black-Karasinski (BKTree)</li> <li>• Heath-Jarrow-Morton (HJMTree)</li> <li>• Hull-White (HWTree)</li> </ul> <p>For information on creating interest-rate trees, see:</p> <ul style="list-style-type: none"> <li>• <code>bktree</code> for information on creating BKTree.</li> <li>• <code>bdttree</code> for information on creating BDTTree.</li> <li>• <code>hjmtree</code> for information on creating HJMTree.</li> <li>• <code>hwtree</code> for information on creating HWTree.</li> </ul> <p><i>Money market trees:</i></p> <ul style="list-style-type: none"> <li>• Money market tree (MMktTree)</li> </ul> <p>For information on creating money-market trees, see:</p> <ul style="list-style-type: none"> <li>• <code>mmktbybdt</code> for information on creating a money-market tree from a BDT interest-rate tree.</li> <li>• <code>mmktbyhjm</code> for information on creating a money-market tree from an HJM interest-rate tree.</li> </ul>
------	---

	<p><b>Note</b> Money market trees cannot be created from BK or HW interest-rate trees.</p>
	<p><i>Stock price trees:</i></p> <ul style="list-style-type: none"> <li>• Cox-Ross-Rubinstein (CRRTree)</li> <li>• Implied Trinomial tree (ITTree)</li> <li>• Leisen-Reimer stock tree (LRTree)</li> <li>• Equal probabilities (EQPTree)</li> </ul> <p>For information on creating stock price trees, see:</p> <ul style="list-style-type: none"> <li>• <code>crrtree</code> for information on creating CRRTree.</li> <li>• <code>eqptree</code> for information on creating EQPTree.</li> <li>• <code>itttree</code> for information on creating ITTree.</li> <li>• <code>lrtree</code> for information on creating LRTree.</li> </ul> <p><i>Cash flow trees:</i></p> <ul style="list-style-type: none"> <li>• Black-Derman-Toy (BDTCFTree)</li> <li>• Heath-Jarrow-Morton (HJMCFTree)</li> </ul> <p>Cash flow trees are created as outputs from the swap functions <code>swapbyhjm</code> and <code>swapbybdt</code>.</p> <hr/> <p><b>Note</b> For the function <code>swapbybdt</code>, which uses a recombining binomial tree, this structure contains only NaNs because cash flows cannot be accurately calculated at every tree node for floating-rate notes.</p>
PriceTree	<p>PriceTree is a Black-Derman-Toy (BDTPriceTree), Black-Karasinski (BKPriceTree), Heath-Jarrow-Morton (HJMPPriceTree), Hull-White (HWPriceTree), Cox-Ross-Rubinstein (<code>crrprice</code>), Equal probabilities (<code>eqpprice</code>), or Implied Trinomial tree (<code>ittprice</code>) tree of instrument prices.</p>

<b>CFTree</b>	<b>CFTree</b> is a tree of swap cash flows. You create cash flow trees when executing the Black-Derman-Toy and Heath-Jarrow-Morton swap functions. (Black-Derman-Toy cash flow trees contain only NaNs.)
<b>InstSet</b>	(Optional) Variable containing a collection of instruments whose prices or cash flows are contained in a tree. The collection can be created with the function <code>instadd</code> or as a cell array containing the names of the instruments. To display the names of the instruments, the field <code>Name</code> should exist in <code>InstSet</code> . If <code>InstSet</code> is not passed, <code>treeviewer</code> uses default instruments names (numbers) when displaying prices or cash flows.

## Description

`treeviewer(Tree)` displays an interest rate, stock price, or money-market tree.

`treeviewer(PriceTree, InstSet)` displays a tree of instrument prices. If you provide the name of an instrument set (`InstSet`) and you have named the instruments using the field `Name`, the `treeviewer` display identifies the instrument being displayed with its name. (See Example 3 for a description.) If you do not provide the optional `InstSet` argument, the instruments are identified by their sequence number in the instrument set. (See Example 6 for a description.)

`treeviewer(CFTree, InstSet)` displays a cash flow tree that has been created with `swapbybdt` or `swapbyhjm`. If you provide the name of an instrument set (`InstSet`) containing cash flow names, the `treeviewer` display identifies the instrument being displayed with its name. (See Example 3 for a description.) If the optional `InstSet` argument is not present, the instruments are identified by their sequence number in the instrument set. See Example 6 for a description.)

`treeviewer` price tree diagrams follow the convention that increasing prices appear on the upper branch of a tree and, consequently, decreasing prices appear on the lower branch. Conversely, for interest rate displays, *decreasing* interest rates appear on the upper branch (prices are rising) and *increasing* interest rates on the lower branch (prices are falling).

`treeviewer` provides an interactive display of prices or interest rates. The display is activated by clicking the nodes along the price or interest rate path shown in the left pane when the function is called. For HJM trees you select the endpoints of the path, and `treeviewer` displays all data from beginning to end. With recombining trees, such as

BDT, BK and HW, you must click *each* node in succession from the beginning ( $t = 1$ ) to the last node ( $t = n$ ). Do not include the *root node*, the node at  $t = 0$ . If you do not click the nodes in the proper order, you are reminded with the message

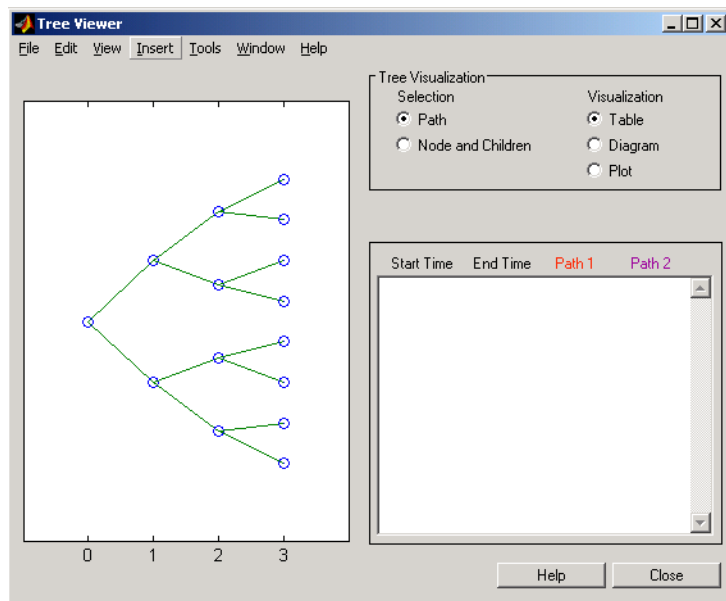
Parent of selected node must be selected.

## Examples

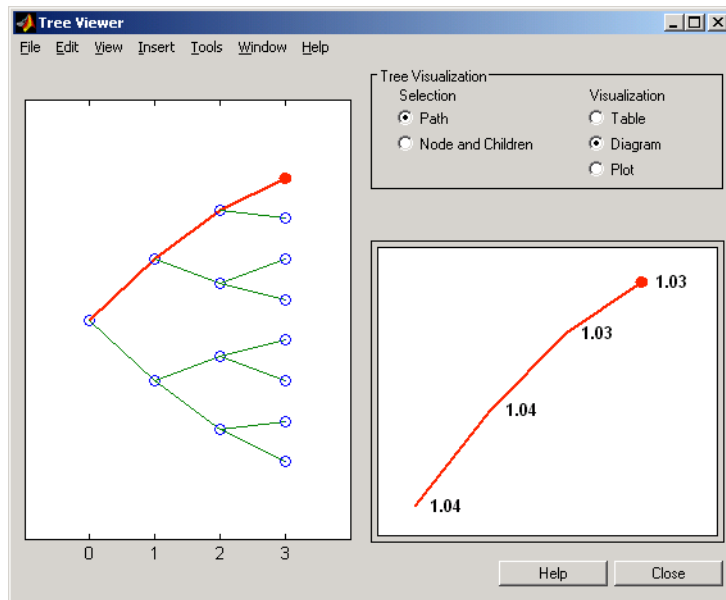
### Example 1. Display an HJM Interest-Rate Tree.

```
load deriv.mat
treeviewer(HJMTree)
```

The `treeviewer` function displays the structure of an HJM tree in the left pane. The tree visualization in the right pane is blank.

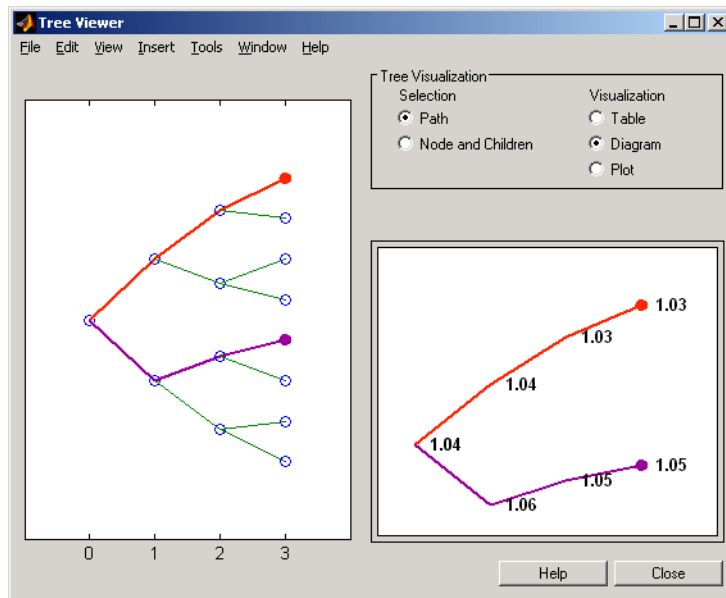


To visualize the actual interest-rate tree, go to the **Tree Visualization** pane and click on **Path** (the default) and **Diagram**. Now, select the first path by clicking on the last node ( $t = 3$ ) of the upper branch.



Note that the entire upper path is highlighted in red.

To complete the process, select a second path by clicking on the last node ( $t = 3$ ) of another branch. The second path is highlighted in purple. The final display looks like this.

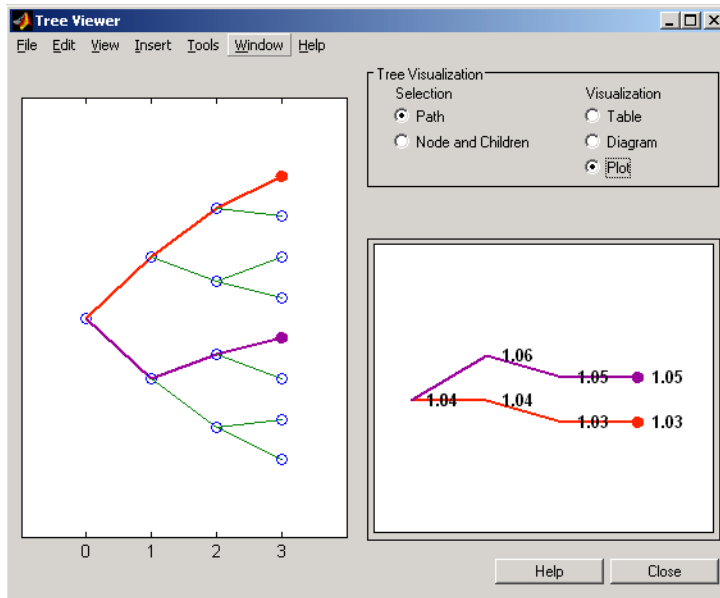


## Alternative Forms of Display

The **Tree Visualization** pane allows you to select alternative ways to display tree data. For example, if you select **Path** and **Table** as your visualization choices, the final display above instead appears in tabular form.

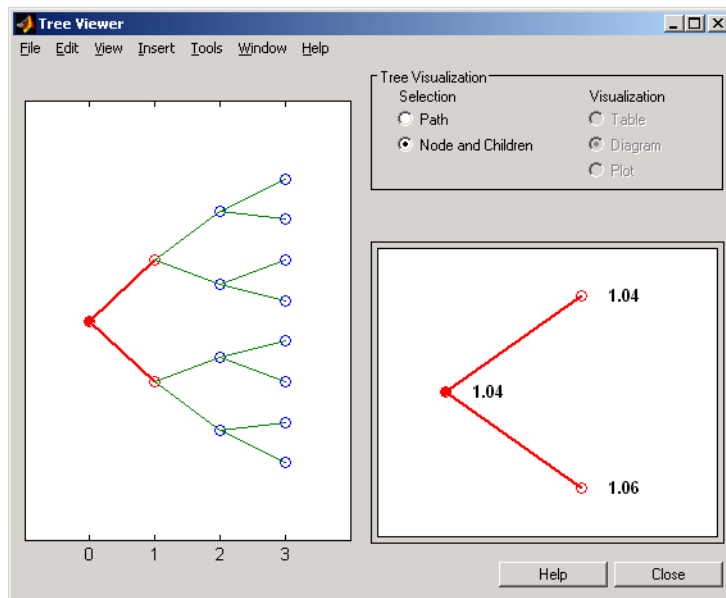






Note that with **Plot** selected, rising interest rates are shown on the upper branch and declining interest rates on the lower.

Finally, if you clicked **Node and Children** under **Tree Visualization**, you restrict the data displayed to just the selected parent node and its children.

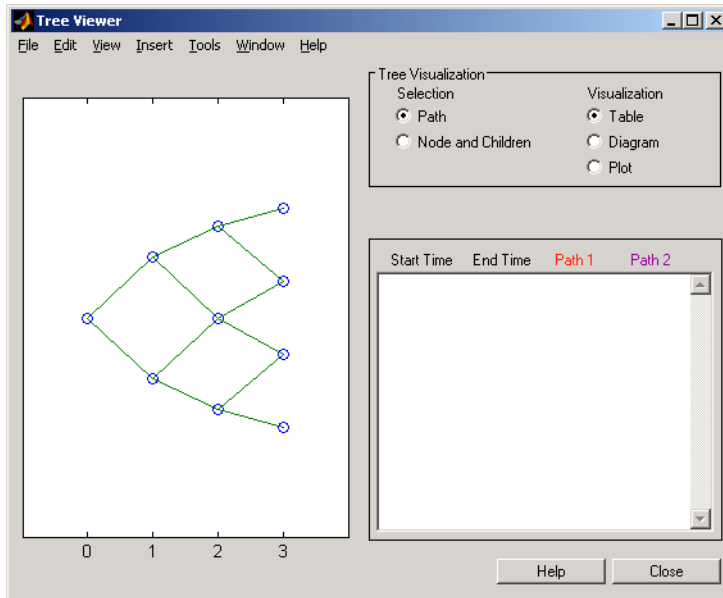


With **Node and Children** selected, the choices under **Visualization** are unavailable.

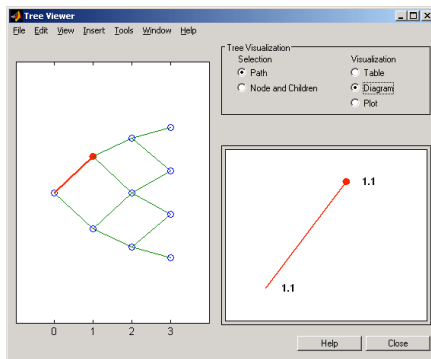
## Example 2. Display a BDT Interest-Rate Tree.

```
load deriv.mat
treeviewer(BDTTree)
```

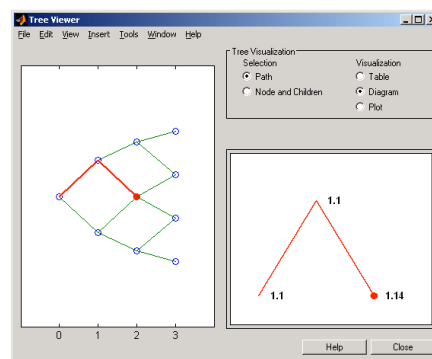
The `treeviewer` function displays the structure of a BDT tree in the left pane. The tree visualization in the right pane is blank.



To visualize the actual interest-rate tree, go to the **Tree Visualization** pane and click **Path** (the default) and **Diagram**. Now, select the first path by clicking on the first node of the up branch ( $t = 1$ ). Continue by clicking the down branch at the next node ( $t = 2$ ). The two figures below show the treeviewer path diagrams for these selections.



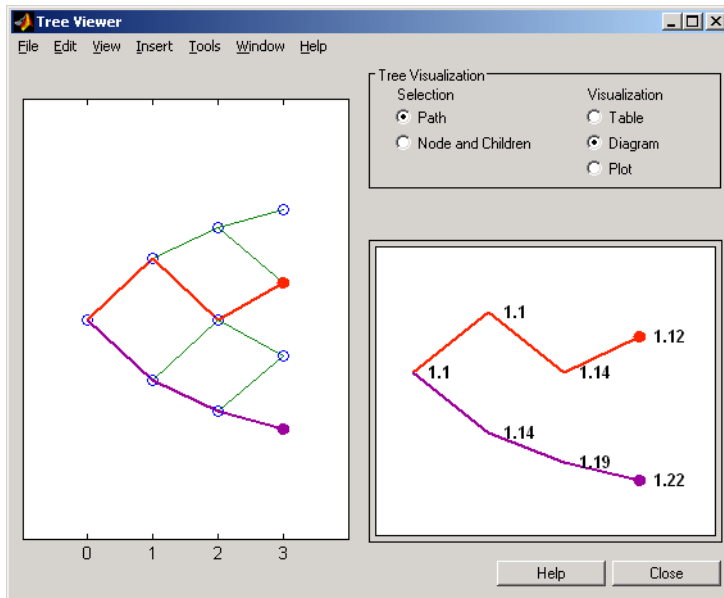
$t = 1$



$t = 2$

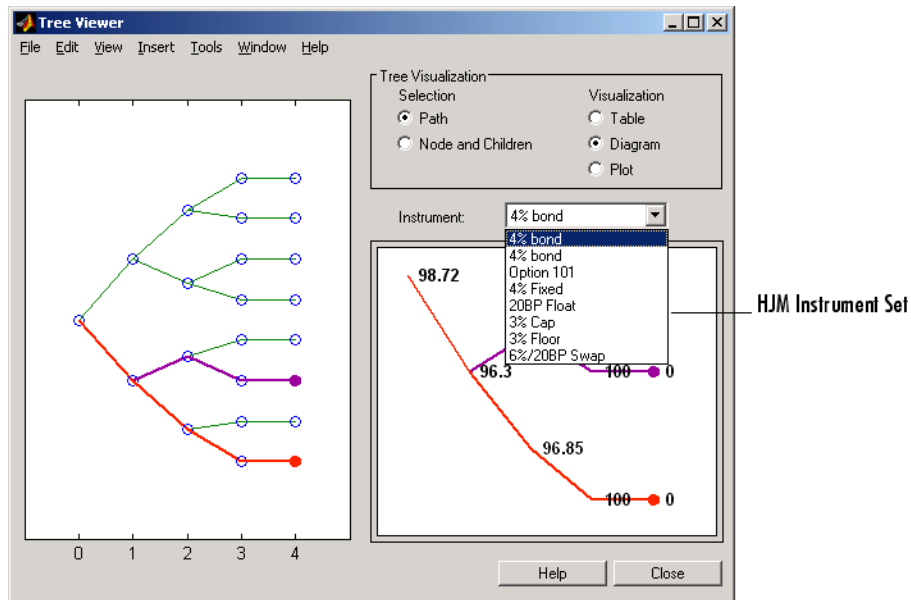
Continue clicking all nodes in succession until you reach the end of the branch. Note that the entire path you have selected is highlighted in red.

Select a second path by clicking the first node of the lower branch ( $t = 1$ ). Continue clicking lower nodes as you did on the first branch. Note that the second branch is highlighted in purple. The final display looks like this.



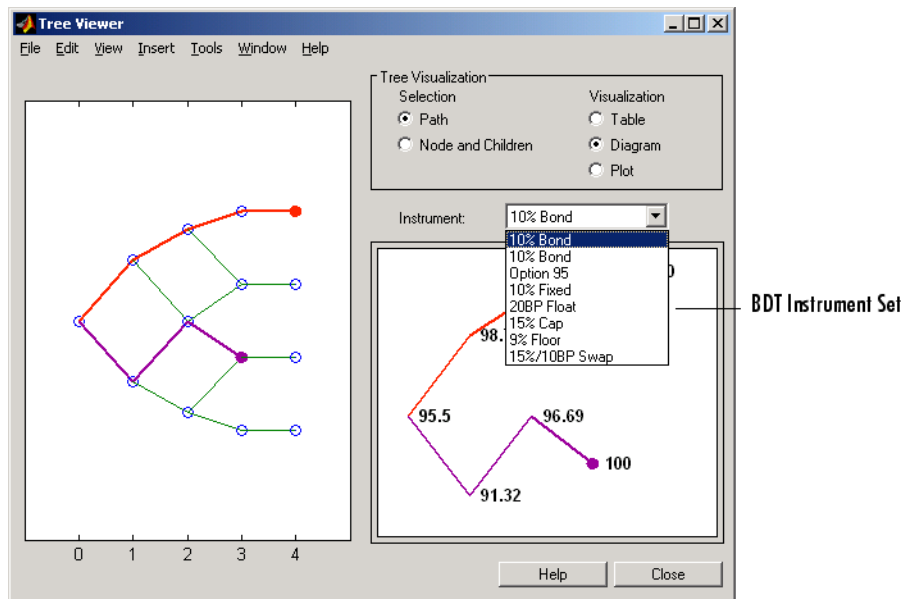
### Example 3. Display an HJM Price Tree for Named Instruments.

```
load deriv.mat
[Price, PriceTree] = hjmprice(HJMTree, HJMInstSet);
treeviewer(PriceTree, HJMInstSet)
```



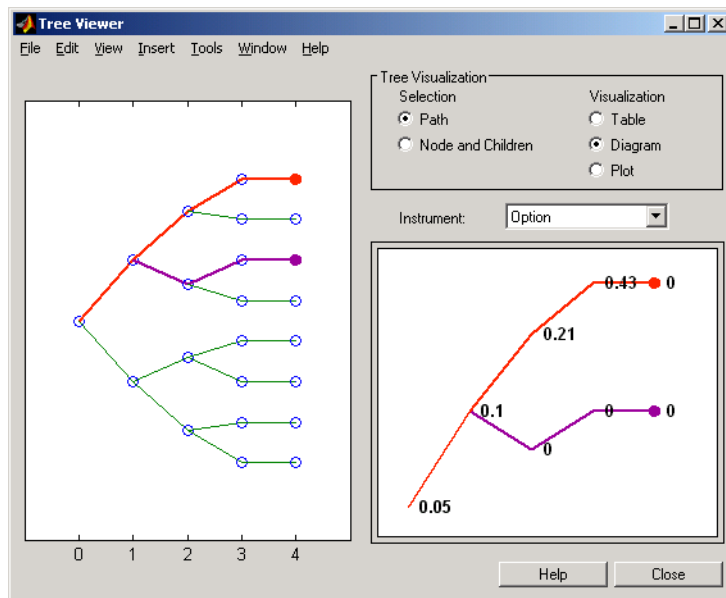
#### Example 4. Display a BDT Price Tree for Named Instruments.

```
load deriv.mat
[Price, PriceTree] = bdtprice(BDTTree, BDTInstSet);
treeviewer(PriceTree, BDTInstSet)
```



### Example 5. Display an HJM Price Tree with Renamed Instruments.

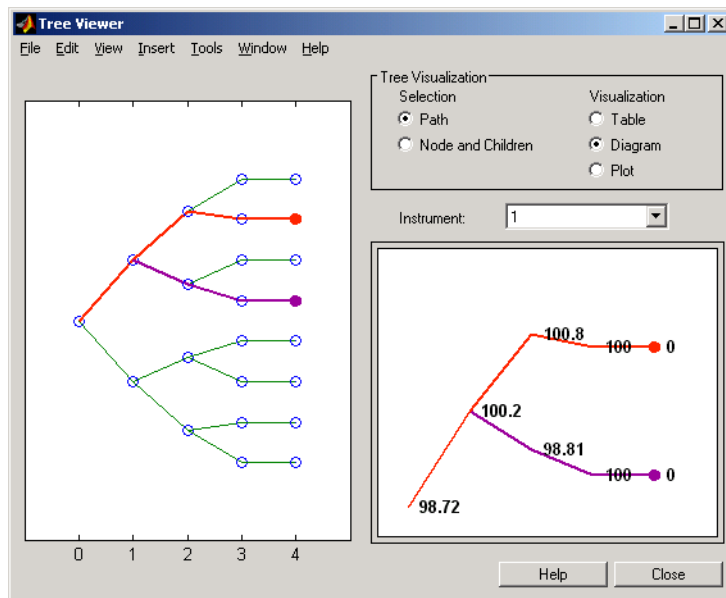
```
load deriv.mat
[Price, PriceTree] = hjmprice(HJMTree, HJMInstSet);
Names = {'Bond1', 'Bond2', 'Option', 'Fixed', 'Float', 'Cap', ...
        'Floor', 'Swap'};
treeviewer(PriceTree, Names)
```



### Example 6. Display an HJM Price Tree Using Default Instrument Names (Numbers).

```
load deriv.mat
[Price, PriceTree] = hjmprice(HJMTTree, HJMInstSet);
treeviewer(PriceTree)
```





## See Also

`bdttree` | `bktree` | `crmtree` | `eqmtree` | `hjmmtree` | `hwtree` | `instadd` | `ittree`  
| `lmtree` | `mmktbybdt` | `mmktbyhjm` | `swapbybdt` | `swapbyhjm`

## trintreepath

Entries from node of recombining trinomial tree

### Syntax

```
Values = trintreepath(TrinTree, BranchList)
```

### Arguments

TrinTree	Recombining price or interest-rate trinomial tree.
BranchList	Number of paths (NUMPATHS) by path length (PATHLENGTH) matrix containing the sequence of branchings.

### Description

`Values = trintreepath(TrinTree, BranchList)` extracts entries of a node of a recombining trinomial tree. The node path is described by the sequence of branchings taken, starting at the root. The top branch is number 1, the middle branch is 2, and the bottom branch is 3. Set the branch sequence to 0 to obtain the entries at the root node.

`Values` is a number of values (NUMVALS)-by-NUMPATHS matrix containing the retrieved entries of a recombining tree.

### Examples

Create a Hull-White tree by loading the example file.

```
load deriv.mat;
```

Then, for example

```
FwdRates = trintreepath(HWTTree, [1 2 3])
```

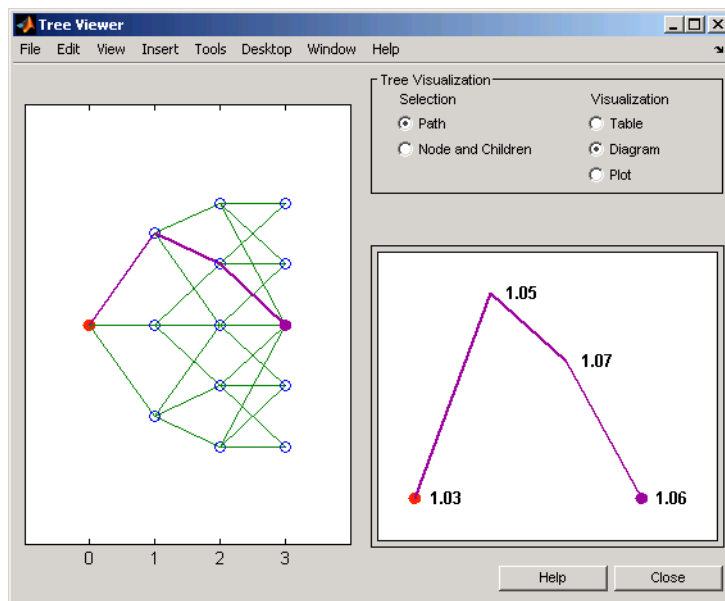
returns the rates at the tree nodes located by starting at 0, taking the up branch at the first node, the middle branch at the second node, and finally the bottom branch at the third node.

```
FwdRates =
```

```
1.0279
1.0528
1.0652
1.0591
```

You can visualize this with the `treeviewer` function.

```
treeviewer(HWTree)
```



## See Also

`mktrintree` | `trintreeshape`

## trintreeshape

Shape of recombining trinomial tree

### Syntax

```
[NumLevels, NumPos, NumStates] = trintreeshape(TrinTree)
```

### Arguments

TrinTree	Recombining price or interest-rate trinomial tree.
----------	--

### Description

`[NumLevels, NumPos, NumStates] = trintreeshape(TrinTree)` returns information on a recombining trinomial tree's shape.

`NumLevels` is the number of time levels of the tree.

`NumPos` is a 1-by-`NUMLEVELS` vector containing the length of the state vectors in each level.

`NumStates` is a 1-by-`NUMLEVELS` vector containing the number of state vectors in each level.

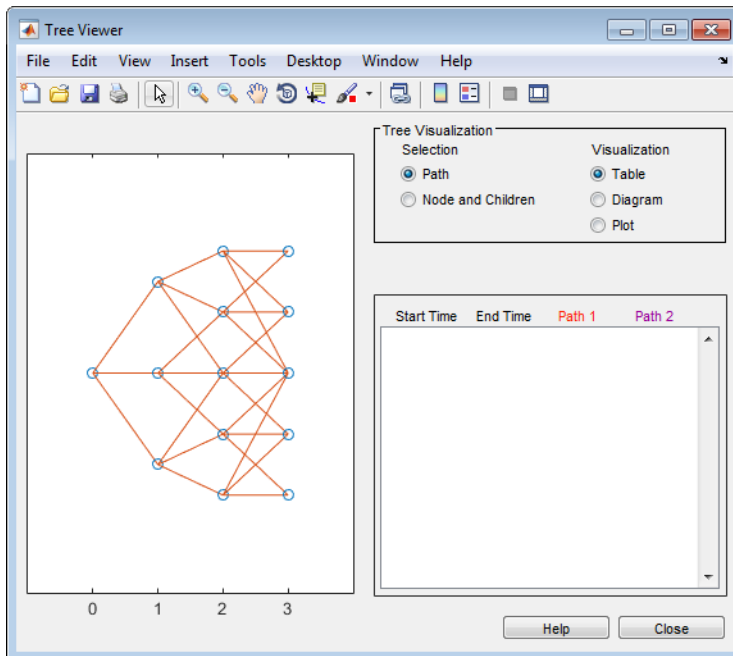
### Examples

Create a Hull-White tree by loading the example file.

```
load deriv.mat;
```

With `treeviewer` you can see the general shape of the HW interest-rate tree.

```
treeviewer(HWTree)
```



With this tree

```
[NumLevels, NumPos, NumStates] = trintreeshape(HWTree)
```

returns

```
NumLevels =
    4
```

```
NumPos =
    1    1    1    1
```

```
NumStates =
    1    3    5    5
```

## See Also

mktrintree | trintreepath

## creditexposures

Compute credit exposures from contract values

### Syntax

```
[exposures,exposurecpty] = creditexposures(values,counterparties)
[exposures,exposurecpty] = creditexposures( ____,Name,Value)
```

### Description

`[exposures,exposurecpty] = creditexposures(values,counterparties)` computes the counterparty credit exposures from an array of mark-to-market OTC contract values. These exposures are used when calculating the CVA (credit value adjustment) for a portfolio.

`[exposures,exposurecpty] = creditexposures( ____,Name,Value)` computes the counterparty credit exposures from an array of mark-to-market OTC contract values using optional name-value pair arguments. These exposures are used when calculating the CVA (credit value adjustment) for a portfolio.

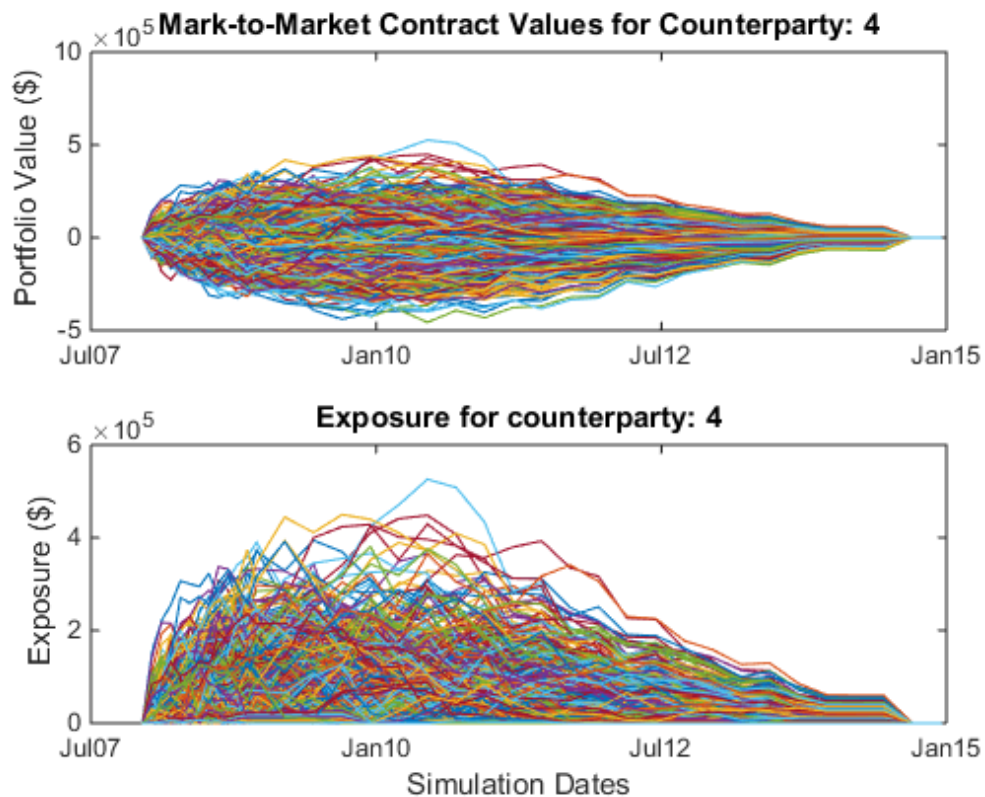
### Examples

#### View Contract Values and Exposures Over Time for a Particular Counterparty

After computing the mark-to-market contract values for a portfolio of swaps over many scenarios, compute the credit exposure for a particular counterparty. View the contract values and credit exposure over time. First, load data containing the mark-to-market contract values for a portfolio of swaps over many scenarios.

```
load ccr.mat
% Look at one counterparty.
cpID = 4;
cpValues = squeeze(sum(values(:,swaps.Counterparty == cpID,:),2));
subplot(2,1,1)
plot(simulationDates,cpValues);
title(sprintf('Mark-to-Market Contract Values for Counterparty: %d',cpID));
datetick('x','mmyy')
ylabel('Portfolio Value ($)')
```

```
% Compute the exposure by counterparty.
[exposures, expcpty] = creditexposures(values,swaps.Counterparty,...
'NettingID',swaps.NettingID);
% View the credit exposure over time for the counterparty.
subplot(2,1,2)
cpIdx = find(expcpty == cpID);
plot(simulationDates,squeeze(exposures(:,cpIdx,:)));
title(sprintf('Exposure for counterparty: %d',cpIdx));
datetick('x','mmyy')
ylabel('Exposure ($)')
xlabel('Simulation Dates')
```



### Compute the Credit Exposure and Determine the Incremental Exposure for a New Trade

Load data containing the mark-to-market contract values for a portfolio of swaps over many scenarios.

```
load ccr.mat
```

Look at one counterparty.

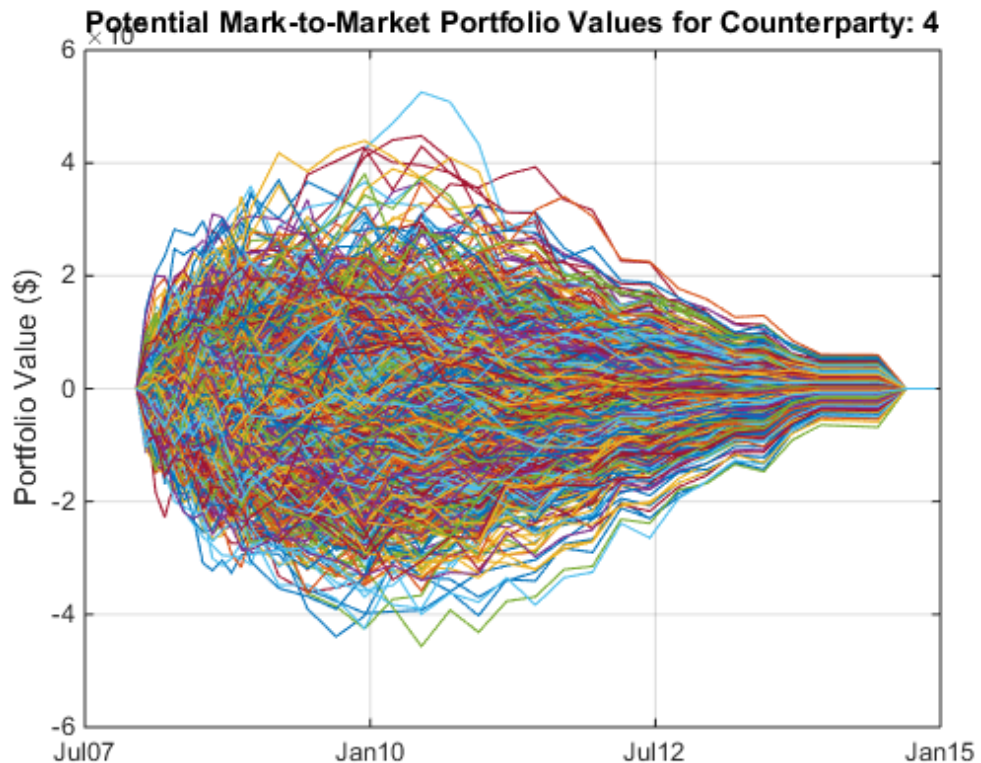
```
cpID = 4;
cpIdx = swaps.Counterparty == cpID;
cpValues = values(:,cpIdx,:);
plot(simulationDates,squeeze(sum(cpValues,2)));
grid on;
title(sprintf('Potential Mark-to-Market Portfolio Values for Counterparty: %d',cpID));
```



```

datetick('x','mmyy')
ylabel('Portfolio Value ($)')

```



Compute the exposures.

```

netting = swaps.NettingID(cpIdx);
exposures = creditexposures(cpValues,cpID,'NettingID',netting);

```

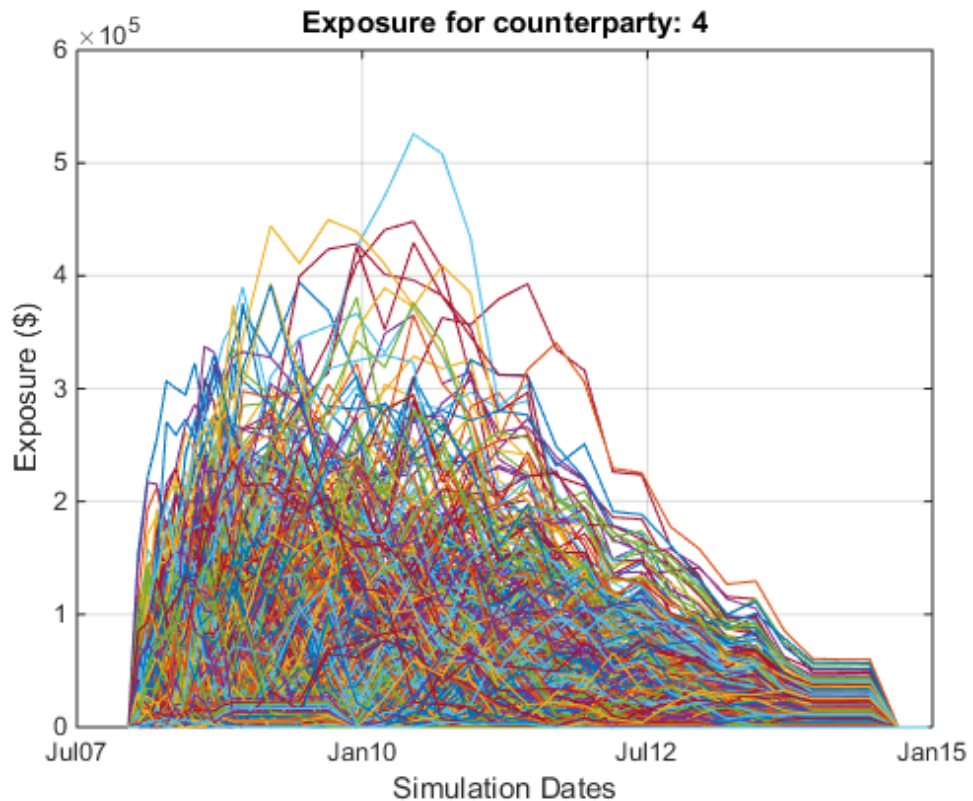
View the credit exposure over time for the counterparty.

```

figure;
plot(simulationDates,squeeze(exposures));
grid on
title(sprintf('Exposure for counterparty: %d',cpID));
datetick('x','mmyy')

```

```
ylabel('Exposure ($)')
xlabel('Simulation Dates')
```



Compute the credit exposure profiles.

```
profilesBefore = exposureprofiles(simulationDates, exposures)
```

```
profilesBefore =
```

```
Dates: [37x1 double]
EE: [37x1 double]
PFE: [37x1 double]
MPFE: 2.1580e+05
EffEE: [37x1 double]
```

```
EPE: 2.8602e+04
EffEPE: 4.9579e+04
```

Consider a new trade with a counterparty. For this example, take another trade from the original swap portfolio and "copy" it for a new counterparty. This example is only for illustrative purposes.

```
newTradeIdx = 3;
newTradeValues = values(:,newTradeIdx,:);

% Append a new trade to your existing portfolio.
cpValues = [cpValues newTradeValues];
netting = [netting; cpID];
exposures = creditexposures(cpValues,cpID,'NettingID',netting);
```

Compute the new credit exposure profiles.

```
profilesAfter = exposureprofiles(simulationDates,exposures)
```

```
profilesAfter =
    Dates: [37x1 double]
         EE: [37x1 double]
        PFE: [37x1 double]
       MPFE: 2.4689e+05
      EffEE: [37x1 double]
         EPE: 3.1609e+04
      EffEPE: 5.6178e+04
```

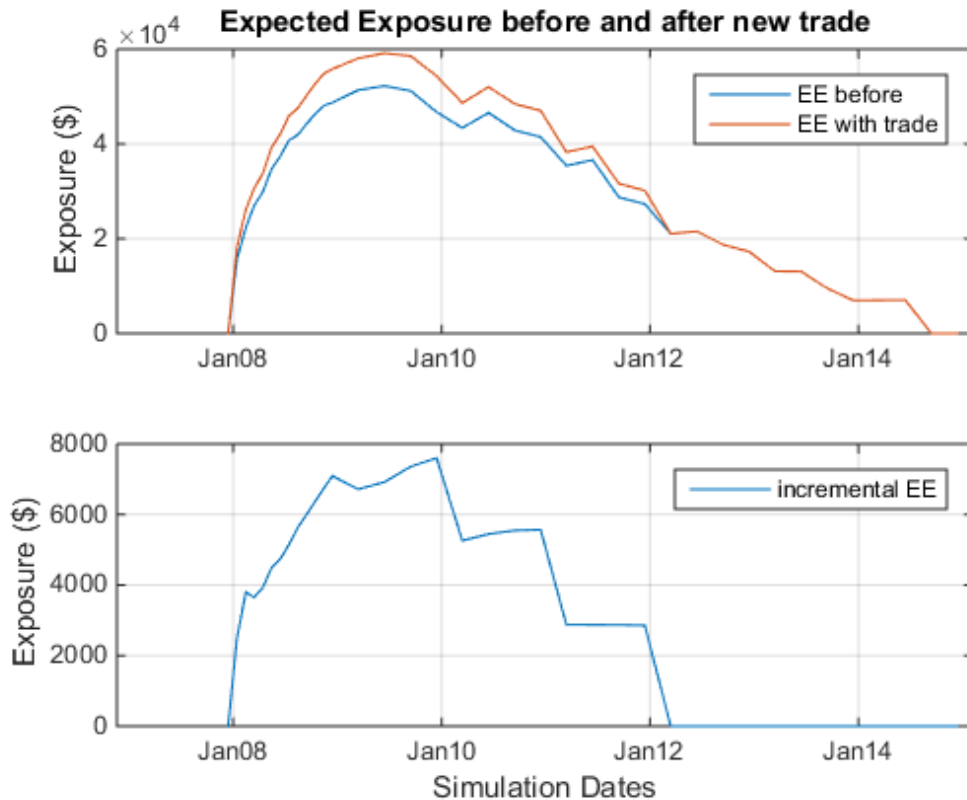
Visualize the expected exposures and the new trade's incremental exposure. The incremental exposure is used to compute the incremental credit value adjustment (CVA) charge.

```
figure;
subplot(2,1,1)
plot(simulationDates,profilesBefore.EE,...
     simulationDates,profilesAfter.EE);
grid on;
legend({'EE before','EE with trade'})
datetick('x','mmyy','keeplimits')
title('Expected Exposure before and after new trade');
ylabel('Exposure ($)')
```

```

subplot(2,1,2)
incrementalEE = profilesAfter.EE - profilesBefore.EE;
plot(simulationDates,incrementalEE);
grid on;
legend('incremental EE')
datetick('x','mmyy','keeplimits')
ylabel('Exposure ($)')
xlabel('Simulation Dates')

```



## Input Arguments

**values** — 3-D array of simulated mark-to-market values of portfolio of contracts  
array

3-D array of simulated mark-to-market values of a portfolio of contracts simulated over a series of simulation dates and across many scenarios, specified as a `NumDates-by-NumContracts-by-NumScenarios` “cube” of contract values. Each row represents a different simulation date, each column a different contract, and each “page” is a different scenario from a Monte-Carlo simulation.

Data Types: `double`

### **counterparties** — Counterparties corresponding to each contract

vector | cell array

Counterparties corresponding to each contract in values, specified as a `NumContracts`-element vector of counterparties. Counterparties can be a vector of numeric IDs or a cell array of counterparty names. By default, each counterparty is assumed to have one netting set that covers all of its contracts. If counterparties are covered by multiple netting sets, then use the `NettingID` parameter. A value of `NaN` (or `' '` in a cell array) indicates that a contract is not included in any netting set unless otherwise specified by `NettingID`. `counterparties` is case insensitive and leading or trailing white spaces are removed.

Data Types: `double` | `cell`

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (`' '`). You can specify several name and value pair arguments in any order as `Name1`, `Value1`, ..., `NameN`, `ValueN`.

Example: `[exposures, exposurecpty] = creditexposures(values, counterparties, 'NettingID', '10', 'ExposureType', 'Additiv`

### **'NettingID'** — Netting set IDs indicate which netting set each contract belongs

(default) | vector | cell array

Netting set IDs to indicate to which netting set each contract in values belongs, specified by a `NumContracts`-element vector of netting set IDs. `NettingID` can be a vector of numeric IDs or else a cell array of string identifiers. The `creditexposures` function uses `counterparties` and `NettingID` to define each unique netting set (all contracts in a netting set must be with the same counterparty). By default, each counterparty has a single netting set which covers all of their contracts. A value of `NaN` (or `' '` in a cell array)

indicates that a contract is not included in any netting set. `NettingID` is case insensitive and leading or trailing white spaces are removed.

Data Types: `double` | `cell`

**'ExposureType'** — Calculation method for exposures

'counterparty' (default) | string with value of 'counterparty' or 'additive'

Calculation method for exposures, specified with values:

- 'Counterparty' — Compute exposures per counterparty.
- 'Additive' — Compute additive exposures at the contract level. Exposures are computed per contract and sum to the total counterparty exposure.

Data Types: `char`

## Output Arguments

**exposures** — 3-D array of credit exposures

array

3-D array of credit exposures representing the potential losses from each counterparty or contract at each date and over all scenarios. The size of exposures depends on the `ExposureType` input argument:

- When `ExposureType` is 'Counterparty', `exposures` returns a `NumDates-by-NumCounterparties-by-NumScenarios` “cube” of credit exposures representing potential losses that could be incur over all dates, counterparties, and scenarios, if a counterparty defaulted (ignoring any post-default recovery).
- When `ExposureType` is 'Additive', `exposures` returns a `NumDates-by-NumContracts-by-NumScenarios` “cube,” where each element is the additive exposure of each contract (over all dates and scenarios). Additive exposures sum to the counterparty-level exposure.

**exposurecpty** — Counterparties that correspond to columns of exposures array

vector

Counterparties that correspond to columns of the exposures array, returned as `NumCounterparties` or `NumContracts` elements depending on the `ExposureType`.

## References

Pykhtin M., and S. Zhu. *A Guide to Modeling Counterparty Credit Risk*, GARP, July/August 2007, issue 37.

Pykhtin, Michael., and Dan Rosen. *Pricing Counterparty Risk at the Trade Level and CVA Allocations*, FEDS Working Paper No. 10., February 1, 2010.

## See Also

exposureprofiles

## agencyoas

Determine option-adjusted spread of callable bond using Agency OAS model

### Syntax

```
OAS = agencyoas(ZeroData, Price, CouponRate, Settle, Maturity,  
Vol, CallDate)
```

```
OAS = agencyoas(ZeroData, Price, CouponRate, Settle, Maturity,  
Vol, CallDate, Name, Value)
```

### Description

OAS = agencyoas(ZeroData, Price, CouponRate, Settle, Maturity, Vol, CallDate) computes OAS of a callable bond given price using the Agency OAS model.

OAS = agencyoas(ZeroData, Price, CouponRate, Settle, Maturity, Vol, CallDate, Name, Value) computes OAS of a callable bond given price using the Agency OAS model with additional options specified by one or more Name, Value pair arguments.

### Input Arguments

#### ZeroData

Zero curve represented as a numRates-by-2 matrix where the first column is zero dates and the second column is the accompanying zero rates.

#### Price

numBonds-by-1 vector of prices.

#### CouponRate

numBonds-by-1 vector of coupon rates in decimal form.



**Settle**

Scalar MATLAB date number for the settlement date for all bonds and the zero data.

---

**Note:** The **Settle** date must be an identical settlement date for all the bonds and the zero curve.

---

**Maturity**

numBonds-by-1 vector of maturity dates.

**Vol**

numBonds-by-1 vector of volatilities in decimal form. This is the volatility of interest rates corresponding to the time of the **CallDate**.

**CallDate**

numBonds-by-1 vector of call dates.

**Name-Value Pair Arguments**

Specify optional comma-separated pairs of **Name**,**Value** arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as **Name1**,**Value1**, . . . ,**NameN**,**ValueN**.

**'Basis'**

N-by-1 vector of day-count basis:

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)

- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

**'CurveBasis'**

Basis of the zero curve, where the choices are identical to **Basis**.

**Default:** 0 (actual/actual)

**'CurveCompounding'**

Compounding frequency of the zero curve. Possible values include: -1, 0, 1, 2, 3, 4, 6, 12.

**Default:** 2 (Semi-annual)

**'EndMonthRule'**

End-of-month rule; 1, indicating in effect, and 0, indicating rule not in effect for the bond(s). When 1, the rule is in effect for the bond(s), this means that a security that pays coupon interest on the last day of the month will always make payment on the last day of the month.

**Default:** 1 — Indicates in effect

**'Face'**

Face value of the bond.

**Default:** 100

**'FirstCouponDate'**

Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

**Default:** If you do not specify a `FirstCouponDate`, the cash flow payment dates are determined from other inputs.

**'InterpMethod'**

Interpolation method used to obtain points from the zero curve. Values are:

- `linear` — linear interpolation
- `cubic` — piecewise cubic spline interpolation
- `pchip` — piecewise cubic Hermite interpolation

**Default:** `linear`

**'IssueDate'**

Bond issue date.

**Default:** If you do not specify an `IssueDate`, the cash flow payment dates are determined from other inputs.

**'LastCouponDate'**

Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate`, regardless of where it falls, and is followed only by the bond's maturity cash flow date.

**Default:** If you do not specify a `LastCouponDate`, the cash flow payment dates are determined from other inputs.

**'Period'**

Number of coupon payments per year. Possible values include: 0, 1, 2, 3, 4, 6, 12.

**Default:** 2

**'StartDate'**

Forward starting date of payments.

**Default:** If you do not specify a `StartDate`, the effective start date is the `Settle` date.

## Output Arguments

**OAS**

numBonds-by-1 matrix of option-adjusted spreads.

## Examples

### Compute the Agency OAS Value

This example shows how to compute the agency OAS value.

```
Settle = datenum('20-Jan-2010');
ZeroRates = [.07 .164 .253 1.002 1.732 2.226 2.605 3.316 ...
3.474 4.188 4.902]'/100;
ZeroDates = daysadd(Settle,360* [.25 .5 1 2 3 4 5 7 10 20 30],1);
ZeroData = [ZeroDates ZeroRates];

Maturity = datenum('30-Dec-2013');
CouponRate = .022;
Price = 99.155;
Vol = .5117;
CallDate = datenum('30-Dec-2010');
OAS = agencyoas(ZeroData, Price, CouponRate, Settle, Maturity, Vol, CallDate)
```

```
OAS =
```

```
8.5837
```

- “Agency Option-Adjusted Spreads”

## More About

### Agency OAS Model

The BMA European Callable Securities Formula provides a standard methodology for computing price and option-adjusted spread for European Callable Securities (ECS).

## References

SIFMA, The BMA European Callable Securities Formula, <http://www.sifma.org>.

### See Also

| [agencyprice](#)

## agencyprice

Price callable bond using Agency OAS model

### Syntax

```
Price = agencyprice(ZeroData, OAS, CouponRate, Settle, Maturity,  
Vol, CallDate)  
Price = agencyprice(ZeroData, OAS, CouponRate, Settle, Maturity,  
Vol, CallDate, Name, Value)
```

### Description

Price = agencyprice(ZeroData, OAS, CouponRate, Settle, Maturity, Vol, CallDate) computes the price for a callable bond, given OAS, using the Agency OAS model.

Price = agencyprice(ZeroData, OAS, CouponRate, Settle, Maturity, Vol, CallDate, Name, Value) computes the price for a callable bond, given OAS, using the Agency OAS model with additional options specified by one or more Name, Value pair arguments.

### Input Arguments

#### ZeroData

Zero curve represented as a numRates-by-2 matrix where the first column is zero dates and the second column is the accompanying zero rates.

#### OAS

numBonds-by-1 vector of option-adjusted spreads, expressed as a decimal (i.e., 50 basis points is entered as .005).

#### CouponRate

numBonds-by-1 vector of coupon rates in decimal form.

**Settle**

Scalar MATLAB date number for the settlement date for all the bonds and the zero data.

---

**Note:** The **Settle** date must be an identical settlement date for all bonds and the zero curve.

---

**Maturity**

numBonds-by-1 vector of maturity dates.

**Vol**

numBonds-by-1 vector of volatilities in decimal form. This is the volatility of interest rates corresponding to the time of the **CallDate**.

**CallDate**

numBonds-by-1 vector of call dates.

**Name-Value Pair Arguments**

Specify optional comma-separated pairs of **Name**,**Value** arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as **Name1**,**Value1**, . . . ,**NameN**,**ValueN**.

**'Basis'**

N-by-1 vector of day-count basis:

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)

- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

**'CurveBasis'**

Basis of the zero curve, where the choices are identical to **Basis**.

**Default:** 0 (actual/actual)

**'CurveCompounding'**

Compounding frequency of the curve. Possible values include: -1, 0, 1, 2, 3, 4, 6, 12.

**Default:** 2 (Semi-annual)

**'EndMonthRule'**

End-of-month rule; 1, indicating in effect, and 0, indicating rule not in effect for the bond(s). When 1, the rule is in effect for the bond(s). This means that a security that pays coupon interest on the last day of the month will always make payment on the last day of the month.

**Default:** 1 — Indicates in effect

**'Face'**

Face value of the bond.

**Default:** 100



**'FirstCouponDate'**

Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

**Default:** If you do not specify a `FirstCouponDate`, the cash flow payment dates are determined from other inputs.

**'InterpMethod'**

Interpolation method used to obtain points from the zero curve. Values are:

- `linear` — linear interpolation
- `cubic` — piecewise cubic spline interpolation
- `pchip` — piecewise cubic Hermite interpolation

**Default:** `linear`

**'IssueDate'**

Bond issue date.

**Default:** If you do not specify an `IssueDate`, the cash flow payment dates are determined from other inputs.

**'LastCouponDate'**

Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate`, regardless of where it falls, and is followed only by the bond's maturity cash flow date.

**Default:** If you do not specify a `LastCouponDate`, the cash flow payment dates are determined from other inputs.

**'Period'**

Number of coupon payments per year. Possible values include: 0, 1, 2, 3, 4, 6, 12.

**Default:** 2

**'StartDate'**

Forward starting date of payments.

**Default:** If you do not specify a `StartDate`, the effective start date is the `Settle` date.

## Output Arguments

**Price**

numBonds-by-1 matrix of the price.

## Examples

### Compute the Agency Price

This example shows how to compute the agency `Price`.

```
Settle = datenum('20-Jan-2010');
ZeroRates = [.07 .164 .253 1.002 1.732 2.226 2.605 3.316 ...
3.474 4.188 4.902]'/100;
ZeroDates = daysadd(Settle,360* [.25 .5 1 2 3 4 5 7 10 20 30],1);
ZeroData = [ZeroDates ZeroRates];

Maturity = datenum('30-Dec-2013');
CouponRate = .022;
OAS = 6.53/10000;
Vol = .5117;
CallDate = datenum('30-Dec-2010');
Price = agencyprice(ZeroData, OAS, CouponRate, Settle, Maturity, Vol, CallDate)
```

```
Price =

    99.4212
```

- “Agency Option-Adjusted Spreads”

## More About

### Agency OAS Model

The BMA European Callable Securities Formula provides a standard methodology for computing price and option-adjusted spread for European Callable Securities (ECS).

## References

SIFMA, The BMA European Callable Securities Formula, <http://www.sifma.org>.

### See Also

| [agencyoas](#)

## bkcall

Price European call option on bonds using Black model

### Syntax

```
CallPrice = bkcall(Strike, ZeroData, Sigma, BondData, Settle,
Expiry, Period, Basis, EndMonthRule, InterpMethod,
StrikeConvention)
```

### Arguments

Strike	Scalar or number of options (NOPT)-by-1 vector of strike prices.
ZeroData	Two-column (optionally three-column) matrix containing zero (spot) rate information used to discount future cash flows. <ul style="list-style-type: none"> <li>• Column 1: Serial maturity date associated with the zero rate in the second column.</li> <li>• Column 2: Annualized zero rates, in decimal form, appropriate for discounting cash flows occurring on the date specified in the first column. All dates must occur after <b>Settle</b> (dates must correspond to future investment horizons) and must be in ascending order.</li> <li>• Column 3 (optional): Annual compounding frequency. Values are 1 (annual), 2 (semiannual, default), 3 (three times per year), 4 (quarterly), 6 (bimonthly), 12 (monthly), and -1 (continuous).</li> </ul>
Sigma	Scalar or NOPT-by-1 vector of annualized price volatilities required by Black's model.
BondData	Row vector with three (optionally four) columns or NOPT-by-3 (optionally NOPT-by-4) matrix specifying characteristics of underlying bonds in the form:  [CleanPrice CouponRate Maturity Face]

	<p><b>CleanPrice</b> is the price excluding accrued interest.</p> <p><b>CouponRate</b> is the decimal coupon rate.</p> <p><b>Maturity</b> is the bond maturity date in serial date number format.</p> <p><b>Face</b> is the face value of the bond. If unspecified, the face value is assumed to be 100.</p>
<b>Settle</b>	Settlement date of the options. May be a serial date number or date string. <b>Settle</b> also represents the starting reference date for the input zero curve.
<b>Expiry</b>	Scalar or NOPT-by-1 vector of option maturity dates. May be a serial date number or date string.
<b>Period</b>	(Optional) Number of coupons per year for the underlying bond. Default = 2 (semiannual). Supported values are 0, 1, 2, 3, 4, 6, and 12.
<b>Basis</b>	<p>(Optional) Day-count basis of the bond. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>

<b>EndMonthRule</b>	(Optional) End-of-month rule. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
<b>InterpMethod</b>	(Optional) Scalar integer zero curve interpolation method. For cash flows that do not fall on a date found in the <b>ZeroData</b> spot curve, indicates the method used to interpolate the appropriate zero discount rate. Available methods are (0) nearest, (1) linear, and (2) cubic. Default = 1. See <b>interp1</b> for more information.
<b>StrikeConvention</b>	(Optional) Scalar or NOPT-by-1 vector of option contract strike price conventions.  <b>StrikeConvention</b> = 0 (default) defines the strike price as the cash (dirty) price paid for the underlying bond.  <b>StrikeConvention</b> = 1 defines the strike price as the quoted (clean) price paid for the underlying bond. When evaluating Black's model, the accrued interest of the bond at option expiration is added to the input strike price.

## Description

`CallPrice = bkcall(Strike, ZeroData, Sigma, BondData, Settle, Expiry, Period, Basis, EndMonthRule, InterpMethod, StrikeConvention)` using Black's model, derives an NOPT-by-1 vector of prices of European call options on bonds.

If cash flows occur beyond the dates spanned by **ZeroData**, the input zero curve, the appropriate zero rate for discounting such cash flows is obtained by extrapolating the nearest rate on the curve (that is, if a cash flow occurs before the first or after the last date on the input zero curve, a flat curve is assumed).

In addition, you can use the Financial Instruments Toolbox method **getZeroRates** for an **IRDataCurve** object with a **Dates** property to create a vector of dates and data

acceptable for `bkcall`. For more information, see “Converting an `IRDataCurve` or `IRFunctionCurve` Object” on page 9-44.

## Examples

### Price a European Call Option On Bonds Using the Black Model

This example shows how to price a European call option on bonds using the Black model. Consider a European call option on a bond maturing in 9.75 years. The underlying bond has a clean price of \$935, a face value of \$1000, and pays 10% semiannual coupons. Since the bond matures in 9.75 years, a \$50 coupon will be paid in 3 months and again in 9 months. Also, assume that the annualized volatility of the forward bond price is 9%. Furthermore, suppose the option expires in 10 months and has a strike price of \$1000, and that the annualized continuously compounded risk-free discount rates for maturities of 3, 9, and 10 months are 9%, 9.5%, and 10%, respectively.

```
% specify the option information
Settle      = '15-Mar-2004';
Expiry      = '15-Jan-2005'; % 10 months from settlement
Strike      = 1000;
Sigma       = 0.09;
Convention  = [0 1]';

% specify the interest-rate environment
ZeroData    = [datenum('15-Jun-2004') 0.09 -1; % 3 months
               datenum('15-Dec-2004') 0.095 -1; % 9 months
               datenum(Expiry)         0.10 -1]; % 10 months

% specify the bond information
CleanPrice  = 935;
CouponRate  = 0.1;
Maturity    = '15-Dec-2013'; % 9.75 years from settlement
Face        = 1000;
BondData    = [CleanPrice CouponRate datenum(Maturity) Face];
Period      = 2;
Basis       = 1;

% call Black's model
CallPrices = bkcall(Strike, ZeroData, Sigma, BondData, Settle,...
Expiry, Period, Basis, [], [], Convention)
```

CallPrices =

9.4873

7.9686

When the strike price is the dirty price (`Convention = 0`), the call option value is \$9.49.

When the strike price is the clean price (`Convention = 1`), the call option value is \$7.97.

## References

[1] Hull, John C., *Options, Futures, and Other Derivatives*, Prentice Hall, 5th edition, 2003, pp. 287-288, 508-515.

## See Also

bkput



# bkcple

Price interest-rate caplet using Black model

## Syntax

```
CapPrices = bkcple(CapData, FwdRates, ZeroPrice, Settle,
StartDate, EndDate, Sigma)
```

## Arguments

CapData	<p>Number of caps (NCAP)-by-2 matrix containing cap rates and bases: [CapRates Basis].</p> <p>Values for bases may be:</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
---------	---

FwdRates	Scalar or NCAP-by-1 vector containing forward rates in decimal. FwdRates accrue on the same basis as CapRates.
ZeroPrice	Scalar or NCAP-by-1 vector containing zero coupon prices with maturities corresponding to those of each cap in CapData, per \$100 nominal value.
Settle	Scalar or NCAP-by-1 vector of identical elements containing settlement date of caplets.
StartDate	Scalar or NCAP-by-1 vector containing start dates of the caplets.
EndDate	Scalar or NCAP-by-1 vector containing maturity dates of caplets.
Sigma	Scalar or NCAP-by-1 vector containing volatility of forward rates in decimal, corresponding to each caplet.

## Description

CapPrices = bkcaplet(CapData, FwdRates, ZeroPrice, Settle, StartDate, EndDate, Sigma) computes the prices of interest-rate caplets for every \$100 face value of principal.

## Examples

### Compute the Price of Interest-Rate Caplets for Every \$100 Face Value of Principal

This example shows how to compute the price of interest-rate caplets for every \$100 face value of principal. Given a notional amount of \$1,000,000, compute the value of a caplet on October 15, 2002 that starts on October 15, 2003 and ends on January 15, 2004.

```
CapData = [0.08, 1];
FwdRates = 0.07;
ZeroPrice = 100*exp(-0.065*1.25);
Settle = datenum('15-Oct-2002');
BeginDates = datenum('15-Oct-2003');
EndDates = datenum('15-Jan-2004');
Sigma = 0.20;
```

```
% because the caplet is $100 notional, divide $1,000,000 by $100
Notional = 1000000/100;
```

---

```
CapPrice = Notional*bkcapiet(CapData, FwdRates, ZeroPrice, ...  
Settle, BeginDates, EndDates, Sigma)
```

```
CapPrice =
```

```
519.0046
```

## **See Also**

bkfloorlet

## bkfloorlet

Price interest-rate floorlet using Black model

### Syntax

```
FloorPrices = bkfloorlet(FloorData, FwdRates, ZeroPrice, Settle,  
StartDate, EndDate, Sigma)
```

### Arguments

FloorData	<p>Number of floors (NFLR)-by-2 matrix containing floor rates and bases: [FloorRate Basis].</p> <p>Values for bases may be:</p> <ul style="list-style-type: none"><li>• 0 = actual/actual (default)</li><li>• 1 = 30/360 (SIA)</li><li>• 2 = actual/360</li><li>• 3 = actual/365</li><li>• 4 = 30/360 (BMA)</li><li>• 5 = 30/360 (ISDA)</li><li>• 6 = 30/360 (European)</li><li>• 7 = actual/365 (Japanese)</li><li>• 8 = actual/actual (ICMA)</li><li>• 9 = actual/360 (ICMA)</li><li>• 10 = actual/365 (ICMA)</li><li>• 11 = 30/360E (ICMA)</li><li>• 12 = actual/actual (ISDA)</li><li>• 13 = BUS/252</li></ul> <p>For more information, see <b>basis</b>.</p>
-----------	---

<b>FwdRates</b>	Scalar or NFLR-by-1 vector containing forward rates in decimal. <b>FwdRates</b> accrue on the same basis as <b>FloorRates</b> .
<b>ZeroPrice</b>	Scalar or NFLR-by-1 vector containing zero coupon prices with maturities corresponding to those of each floor in <b>FloorData</b> , per \$100 nominal value.
<b>Settle</b>	Scalar or NFLR-by-1 vector of identical elements containing settlement date of floorlets.
<b>StartDate</b>	Scalar or NFLR-by-1 vector containing start dates of the floorlets.
<b>EndDate</b>	Scalar or NFLR-by-1 vector containing maturity dates of floorlets.
<b>Sigma</b>	Scalar or NFLR-by-1 vector containing volatility of forward rates in decimal, corresponding to each floorlet.

## Description

`FloorPrices = bkfloorlet(FloorData, FwdRates, ZeroPrice, Settle, StartDate, EndDate, Sigma)` computes the prices of interest-rate floorlets for every \$100 of notional value.

## Examples

### Price an Interest-Rate Floorlet For Every \$100 of Notional Value Using the Black Model

This example shows how to price an interest-rate floorlet for every \$100 of notional value using the Black model. Given a notional amount of \$1,000,000, compute the value of a floorlet on October 15, 2002 that starts on October 15, 2003 and ends on January 15, 2004.

```
FloorData = [0.08, 1];
FwdRates = 0.07;
ZeroPrice = 100*exp(-0.065*1.25);
Settle = datenum('15-Oct-2002');
BeginDates = datenum('15-Oct-2003');
EndDates = datenum('15-Jan-2004');
Sigma = 0.20;

% because floorlet is $100 notional, divide $1,000,000 by $100
Notional = 1000000/100;
```

```
FloorPrice = Notional*bkfloorlet(FloorData, FwdRates, ...  
ZeroPrice, Settle, BeginDates, EndDates, Sigma)
```

```
FloorPrice =
```

```
2.8239e+03
```

### **See Also**

bkcaplet

# bkput

Price European put option on bonds using Black model

## Syntax

PutPrice = bkput(Strike, ZeroData, Sigma, BondData, Settle, Expiry, Period, Basis, EndMonthRule, InterpMethod, StrikeConvention)

## Arguments

Strike	Scalar or number of options (NOPT)-by-1 vector of strike prices.
ZeroData	Two-column (optionally three-column) matrix containing zero (spot) rate information used to discount future cash flows. <ul style="list-style-type: none"> <li>Column 1: Serial maturity date associated with the zero rate in the second column.</li> <li>Column 2: Annualized zero rates, in decimal form, appropriate for discounting cash flows occurring on the date specified in the first column. All dates must occur after <b>Settle</b> (dates must correspond to future investment horizons) and must be in ascending order.</li> <li>Column 3 (optional): Annual compounding frequency. Values are 1 (annual), 2 (semiannual, default), 3 (three times per year), 4 (quarterly), 6 (bimonthly), 12 (monthly), and -1 (continuous).</li> </ul>
Sigma	Scalar or NOPT-by-1 vector of annualized price volatilities required by Black's model.
BondData	Row vector with three (optionally four) columns or NOPT-by-3 (optionally NOPT-by-4) matrix specifying characteristics of underlying bonds in the form [ <b>CleanPrice</b> <b>CouponRate</b> <b>Maturity</b> <b>Face</b> ] where: <ul style="list-style-type: none"> <li><b>CleanPrice</b> is the price excluding accrued interest.</li> <li><b>CouponRate</b> is the decimal coupon rate.</li> </ul>

	<ul style="list-style-type: none"> <li>• <b>Maturity</b> is the bond maturity date in serial date number format.</li> <li>• <b>Face</b> is the face value of the bond. If unspecified, the face value is assumed to be 100.</li> </ul>
<b>Settle</b>	Settlement date of the options. May be a serial date number or date string. <b>Settle</b> also represents the starting reference date for the input zero curve.
<b>Expiry</b>	Scalar or NOPT-by-1 vector of option maturity dates. May be a serial date number or date string.
<b>Period</b>	(Optional) Number of coupons per year for the underlying bond. Default = 2 (semiannual). Supported values are 0, 1, 2, 3, 4, 6, and 12.
<b>Basis</b>	<p>(Optional) Day-count basis of the bond. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>



EndMonthRule	(Optional) End-of-month rule. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
InterpMethod	(Optional) Scalar integer zero curve interpolation method. For cash flows that do not fall on a date found in the <b>ZeroData</b> spot curve, indicates the method used to interpolate the appropriate zero discount rate. Available methods are (0) nearest, (1) linear, and (2) cubic. Default = 1. See <b>interp1</b> for more information.
StrikeConvention	(Optional) Scalar or NOPT-by-1 vector of option contract strike price conventions.  <b>StrikeConvention</b> = 0 (default) defines the strike price as the cash (dirty) price paid for the underlying bond.  <b>StrikeConvention</b> = 1 defines the strike price as the quoted (clean) price paid for the underlying bond. The accrued interest of the bond at option expiration is added to the input strike price when evaluating Black's model.

## Description

`PutPrice = bkput(Strike, ZeroData, Sigma, BondData, Settle, Expiry, Period, Basis, EndMonthRule, InterpMethod, StrikeConvention)` using Black's model, derives an NOPT-by-1 vector of prices of European put options on bonds.

If cash flows occur beyond the dates spanned by **ZeroData**, the input zero curve, the appropriate zero rate for discounting such cash flows is obtained by extrapolating the nearest rate on the curve (that is, if a cash flow occurs before the first or after the last date on the input zero curve, a flat curve is assumed).

In addition, you can use the Financial Instruments Toolbox method `getZeroRates` for an **IRDataCurve** object with a **Dates** property to create a vector of dates and data acceptable for `bkput`. For more information, see “Converting an **IRDataCurve** or **IRFunctionCurve** Object” on page 9-44.

## Examples

### Price European Put Options On Bonds Using the Black Model

This example shows how to price European put options on bonds using the Black model. Consider a European put option on a bond maturing in 10 years. The underlying bond has a clean price of \$122.82, a face value of \$100, and pays 8% semiannual coupons. Also, assume that the annualized volatility of the forward bond yield is 20%. Furthermore, suppose the option expires in 2.25 years and has a strike price of \$115, and that the annualized continuously compounded risk free zero (spot) curve is flat at 5%. For a hypothetical settlement date of March 15, 2004, the following code illustrates the use of Black's model to duplicate the put prices in Example 22.2 of the Hull reference. In particular, it illustrates how to convert a broker's yield volatility to a price volatility suitable for Black's model.

```
% Specify the option information.
Settle      = '15-Mar-2004';
Expiry      = '15-Jun-2006'; % 2.25 years from settlement
Strike      = 115;
YieldSigma  = 0.2;
Convention  = [0; 1];

% Specify the interest-rate environment. Since the
% zero curve is flat, interpolation into the curve always returns
% 0.05. Thus, the following curve is not unique to the solution.
ZeroData    = [datenum('15-Jun-2004') 0.05 -1;
               datenum('15-Dec-2004') 0.05 -1;
               datenum(Expiry)        0.05 -1];

% Specify the bond information.
CleanPrice  = 122.82;
CouponRate  = 0.08;
Maturity    = '15-Mar-2014'; % 10 years from settlement
Face        = 100;
BondData    = [CleanPrice CouponRate datenum(Maturity) Face];
Period      = 2; % semiannual coupons
Basis       = 1; % 30/360 day-count basis

% Convert a broker's yield volatility quote to a price volatility
% required by Black's model. To duplicate Example 22.2 in Hull,
% first compute the periodic (semiannual) yield to maturity from
% the clean bond price.
Yield = bndyield(CleanPrice, CouponRate, Settle, Maturity, ...
```

```

Period, Basis);

% Compute the duration of the bond at option expiration. Most
% fixed-income sensitivity analyses use the modified duration
% statistic to examine the impact of small changes in periodic
% yields on bond prices. However, Hull's example operates in
% continuous time (annualized instantaneous volatilities and
% continuously compounded zero yields for discounting coupons).
% To duplicate Hull's results, use the second output of BNDDURY,
% the Macaulay duration.
[Modified, Macaulay] = bnddury(Yield, CouponRate, Expiry,...
Maturity, Period, Basis);

% Convert the yield-to-maturity from a periodic to a
% continuous yield.
Yield = Period .* log(1 + Yield./Period);

% Convert the yield volatility to a price volatility via
% Hull's Equation 22.6 (page 514).
PriceSigma = Macaulay .* Yield .* YieldSigma;

% Finally, call Black's model.
PutPrices = bkput(Strike, ZeroData, PriceSigma, BondData,...
Settle, Expiry, Period, Basis, [], [], Convention)

PutPrices =

    1.7838
    2.4071

```

When the strike price is the dirty price (`Convention = 0`), the call option value is \$1.78.  
When the strike price is the clean price (`Convention = 1`), the call option value is \$2.41.

## References

[1] Hull, John C., *Options, Futures, and Other Derivatives*, Prentice Hall, 5th edition, 2003, pp. 287-288, 508-515.

## See Also

bkcall

## bndfutimprepo

Implied repo rates for bond future given price

### Syntax

```
ImpRepo = bndfutimprepo(Price, FutPrice, FutSettle,  
Delivery, ConvFactor, CouponRate, Maturity)  
ImpRepo = bndfutimprepo(Price, FutPrice, FutSettle,  
Delivery, ConvFactor, CouponRate, Maturity,  
'ParameterName', 'ParameterValue ...)
```

### Description

`ImpRepo = bndfutimprepo(Price, FutPrice, FutSettle, Delivery, ConvFactor, CouponRate, Maturity)` computes the implied repo rate for a bond future given the price of a bond, the bond properties, the price of the bond future, and the bond conversion factor.

`ImpRepo = bndfutimprepo(Price, FutPrice, FutSettle, Delivery, ConvFactor, CouponRate, Maturity, 'ParameterName', 'ParameterValue ...)` accepts optional inputs as one or more comma-separated parameter/value pairs. *ParameterName* is the name of the parameter inside single quotes. *ParameterValue* is the value corresponding to *ParameterName*. Specify parameter-value pairs in any order. Names are case-insensitive.

### Input Arguments

#### Price

numBonds-by-1 vector of bond prices.

#### FutPrice

numBonds-by-1 vector of future prices

**FutSettle**

numBonds-by-1 vector of future settle dates.

**Delivery**

numBonds-by-1 vector of future delivery dates.

**ConvFactor**

numBonds-by-1 vector of bond conversion factors. For more information, see `convfactor`.

**CouponRate**

numBonds-by-1 vector of coupon rates in decimal form.

**Maturity**

numBonds-by-1 vector of coupon rates in decimal form.

**Parameter–Value Pairs****Basis**

Day-count basis. Possible values include

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)

- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0

### **EndMonthRule**

End-of-month rule. Values are:

- 0 — Rule is not in effect for the bond.
- 1 — Rule is in effect for the bond. This means that a security that pays coupon interest on the last day of the month always makes payment on the last day of the month.

**Default:** 1

### **Face**

Face value of the bond. **Face** has no impact on key rate duration. This calling sequence is preserved for consistency.

**Default:** 100

### **FirstCouponDate**

Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When **FirstCouponDate** and **LastCouponDate** are both specified, **FirstCouponDate** takes precedence in determining the coupon payment structure.

**Default:** If you do not specify a **FirstCouponDate**, the cash flow payment dates are determined from other inputs.

### **IssueDate**

Issue date for a bond.

### **LastCouponDate**

Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified **FirstCouponDate**, a specified **LastCouponDate** determines the coupon structure of the bond. The coupon structure of

a bond is truncated at the **LastCouponDate**, regardless of where it falls, and is followed only by the bond's maturity cash flow date.

**Default:** If you do not specify a **LastCouponDate**, the cash flow payment dates are determined from other inputs.

**Period**

Number of coupons payments per year. Possible values include:

- 0
- 1
- 2
- 3
- 4
- 6
- 12

**Default:** 2

**ReinvestBasis**

Day count basis for reinvestment rate.

**Default:** Identical to **RepoBasis**.

**ReinvestRate**

Rate for reinvesting intermediate coupons from the bond.

**Default:** Identical to **ImpRepo**.

**RepoBasis**

Day count basis for **ImpRepo**.

**Default:** 2

**StartDate**

Date when a bond actually starts (the date from which a bond cash flow is considered). To make an instrument forward-starting, specify this date as a future date. If you do not specify **StartDate**, the effective start date is the **Settle** date.

## Output Arguments

### ImpRepo

Implied repo rate, or the repo rate that would produce the price input.

## Definitions

`bndfutimprepo` computes the implied repo rate for a bond future given:

- Price of a bond
- Bond properties
- Price of the bond future
- Bond conversion factor

The default behavior is that the coupon reinvestment rate matches the repo rate. However, you can specify a separate reinvestment rate using optional inputs.

## Examples

### Compute the Repo Rate For a Bond Future

This example shows how to compute the repo rate for a bond future using the following data.

```
bndfutimprepo(129,98, '9/21/2000', '12/29/2000', 1.3136, .0875, '8/15/2020')
```

```
ans =
```

```
0.0584
```

## More About

- “Bond Futures”



## References

Burghardt, G., T. Belton, M. Lane, and J. Papa, *The Treasury Bond Basis*, McGraw-Hill, 2005.

Krgin, Dragomir, *Handbook of Global Fixed Income Calculations*, John Wiley & Sons, 2002.

## See Also

bndfutprice | convfactor

## bndfutprice

Price bond future given repo rates

### Syntax

```
[FutPrice,AccrInt] = bndfutprice(RepoRate, Price, FutSettle,  
Delivery, ConvFactor, CouponRate, Maturity)  
FutPrice,AccrInt] = bndfutprice(RepoRate, FutPrice, FutSettle,  
Delivery, ConvFactor, CouponRate, Maturity,  
'ParameterName', 'ParameterValue ...)
```

### Description

[FutPrice,AccrInt] = bndfutprice(RepoRate, Price, FutSettle, Delivery, ConvFactor, CouponRate, Maturity) computes the price of a bond futures contract for one or more bonds given a repo rate, and bond properties, including the bond conversion factor.

FutPrice,AccrInt] = bndfutprice(RepoRate, FutPrice, FutSettle, Delivery, ConvFactor, CouponRate, Maturity, 'ParameterName', 'ParameterValue ...) accepts optional inputs as one or more comma-separated parameter/value pairs. 'ParameterName' is the name of the parameter inside single quotes. ParameterValue is the value corresponding to 'ParameterName'. Specify parameter-value pairs in any order. Names are case-insensitive.

### Input Arguments

#### RepoRate

numBonds-by-1 vector of repo rates.

#### Price

numBonds-by-1 vector of bond prices

**FutSettle**

numBonds-by-1 vector of future settle dates.

**Delivery**

numBonds-by-1 vector of future delivery dates.

**ConvFactor**

numBonds-by-1 vector of bond conversion factors. For more information, see convfactor.

**CouponRate**

numBonds-by-1 vector of coupon rates in decimal form.

**Maturity**

numBonds-by-1 vector of coupon rates in decimal form.

**Parameter–Value Pairs****Basis**

Day-count basis. Possible values include

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)

- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0

### **EndMonthRule**

End-of-month rule. Values are:

- 0 — Rule is not in effect for the bond.
- 1 — Rule is in effect for the bond. This means that a security that pays coupon interest on the last day of the month always makes payment on the last day of the month.

**Default:** 1

### **IssueDate**

Issue date for a bond.

### **Face**

Face value of the bond. **Face** has no impact on key rate duration. This calling sequence is preserved for consistency.

**Default:** 100

### **FirstCouponDate**

Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When **FirstCouponDate** and **LastCouponDate** are both specified, **FirstCouponDate** takes precedence in determining the coupon payment structure.

**Default:** If you do not specify a **FirstCouponDate**, the cash flow payment dates are determined from other inputs.

### **LastCouponDate**

Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified **FirstCouponDate**, a specified **LastCouponDate** determines the coupon structure of the bond. The coupon structure of

a bond is truncated at the **LastCouponDate**, regardless of where it falls, and is followed only by the bond's maturity cash flow date.

**Default:** If you do not specify a **LastCouponDate**, the cash flow payment dates are determined from other inputs.

### **Period**

Number of coupons payments per year. Possible values include:

- 0
- 1
- 2
- 3
- 4
- 6
- 12

**Default:** 2

### **ReinvestBasis**

Day count basis for reinvestment rate.

**Default:** Identical to **RepoBasis**.

### **ReinvestRate**

Compounding convention for reinvestment rate.

**Default:** Identical to **RepoRate**.

### **RepoBasis**

Day count basis for **RepoRate**.

**Default:** 2

### **StartDate**

Date when a bond actually starts (the date from which a bond cash flow is considered). To make an instrument forward-starting, specify this date as a future date. If you do not specify **StartDate**, the effective start date is the **Settle** date.

## Output Arguments

### **FutPrice**

Quoted futures price, per \$100 notional.

### **AccrInt**

Accrued interest due at delivery date, per \$100 notional.

## Definitions

`bndfutprice` computes the price of a bond futures contract for one or more bonds, given a repo rate, and bond properties, including the bond conversion factor. The default behavior is that the coupon reinvestment rate matches the repo rate. However, you can specify a separate reinvestment rate using optional inputs.

## Examples

### **Compute the Price For a Bond Future**

This example shows how to compute the price for a bond future using the following data.

```
bndfutprice(.064, 129, '9/21/2000', '12/29/2000', 1.3136, .0875, '8/15/2020')
```

```
ans =
```

```
98.1516
```

## More About

- “Bond Futures”

## References

Burghardt, G., T. Belton, M. Lane, and J. Papa, *The Treasury Bond Basis*, McGraw-Hill, 2005.

Krgin, Dragomir, *Handbook of Global Fixed Income Calculations*, John Wiley & Sons, 2002.

**See Also**

bndfutimprepo | convfactor

# bootstrap

Bootstrap interest-rate curve from market data

## Class

@IRDataCurve

## Syntax

```
Dcurve = IRDataCurve.bootstrap(Type, Settle, InstrumentTypes,
Instruments)
```

```
Dcurve = IRDataCurve.bootstrap(Type, Settle, InstrumentTypes,
Instruments, 'Parameter1', Value1, 'Parameter2', Value2, ...)
```

## Arguments

Type	Type of interest-rate curve. Acceptable values are: <b>discount</b> , <b>forward</b> , or <b>zero</b> .
Settle	Scalar or column vector of settlement dates.
InstrumentTypes	N-by-1 cell array (where N is the number of instruments) indicating what kind of instrument is in the <b>Instruments</b> matrix. Acceptable values are <b>deposit</b> , <b>futures</b> , <b>swap</b> , <b>bond</b> , and <b>fra</b> .
Instruments	N-by-3 data matrix for <b>Instruments</b> where the first column is <b>Settle</b> date, the second column is <b>Maturity</b> , and the third column is the market quote (dates must be MATLAB date numbers). The market quote represents the following for each instrument: <ul style="list-style-type: none"> <li>• <b>deposit</b>: rate</li> <li>• <b>futures</b>: price (e.g., 9628.54)</li> <li>• <b>swap</b>: rate</li> </ul>



	<ul style="list-style-type: none"><li>• <code>bond</code>: clean price</li><li>• <code>fra</code>: forward rate</li></ul> <hr/> <p><b>Note:</b> When using <code>fra</code>, the first column of N-by-3 data matrix for <code>Instruments</code> is the start dates for the forward rate agreement (FRA).</p>
Compounding	<p>(Optional) Scalar that sets the compounding frequency per year for an <code>IRDataCurve</code> object:</p> <ul style="list-style-type: none"><li>• -1 = Continuous compounding</li><li>• 1 = Annual compounding</li><li>• 2 = Semiannual compounding (default)</li><li>• 3 = Compounding three times per year</li><li>• 4 = Quarterly compounding</li><li>• 6 = Bimonthly compounding</li><li>• 12 = Monthly compounding</li></ul> <hr/> <p><b>Note:</b> Simple interest can be specified for an instrument by specifying the <code>Compounding</code> value as 0.</p>

Basis	<p>(Optional) Day-count basis of the interest-rate curve. A scalar of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
InterpMethod	<p>(Optional) Values are:</p> <ul style="list-style-type: none"> <li>• 'linear' — Linear interpolation (default).</li> <li>• 'constant' — Piecewise constant interpolation.</li> <li>• 'pchip' — Piecewise cubic Hermite interpolation.</li> <li>• 'spline' — Cubic spline interpolation.</li> </ul>
IRBootstrapOptionsObj	<p>(Optional) An <code>IRBootstrapOptions</code> object.</p>
DiscountCurve	<p>(Optional) <code>RateSpec</code> for a curve used to discount the cash flows.</p>

## Instrument Parameters

For each bond **Instrument**, you can specify the following additional instrument parameters as parameter/value pairs. For example, **InstrumentBasis** distinguishes a bond instrument's **Basis** value from the curve's **Basis** value. For instruments of type **deposit**, **futures**, or **swap** the **Basis** and **Compounding** values must be identical for each instance of the instrument.

<b>InstrumentCouponRate</b>	(Optional) Decimal number indicating the annual percentage rate used to determine the coupons payable on an instrument.
<b>InstrumentPeriod</b>	(Optional) Coupons per year of the instrument. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
<b>InstrumentBasis</b>	<p>(Optional) Day-count basis of the instrument. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<b>InstrumentEndMonthRule</b>	(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month

	having 30 or fewer days. 0 = ignore rule, meaning that an instrument's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that an instrument's coupon payment date is always the last actual day of the month.
<b>InstrumentIssueDate</b>	(Optional) Date when an instrument was issued.
<b>InstrumentFirstCoupon</b>	(Optional) Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When <b>FirstCouponDate</b> and <b>LastCouponDate</b> are both specified, <b>FirstCouponDate</b> takes precedence in determining the coupon payment structure. If you do not specify a <b>FirstCouponDate</b> , the cash flow payment dates are determined from other inputs.
<b>InstrumentLastCouponD</b>	(Optional) Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified <b>FirstCouponDate</b> , a specified <b>LastCouponDate</b> determines the coupon structure of the bond. The coupon structure of a bond is truncated at the <b>LastCouponDate</b> , regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a <b>LastCouponDate</b> , the cash flow payment dates are determined from other inputs.
<b>InstrumentFace</b>	(Optional) Face or par value. Default = 100.

**Note:** When using **Instrument** parameter/value pairs, you can specify simple interest for an **Instrument** by specifying the **InstrumentPeriod** value as 0. If **InstrumentBasis** and **InstrumentPeriod** are not specified for an **Instrument**, the following default values are used:

- **deposit** instrument uses **Basis** as 2 (act/360) and **Compounding** is 0 (simple interest).
- **futures** instrument uses **Basis** as 2 (act/360) and **Compounding** is 4 (quarterly).
- **swap** instrument uses **Basis** as 2 (act/360) and **Compounding** is 2.
- **bond** instrument uses **Basis** as 0 (act/act) and **Compounding** is 2.
- **FRA** instrument uses **Basis** as 2 (act/360) and **Compounding** is 4 (quarterly).

## Description

`Dcurve = IRDataCurve.bootstrap(Type, Settle, InstrumentTypes, Instruments, 'Parameter1', Value1, 'Parameter2', Value2, ...)` bootstraps an interest-rate curve from market data. The dates of the bootstrapped curve correspond to the maturity dates of the input instruments. You must enter the optional arguments for `Basis`, `Compounding`, `Interpmethod`, `IRBootstrapOptionsObj`, and `DiscountCurve` as parameter/value pairs.

## Examples

### Use the bootstrap Method to Create an IRDataCurve Object

In this bootstrapping example, `InstrumentTypes`, `Instruments`, and a `Settle` date are defined:

```
InstrumentTypes = {'Deposit';'Deposit';...
'Futures';'Futures';'Futures';'Futures';'Futures';'Futures';...
'Swap';'Swap';'Swap';'Swap'};

Instruments = [datenum('08/10/2007'),datenum('09/17/2007'),.0532000; ...
datenum('08/10/2007'),datenum('11/17/2007'),.0535866; ...
datenum('08/08/2007'),datenum('19-Dec-2007'),9485; ...
datenum('08/08/2007'),datenum('19-Mar-2008'),9502; ...
datenum('08/08/2007'),datenum('18-Jun-2008'),9509.5; ...
datenum('08/08/2007'),datenum('17-Sep-2008'),9509; ...
datenum('08/08/2007'),datenum('17-Dec-2008'),9505.5; ...
datenum('08/08/2007'),datenum('18-Mar-2009'),9501; ...
datenum('08/08/2007'),datenum('08/08/2014'),.0530; ...
datenum('08/08/2007'),datenum('08/08/2019'),.0551; ...
datenum('08/08/2007'),datenum('08/08/2027'),.0565; ...
datenum('08/08/2007'),datenum('08/08/2037'),.0566];

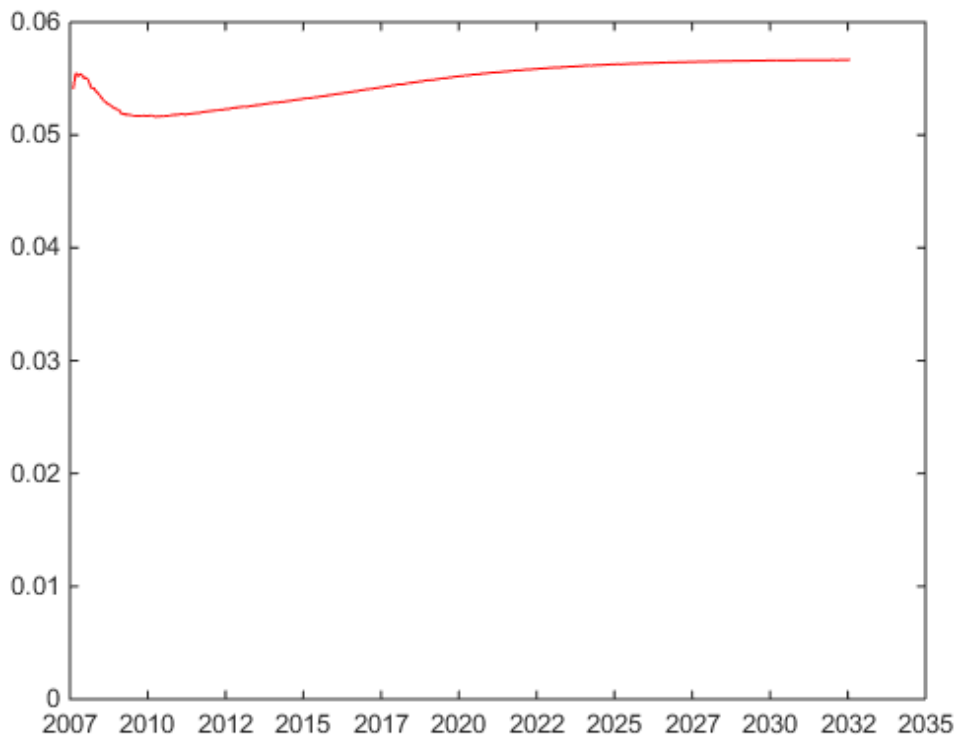
CurveSettle = datenum('08/10/2007');
```

Use the `bootstrap` method to create an `IRDataCurve` object.

```
bootModel = IRDataCurve.bootstrap('Forward', CurveSettle, ...
InstrumentTypes, Instruments,'InterpMethod','pchip');
```

To create the plot for the bootstrapped market data:

```
PlottingDates = (datenum('08/11/2007'):30:CurveSettle+365*25)';
plot(PlottingDates, getParYields(bootModel, PlottingDates), 'r')
ylim([0 .06])
datetick
```



### Use the bootstrap Method to Create an IRDataCurve Object That Includes Bonds

In this bootstrapping example, InstrumentTypes, Instruments, and a Settle date are defined:

```
CurveSettle = datenum('8-Mar-2010');

InstrumentTypes = {'Deposit'; 'Deposit'; 'Deposit'; 'Deposit'; ...
                  'Futures'; 'Futures'; 'Futures'; 'Futures'; 'Swap'; 'Swap'; 'Bond'; 'Bond'};
```

```
Instruments = [datenum('8-Mar-2010'),datenum('8-Apr-2010'),.003; ...
    datenum('8-Mar-2010'),datenum('8-Jun-2010'),.005; ...
    datenum('8-Mar-2010'),datenum('8-Sep-2010'),.007; ...
    datenum('8-Mar-2010'),datenum('8-Mar-2011'),.009; ...
    datenum('8-Mar-2010'),datenum('18-Jun-2011'),9840; ...
    datenum('8-Mar-2010'),datenum('17-Sep-2011'),9820; ...
    datenum('8-Mar-2010'),datenum('17-Dec-2011'),9810; ...
    datenum('8-Mar-2010'),datenum('18-Mar-2012'),9800; ...
    datenum('8-Mar-2010'),datenum('8-Mar-2015'),.025; ...
    datenum('8-Mar-2010'),datenum('8-Mar-2020'),.035; ...
    datenum('8-Mar-2010'),datenum('8-Mar-2030'),99; ...
    datenum('8-Mar-2010'),datenum('8-Mar-2040'),101];
```

When bonds are used, `InstrumentCouponRate` must be specified:

```
InstrumentCouponRate = [zeros(10,1);.045;.05];
```

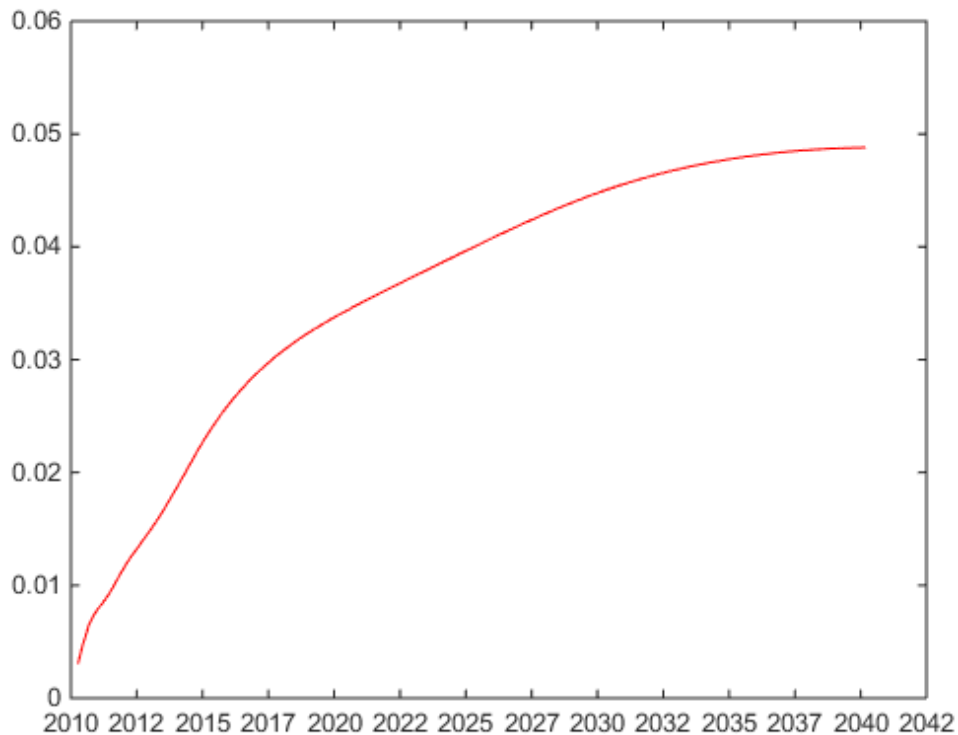
Note, for parameters that are only applicable to bonds (e.g.: `InstrumentFirstCouponDate`, `InstrumentLastCouponDate`, `InstrumentIssueDate`, `InstrumentFace`) the entries for non-bond instruments (deposits and futures) are ignored.

Use the `bootstrap` method to create an `IRDataCurve` object.

```
bootModel = IRDataCurve.bootstrap('Forward', CurveSettle, ...
    InstrumentTypes, Instruments, 'InterpMethod', 'pchip', ...
    'InstrumentCouponRate', InstrumentCouponRate);
```

To create the plot for the bootstrapped market data:

```
PlottingDates = daysadd(CurveSettle,30:30:30*360,1);
plot(PlottingDates, getParYields(bootModel, PlottingDates), 'r')
ylim([0 .06])
datetick
```



- “IRDataCurve Bootstrapping Based on Market Instruments” on page 9-7
- “Dual Curve Bootstrapping”

### See Also

“@IRDataCurve” | “@IRBootstrapOptions” | toRateSpec



# cbprice

Price convertible bond

## Syntax

```
[CbMatrix, UndMatrix, DebtMatrix, EqtyMatrix] =  
cbprice(RiskFreeRate, StaticSpread, Sigma, Price, ConvRatio,  
NumSteps, IssueDate, Settle, Maturity, CouponRate)  
[CbMatrix, UndMatrix, DebtMatrix, EqtyMatrix] =  
cbprice(RiskFreeRate, StaticSpread, Sigma, Price, ConvRatio,  
NumSteps, IssueDate, Settle, Maturity, CouponRate,  
Name, Value)
```

## Description

```
[CbMatrix, UndMatrix, DebtMatrix, EqtyMatrix] =  
cbprice(RiskFreeRate, StaticSpread, Sigma, Price, ConvRatio,  
NumSteps, IssueDate, Settle, Maturity, CouponRate) price a convertible bond  
with a one-factor lattice method.
```

```
[CbMatrix, UndMatrix, DebtMatrix, EqtyMatrix] =  
cbprice(RiskFreeRate, StaticSpread, Sigma, Price, ConvRatio,  
NumSteps, IssueDate, Settle, Maturity, CouponRate,  
Name, Value) price a convertible bond with a one-factor lattice method with additional  
options specified by one or more Name, Value pair arguments.
```

## Input Arguments

### RiskFreeRate

Annual yield of the risk-free bond with the same maturity as the convertible, compounded continuously. Scalar value of risk-free rates is in decimal. (Recommended value is the yield of a risk-free bond with the same maturity as the convertible.)

**StaticSpread**

Scalar value of the constant spread to risk-free rate. Adding `StaticSpread` to the `RiskFreeRate` produces the issuer's yield, which reflects the credit risk.

**Sigma**

Scalar value of the annual volatility environment in decimal.

**Price**

Scalar value of the price of the asset at the settlement or valuation date.

**ConvRatio**

Scalar value of the number of assets convertible to one bond. `cbprice` expects the `ConvRatio` to be in terms of a \$100 face or par value.

**NumSteps**

Scalar value of the number of steps within the binomial tree.

**IssueDate**

Scalar value of the issue date of the convertible bond.

**Settle**

Scalar value of the settlement date of the convertible bond.

**Maturity**

Scalar value of the maturity date of the convertible bond.

**CouponRate**

Scalar value of the coupon rate in decimal form or a C-by-2 vector of dates and associated coupon rates.

**Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single

quotes (' '). You can specify several name and value pair arguments in any order as Name1, Value1, ..., NameN, ValueN.

### 'Basis'

Day-count basis of the bond. A vector of integers.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 0 (actual/actual)

### 'CallType'

Scalar value for the call type. Values are 0 for a call on cash price, or 1 for a call on clean price.

**Default:** 0 (cash price)

### 'CallInfo'

Two-column matrix containing the call information. The first column is the call dates and the second column is the call prices for every \$100 face of the bond. The call, in the amount of call prices, is activated *after* the corresponding call date.

**Default:** No call feature

**'ConvInfo'**

Two-column matrix containing convertible information. The first column is the convertible dates and the second column is whether the issue is convertible or not.

**Default:** Bond is always convertible

**'DividendInfo'**

Two-column matrix of dividend information. The first column is the ex-dividend date and the second column is the corresponding amount. Enter any amount known at any time; only the amounts that are within the lifespan of the option are used. If the **DividendType** is 2, **DividendInfo** is a 1-by-2 matrix where the first entry is the **Settle** date and the second entry is the continuous dividend yield.

**Default:** No dividend

**'DividendType'**

Scalar value for dividend type. Values are:

- 0 — Dollar dividend
- 1 — Dividend yield
- 2 — Continuous dividend yield

**Default:** 0 (Dollar dividend)

**'EndMonthRule'**

NINST-by-1 vector for end-of-month rule. Values are 1 (on, in effect) and 0 (off, not in effect).

**Default:** 1 (on, in effect)

**'Period'**

Scalar value for number of coupon payments. Values are:

- 1 — One coupon per year

- 2 — Semiannual
- 3 — Three times a year
- 4 — Quarterly
- 6 — Bimonthly compounding
- 12 — Monthly

**Default:** 2 (Semiannual)

#### **'PutInfo'**

Two-column matrix containing put information. The first column is the put dates and the second column is the put prices for every \$100 face of the bond. The put, in the amount of put prices, is activated *after* the corresponding put date.

**Default:** No put feature

#### **'PutType'**

Scalar value for put type. Value are 0 for a put on cash price or 1 for a put on clean price.

**Default:** 0 (put on cash price)

#### **'TreeType'**

Scalar value for tree type. Values are 0 for binomial lattice or 1 for trinomial lattice.

**Default:** 0 (binomial lattice)

## **Output Arguments**

### **CbMatrix**

Matrix of CB prices in binomial format. Price of convertible is `CbMatrix(1,1)`.

### **UndMatrix**

Matrix of stock prices in binomial format.

**DebtMatrix**

Matrix of CB debt component in binomial format.

**EqtyMatrix**

Matrix of CB equity component in binomial format.

## Examples

**Price a Convertible Bond**

This example shows how to price a convertible bond that matures in 2035 and is callable after 2025.

Define the convertible bond characteristics.

```
Settle = datenum('20-Sep-2013');
IssueDate = datenum('15-Dec-2005');
Maturity = datenum('15-Dec-2035');
CouponRate = .03;
ConvRatio = 3.4; % Per 100 face value
CallDate = datenum('15-Dec-2025');
CallPrice = 100;
RiskFreeRate = 0.03;
StockPrice = 24;
Volatility = 0.2;
CreditSpread = 0.005;
DivType = 2; % Continuous
DivYield = 0.04;
```

Calculate the price for the convertible bond.

```
NumberSteps = 100;
```

```
ConvPrice = cbprice(RiskFreeRate,CreditSpread,Volatility,StockPrice,ConvRatio,...
NumberSteps,IssueDate,Settle,Maturity,CouponRate,'DividendType',DivType,...
'DividendInfo',[Settle DivYield],'CallInfo',[CallDate CallPrice]);
```

**Price a Convertible Bond With a One-Factor Lattice Method**

This example shows how to perform a spread effect analysis of a 4% coupon convertible bond callable at 110 at the end of the second year, maturing at par in 5 years, with yield

to maturity of 5%, and spread (of yield to maturity versus 5-year treasury) of 0, 50, 100, and 150 basis points. The underlying stock pays no dividend.

```

RiskFreeRate = 0.05;
Sigma        = 0.3;
ConvRatio    = 1;
NumSteps     = 200;
IssueDate    = '2-Jan-2002';
Settle       = '2-Jan-2002';
Maturity     = '2-Jan-2007';
CouponRate   = 0.04;
Period       = 2;
Basis        = 1;
EndMonthRule = 1;
DividendType = 0;
DividendInfo = [];
CallInfo     = [datenum('2-Jan-2004') , 110];
CallType     = 1;
TreeType     = 1;
Spreads      = 0:0.005:0.015;
Prices       = 40:10:140;
stock        = repmat(Prices',1,length(Spreads));

convprice    = zeros(length(Prices),length(Spreads));

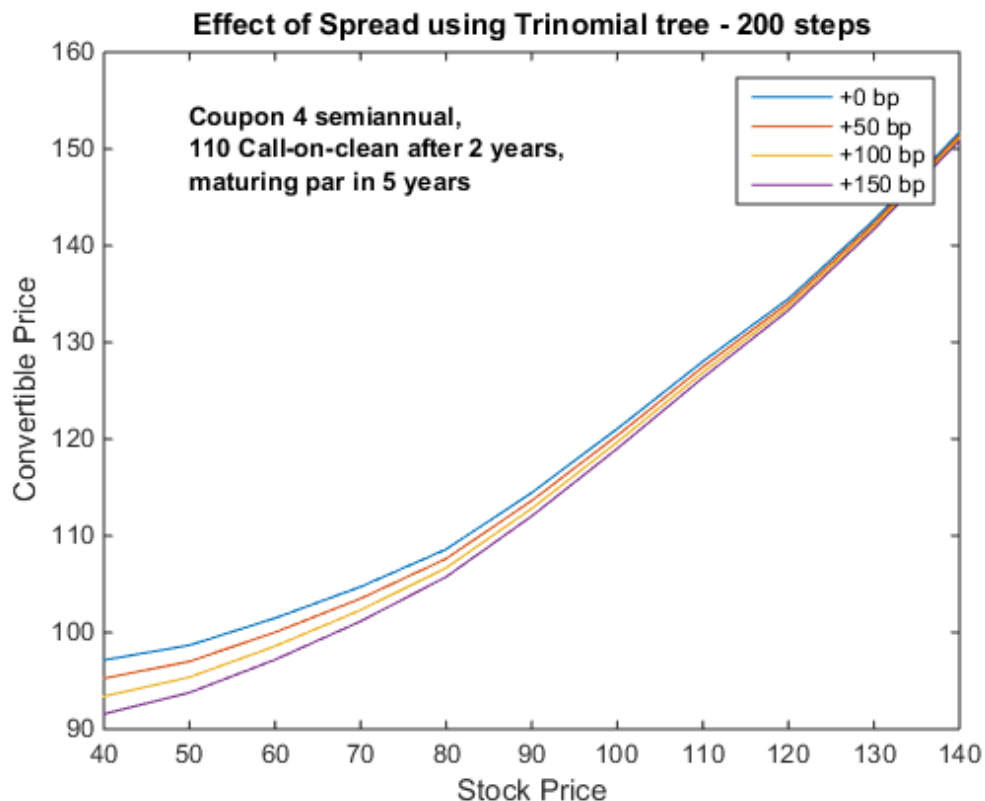
for spreadidx = 1:length(Spreads)
    for priceidx = 1:length(Prices)
        [CbMatrix, UndMatrix, DebtMatrix, EqtyMatrix] = ...
            cbprice(RiskFreeRate, Spreads(spreadidx), Sigma, Prices(priceidx), ...
                ConvRatio, NumSteps, IssueDate, Settle, ...
                Maturity, CouponRate, Period, Basis, EndMonthRule, ...
                DividendType, DividendInfo, CallType, CallInfo, TreeType);

        convprice(priceidx,spreadidx) = CbMatrix(1,1);
    end
end

plot(stock,convprice);
legend({'+0 bp'; '+50 bp'; '+100 bp'; '+150 bp'});
title ('Effect of Spread using Trinomial tree - 200 steps')
xlabel('Stock Price');
ylabel('Convertible Price');
text(50, 150, ['Coupon 4 semiannual,', sprintf('\n'), ...
    '110 Call-on-clean after 2 years,' sprintf('\n'), ...

```

```
'maturing par in 5 years'], 'fontweight', 'Bold')
```



- “Convertible Bond Valuation”

## More About

### Convertible Bond

A convertible bond (CB) is a debt instrument that you can convert into a predetermined amount of the issuing company's equity at certain times before the bond's maturity. In addition to standard bond features (for example, maturity date, face value, coupon), a convertible bond often has callable and puttable features.



## References

Andersen, L. and D. Buffum, "Calibration and implementation of convertible bonds models," Working paper, Banc of America Securities, 2003.

Ayache, E., P.A. Forsyth, and K.R. Vetzal, "Valuation of Convertible Bonds with Credit Risk," *Journal of Derivatives*, 11 (Fall 2003), 9-29.

Tsiveriotis, K. and C. Fernandes, "Valuing Convertible Bonds with Credit Risk," *Journal of Fixed Income* 8, 95-102, 1998

Zabolotnyuk, Yuriy, Jones, Robert A. and Veld, Chris H., "An Empirical Comparison of Convertible Bond Valuation Models," (October 15, 2009). Available at SSRN: <http://ssrn.com/abstract=994805>.

## cdsbootstrap

Bootstrap default probability curve from credit default swap market quotes

### Syntax

```
[ProbData, HazData] = cdsbootstrap(ZeroData, MarketData, Settle)
[ProbData, HazData] = cdsbootstrap(ZeroData, MarketData, Settle, Name, Value)
```

### Description

[ProbData, HazData] = cdsbootstrap(ZeroData, MarketData, Settle) bootstraps the default probability curve using credit default swap (CDS) market quotes. The market quotes can be expressed as a list of maturity dates and corresponding CDS market spreads, or as a list of maturities and corresponding upfronts and standard spreads for standard CDS contracts. The estimation uses the standard model of the survival probability.

[ProbData, HazData] = cdsbootstrap(ZeroData, MarketData, Settle, Name, Value) bootstraps the default probability curve using CDS market quotes with additional options specified by one or more Name, Value pair arguments. The market quotes can be expressed as a list of maturity dates and corresponding CDS market spreads, or as a list of maturities and corresponding upfronts and standard spreads for standard CDS contracts. The estimation uses the standard model of the survival probability.

### Input Arguments

#### ZeroData

M-by-2 vector of dates and zero rates or an IRDataCurve object of zero rates.

#### MarketData

N-by-2 matrix of dates and corresponding market spreads or N-by-3 matrix of dates, upfronts, and standard spreads of CDS contracts.

## Settle

Settlement date is a serial date number or date string. This must be earlier than or equal to the dates in `MarketData`.

## Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name`, `Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1, Value1, ..., NameN, ValueN`.

---

**Note:** Any optional input of size N-by-1 is also acceptable as an array of size 1-by-N, or as a single value applicable to all contracts. Single values are internally expanded to an array of size N-by-1.

---

### 'Basis'

N-by-1 vector of day-count basis of the CDS:

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 2 (actual/360)

**'BusDayConvention'**

String or N-by-1 cell array of strings of business day conventions. Values are:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

**'PayAccruedPremium'**

N-by-1 vector of Boolean flags, **True** (default), if accrued premiums are paid upon default, **False** otherwise.

**Default:** True

**'Period'**

N-by-1 vector of the number of premiums per year of the CDS. Allowed values are 1, 2, 3, 4, 6, and 12.

**Default:** 4

**'ProbDates'**

P-by-1 vector of dates for ProbData.

**Default:** Column of dates in MarketData

**'RecoveryRate'**

N-by-1 vector of recovery rates, expressed as a decimal from 0 to 1.

**Default:** 0.4

**'TimeStep'**

Positive integer indicating the number of days to take as time step for the numerical integration.

**Default:** 10 (days)

**'ZeroBasis'**

Basis of the zero curve. Choices are identical to **Basis**.

**Default:** 0 (actual/actual)

**'ZeroCompounding'**

Compounding frequency of the zero curve. Allowed values are:

- 1 — Annual compounding
- 2 — Semiannual compounding
- 3 — Compounding three times per year
- 4 — Quarterly compounding
- 6 — Bimonthly compounding
- 12 — Monthly compounding
- -1 — Continuous compounding

---

**Note:** When **ZeroData** is an **IRDataCurve** object, the arguments **ZeroCompounding** and **ZeroBasis** are implicit in **ZeroData** and are redundant inside this function. In that case, specify these optional arguments when constructing the **IRDataCurve** object before calling this function.

---

**Default:** 2 (Semiannual compounding)

## Output Arguments

**ProbData**

P-by-2 matrix with dates and corresponding cumulative default probability values. The dates match those in **MarketData**, unless the optional input parameter **ProbDates** is provided.

## HazData

N-by-2 matrix with dates and corresponding hazard rate values for the standard survival probability model. The dates match those in `MarketData`.

---

**Note:** A warning is displayed when non-monotone default probabilities (i.e., negative hazard rates) are found.

---

## Examples

### Bootstrap Default Probability Curve from Credit Default Swap Market Quotes

This example shows how to use `cdsbootstrap` with market quotes for CDS contracts to generate `ProbData` and `HazData` values.

```
Settle = '17-Jul-2009'; % valuation date for the CDS
Spread_Time = [1 2 3 5 7]';
Spread = [140 175 210 265 310]';
Market_Dates = daysadd(datenum(Settle),360*Spread_Time,1);
MarketData = [Market_Dates Spread];
Zero_Time = [.5 1 2 3 4 5]';
Zero_Rate = [1.35 1.43 1.9 2.47 2.936 3.311]'/100;
Zero_Dates = daysadd(datenum(Settle),360*Zero_Time,1);
ZeroData = [Zero_Dates Zero_Rate];

[ProbData,HazData] = cdsbootstrap(ZeroData,MarketData,Settle)
```

ProbData =

```
1.0e+05 *
    7.3434    0.0000
    7.3470    0.0000
    7.3507    0.0000
    7.3580    0.0000
    7.3653    0.0000
```

HazData =

```

1.0e+05 *
7.3434  0.0000
7.3470  0.0000
7.3507  0.0000
7.3580  0.0000
7.3653  0.0000

```

- “Credit Default Swap (CDS)” on page 8-2

## More About

### Algorithms

If the time to default is denoted by  $\tau$ , the default probability curve, or function,  $PD(t)$ , and its complement, the survival function  $Q(t)$ , are given by:

$$PD(t) = P[\tau \leq t] = 1 - P[\tau > t] = 1 - Q(t)$$

In the standard model, the survival probability is defined in terms of a piecewise constant hazard rate  $h(t)$ . For example, if  $h(t) =$

$$\lambda_1, \text{ for } 0 \leq t \leq t_1$$

$$\lambda_2, \text{ for } t_1 < t \leq t_2$$

$$\lambda_3, \text{ for } t_2 < t$$

then the survival function is given by  $Q(t) =$

$$e^{-\lambda_1 t}, \text{ for } 0 \leq t \leq t_1$$

$$e^{-\lambda_1 t_1 - \lambda_2(t-t_1)}, \text{ for } t_1 < t \leq t_2$$

$$e^{-\lambda_1 t_1 - \lambda_2(t_2-t_1) - \lambda_3(t-t_2)}, \text{ for } t_2 < t$$

Given  $n$  market dates  $t_1, \dots, t_n$  and corresponding market CDS spreads  $S_1, \dots, S_n$ , `cbsbootstrap` calibrates the parameters  $\lambda_1, \dots, \lambda_n$  and evaluates  $PD(t)$  on the market dates, or an optional user-defined set of dates.

## References

Beumee, J., D. Brigo, D. Schiemert, and G. Stoye. “Charting a Course Through the CDS Big Bang,” *Fitch Solutions, Quantitative Research*, Global Special Report. April 7, 2009.

Hull, J., and A. White, “Valuing Credit Default Swaps I: No Counterparty Default Risk,” *Journal of Derivatives* 8, 29-40.

O'Kane, D. and S. Turnbull, “Valuation of Credit Default Swaps.” *Lehman Brothers, Fixed Income Quantitative Credit Research*, April, 2003.

## See Also

“@IRDataCurve” | `cdsprice` | `cdsrpv01` | `cdsspread`



# cdsoptprice

Price payer and receiver credit default swap options

## Syntax

```
[Payer, Receiver] = cdsoptrprice(ZeroData, ProbData, Settle,  
OptionMaturity, CDSMaturity, Strike, SpreadVol)  
[Payer, Receiver] = cdsoptrprice(ZeroData, ProbData, Settle,  
OptionMaturity, CDSMaturity, Strike, SpreadVol,  
Name, Value)
```

## Description

[Payer, Receiver] = cdsoptrprice(ZeroData, ProbData, Settle, OptionMaturity, CDSMaturity, Strike, SpreadVol) computes the price of payer and receiver credit default swap options.

[Payer, Receiver] = cdsoptrprice(ZeroData, ProbData, Settle, OptionMaturity, CDSMaturity, Strike, SpreadVol, Name, Value) computes the price of payer and receiver credit default swap options with additional options specified by one or more Name, Value pair arguments.

## Input Arguments

### ZeroData

M-by-2 vector of dates and zero rates or an IRDataCurve object of zero rates.

### ProbData

P-by-2 array of dates and default probabilities.

### Settle

Settlement date is a serial date number or date string. Settle must be earlier than the maturity date.

**OptionMaturity**

N-by-1 vector of serial date numbers or date strings containing the option maturity dates.

**CDSMaturity**

N-by-1 vector of serial date numbers or date strings containing the CDS maturity dates.

**Strike**

N-by-1 vector of option strikes expressed in basis points.

**SpreadVol**

N-by-1 vector of annualized credit spread volatilities expressed as a positive decimal number.

**Name-Value Pair Arguments**

Specify optional comma-separated pairs of `Name`,`Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

---

**Note:** Any optional input of size N-by-1 is also acceptable as an array of size 1-by-N, or as a single value applicable to all contracts. Single values are internally expanded to an array of size N-by-1.

---

**'AdjustedForwardSpread'**

N-by-1 vector of adjusted forward spreads (in basis points) to be used when pricing CDS index options.

**Default:** unadjusted forward spread normally used for single-name CDS options

**'Basis'**

N-by-1 vector of contract day-count basis:

- 0 = actual/actual

- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 2 (actual/360)

### 'BusDayConvention'

String or N-by-1 cell array of strings of business day conventions. Values are:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

### 'Knockout'

N-by-1 vector of Boolean flags. If the credit default swaptions is a knockout, the flag is True, otherwise it is False.

**Default:** False

**'PayAccruedPremium'**

N-by-1 vector of Boolean flags. If accrued premiums are paid upon default, the flag is `True`, otherwise it is `False`.

**Default:** `True`

**'Period'**

N-by-1 vector of the number of premiums per year of the CDS. Allowed values are 1, 2, 3, 4, 6, and 12.

**Default:** `4`

**'RecoveryRate'**

N-by-1 vector of recovery rates, expressed as a decimal from 0 to 1.

**Default:** `0.4`

**'ZeroBasis'**

Basis of the zero curve. Choices are identical to `Basis`.

**Default:** `0` (actual/actual)

**'ZeroCompounding'**

Compounding frequency of the zero curve. Allowed values are:

- 1 — Annual compounding
- 2 — Semiannual compounding
- 3 — Compounding three times per year
- 4 — Quarterly compounding
- 6 — Bimonthly compounding
- 12 — Monthly compounding
- -1 — Continuous compounding

---

**Note:** When `ZeroData` is an `IRDataCurve` object, the arguments `ZeroCompounding` and `ZeroBasis` are implicit in `ZeroData` and are redundant inside this function. In that

case, specify these optional arguments when constructing the `IRDataCurve` object before calling this function.

---

**Default:** 2 (Semiannual compounding)

## Output Arguments

### Payer

N-by-1 vector of prices for payer swap options in `Basis` points.

### Receiver

N-by-1 vector of prices for receiver swap options in `Basis` points.

## Examples

### Obtain Payer and Receiver Values for a Credit Default Swap Option

Use `cdsoptprice` to generate `Payer` and `Receiver` values for a credit default swap option.

```
Settle = datenum('12-Jun-2012');
OptionMaturity = datenum('20-Sep-2012');
CDSMaturity = datenum('20-Sep-2017');
OptionStrike = 200;
SpreadVolatility = .4;

Zero_Time = [.5 1 2 3 4 5]';
Zero_Rate = [.5 .75 1.5 1.7 1.9 2.2]'/100;
Zero_Dates = daysadd(Settle,360*Zero_Time,1);
ZeroData = [Zero_Dates Zero_Rate];

Market_Time = [1 2 3 5 7 10]';
Market_Rate = [100 120 145 220 245 270]';
Market_Dates = daysadd(Settle,360*Market_Time,1);
MarketData = [Market_Dates Market_Rate];

ProbData = cdsbootstrap(ZeroData, MarketData, Settle);
```

```
[Payer,Receiver] = cdsoptprice(ZeroData, ProbData, Settle,...  
OptionMaturity, CDSMaturity, OptionStrike, SpreadVolatility)
```

```
Payer =
```

```
223.5780
```

```
Receiver =
```

```
22.7460
```

- “Pricing a Single-Name CDS Option”
- “Pricing a CDS Index Option”

## More About

### Credit Default Swap Option

A credit default swap (CDS) option, or credit default swaption, is a contract that provides the option holder with the right, but not the obligation, to enter into a credit default swap in the future. CDS options can either be payer swaptions or receiver swaptions. In a payer swaption, the option holder has the right to enter into a CDS in which they are paying premiums and in a receiver swaptions, the option holder is receiving premiums.

### Algorithms

The payer and receiver credit default swap options are computed using the Black's model as described in O'Kane [1]:

$$V_{Pay(Knockout)} = RPV01(t, t_E, T)(F\Phi(d_1) - K\Phi(d_2))$$

$$V_{Rec(Knockout)} = RPV01(t, t_E, T)(K\Phi(-d_2) - F\Phi(-d_1))$$

$$d_1 = \frac{\ln\left(\frac{F}{K}\right) + \frac{1}{2}\sigma^2(t_E - t)}{\sigma\sqrt{t_E - t}}$$

$$d_2 = d_1 - \sigma \sqrt{t_E - t}$$

$$V_{Pay(Non-Knockout)} = V_{Pay(Knockout)} + FEP$$

$$V_{Pay(Non-Knockout)} = V_{Rec(Knockout)}$$

where

$RPV01$  is the risky present value of a basis point (see `cdsrpv01`).

$\Phi$  is the normal cumulative distribution function.

$\sigma$  is the spread volatility.

$t$  is the valuation date.

$t_E$  is the option expiry date.

$T$  is the CDS maturity date.

$F$  is the forward spread (from option expiry to CDS maturity).

$K$  is the strike spread.

$FEP$  is the front end protection (from option initiation to option expiry).

- “Credit Default Swap Option” on page 8-49

## References

[1] O’Kane, D., *Modelling Single-name and Multi-name Credit Derivatives*, Wiley, 2008, pp. 156–169.

## See Also

“@IRDataCurve” | `cdsbootstrap` | `cdsprice` | `cdsrpv01` | `cdsspread`

## cdsprice

Determine price for credit default swap

### Syntax

```
[Price, AccPrem, PaymentDates, PaymentTimes,  
PaymentCF] = cdsprice(ZeroData, ProbData, Settle,  
Maturity, ContractSpread)  
[Price, AccPrem, PaymentDates, PaymentTimes,  
PaymentCF] = cdsprice(ZeroData, ProbData,  
Settle, Maturity, ContractSpread,  
Name, Value)
```

### Description

[Price, AccPrem, PaymentDates, PaymentTimes, PaymentCF] = cdsprice(ZeroData, ProbData, Settle, Maturity, ContractSpread) computes the price, or the mark-to-market value for CDS instruments.

[Price, AccPrem, PaymentDates, PaymentTimes, PaymentCF] = cdsprice(ZeroData, ProbData, Settle, Maturity, ContractSpread, Name, Value) computes the price, or the mark-to-market value for CDS instruments with additional options specified by one or more Name, Value pair arguments.

### Input Arguments

#### ZeroData

M-by-2 vector of dates and zero rates or an `IRDataCurve` object of zero rates.

#### ProbData

P-by-2 array of dates and default probabilities.



## Settle

Settlement date is a serial date number or date string. This must be earlier than or equal to the Maturity dates.

## Maturity

N-by-1 vector of serial date numbers or date strings containing the maturity dates.

## ContractSpread

N-by-1 vector of contract spreads, expressed in basis points.

## Name-Value Pair Arguments

Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

---

**Note:** Any optional input of size N-by-1 is also acceptable as an array of size 1-by-N, or as a single value applicable to all contracts. Single values are internally expanded to an array of size N-by-1.

---

## 'Basis'

N-by-1 vector of day-count basis of the CDS:

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)

- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

**Default:** 2 (actual/360)

**'BusDayConvention'**

String or N-by-1 cell array of strings of business day conventions. Values are:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

**'Notional'**

N-by-1 vector of contract notional values. Use positive values for long positions and negative values for short positions.

**Default:** 10MM

**'PayAccruedPremium'**

N-by-1 vector of Boolean flags. **True**, if accrued premiums are paid upon default, **False** otherwise.

**Default:** True

**'Period'**

N-by-1 vector of number of premiums per year of the CDS. Allowed values are 1, 2, 3, 4, 6, and 12.

**Default:** 4

**'RecoveryRate'**

N-by-1 vector of recovery rates, expressed as a decimal from 0 to 1.

**Default:** 0.4

**'TimeStep'**

Positive integer indicating the number of days to take as time step for the numerical integration.

**Default:** 10 (days)

**'ZeroBasis'**

Basis of the zero curve, where the choices are identical to `Basis`.

**Default:** 0 (actual/actual)

**'ZeroCompounding'**

Compounding frequency of the zero curve. Allowed values are:

- 1 — Annual compounding
- 2 — Semiannual compounding
- 3 — Compounding three times per year
- 4 — Quarterly compounding
- 6 — Bimonthly compounding
- 12 — Monthly compounding
- -1 — Continuous compounding

---

**Note:** When `ZeroData` is an `IRDataCurve` object, the arguments `ZeroCompounding` and `ZeroBasis` are implicit in `ZeroData` and are redundant inside this function. In that case, specify these optional arguments when constructing the `IRDataCurve` object before calling this function.

---

**Default:** 2 (Semiannual compounding)

## Output Arguments

### Price

N-by-1 vector of CDS clean prices.

### AccPrem

N-by-1 vector of accrued premiums.

### PaymentDates

N-by-numCF matrix of payment dates.

### PaymentTimes

N-by-numCF matrix of accrual fractions.

### PaymentCF

N-by-numCF matrix of payments.

## Examples

### Determine the Price For a Credit Default Swap

This example shows how to use `cdsprice` to compute the clean price for a CDS contract using the following data.

```
Settle = '17-Jul-2009'; % valuation date for the CDS
Zero_Time = [.5 1 2 3 4 5]';
Zero_Rate = [1.35 1.43 1.9 2.47 2.936 3.311]'/100;
Zero_Dates = daysadd(Settle,360*Zero_Time,1);
ZeroData = [Zero_Dates Zero_Rate];
```

```
ProbData = [daysadd(datenum(Settle),360,1), 0.0247];
Maturity = '20-Sep-2010';
ContractSpread = 135;
```

```
[Price,AccPrem] = cdsprice(ZeroData,ProbData,Settle,Maturity,ContractSpread)
```

Price =  
1.5461e+04

AccPrem =  
10500

- “Credit Default Swap (CDS)” on page 8-2

## More About

### CDS Price

The price or mark-to-market (MtM) value of an existing CDS contract is computed using the following formula:

$$\text{CDS price} = \text{Notional} * (\text{Current Spread} - \text{Contract Spread}) * \text{RPV01}$$

**Current Spread** is the current breakeven spread for a similar contract, according to current market conditions. **RPV01** is the 'risky present value of a basis point,' the present value of the premium payments, taking into consideration the default probability. This formula assumes a long position, and the right side is multiplied by -1 for short positions.

### Algorithms

The premium leg is computed as the product of a spread  $S$  and the risky present value of a basis point (RPV01). The RPV01 is given by:

$$RPV01 = \sum_{j=1}^N Z(t_j) \Delta(t_{j-1}, t_j, B) Q(t_j)$$

when no accrued premiums are paid upon default, and it can be approximated by

$$RPV01 \approx \frac{1}{2} \sum_{j=1}^N Z(t_j) \Delta(t_{j-1}, t_j, B) (Q(t_{j-1}) + Q(t_j))$$

when accrued premiums are paid upon default. Here,  $t_0 = 0$  is the valuation date, and  $t_1, \dots, t_n = T$  are the premium payment dates over the life of the contract,  $T$  is the maturity of the contract,  $Z(t)$  is the discount factor for a payment received at time  $t$ , and  $\Delta(t_{j-1}, t_j, B)$  is a day count between dates  $t_{j-1}$  and  $t_j$  corresponding to a basis  $B$ .

The protection leg of a CDS contract is given by the following formula:

$$\begin{aligned} \text{ProtectionLeg} &= \int_0^T Z(\tau)(1 - R)dPD(\tau) \\ &\approx (1 - R) \sum_{i=1}^M Z(\tau_i)(PD(\tau_i) - PD(\tau_{i-1})) \\ &= (1 - R) \sum_{i=1}^M Z(\tau_i)(Q(\tau_{i-1}) - Q(\tau_i)) \end{aligned}$$

where the integral is approximated with a finite sum over the discretization  $\tau_0 = 0, \tau_1, \dots, \tau_M = T$ .

If the spread of an existing CDS contract is  $S_C$ , and the current breakeven spread for a comparable contract is  $S_0$ , the current price, or mark-to-market value of the contract is given by:

$$\text{MtM} = \text{Notional} (S_0 - S_C) \text{RPV01}$$

This assumes a long position from the protection standpoint (protection was bought). For short positions, the sign is reversed.

## References

- Beumee, J., D. Brigo, D. Schiemert, and G. Stoye. "Charting a Course Through the CDS Big Bang," *Fitch Solutions, Quantitative Research*, Global Special Report. April 7, 2009.
- Hull, J., and A. White, "Valuing Credit Default Swaps I: No Counterparty Default Risk," *Journal of Derivatives* 8, 29-40.

O'Kane, D. and S. Turnbull, "Valuation of Credit Default Swaps." *Lehman Brothers, Fixed Income Quantitative Credit Research*, April, 2003.

**See Also**

"@IRDataCurve" | cdsbootstrap | cdsoptprice | cdsspread

## cdsrpv01

Compute risky present value of a basis point for credit default swap

### Syntax

```
RPV01 = cdsrpv01(ZeroData,ProbData,Settle,  
Maturity)
```

```
RPV01 = cdsrpv01( ____,Name,Value)
```

```
[RPV01,PaymentDates,PaymentTimes] = cdsrpv01(ZeroData,ProbData,  
Settle,  
Maturity)
```

```
[RPV01,PaymentDates,PaymentTimes] = cdsrpv01( ____,Name,Value)
```

### Description

`RPV01 = cdsrpv01(ZeroData,ProbData,Settle, Maturity)` computes the risky present value of a basis point (RPV01) for a credit default swap (CDS).

`RPV01 = cdsrpv01( ____,Name,Value)` computes the risky present value of a basis point (RPV01) for a credit default swap (CDS) using optional name-value pair arguments.

```
[RPV01,PaymentDates,PaymentTimes] = cdsrpv01(ZeroData,ProbData,  
Settle,  
Maturity)
```

 computes the risky present value of a basis point (RPV01), `PaymentDates`, and `PaymentTimes` for a credit default swap (CDS).

```
[RPV01,PaymentDates,PaymentTimes] = cdsrpv01( ____,Name,Value)
```

 computes the risky present value of a basis point (RPV01), `PaymentDates`, and `PaymentTimes` for a credit default swap (CDS) using optional name-value pair arguments.

### Examples

#### Calculate the RPV01 Value for a CDS

Calculate the RPV01 value, given the following specification for a CDS.



```

Settle = '17-Jul-2009'; % valuation date for the CDS
Zero_Time = [.5 1 2 3 4 5]';
Zero_Rate = [1.35 1.43 1.9 2.47 2.936 3.311]'/100;
Zero_Dates = daysadd(Settle,360*Zero_Time,1);
ZeroData = [Zero_Dates Zero_Rate];
ProbData = [daysadd(datenum(Settle),360,1), 0.0247];
Maturity = '20-Sep-2010';

RPV01 = cdsrpv01(ZeroData,ProbData,Settle,Maturity)

```

```

RPV01 =

    1.1651

```

- “Pricing a CDS Index Option”

## Input Arguments

### **ZeroData** — Dates and zero rates

object from `IRDataCurve` or vector of dates and zero rates

Dates and zero rates, specified by an M-by-2 vector of dates and zero rates or the object `IRDataCurve` for zero rates.

Data Types: `struct` | `double`

### **ProbData** — Dates and default probabilities

vector of dates and default probabilities

Dates and default probabilities, specified by a P-by-2 array.

Data Types: `double`

### **Settle** — Settlement date

string or cell array of dates or numeric dates

Settlement date, specified by a serial date number or date string. This must be earlier than or equal to the dates in `Maturity`.

Data Types: `char` | `cell` | `double`

**Maturity — CDS maturity date**

string or cell array of dates or numeric dates

CDS maturity date, specified by an N-by-1 vector of serial date numbers or date strings containing the maturity dates. The CDS premium payment dates occur at regular intervals, and the last payment occurs on these maturity dates.

Data Types: char | cell | double

**Name-Value Pair Arguments**

Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

Example: RPV01 =

```
cdsrpv01(ZeroData,ProbData,Settle,Maturity,'Period',1,'StartDate','20-Sep-2010','Basis',1,'BusDayConvention','actual','CleanRPV01',true,'PayAccruedPremium',true,'ZeroComp
```

**'Period' — Number of premium payments per year**

4 (default) | positive integer from the set [1,2,3,4,6,12] | vector of positive integers from the set [1,2,3,4,6,12]

Number of premium payments per year, specified by an N-by-1 vector. Values are 1, 2, 3, 4, 6, and 12.

Data Types: double

**'StartDate' — Dates the CDS premium leg starts**

Settle date (default) | string | cell array

Dates when the CDS premium leg actually starts, specified by an N-by-1 vector of serial date numbers or date strings. Must be on or between the Settle and Maturity dates. For a forward-starting CDS, specify this date as a future date after Settle.

Data Types: double

**'Basis' — Day-count basis of contract**

2 (actual/360) (default) | positive integers of the set [1...13] | vector of positive integers of the set [1...13]

Day-count basis of the contract, specified as a positive integer using a NINST-by-1 vector.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: double

**'BusDayConvention' — Business day conventions**

actual (default) | string | cell array

Business day conventions, specified by a string or N-by-1 cell array of strings of business day conventions. Values are:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

Data Types: char | cell

**'CleanRPV01' — Flag for premium accrual**

true (default) | boolean flag with value true or false

Flag for premium accrual, specified as an N-by-1 vector of Boolean flags, which is true if the premium accrued at `StartDate` is excluded in the RPV01, and false otherwise.

Data Types: logical

**'PayAccruedPremium' — Flag for accrued premium payment**

true (default) | boolean flag with value true or false

Flag for accrued premium payment, specified as a N-by-1 vector of Boolean flags, true if accrued premiums are paid upon default, false otherwise.

Data Types: logical

**'ZeroCompounding' — Compounding frequency of zero curve**

2 semiannual compounding (default) | integer with acceptable value [1,2,3,4,6,12, -1]

Compounding frequency of the zero curve, specified with integer values:

- 1 — Annual compounding
- 2 — Semiannual compounding
- 3 — Compounding three times per year
- 4 — Quarterly compounding
- 6 — Bimonthly compounding
- 12 — Monthly compounding
- -1 — Continuous compounding

---

**Note:** When ZeroData is an IRDataCurve object, the arguments ZeroCompounding and ZeroBasis are implicit in ZeroData and are redundant inside this function. In that case, specify these optional arguments when constructing the IRDataCurve object before calling this function.

---

Data Types: double

**'ZeroBasis' — Basis of zero curve**

0 (actual/actual) (default) | positive integers of the set [1...13] | vector of positive integers of the set [1...13]

Basis of the zero curve, specified as a positive integer using a NINST-by-1 vector.

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365

- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)
- 13 = BUS/252

Data Types: double

## Output Arguments

### **RPV01** — **RPV01 value**

scalar | vector

RPV01 value, returned as an N-by-1 vector.

### **PaymentDates** — **Payment dates**

scalar | vector

Payment dates, returned as an N-by-numCF matrix of dates.

### **PaymentTimes** — **Payment times**

scalar | vector

Payment times, returned as an N-by-numCF matrix of accrual fractions.

## More About

### **RPV01**

RPV01, associated with a CDS, is the value of a stream of 1-basis-point premiums according to the payment structure of the CDS contract, and taking into consideration the default probability over time.

For more information, see [3] and [4] for details.

- **basis**
- [www.cdsmodel.com](http://www.cdsmodel.com)

## References

[1] Beumee, J., D. Brigo, D. Schiemert, and G. Stoye. “Charting a Course Through the CDS Big Bang,” *Fitch Solutions, Quantitative Research*, Global Special Report. April 7, 2009.

[2] Hull, J., and A. White, “Valuing Credit Default Swaps I: No Counterparty Default Risk,” *Journal of Derivatives* 8, 29–40.

[3] O’Kane, D. and S. Turnbull, “Valuation of Credit Default Swaps,” *Lehman Brothers, Fixed Income Quantitative Credit Research*, April, 2003.

[4] O’Kane, D., *Modelling Single-name and Multi-name Credit Derivatives*, Wiley Finance, 2008.

## See Also

“@IRDataCurve” | [cdsbootstrap](#) | [cdsoptprice](#) | [cdsprice](#) | [cdsspread](#)

# cdsspread

Determine spread of credit default swap

## Syntax

```
[Spread, PaymentDates, PaymentTimes] = cdsspread(ZeroData,  
ProbData, Settle, Maturity)  
[Spread, PaymentDates, PaymentTimes] = cdsspread(ZeroData,  
ProbData, Settle, Maturity,  
Name, Value)
```

## Description

[Spread, PaymentDates, PaymentTimes] = cdsspread(ZeroData, ProbData, Settle, Maturity) computes the spread of the CDS.

[Spread, PaymentDates, PaymentTimes] = cdsspread(ZeroData, ProbData, Settle, Maturity, Name, Value) computes the spread of the CDS with additional options specified by one or more Name, Value pair arguments.

## Input Arguments

### ZeroData

M-by-2 vector of dates and zero rates or IRCurve of zero rates.

### ProbData

P-by-2 array of dates and default probabilities.

### Settle

Settlement date is a serial date number or date string. This must be earlier than or equal to the dates in MarketData.

## **Maturity**

N-by-1 vector of serial date numbers or date strings containing the maturity dates.

## **Name-Value Pair Arguments**

Specify optional comma-separated pairs of **Name**,**Value** arguments. **Name** is the argument name and **Value** is the corresponding value. **Name** must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as **Name1**,**Value1**, . . . ,**NameN**,**ValueN**.

---

**Note:** Any optional input of size N-by-1 is also acceptable as an array of size 1-by-N, or as a single value applicable to all contracts. Single values are internally expanded to an array of size N-by-1.

---

## **'Basis'**

N-by-1 vector of day-count basis of the CDS:

- 0 = actual/actual
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252



For more information, see **basis**.

**Default:** 2 (actual/360)

**'BusDayConvention'**

String or N-by-1 cell array of strings of business day conventions. Values are:

- actual
- follow
- modifiedfollow
- previous
- modifiedprevious

**Default:** actual

**'PayAccruedPremium'**

N-by-1 vector of Boolean flags, **True**, if accrued premiums are paid upon default, **False** otherwise.

**Default:** True

**'Period'**

N-by-1 vector of number of premiums per year of the CDS. Allowed values are 1, 2, 3, 4, 6, and 12.

**Default:** 4

**'RecoveryRate'**

N-by-1 vector of recovery rates, expressed as a decimal from 0 to 1.

**Default:** 0.4

**'TimeStep'**

Positive integer indicating the number of days to take as time step for the numerical integration.

**Default:** 10 (days)

**'ZeroBasis'**

Basis of the zero curve, where the choices are identical to **Basis**.

**Default:** 0 (actual/actual)

**'ZeroCompounding'**

Compounding frequency of the zero curve. Allowed values are:

- 1 — Annual compounding
- 2 — Semiannual compounding
- 3 — Compounding three times per year
- 4 — Quarterly compounding
- 6 — Bimonthly compounding
- 12 — Monthly compounding
- -1 — Continuous compounding

---

**Note:** When **ZeroData** is an **IRCurve** object, the arguments **ZeroCompounding** and **ZeroBasis** are implicit in **ZeroData** and are redundant inside this function. In that case, specify these optional arguments when constructing the **IRCurve** object before calling this function.

---

**Default:** 2 (semiannual compounding )

## Output Arguments

### Spread

N-by-1 vector of spreads (in basis points).

### PaymentDates

N-by-numCF matrix of payment dates.

## PaymentTimes

N-by-numCF matrix of accrual fractions.

## Examples

### Determine the Spread of a Credit Default Swap

This example shows how to use `cdsspread` to compute the clean price for a CDS contract with the following data.

```

Settle = '17-Jul-2009'; % valuation date for the CDS
Zero_Time = [.5 1 2 3 4 5]';
Zero_Rate = [1.35 1.43 1.9 2.47 2.936 3.311]'/100;
Zero_Dates = daysadd(Settle,360*Zero_Time,1);
ZeroData = [Zero_Dates Zero_Rate];
ProbData = [daysadd(datenum(Settle),360,1), 0.0247];
Maturity = '20-Sep-2010';

```

```

Spread = cdsspread(ZeroData,ProbData,Settle,Maturity)

```

```

Spread =

```

```

    148.2705

```

- “Credit Default Swap (CDS)” on page 8-2

## More About

### CDS Spread

The market, or breakeven, spread value of a CDS can be computed by equating the value of the protection leg with the value of the premium leg:

$$\text{Market Spread} * \text{RPV01} = \text{Value of Protection Leg}$$

The left side corresponds to the value of the premium leg, and this has been decomposed as the product of the market or breakeven spread times the RPV01 or 'risky present value of a basis point' of the contract. The latter is the present value of the premium payments,

taking into consideration the default probability. The `Market Spread` can be computed as the ratio of the value of the protection leg, to the `RPV01` of the contract. `cdsspread` returns the resulting spread in basis points.

### Algorithms

The premium leg is computed as the product of a spread  $S$  and the risky present value of a basis point (`RPV01`). The `RPV01` is given by:

$$RPV01 = \sum_{j=1}^N Z(t_j) \Delta(t_{j-1}, t_j, B) Q(t_j)$$

when no accrued premium are paid upon default, and it can be approximated by

$$RPV01 \approx \frac{1}{2} \sum_{j=1}^N Z(t_j) \Delta(t_{j-1}, t_j, B) (Q(t_{j-1}) + Q(t_j))$$

when accrued premiums are paid upon default. Here,  $t_0 = 0$  is the valuation date, and  $t_1, \dots, t_n = T$  are the premium payment dates over the life of the contract,  $T$  is the maturity of the contract,  $Z(t)$  is the discount factor for a payment received at time  $t$ , and  $\Delta(t_{j-1}, t_j, B)$  is a day count between dates  $t_{j-1}$  and  $t_j$  corresponding to a basis  $B$ .

The protection leg of a CDS contract is given by the following formula:

$$\begin{aligned} ProtectionLeg &= \int_0^T Z(\tau)(1 - R)dPD(\tau) \\ &\approx (1 - R) \sum_{i=1}^M Z(\tau_i)(PD(\tau_i) - PD(\tau_{i-1})) \\ &= (1 - R) \sum_{i=1}^M Z(\tau_i)(Q(\tau_{i-1}) - Q(\tau_i)) \end{aligned}$$

where the integral is approximated with a finite sum over the discretization  $\tau_0 = 0, \tau_1, \dots, \tau_M = T$ .

A breakeven spread  $S_0$  makes the value of the premium and protection legs equal. It follows that:

$$S_0 = \frac{\textit{ProtectionLeg}}{\textit{RPV01}}$$

## References

Beumee, J., D. Brigo, D. Schiemert, and G. Stoye. "Charting a Course Through the CDS Big Bang," *Fitch Solutions, Quantitative Research*, Global Special Report. April 7, 2009.

Hull, J., and A. White, "Valuing Credit Default Swaps I: No Counterparty Default Risk," *Journal of Derivatives* 8, 29-40.

O'Kane, D. and S. Turnbull, "Valuation of Credit Default Swaps." *Lehman Brothers, Fixed Income Quantitative Credit Research*, April, 2003.

## See Also

| [cdsprice](#) | [cdsbootstrap](#)

## cmosched

Generate principal balance schedule for planned amortization class (PAC) or targeted amortization class (TAC) bond

### Syntax

```
[BalanceSchedule, InitialBalance] = cmosched(Principal,  
Coupon, OriginalTerm, TermRemaining, PrepaySpeed)  
[BalanceSchedule, InitialBalance] = cmosched(Principal,  
Coupon, OriginalTerm, TermRemaining, PrepaySpeed,  
TranchePrincipal)
```

### Description

[BalanceSchedule, InitialBalance] = cmosched(Principal, Coupon, OriginalTerm, TermRemaining, PrepaySpeed) generates a principal balance schedule for planned amortization class (PAC) bonds using two bands of Public Securities Association Prepayment Model (PSA) speeds or targeted amortization class (TAC) bonds using a single PSA speed.

[BalanceSchedule, InitialBalance] = cmosched(Principal, Coupon, OriginalTerm, TermRemaining, PrepaySpeed, TranchePrincipal) with a specified tranche principal generates a principal balance schedule for planned amortization class (PAC) bonds using two bands of PSA speeds or targeted amortization class (TAC) bonds using a single PSA speed.

### Input Arguments

#### Principal

Principal of the underlying mortgage pool.

#### Coupon

Coupon of the underlying mortgage pool.

**OriginalTerm**

Original term in months of the underlying mortgage pool.

**TermRemaining**

Terms remaining in months of the underlying mortgage pool.

**PrepaySpeed**

PSA speed. For a PAC, the speed is a 1-by-2 matrix where the first element is the lower band and the second element is the upper band. For a TAC, the speed is a scalar.

**TranchePrincipal**

(Optional) Principal of the scheduled tranche. If it is unspecified or empty [ ], the principal of the scheduled tranche is assumed to be the sum of the payment schedule calculated from the PSA prepayment speeds.

## Output Arguments

**BalanceSchedule**

Matrix of size 1-by-`NUMTERMS`, where `NUMTERMS` is the number of terms remaining. Each column contains the scheduled principal balance for the time period corresponding to the column number.

**InitialBalance**

Scalar containing the initial principal balance of the scheduled tranche.

## Examples

**Calculate the Principal Balance Schedule for a CMO PAC Bond**

Define the mortgage pool under consideration and generate a principal balance schedule for planned amortization class (PAC) bonds using two bands of PSA speeds.

```
Principal = 128687000;  
GrossRate = 0.0648;  
OriginalTerm = 360;  
TermRemaining = 325;
```

```
PrepaySpeed = [300 525];
PacPrincipal = 100250000;
```

```
[BalanceSchedule, InitialBalance] ...
= cmosched(Principal, GrossRate, OriginalTerm, TermRemaining, ...
PrepaySpeed, PacPrincipal)
```

```
BalanceSchedule =
```

```
1.0e+07 *
```

```
Columns 1 through 7
```

```
9.7996 9.5780 9.3602 9.1461 8.9357 8.7289 8.5257
```

```
Columns 8 through 14
```

```
8.3259 8.1296 7.9366 7.7469 7.5605 7.3773 7.1972
```

```
Columns 15 through 21
```

```
7.0202 6.8463 6.6754 6.5073 6.3422 6.1799 6.0204
```

```
Columns 22 through 28
```

```
5.8637 5.7096 5.5582 5.4094 5.2632 5.1194 4.9782
```

```
Columns 29 through 35
```

```
4.8394 4.7030 4.5689 4.4372 4.3077 4.1804 4.0554
```

```
Columns 36 through 42
```

```
3.9325 3.8118 3.6931 3.5765 3.4619 3.3494 3.2406
```

```
Columns 43 through 49
```

```
3.1353 3.0334 2.9348 2.8394 2.7470 2.6576 2.5711
```

```
Columns 50 through 56
```

```
2.4873 2.4063 2.3279 2.2520 2.1786 2.1075 2.0387
```

```
Columns 57 through 63
```



---

1.9722	1.9078	1.8455	1.7852	1.7268	1.6703	1.6157
Columns 64 through 70						
1.5628	1.5117	1.4622	1.4142	1.3679	1.3231	1.2797
Columns 71 through 77						
1.2377	1.1970	1.1577	1.1197	1.0829	1.0473	1.0129
Columns 78 through 84						
0.9795	0.9473	0.9161	0.8859	0.8567	0.8285	0.8011
Columns 85 through 91						
0.7747	0.7491	0.7244	0.7004	0.6773	0.6549	0.6332
Columns 92 through 98						
0.6122	0.5920	0.5723	0.5534	0.5350	0.5172	0.5001
Columns 99 through 105						
0.4835	0.4674	0.4518	0.4368	0.4223	0.4082	0.3946
Columns 106 through 112						
0.3814	0.3687	0.3564	0.3445	0.3330	0.3219	0.3111
Columns 113 through 119						
0.3007	0.2906	0.2809	0.2715	0.2623	0.2535	0.2450
Columns 120 through 126						
0.2368	0.2288	0.2211	0.2137	0.2065	0.1995	0.1928
Columns 127 through 133						
0.1863	0.1800	0.1739	0.1680	0.1623	0.1568	0.1515
Columns 134 through 140						

0.1464	0.1414	0.1366	0.1319	0.1275	0.1231	0.1189
Columns 141 through 147						
0.1149	0.1109	0.1072	0.1035	0.0999	0.0965	0.0932
Columns 148 through 154						
0.0900	0.0869	0.0839	0.0811	0.0783	0.0756	0.0730
Columns 155 through 161						
0.0704	0.0680	0.0657	0.0634	0.0612	0.0591	0.0570
Columns 162 through 168						
0.0550	0.0531	0.0513	0.0495	0.0478	0.0461	0.0445
Columns 169 through 175						
0.0429	0.0414	0.0400	0.0386	0.0372	0.0359	0.0346
Columns 176 through 182						
0.0334	0.0322	0.0311	0.0300	0.0289	0.0279	0.0269
Columns 183 through 189						
0.0260	0.0250	0.0241	0.0233	0.0224	0.0216	0.0209
Columns 190 through 196						
0.0201	0.0194	0.0187	0.0180	0.0174	0.0167	0.0161
Columns 197 through 203						
0.0155	0.0150	0.0144	0.0139	0.0134	0.0129	0.0124
Columns 204 through 210						
0.0120	0.0115	0.0111	0.0107	0.0103	0.0099	0.0096
Columns 211 through 217						

---

0.0092	0.0089	0.0085	0.0082	0.0079	0.0076	0.0073
Columns 218 through 224						
0.0070	0.0068	0.0065	0.0063	0.0060	0.0058	0.0056
Columns 225 through 231						
0.0054	0.0052	0.0050	0.0048	0.0046	0.0044	0.0042
Columns 232 through 238						
0.0041	0.0039	0.0037	0.0036	0.0035	0.0033	0.0032
Columns 239 through 245						
0.0031	0.0029	0.0028	0.0027	0.0026	0.0025	0.0024
Columns 246 through 252						
0.0023	0.0022	0.0021	0.0020	0.0019	0.0018	0.0018
Columns 253 through 259						
0.0017	0.0016	0.0016	0.0015	0.0014	0.0014	0.0013
Columns 260 through 266						
0.0012	0.0012	0.0011	0.0011	0.0010	0.0010	0.0009
Columns 267 through 273						
0.0009	0.0009	0.0008	0.0008	0.0007	0.0007	0.0007
Columns 274 through 280						
0.0006	0.0006	0.0006	0.0005	0.0005	0.0005	0.0005
Columns 281 through 287						
0.0004	0.0004	0.0004	0.0004	0.0004	0.0003	0.0003
Columns 288 through 294						

0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002
Columns 295 through 301						
0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001
Columns 302 through 308						
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Columns 309 through 315						
0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Columns 316 through 322						
0.0000	0.0000	0.0000	0	0	0	0
Columns 323 through 325						
0	0	0				

InitialBalance =  
100250000

- “Using Collateralized Mortgage Obligations (CMOs)” on page 5-45

## More About

### Planned Amortization Class (PAC) Bond

PAC bonds are a type of CMO bond. They are designed to largely eliminate prepayment risk for investors. They do this by transferring essentially all prepayment risk to other bonds in the CMO that are called support bonds.

### **Targeted Amortization Class (TAC) Bond**

TAC bonds are analogous to PAC bonds, but are structured differently. TAC bonds offer one-sided protection, shielding investors from high prepayment rates up to a specified PSA and do not protect against low prepayment rates.

- “Create PAC and Sequential CMO” on page 5-55

## **References**

Hayre, Lakhbir, ed., *Salomon Smith Barney Guide to Mortgage-Backed and Asset-Backed Securities*, John Wiley and Sons, New York, 2001.

Lyu, Yuh-Dah, *Financial Engineering and Computation*, Cambridge University Press, 2004.

### **See Also**

| cmoschedcf

## cmoschedcf

Generate cash flows for scheduled collateralized mortgage obligation (CMO) using PAC or TAC model

### Syntax

```
[Balances, Principal, Interest] =  
cmoschedcf(PrincipalPayments, TranchePrincipals,  
TrancheCoupons, BalanceSchedule)
```

### Description

```
[Balances, Principal, Interest] =  
cmoschedcf(PrincipalPayments, TranchePrincipals,  
TrancheCoupons, BalanceSchedule)
```

 generate cash flows for a scheduled CMO such as the planned amortization class (PAC) or targeted amortization class (TAC), given the underlying mortgage pool payments (or payments from another CMO tranche). The output **Balance**, **Principal**, and **Interest** from this function can be used as input into `cmoseqcf` to further divide the PAC, TAC, or support tranche into sequential tranches.

### Input Arguments

#### **PrincipalPayments**

Matrix of size 1-by-**NUMTERMS**, where **NUMTERMS** is the number of terms remaining. Each column contains the underlying principal payment for the time period corresponding to the row number. Calculate underlying principal payments using `mbscfamounts` or `mbspassthrough`. The underlying principal payments can also be outputs from other CMO cash flow functions.

#### **TranchePrincipals**

Matrix of size 2-by-1 specifying the initial principal for the scheduled and the support tranche.

### **TrancheCoupons**

Matrix of size 2-by-1 specifying the coupons for the schedule tranche and the support tranche. The weighted average coupon for the CMO should not exceed the coupon of the underlying mortgage.

### **BalanceSchedule**

Matrix of size 1-by-NUMTERMS, where NUMTERMS is the number of terms remaining. Each element represents the targeted balance schedule for the time period corresponding to that column.

## **Output Arguments**

### **Balance**

Matrix of size 2-by-NUMTERMS, where NUMTERMS is the number of terms remaining. The first row is the principal balances of the scheduled tranche, and the second row is the principal balances of the support tranche at the time period corresponding to the column.

### **Principal**

Matrix of size 2-by-NUMTERMS, where NUMTERMS is the number of terms remaining. The first row is the principal payments of the scheduled tranche, and the second row is the principal payments of the support tranche at the time period corresponding to the column.

### **Interest**

Matrix of size 2-by-NUMTERMS, where NUMTERMS is the number of terms remaining. The first row is the interest payments of the schedule tranche, and the second row is the interest payments of the support tranche at the time period corresponding to the column.

## **Examples**

### **Calculate Cash Flows for Each PAC Tranche**

Define the mortgage pool under consideration for CMO structuring using `mbscfamounts` or `mbspassthrough`. Calculate the underlying mortgage cash flow, define the PAC schedule and CMO tranches, and calculate the cash flows for each tranche.

```
MortgagePrincipal = 1000000; % underlying mortgage
Coupon = 0.12;
Terms = 6; % months

[PrincipalBalance, MonthlyPayments, SchedPrincipalPayments, ...
InterestPayments, Prepayments] = ...
mbspassthrough(MortgagePrincipal, Coupon, Terms, Terms, 0, []);
PrincipalPayments = SchedPrincipalPayments.' + Prepayments.'
```

```
PrincipalPayments =

    1.0e+05 *

    1.6255    1.6417    1.6582    1.6747    1.6915    1.7084
```

Calculate the PAC schedule for CMO using `cmosched`.

```
PrepaySpeed = [100 300];
[BalanceSchedule, InitialBalance] ...
= cmosched(MortgagePrincipal, Coupon, Terms, Terms, PrepaySpeed, [])
```

```
BalanceSchedule =

    1.0e+05 *

    8.3617    6.7180    5.0581    3.3828    1.6955    0
```

```
InitialBalance =

    9.9886e+05
```

Define CMO tranches.

```
TranchePrincipals = ...
[InitialBalance; MortgagePrincipal-InitialBalance];
TrancheCoupons = [0.12; 0.12];
```

Calculate cash flows for each tranche.

```
[Balance, Principal, Interest] = ...
```



```
cmoschedcf(PrincipalPayments, TranchePrincipals, ...
TrancheCoupons, BalanceSchedule)
```

Balance =

```
1.0e+05 *
8.3631  6.7213  5.0632  3.3885  1.6970  0
0.0114  0.0114  0.0114  0.0114  0.0114  0.0000
```

Principal =

```
1.0e+05 *
1.6255  1.6417  1.6582  1.6747  1.6915  1.6970
0 0 0 0 0 0.0114
```

Interest =

```
1.0e+03 *
9.9886  8.3631  6.7213  5.0632  3.3885  1.6970
0.0114  0.0114  0.0114  0.0114  0.0114  0.0114
```

- “Using Collateralized Mortgage Obligations (CMOs)” on page 5-45

## More About

### Planned Amortization Class (PAC) Tranches

In a PAC CMO, there is a main tranche, known as the schedule tranche, and a support tranche. The main purpose of a schedule tranche is to give investors in the PAC tranche a more certain cash flow.

### Targeted Amortization Class (TAC) Tranches

TACs are like PACs, but principal payment is specified for only one prepayment rate. If prepayment rates are higher or lower, then the principal payment to TAC holders will be higher or lower accordingly.

### **Schedule and Support Tranche**

The main purpose of a PAC tranche is to give investors in the PAC tranche a more certain cash flow. The PAC tranche receives priority for receiving payments of principal and interest that gives investors in the PAC tranche a steadier income. If prepayments differ from what was expected, then the support tranche gets the variable portion of the payments. While income to the support tranche is more variable, it is also higher yielding. Estimates of the yield, average life, and lockout periods of the PAC tranche is more certain.

- “Create PAC and Sequential CMO” on page 5-55

### **References**

Hayre, Lakhbir, ed., *Salomon Smith Barney Guide to Mortgage-Backed and Asset-Backed Securities*, John Wiley and Sons, New York, 2001.

Lyu, Yuh-Dah, *Financial Engineering and Computation*, Cambridge University Press, 2004.

### **See Also**

| cmoseqcf | cmosched | mbscfamounts | mbspassthrough

## cmoseqcf

Generate cash flows for sequential collateralized mortgage obligation (CMO)

### Syntax

```
[balances, principals, interests] =
cmoseqcf(PrincipalPayments, TranchePrincipals, TrancheCoupons)
[balances, principals, interests] =
cmoseqcf(PrincipalPayments, TranchePrincipals, TrancheCoupons, HasZ)
```

### Description

```
[balances, principals, interests] =
cmoseqcf(PrincipalPayments, TranchePrincipals, TrancheCoupons)
generates cash flows for a sequential CMO without a Z-bond, given the underlying
mortgage pool payments.
```

```
[balances, principals, interests] =
cmoseqcf(PrincipalPayments, TranchePrincipals, TrancheCoupons, HasZ)
generates cash flows for a sequential CMO with a Z-bond, given the underlying mortgage
pool payments.
```

### Input Arguments

#### PrincipalPayments

Matrix of size 1-by-**NUMTERMS**, where **NUMTERMS** is the number of terms remaining. Each row contains the underlying principal payment for the time period corresponding to the row number. The underlying principal payments can be calculated using **mbscfamounts** or **mbspassthrough**. The underlying principal payments can also be outputs from other CMO cash flow functions

#### TranchePrincipals

Matrix of size **NUMTRANCHES**-by-1, where **NUMTRANCHES** is the number of tranches in the sequential CMO. Each element of the matrix represents the initial principal for each

tranche. If the sequential CMO includes a Z-bond (`HasZ` is `true`), the last element of this matrix is the principal of the Z-bond.

### **TrancheCoupons**

Matrix of size `NUMTRANCHES`-by-1, where `NUMTRANCHES` is the number of tranches in the sequential CMO. Each element of the matrix represents the coupon for each tranche. If the sequential CMO includes a Z-bond (`HasZ` is `true`), the last element of this matrix is the coupon of the Z-bond. The weighted average coupon for the CMO should not exceed the coupon of the underlying mortgage.

### **HasZ**

(Optional) Boolean (`true` or `false`). A value of `true` indicates that the sequential CMO contains a Z-bond, and the last element of `TranchePrincipals` and `TrancheCoupons` will be treated as that of the Z-bond. A value of `false` indicates that there is no Z-bond in the sequential CMO, and the last element of `TranchePrincipals` and `TrancheCoupons` will be treated as an ordinary tranche.

**Default:** `false`

## **Output Arguments**

### **Balance**

Matrix of size `NUMTRANCHES`-by-`NUMTERMS`, where `NUMTRANCHES` is the number of terms remaining and `NUMTRANCHES` is the number of tranches. Each element represents the principal balance at the time period corresponding to the column, and for the tranche corresponding to the row.

### **Principal**

Matrix of size `NUMTRANCHES`-by-`NUMTERMS`, where `NUMTRANCHES` is the number of terms remaining and `NUMTRANCHES` is the number of tranches. Each element represents the principal payments made at the time period corresponding to the column, and to the tranche corresponding to the row.

### **Interest**

Matrix of size `NUMTRANCHES`-by-`NUMTERMS`, where `NUMTRANCHES` is the number of terms remaining and `NUMTRANCHES` is the number of tranches. Each element represents the

interest payments made at the time period corresponding to the column, and to the tranche corresponding to the row.

## Examples

### Calculate Cash Flows for a Sequential Collateralized Mortgage Obligation (CMO)

Define the mortgage pool under consideration for CMO structuring using `mbscfamounts` or `mbspassthrough` and calculate the cash flows with an A and B tranche for a sequential CMO.

```
MortgagePrincipal = 1000000;
Coupon = 0.12;
Terms = 6; % months
```

```
% Calculate underlying mortgage cash flows
[PrincipalBalance, MonthlyPayments, SchedPrincipalPayments, ...
InterestPayments, Prepayments] = ...
mbspassthrough(MortgagePrincipal, Coupon, Terms, Terms, 0, []);
PrincipalPayments = SchedPrincipalPayments.' + Prepayments.'
```

```
PrincipalPayments =
```

```
1.0e+05 *
1.6255    1.6417    1.6582    1.6747    1.6915    1.7084
```

Define CMO tranches, A and B.

```
TranchePrincipals = [500000; 500000];
TrancheCoupons = [0.12; 0.12];
```

Calculate cash flows for each tranche.

```
[Balance, Principal, Interest] = ...
cmoseqcf(PrincipalPayments, TranchePrincipals, TrancheCoupons, false)
```

```
Balance =
```

```
1.0e+05 *
```

3.3745	1.7328	0.0746	0	0	0
5.0000	5.0000	5.0000	3.3999	1.7084	0.0000

Principal =

1.0e+05 \*

1.6255	1.6417	1.6582	0.0746	0	0
0	0	0	1.6001	1.6915	1.7084

Interest =

1.0e+03 \*

5.0000	3.3745	1.7328	0.0746	0	0
5.0000	5.0000	5.0000	5.0000	3.3999	1.7084

- “Using Collateralized Mortgage Obligations (CMOs)” on page 5-45

## More About

### Sequential Pay CMO

A sequential pay CMO involves tranches that pay off principal sequentially. For example, consider the following case, where all principal from the underlying mortgage pool is repaid on tranche A first, then tranche B, then tranche C. Note that interest is paid on each tranche as long as the principal for the tranche has not been retired.

### CMO Tranche

Tranche is a term often used to describe a specific class of bonds within an offering wherein each tranche offers varying degrees of risk to the investor.

- “Create PAC and Sequential CMO” on page 5-55

## References

Hayre, Lakhbir, ed., *Salomon Smith Barney Guide to Mortgage-Backed and Asset-Backed Securities*, John Wiley and Sons, New York, 2001.

Lyu, Yuh-Dah, *Financial Engineering and Computation*, Cambridge University Press, 2004.

**See Also**

| cmoschedcf | mbscfamounts | mbspassthrough | cmosched

## convfactor

Bond conversion factors

### Syntax

```
CF = convfactor(RefDate, Maturity, CouponRate)
CF = convfactor(RefDate, Maturity, CouponRate,
'ParameterName',ParameterValue ...)
```

### Description

CF = convfactor(RefDate, Maturity, CouponRate) computes a conversion factor for a bond futures contract.

CF = convfactor(RefDate, Maturity, CouponRate, '*ParameterName*',*ParameterValue* ...) accepts optional inputs as one or more comma-separated parameter-value pairs. '*ParameterName*' is the name of the parameter inside single quotes. '*ParameterValue*' is the value corresponding to '*ParameterName*'. Specify parameter/value pairs in any order. Names are case-insensitive. convfactor computes a conversion factor for a bond futures contract, given a **Convention** value for a U.S. Treasury bond, German bond, U.K. Gilt, or Japanese Government Bond.

### Input Arguments

#### RefDate

Reference dates, for which conversion factor is computed (usually the first day of delivery months).

#### Maturity

Maturity date of the underlying bond.

#### CouponRate

Annual coupon rate of the underlying bond in decimal.



## Parameter–Value Pairs

Enter the following inputs only as parameter–value pairs.

### **Convention**

Conversion factor convention. Scalar. Valid values are:

- 1 = U.S. Treasury bond (30-year) and Treasury note (10-year) futures contract
- 2 = U.S. 2-year and 5-year Treasury note futures contract
- 3 = German Bobl, Bund, Buxl, and Schatz
- 4 = U.K. gilts
- 5 = Japanese Government Bonds (JGBs)

**Default:** 1

### **FirstCouponDate**

Irregular or normal first coupon date.

### **RefYield**

Reference semiannual yield.

**Default:** 0.06 (6%)

### **StartDate**

Forward starting date of payments.

## Output Arguments

### **CF**

N-by1 vector of conversion factors against the 6% yield par-bond.

## Definitions

Conversion factors of U.S. Treasury bonds and other government bonds are based on a bond yielding 6%. Optionally, you can specify other types of bonds and yields using

inputs for `RefYield` and `Convention`. For U.S. Treasury bonds, verify the output of `convfactor` by comparing the output against the quotations provided by the Chicago Board of Trade (<http://www.cmegroup.com/company/cbot.html>).

For German bonds, verify the output of `convfactor` by comparing the output against the quotations provided by Eurex (<http://www.eurexchange.com>).

For U.K. Gilts, verify the output of `convfactor` by comparing the output against the quotations provided by Euronext (<http://www.euronext.com>).

For Japanese Government Bonds, verify the output of `convfactor` by comparing the output against the quotations provided by the Tokyo Stock Exchange (<http://www.tse.or.jp/english/>).

## Examples

### Compute the Conversion Factors For a Bond Futures Contract

This example shows how to calculate CF, given the following `RefDate`, `Maturity`, and `CouponRate`.

```
RefDate = { '1-Dec-2002';  
           '1-Mar-2003';  
           '1-Jun-2003';  
           '1-Sep-2003';  
           '1-Dec-2003';  
           '1-Sep-2003';  
           '1-Dec-2002';  
           '1-Jun-2003' };  
  
Maturity = { '15-Nov-2012';  
           '15-Aug-2012';  
           '15-Feb-2012';  
           '15-Feb-2011';  
           '15-Aug-2011';  
           '15-Aug-2010';  
           '15-Aug-2009';  
           '15-Feb-2010' };  
  
CouponRate = [0.04; 0.04375; 0.04875; 0.05; 0.05; 0.0575; 0.06; 0.065];  
  
CF = convfactor(RefDate, Maturity, CouponRate)
```

```
CF =  
    0.8539  
    0.8858  
    0.9259  
    0.9418  
    0.9403  
    0.9862  
    1.0000  
    1.0266
```

### Compute the Conversion Factor For a German Bond

This example shows how to calculate `cf`, given the following `RefDate`, `Maturity`, and `CouponRate` for a German bond.

```
cf = convfactor('3/10/2009', '1/04/2018', .04, .06, 3)
```

```
cf =  
    0.8659
```

## More About

- “Bond Futures”

## References

Burghardt, G., T. Belton, M. Lane, and J. Papa, *The Treasury Bond Basis*, McGraw-Hill, 2005.

Krgin, Dragomir, *Handbook of Global Fixed Income Calculations*, John Wiley & Sons, 2002.

## See Also

`tfutbyprice` | `tfutbyyield` | `tfutimprepo` | `bndfutimprepo` | `bndfutprice`

## fitFunction

Custom fit interest-rate curve object to bond market data

### Class

@IRFunctionCurve

### Syntax

```
CurveObj = IRFunctionCurve.fitFunction(Type, Settle,
FunctionHandle, Instruments, IRFitOptionsObj)
```

```
CurveObj = IRFunctionCurve.fitFunction(Type, Settle,
FunctionHandle, Instruments, IRFitOptionsObj, 'Parameter1',
Value1, 'Parameter2', Value2, ...)
```

### Arguments

Type	Type of interest-rate curve for a bond: <b>zero</b> , <b>forward</b> , or <b>discount</b> .
Settle	Scalar for the <b>Settle</b> date of the curve.
FunctionHandle	Function handle that defines the interest-rate curve. The function handle takes two numeric vectors (time-to-maturity and a vector of function coefficients) and returns one numeric output (interest rate or discount factor). For more information on defining a function handle, see the MATLAB Programming Fundamentals documentation.
Instruments	N-by-4 data matrix for <b>Instruments</b> where the first column is <b>Settle</b> date, the second column is <b>Maturity</b> , the third column is the clean price, and the fourth column is a <b>CouponRate</b> for the bond.
IRFitOptionsObj	Object constructed from <b>IRFitOptions</b> .
Compounding	(Optional) Scalar that sets the compounding frequency per year for the <b>IRFunctionCurve</b> object:

	<ul style="list-style-type: none"> <li>• -1 = Continuous compounding</li> <li>• 1 = Annual compounding</li> <li>• 2 = Semiannual compounding (default)</li> <li>• 3 = Compounding three times per year</li> <li>• 4 = Quarterly compounding</li> <li>• 6 = Bimonthly compounding</li> <li>• 12 = Monthly compounding</li> </ul>
<b>Basis</b>	<p>(Optional) Day-count basis of the bond. A scalar of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>

## Instrument Parameters

For each bond **Instrument**, you can specify the following additional instrument parameters as parameter/value pairs. For example, **InstrumentBasis** distinguishes a bond instrument's **Basis** value from the curve's **Basis** value.

InstrumentPeriod	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
InstrumentBasis	<p>(Optional) Day-count basis of the bond. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
InstrumentEndMonthRule	(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
InstrumentIssueDate	(Optional) Date when an instrument was issued.

InstrumentFirstCoupon	(Optional) Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When FirstCouponDate and LastCouponDate are both specified, FirstCouponDate takes precedence in determining the coupon payment structure. If you do not specify a FirstCouponDate, the cash flow payment dates are determined from other inputs.
InstrumentLastCouponD	(Optional) Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified FirstCouponDate, a specified LastCouponDate determines the coupon structure of the bond. The coupon structure of a bond is truncated at the LastCouponDate, regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a LastCouponDate, the cash flow payment dates are determined from other inputs.
InstrumentFace	(Optional) Face or par value. Default = 100.

---

**Note:** When using Instrument parameter/value pairs, you can specify simple interest for a bond by specifying the InstrumentPeriod value as 0. If InstrumentBasis and InstrumentPeriod are not specified for a bond, the following default values are used: Basis is 0 (act/act) and Period is 2.

---

## Description

CurveObj = IRFunctionCurve.fitFunction(Type, Settle, FunctionHandle, Instruments, IRFitOptionsObj, 'Parameter1', Value1, 'Parameter2', Value2, ...) fits a bond to a custom fitting function. You must enter the optional arguments for Basis and Compounding as parameter/value pairs.

## Examples

```
Settle = repmat(datenum('30-Apr-2008'),[6 1]);
Maturity = [datenum('07-Mar-2009');datenum('07-Mar-2011');...
datenum('07-Mar-2013');datenum('07-Sep-2016');...
datenum('07-Mar-2025');datenum('07-Mar-2036')];
CleanPrice = [100.1;100.1;100.8;96.6;103.3;96.3];
CouponRate = [0.0400;0.0425;0.0450;0.0400;0.0500;0.0425];
```

```

Instruments = [Settle Maturity CleanPrice CouponRate];
CurveSettle = datenum('30-Apr-2008');
OptOptions = optimoptions('lsqnonlin','display','iter');
functionHandle = @(t,theta) polyval(theta,t);

CustomModel = IRFunctionCurve.fitFunction('Zero', CurveSettle, ...
functionHandle, Instruments, ...
IRFitOptions([.05 .05 .05], 'FitType', 'price', ...
'OptOptions', OptOptions));

```

Iteration	Func-count	f(x)	Norm of step	First-order optimality	CG-iterations
0	4	38036.7		4.92e+04	
1	8	38036.7	10	4.92e+04	0
2	12	38036.7	2.5	4.92e+04	0
3	16	38036.7	0.625	4.92e+04	0
4	20	38036.7	0.15625	4.92e+04	0
5	24	30741.5	0.0390625	1.72e+05	0
6	28	30741.5	0.078125	1.72e+05	0
7	32	30741.5	0.0195312	1.72e+05	0
8	36	28713.6	0.00488281	2.33e+05	0
9	40	20323.3	0.00976562	9.47e+05	0
10	44	20323.3	0.0195312	9.47e+05	0
11	48	20323.3	0.00488281	9.47e+05	0
12	52	20323.3	0.0012207	9.47e+05	0
13	56	19698.8	0.000305176	1.08e+06	0
14	60	17493	0.000610352	7e+06	0
15	64	17493	0.0012207	7e+06	0
16	68	17493	0.000305176	7e+06	0
17	72	15455.1	7.62939e-05	2.25e+07	0
18	76	15455.1	0.000177499	2.25e+07	0
19	80	13317.1	3.8147e-05	3.18e+07	0
20	84	12865.3	7.62939e-05	7.83e+07	0
21	88	11779.8	7.62939e-05	7.58e+06	0
22	92	11747.6	0.000152588	1.45e+05	0
23	96	11720.9	0.000305176	2.33e+05	0
24	100	11667.2	0.000610352	1.48e+05	0
25	104	11558.6	0.0012207	3.55e+05	0
26	108	11335.5	0.00244141	1.57e+05	0
27	112	10863.8	0.00488281	6.36e+05	0
28	116	9797.14	0.00976562	2.53e+05	0
29	120	6882.83	0.0195312	9.18e+05	0
30	124	6882.83	0.0373993	9.18e+05	0
31	128	3218.45	0.00934981	1.96e+06	0
32	132	612.703	0.0186996	3.01e+06	0
33	136	13.0998	0.0253882	3.05e+06	0
34	140	0.0762922	0.00154002	5.05e+04	0
35	144	0.0731652	3.61102e-06	29.9	0
36	148	0.0731652	6.32335e-08	0.063	0

Local minimum possible.

lsqnonlin stopped because the final change in the sum of squares relative to its initial value is less than the default value of the function tolerance.

## More About

- “@IRFitOptions”
- “@IRFunctionCurve”



# fitNelsonSiegel

Fit Nelson-Siegel function to bond market data

## Class

@IRFunctionCurve

## Syntax

```
CurveObj = IRFunctionCurve.fitNelsonSiegel(Type, Settle, Instruments)
```

```
CurveObj = IRFunctionCurve.fitNelsonSiegel(Type, Settle, Instruments,  
'Parameter1', Value1, 'Parameter2', Value2, ...)
```

## Arguments

Type	Type of interest-rate curve for a bond: <b>zero</b> or <b>forward</b> .
Settle	Scalar for the <b>Settle</b> date of the curve.
Instruments	N-by-4 data matrix for <b>Instruments</b> where the first column is <b>Settle</b> date, the second column is <b>Maturity</b> , the third column is the clean price, and the fourth column is a <b>CouponRate</b> for the bond.
Compounding	(Optional) Scalar that sets the compounding frequency per year for the <b>IRFunctionCurve</b> object: <ul style="list-style-type: none"> <li>• -1 = Continuous compounding</li> </ul>
Basis	(Optional) Day-count basis of the interest-rate curve. A scalar of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> </ul>

	<ul style="list-style-type: none"> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<b>IRFitOptionsObj</b>	<p>(Optional) Object constructed from <b>IRFitOptions</b>. When using <b>IRFitOption</b>, the default <b>FitType</b> is <b>DurationWeightedPrice</b>. Duration weighted price refers to the form of the objective function that needs to be minimized to find the optimal Nelson-Siegel parameters. Specifically, this objective function minimizes using the following three algorithms:</p> <ul style="list-style-type: none"> <li>• The difference between observed and model-predicted yields for each bond, <math>ObsY_i - PredY_i</math></li> <li>• The difference between observed and model-predicted prices for each bond, <math>ObsP_i - PredP_i</math></li> <li>• The difference between observed and model-predicted prices, weighted by the inverse of the duration of each bond, <math>(ObsP_i - PredP_i) / D_i</math>. Weighting price by inverse duration converts the pricing errors into yield fitting errors, to a first approximation.</li> </ul>

## Instrument Parameters

For each bond **Instrument**, you can specify the following additional instrument parameters as parameter/value pairs. For example, **InstrumentBasis** distinguishes a bond instrument's **Basis** value from the curve's **Basis** value.

<b>InstrumentPeriod</b>	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
<b>InstrumentBasis</b>	<p>(Optional) Day-count basis of the bond. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see “”.</p>
<b>InstrumentEndMonthRule</b>	(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
<b>InstrumentIssueDate</b>	(Optional) Date when an instrument was issued.

<code>InstrumentFirstCoupon</code>	(Optional) Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When <code>FirstCouponDate</code> and <code>LastCouponDate</code> are both specified, <code>FirstCouponDate</code> takes precedence in determining the coupon payment structure. If you do not specify a <code>FirstCouponDate</code> , the cash flow payment dates are determined from other inputs.
<code>InstrumentLastCouponD</code>	(Optional) Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified <code>FirstCouponDate</code> , a specified <code>LastCouponDate</code> determines the coupon structure of the bond. The coupon structure of a bond is truncated at the <code>LastCouponDate</code> , regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a <code>LastCouponDate</code> , the cash flow payment dates are determined from other inputs.
<code>InstrumentFace</code>	(Optional) Face or par value. Default = 100.

---

**Note:** When using `Instrument` parameter/value pairs, you can specify simple for a bond by specifying the `InstrumentPeriod` value as 0. If `InstrumentBasis` and `InstrumentPeriod` are not specified for a bond, the following default values are used: `Basis` is 0 (act/act) and `Period` is 2.

---

## Description

`CurveObj = IRFunctionCurve.fitNelsonSiegel(Type, Settle, Instruments, 'Parameter1', Value1, 'Parameter2', Value2, ...)` fits a Nelson-Siegel function to market data for a bond. You must enter the optional arguments for `Basis`, `Compounding`, and `IRFitOptionsObj` as parameter/value pairs. After creating a Nelson-Siegel model, you can view the model parameters using:

```
CurveObj.Parameters
```

where the order of parameters is [`Beta0`,`Beta1`,`Beta2`,`tau1`].

## Examples

### Use the Nelson-Siegel Function to Fit Bond Market Data

This example shows how to use the Nelson-Siegel function to fit bond market data.

```

Settle = repmat(datenum('30-Apr-2008'),[6 1]);
Maturity = [datenum('07-Mar-2009');datenum('07-Mar-2011');...
datenum('07-Mar-2013');datenum('07-Sep-2016');...
datenum('07-Mar-2025');datenum('07-Mar-2036')];

CleanPrice = [100.1;100.1;100.8;96.6;103.3;96.3];
CouponRate = [0.0400;0.0425;0.0450;0.0400;0.0500;0.0425];
Instruments = [Settle Maturity CleanPrice CouponRate];
PlottingPoints = datenum('07-Mar-2009'):180:datenum('07-Mar-2036');
Yield = bndyield(CleanPrice,CouponRate,Settle,Maturity);

NSModel = IRFunctionCurve.fitNelsonSiegel('Zero',datenum('30-Apr-2008'),Instruments);

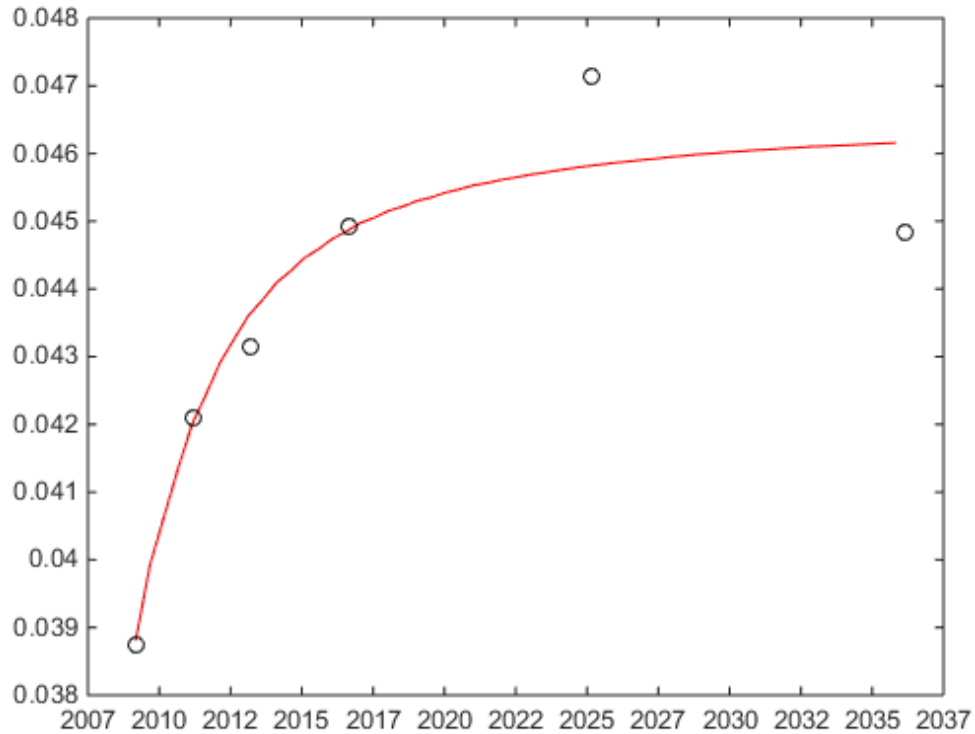
NSModel.Parameters

% create the plot
plot(PlottingPoints, getParYields(NSModel, PlottingPoints),'r')
hold on
scatter(Maturity,Yield,'black')
datetick('x')

ans =

    4.6617    -1.0227    -0.3484     1.2386

```



- “Fitting Interest Rate Curve Functions”

## More About

### Algorithms

The Nelson-Siegel model proposes that the instantaneous forward curve can be modeled with the following:

$$f = \beta_0 + \beta_1 e^{\frac{-m}{\tau}} + \beta_2 \frac{m}{\tau} e^{\frac{-m}{\tau}}$$

This can be integrated to derive an equation for the zero curve (see [6] for more information on the equations and the derivation):

$$s = \beta_0 + (\beta_1 + \beta_2) \frac{\tau}{m} (1 - e^{-\frac{m}{\tau}}) - \beta_2 e^{-\frac{m}{\tau}}$$

See [1] for more information.

## References

- [1] Nelson, C.R., Siegel, A.F., (1987), "Parsimonious modelling of yield curves", *Journal of Business*, 60, pp 473-89
- [2] Svensson, L.E.O. (1994), "Estimating and interpreting forward interest rates: Sweden 1992-4", *International Monetary Fund, IMF Working Paper*, 1994/114
- [3] Fisher, M., Nychka, D., Zervos, D. (1995), "Fitting the term structure of interest rates with smoothing splines", *Board of Governors of the Federal Reserve System, Federal Reserve Board Working Paper* 95-1
- [4] Anderson, N., Sleath, J. (1999), "New estimates of the UK real and nominal yield curves", *Bank of England Quarterly Bulletin*, November, pp 384-92
- [5] Waggoner, D. (1997), "Spline Methods for Extracting Interest Rate Curves from Coupon Bond Prices", *Federal Reserve Board Working Paper* 97-10
- [6] "Zero-coupon yield curves: technical documentation", *BIS Papers No. 25*, October 2005
- [7] Bolder, D.J., Gusba, S (2002), "Exponentials, Polynomials, and Fourier Series: More Yield Curve Modelling at the Bank of Canada," *Working Papers 02-29*, Bank of Canada
- [8] Bolder, D.J., Streliski, D (1999), "Yield Curve Modelling at the Bank of Canada," *Technical Reports 84*, Bank of Canada

## See Also

"@IRFitOptions" | "@IRFunctionCurve"

# fitSmoothingSpline

Fit smoothing spline to bond market data

## Class

@IRFunctionCurve

## Syntax

```
CurveObj = IRFunctionCurve.fitSmoothingSpline(Type, Settle,
Instruments, Lambdafun)
```

```
CurveObj = IRFunctionCurve.fitSmoothingSpline(Type, Settle,
Instruments, Lambdafun, 'Parameter1', Value1, 'Parameter2',
Value2, ...)
```

## Arguments

---

**Note:** You must have a license for Curve Fitting Toolbox software to use the `fitSmoothingSpline` method.

---

Type	Type of interest-rate curve for a bond: <b>Forward</b> , <b>Zero</b> , or <b>Discount</b> .
Settle	Scalar for the <b>Settle</b> date of the curve.
Instruments	N-by-4 data matrix for <b>Instruments</b> where the first column is <b>Settle</b> date, the second column is <b>Maturity</b> , the third column is the clean price, and the fourth column is a <b>CouponRate</b> for the bond.
Lambdafun	Penalty function that takes as its input time and returns a penalty value. Use a function handle to support the penalty function. The function handle for the penalty function which takes one numeric input (time-to-maturity) and returns one numeric output (penalty to be applied to the curvature of the spline). For more information



	<p>on defining a function handle, see the MATLAB Programming Fundamentals documentation.</p> <hr/> <p><b>Note:</b> The smoothing spline represents the forward curve. The spline is penalized for curvature by specifying a penalty function. This fit may only be done with a <code>FitType</code> of <code>DurationWeightedPrice</code>.</p>
<b>Knots</b>	<p>(Optional) Vector of knot locations (times-to-maturity); by default, knots is set to be a vector comprised of 0 and the time to maturity of all input instruments. The default is for the spline type to be cubic but you can specify any spline type by explicitly specifying the knots. User-defined knots can be specified using the following command, where <code>k</code> is the order: <code>augknt(knots,k)</code>.</p>
<b>Compounding</b>	<p>(Optional) Scalar that sets the compounding frequency per year for the <code>IRFunctionCurve</code> object:</p> <ul style="list-style-type: none"> <li>• -1 = Continuous compounding (default)</li> <li>• 1 = Annual compounding</li> <li>• 2 = Semiannual compounding</li> <li>• 3 = Compounding three times per year</li> <li>• 4 = Quarterly compounding</li> <li>• 6 = Bimonthly compounding</li> <li>• 12 = Monthly compounding</li> </ul>

<b>Basis</b>	<p>(Optional) Day-count basis of the interest-rate curve. A scalar of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
--------------	--

## Instrument Parameters

For each bond **Instrument**, you can specify the following additional instrument parameters as parameter/value pairs. For example, **InstrumentBasis** distinguishes a bond instrument's **Basis** value from the curve's **Basis** value.

<b>InstrumentPeriod</b>	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
<b>InstrumentBasis</b>	<p>(Optional) Day-count basis of the bond. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> </ul>

	<ul style="list-style-type: none"> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<b>InstrumentEndMonthRule</b>	(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
<b>InstrumentIssueDate</b>	(Optional) Date when an instrument was issued.
<b>InstrumentFirstCouponDate</b>	(Optional) Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When <b>FirstCouponDate</b> and <b>LastCouponDate</b> are both specified, <b>FirstCouponDate</b> takes precedence in determining the coupon payment structure. If you do not specify a <b>FirstCouponDate</b> , the cash flow payment dates are determined from other inputs.

InstrumentLastCouponD	(Optional) Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified <b>FirstCouponDate</b> , a specified <b>LastCouponDate</b> determines the coupon structure of the bond. The coupon structure of a bond is truncated at the <b>LastCouponDate</b> , regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a <b>LastCouponDate</b> , the cash flow payment dates are determined from other inputs.
InstrumentFace	(Optional) Face or par value. Default = 100.

---

**Note:** When using **Instrument** parameter/value pairs, you can specify simple interest for a bond by specifying the **InstrumentPeriod** value as 0. If **InstrumentBasis** and **InstrumentPeriod** are not specified for a bond, the following default values are used: **Basis** is 0 (act/act) and **Period** is 2.

---

## Description

`Fcurve = IRFunctionCurve.fitSmoothingSpline(Type, Settle, Instruments, Lambdafun, 'Parameter1', Value1, 'Parameter2', Value2, ...)` fits a smoothing spline to market data for a bond. You must enter the optional arguments for **Basis**, **Compounding**, and **Knots** as parameter/value pairs.

## Examples

### Use a Smoothing Spline Function to Fit Market Data For a Bond

This example shows how to use a smoothing spline function to fit market data for a bond.

```
Settle = repmat(datenum('30-Apr-2008'),[6 1]);
Maturity = [datenum('07-Mar-2009');datenum('07-Mar-2011');...
datenum('07-Mar-2013');datenum('07-Sep-2016');...
datenum('07-Mar-2025');datenum('07-Mar-2036')];

CleanPrice = [100.1;100.1;100.8;96.6;103.3;96.3];
CouponRate = [0.0400;0.0425;0.0450;0.0400;0.0500;0.0425];
Instruments = [Settle Maturity CleanPrice CouponRate];
```

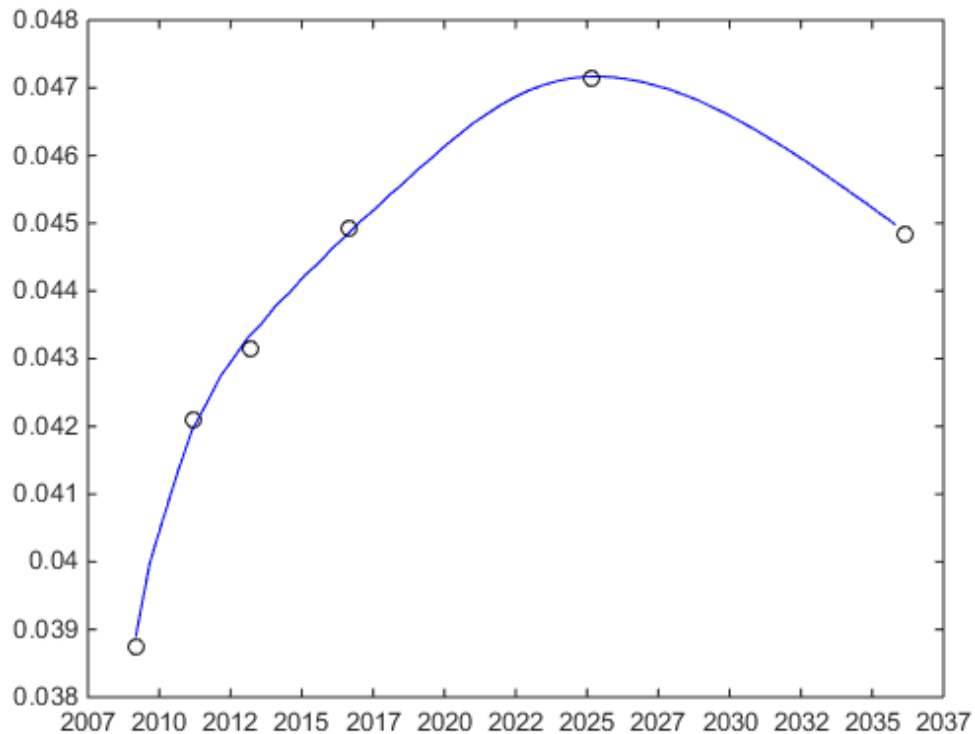
```

PlottingPoints = datenum('07-Mar-2009'):180:datenum('07-Mar-2036');
Yield = bndyield(CleanPrice,CouponRate,Settle,Maturity);

% use the AUGKNT function to construct the knots for a cubic spline at every 5 years
CustomKnots = augknt(0:5:30,4);
SmoothingModel = IRFunctionCurve.fitSmoothingSpline('Zero',datenum('30-Apr-2008'),...
Instruments,@(t) 1000,'knots', CustomKnots);

% create the plot
plot(PlottingPoints, getParYields(SmoothingModel, PlottingPoints),'b')
hold on
scatter(Maturity,Yield,'black')
datetick('x')

```



- “Fitting Interest Rate Curve Functions”

## More About

### Algorithms

The term structure can be modeled with a spline — specifically, one way to model the term structure is by representing the forward curve with a cubic spline. To ensure that the spline is sufficiently smooth, a penalty is imposed relating to the curvature (second derivative) of the spline:

$$\sum_{i=1}^N \left[ \frac{P_i - \hat{P}_i(f)}{D_i} \right]^2 + \int_0^M \lambda_t(m) [f''(m)]^2 dm$$

where the first term is the difference between the observed price  $P$  and the predicted price,  $\hat{P}$ , (weighted by the bond's duration,  $D$ ) summed over all bonds in our data set and the second term is the penalty term (where  $\lambda$  is a penalty function and  $f$  is the spline).

See [3], [4], [5] below.

There have been different proposals for the specification of the penalty function  $\lambda$ . One approach, advocated by [4], and currently used by the UK Debt Management Office, is a penalty function of the following form:

$$\log(\lambda(m)) = L - (L - S)e^{-\frac{m}{\tau}}$$

## References

- [1] Nelson, C.R., Siegel, A.F., (1987), "Parsimonious modelling of yield curves", *Journal of Business*, 60, pp 473-89
- [2] Svensson, L.E.O. (1994), "Estimating and interpreting forward interest rates: Sweden 1992-4", *International Monetary Fund, IMF Working Paper*, 1994/114
- [3] Fisher, M., Nychka, D., Zervos, D. (1995), "Fitting the term structure of interest rates with smoothing splines", *Board of Governors of the Federal Reserve System, Federal Reserve Board Working Paper* 95-1
- [4] Anderson, N., Sleath, J. (1999), "New estimates of the UK real and nominal yield curves", *Bank of England Quarterly Bulletin*, November, pp 384-92

[5] Waggoner, D. (1997), "Spline Methods for Extracting Interest Rate Curves from Coupon Bond Prices", Federal Reserve Board Working Paper 97-10

[6] "Zero-coupon yield curves: technical documentation", BIS Papers No. 25, October 2005

[7] Bolder, D.J., Gusba,S (2002), "Exponentials, Polynomials, and Fourier Series: More Yield Curve Modelling at the Bank of Canada," Working Papers 02-29, Bank of Canada

[8] Bolder, D.J., Streliski, D (1999), "Yield Curve Modelling at the Bank of Canada," Technical Reports 84, Bank of Canada

### **See Also**

"@IRFunctionCurve"

## fitSvensson

Fit Svensson function to bond market data

### Class

@IRFunctionCurve

### Syntax

```
CurveObj = IRFunctionCurve.fitSvensson(Type, Settle,
Instruments)
```

```
CurveObj = IRFunctionCurve.fitSvensson(Type, Settle,
Instruments, 'Parameter1', Value1, 'Parameter2', Value2, ...)
```

### Arguments

Type	Type of interest-rate curve for a bond: zero or forward.
Settle	Scalar for the <b>Settle</b> date of the curve.
Instruments	N-by-4 data matrix for <b>Instruments</b> where the first column is <b>Settle</b> date, the second column is <b>Maturity</b> , the third column is the clean price, and the fourth column is a <b>CouponRate</b> for the bond.
Compounding	(Optional) Scalar that sets the compounding frequency per year for the <b>IRFunctionCurve</b> object: <ul style="list-style-type: none"> <li>• -1 = Continuous compounding</li> </ul>
Basis	(Optional) Day-count basis of the interest-rate curve. A scalar of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> </ul>



	<ul style="list-style-type: none"> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<b>IRFitOptions</b>	(Optional) Object constructed from <b>IRFitOptions</b> .

## Instrument Parameters

For each bond **Instrument**, you can specify the following additional instrument parameters as parameter/value pairs. For example, **InstrumentBasis** distinguishes a bond instrument's **Basis** value from the curve's **Basis** value.

<b>InstrumentPeriod</b>	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
<b>InstrumentBasis</b>	<p>(Optional) Day-count basis of the bond. A vector of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> </ul>

	<ul style="list-style-type: none"> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see “”.</p>
<b>InstrumentEndMonthRule</b>	(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
<b>InstrumentIssueDate</b>	(Optional) Date when an instrument was issued.
<b>InstrumentFirstCouponDate</b>	(Optional) Date when a bond makes its first coupon payment; used when bond has an irregular first coupon period. When <b>FirstCouponDate</b> and <b>LastCouponDate</b> are both specified, <b>FirstCouponDate</b> takes precedence in determining the coupon payment structure. If you do not specify a <b>FirstCouponDate</b> , the cash flow payment dates are determined from other inputs.
<b>InstrumentLastCouponDate</b>	(Optional) Last coupon date of a bond before the maturity date; used when bond has an irregular last coupon period. In the absence of a specified <b>FirstCouponDate</b> , a specified <b>LastCouponDate</b> determines the coupon structure of the bond. The coupon structure of a bond is truncated at the <b>LastCouponDate</b> , regardless of where it falls, and is followed only by the bond's maturity cash flow date. If you do not specify a <b>LastCouponDate</b> , the cash flow payment dates are determined from other inputs.
<b>InstrumentFace</b>	(Optional) Face or par value. Default = 100.

**Note:** When using **Instrument** parameter/value pairs, you can specify simple interest for a bond by specifying the **InstrumentPeriod** value as 0. If **InstrumentBasis** and

InstrumentPeriod are not specified for a bond, the following default values are used: Basis is 0 (act/act) and Period is 2.

---

## Description

CurveObj = IRFunctionCurve.fitSvensson(Type, Settle, Instruments, 'Parameter1', Value1, 'Parameter2', Value2, ...) fits the Svensson function to bond market data. You must enter the optional arguments for Basis, Compounding, and IRFitOptions as parameter/value pairs. After creating a Svensson model, you can view the model parameters using:

```
CurveObj.Parameters
```

where the order of parameters is [Beta0,Beta1,Beta2,Beta3,tau1,tau2].

## Examples

### Use a Svensson Function to Fit Bond Market Data

This example shows how to use a Svensson function to fit bond market data.

```
Settle = datenum('15-Apr-2014');
Maturity = datemnth(Settle,12*[1 2 3 5 7 10 20 30]');

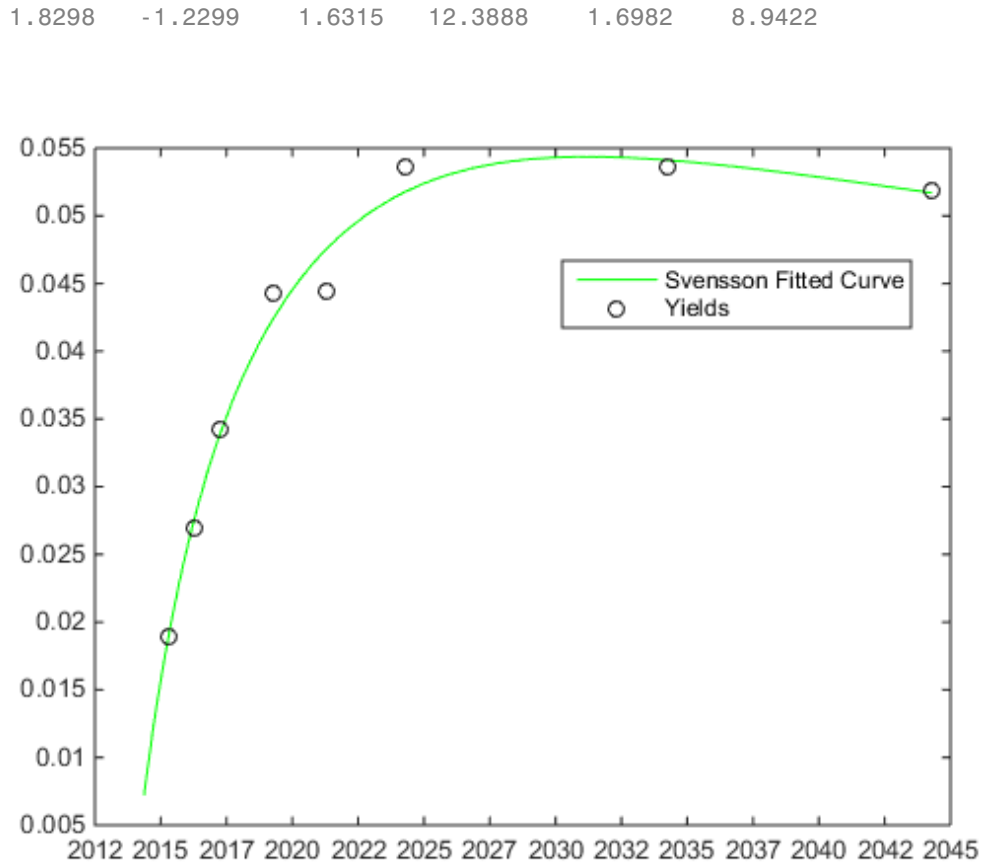
CleanPrice = [100.1 100.1 100.2 99.0 101.8 99.2 101.7 100.2]';
CouponRate = [0.0200 0.0275 0.035 0.042 0.0475 0.0525 0.055 0.052]';
Instruments = [repmat(Settle,size(Maturity)) Maturity CleanPrice CouponRate];
PlottingPoints = datemnth(Settle,1:360);
Yield = bndyield(CleanPrice,CouponRate,Settle,Maturity);

SvenssonModel = IRFunctionCurve.fitSvensson('Zero',Settle,Instruments);

SvenssonModel.Parameters

% create the plot
plot(PlottingPoints, getParYields(SvenssonModel, PlottingPoints),'g')
hold on
scatter(Maturity,Yield,'black')
datetick('x')
legend({'Svensson Fitted Curve','Yields'},'location','best')

ans =
```



- “Fitting Interest Rate Curve Functions”

## More About

### Algorithms

A very similar model to the Nelson-Siegel is the Svensson model, which adds two additional parameters to account for greater flexibility in the term structure. This model proposes that the forward rate can be modeled with the following form:

$$f = \beta_0 + \beta_1 e^{-\frac{m}{\tau_1}} + \beta_2 e^{-\frac{m}{\tau_1}} \frac{m}{\tau_1} + \beta_3 e^{-\frac{m}{\tau_2}} \frac{m}{\tau_2}$$

As above, this can be integrated to derive an equation for the zero curve:

$$s = \beta_0 + \beta_1(1 - e^{-\frac{m}{\tau_1}})\left(-\frac{\tau_1}{m}\right) + \beta_2\left(\left(1 - e^{-\frac{m}{\tau_1}}\right)\frac{\tau_1}{m} - e^{-\frac{m}{\tau_1}}\right) + \beta_3\left(\left(1 - e^{-\frac{m}{\tau_2}}\right)\frac{\tau_2}{m} - e^{-\frac{m}{\tau_2}}\right)$$

## References

- [1] Nelson, C.R., Siegel, A.F., (1987), "Parsimonious modelling of yield curves", *Journal of Business*, 60, pp 473-89
- [2] Svensson, L.E.O. (1994), "Estimating and interpreting forward interest rates: Sweden 1992-4", *International Monetary Fund, IMF Working Paper*, 1994/114
- [3] Fisher, M., Nychka, D., Zervos, D. (1995), "Fitting the term structure of interest rates with smoothing splines", *Board of Governors of the Federal Reserve System, Federal Reserve Board Working Paper* 95-1
- [4] Anderson, N., Sleath, J. (1999), "New estimates of the UK real and nominal yield curves", *Bank of England Quarterly Bulletin*, November, pp 384-92
- [5] Waggoner, D. (1997), "Spline Methods for Extracting Interest Rate Curves from Coupon Bond Prices", *Federal Reserve Board Working Paper* 97-10
- [6] "Zero-coupon yield curves: technical documentation", *BIS Papers No. 25*, October 2005
- [7] Bolder, D.J., Gusba, S (2002), "Exponentials, Polynomials, and Fourier Series: More Yield Curve Modelling at the Bank of Canada," *Working Papers 02-29*, Bank of Canada
- [8] Bolder, D.J., Streliski, D (1999), "Yield Curve Modelling at the Bank of Canada," *Technical Reports 84*, Bank of Canada

## See Also

"@IRFunctionCurve" | "@IRFitOptions"

## getDiscountFactors

Get discount factors for input dates for IRDataCurve

### Class

@IRDataCurve

### Syntax

```
F = getDiscountFactors(CurveObj, InpDates)
```

### Arguments

CurveObj	Interest-rate curve object that is constructed using IRDataCurve.
InpDates	Vector of input dates using MATLAB date format. The input dates must be after the settle date.

### Description

F = getDiscountFactors(CurveObj, InpDates) returns discount factors for the input dates.

### Examples

#### Get Discount Factors For Input Dates for an IRDataCurve

This example shows how to get discount factors for input dates for an IRDataCurve.

```
Data = [2.09 2.47 2.71 3.12 3.43 3.85 4.57 4.58]/100;  
Dates = daysadd(today,[360 2*360 3*360 5*360 7*360 10*360 20*360 30*360],1);  
irdc = IRDataCurve('Zero',today,Dates,Data);
```

```
getDiscountFactors(irdc, today+30:30:today+720)
```

```
ans =
```

```
0.9986  
0.9971  
0.9956  
0.9940  
0.9924  
0.9907  
0.9890  
0.9873  
0.9854  
0.9836  
0.9817  
0.9798  
0.9778  
0.9757  
0.9736  
0.9715  
0.9693  
0.9671  
0.9649  
0.9626  
0.9602  
0.9578  
0.9554  
0.9529
```

## More About

- “@IRDataCurve”

## getDiscountFactors

Get discount factors for input dates for `IRFunctionCurve`

### Class

@`IRFunctionCurve`

### Syntax

```
F = getDiscountFactors(CurveObj, InpDates)
```

### Arguments

CurveObj	Interest-rate curve object that is constructed using the <code>IRFunctionCurve</code> .
InpDates	Vector of input dates using MATLAB date format. The input dates must be after the settle date.

### Description

`F = getDiscountFactors(CurveObj, InpDates)` returns discount factors for the input dates.

### Examples

#### Get Discount Factors for Input Dates For an `IRFunctionCurve`

This example shows how to get discount factors for input dates for an `IRFunctionCurve`.

```
irfc = IRFunctionCurve('Forward',today,@(t) polyval([-0.0001 0.003 0.02],t));  
getDiscountFactors(irfc, today+30:30:today+720)
```



ans =

0.9984  
0.9967  
0.9950  
0.9933  
0.9916  
0.9899  
0.9881  
0.9864  
0.9846  
0.9828  
0.9810  
0.9792  
0.9773  
0.9755  
0.9736  
0.9717  
0.9698  
0.9679  
0.9660  
0.9641  
0.9621  
0.9602  
0.9582  
0.9562

## More About

- “@IRFunctionCurve”

## getForwardRates

Get forward rates for input dates for `IRDataCurve`

### Class

@`IRDataCurve`

### Syntax

```
F = getForwardRates(CurveObj, InpDates)
```

```
F = getForwardRates(CurveObj, InpDates, 'Parameter1', Value1,  
'Parameter2', Value2, ...)
```

### Arguments

<b>CurveObj</b>	Interest-rate curve object that is constructed using <code>IRDataCurve</code> .
<b>InpDates</b>	Vector of input dates using MATLAB date format. The input dates must be after the settle date.
<b>Compounding</b>	(Optional) Scalar that sets the compounding frequency per year for forward rates are: <ul style="list-style-type: none"> <li>• -1 = Continuous compounding</li> <li>• 1 = Annual compounding</li> <li>• 2 = Semiannual compounding (default)</li> <li>• 3 = Compounding three times per year</li> <li>• 4 = Quarterly compounding</li> <li>• 6 = Bimonthly compounding</li> <li>• 12 = Monthly compounding</li> </ul>
<b>Basis</b>	(Optional) Day-count basis values for the forward rates: <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> </ul>

- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

## Description

`F = getForwardRates(CurveObj, InpDates, 'Parameter1', Value1, 'Parameter2', Value2, ...)` returns forward rates for the input dates. You must enter the optional arguments for **Basis** and **Compounding** as parameter/value pairs. The `getForwardRates` method returns forward rates corresponding to the periodicity of the dates input to `getForwardRates`. For example, where the dates are monthly, monthly forward rates are returned. The first element of the output is the forward rate from the **Settle** to 1 month, the second element is the forward rate from 1 month to 2 months, etc.

## Examples

### Get Forward Rates For Input Dates for an `IRDataCurve`

This example shows how to get forward rates for input dates for an `IRDataCurve`.

```
Data = [2.09 2.47 2.71 3.12 3.43 3.85 4.57 4.58]/100;
```

```
Dates = daysadd(today,[360 2*360 3*360 5*360 7*360 10*360 20*360 30*360],1);
irdc = IRDataCurve('Zero',today,Dates,Data);
getForwardRates(irdc, today+30:30:today+720)
```

```
ans =
```

```
0.0174
0.0180
0.0187
0.0193
0.0199
0.0205
0.0212
0.0218
0.0224
0.0230
0.0237
0.0243
0.0249
0.0255
0.0261
0.0268
0.0274
0.0280
0.0286
0.0293
0.0299
0.0305
0.0311
0.0318
```

## More About

- “@IRDataCurve”

# getForwardRates

Get forward rates for input dates for IRFunctionCurve

## Class

@IRFunctionCurve

## Syntax

```
F = getForwardRates(CurveObj, InpDates)
```

```
F = getForwardRates(CurveObj, InpDates, 'Parameter1',  
Value1, 'Parameter2', Value2, ...)
```

## Arguments

CurveObj	Interest-rate curve object that is constructed using IRFunctionCurve.
InpDates	Vector of input dates using MATLAB date format. The input dates must be after the settle date.
Compounding	(Optional) Scalar that sets the compounding frequency per year for the forward rates are: <ul style="list-style-type: none"> <li>• -1 = Continuous compounding</li> <li>• 1 = Annual compounding</li> <li>• 2 = Semiannual compounding (default)</li> <li>• 3 = Compounding three times per year</li> <li>• 4 = Quarterly compounding</li> <li>• 6 = Bimonthly compounding</li> <li>• 12 = Monthly compounding</li> </ul>
Basis	(Optional) Day-count basis for the forward rates: <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> </ul>

- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

## Description

`F = getForwardRates(CurveObj, InpDates, 'Parameter1', Value1, 'Parameter2', Value2, ...)` returns forward rates for the input dates. You must enter the optional arguments for **Basis** and **Compounding** as parameter/value pairs.

## Examples

### Get Forward Rates For Input Dates For an IRFunctionCurve

This example shows how to get forward rates for input dates for an `IRFunctionCurve`.

```
irfc = IRFunctionCurve('Forward',today,@(t) polyval([-0.0001 0.003 0.02],t));
getForwardRates(irfc, today+30:30:today+720)
```

```
ans =
```

```
0.0202
```

0.0205  
0.0207  
0.0210  
0.0212  
0.0215  
0.0217  
0.0219  
0.0222  
0.0224  
0.0226  
0.0229  
0.0231  
0.0233  
0.0235  
0.0238  
0.0240  
0.0242  
0.0244  
0.0247  
0.0249  
0.0251  
0.0253  
0.0255

## More About

- “@IRFunctionCurve”

## getParYields

Get par yields for input dates for `IRDataCurve`

### Class

@`IRDataCurve`

### Syntax

```
F = getParYields(CurveObj, InpDates)
```

```
F = getParYields(CurveObj, InpDates, 'Parameter1',  
Value1, 'Parameter2', Value2, ...)
```

### Arguments

<b>CurveObj</b>	Interest-rate curve object that is constructed using <code>IRDataCurve</code> .
<b>InpDates</b>	Vector of input dates using MATLAB date format. The input dates must be after the settle date.
<b>Compounding</b>	(Optional) Scalar that sets the compounding frequency per year for the par yield rates are: <ul style="list-style-type: none"> <li>• -1 = Continuous compounding</li> <li>• 1 = Annual compounding</li> <li>• 2 = Semiannual compounding (default)</li> <li>• 3 = Compounding three times per year</li> <li>• 4 = Quarterly compounding</li> <li>• 6 = Bimonthly compounding</li> <li>• 12 = Monthly compounding</li> </ul>
<b>Basis</b>	(Optional) Day-count basis values for the par yield rates: <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> </ul>



- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

## Description

`F = getParYields(CurveObj, InpDates, 'Parameter1', Value1, 'Parameter2', Value2, ...)` returns par yields for the input dates. You must enter the optional arguments for **Basis** and **Compounding** as parameter/value pairs.

## Examples

### Get Par Yields For Input Dates For an IRDataCurve

This example shows how to get par yields for input dates for an `IRDataCurve`.

```
Data = [2.09 2.47 2.71 3.12 3.43 3.85 4.57 4.58]/100;
Dates = daysadd(today,[360 2*360 3*360 5*360 7*360 10*360 20*360 30*360],1);
irdc = IRDataCurve('Zero',today,Dates,Data);
getParYields(irdc, today+30:30:today+720)
```

ans =

0.0175  
0.0179  
0.0181  
0.0185  
0.0188  
0.0188  
0.0193  
0.0195  
0.0199  
0.0202  
0.0205  
0.0208  
0.0212  
0.0215  
0.0218  
0.0221  
0.0224  
0.0227  
0.0230  
0.0233  
0.0236  
0.0239  
0.0243  
0.0246

## More About

- “@IRDataCurve”

# getParYields

Get par yields for input dates for `IRFunctionCurve`

## Class

@`IRFunctionCurve`

## Syntax

```
F = getParYields(CurveObj, InpDates)
```

```
F = getParYields(CurveObj, InpDates, 'Parameter1',  
Value1, 'Parameter2', Value2, ...)
```

## Arguments

<b>CurveObj</b>	Interest-rate curve object that is constructed using <code>IRFunctionCurve</code> .
<b>InpDates</b>	Vector of input dates using MATLAB date format. The input dates must be after the settle date.
<b>Compounding</b>	(Optional) Scalar that sets the compounding frequency per year for par yield rates are: <ul style="list-style-type: none"> <li>• -1 = Continuous compounding</li> <li>• 1 = Annual compounding</li> <li>• 2 = Semiannual compounding (default)</li> <li>• 3 = Compounding three times per year</li> <li>• 4 = Quarterly compounding</li> <li>• 6 = Bimonthly compounding</li> <li>• 12 = Monthly compounding</li> </ul>
<b>Basis</b>	(Optional) Day-count basis values for par yield rates: <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> </ul>

- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

## Description

`F = getParYields(CurveObj, InpDates, 'Parameter1', Value1, 'Parameter2', Value2, ...)` returns par yields for the input dates. You must enter the optional arguments for **Basis** and **Compounding** as parameter/value pairs.

## Examples

### Get Par Yields For Input Dates For an IRFunctionCurve

This example shows how to get par yields for input dates for an `IRFunctionCurve`.

```
irfc = IRFunctionCurve('Forward',today,@(t) polyval([-0.0001 0.003 0.02],t));
getParYields(irfc, today+30:30:today+720)
```

```
ans =
```

```
0.0203
```

0.0205  
0.0205  
0.0207  
0.0208  
0.0206  
0.0208  
0.0209  
0.0211  
0.0212  
0.0213  
0.0214  
0.0216  
0.0217  
0.0218  
0.0220  
0.0221  
0.0221  
0.0223  
0.0224  
0.0225  
0.0226  
0.0227  
0.0228

## More About

- “@IRFunctionCurve”

## getZeroRates

Get zero rates for input dates for `IRDataCurve`

### Class

@`IRDataCurve`

### Syntax

```
F = getZeroRates(CurveObj, InpDates)
```

```
F = getZeroRates(CurveObj, InpDates, 'Parameter1',  
Value1, 'Parameter2', Value2, ...)
```

### Arguments

<b>CurveObj</b>	Interest-rate curve object that is constructed using <code>IRDataCurve</code> .
<b>InpDates</b>	Vector of input dates using MATLAB date format. The input dates must be after the settle date.
<b>Compounding</b>	(Optional) Scalar that sets the compounding frequency per year for zero rates are: <ul style="list-style-type: none"> <li>• -1 = Continuous compounding</li> <li>• 1 = Annual compounding</li> <li>• 2 = Semiannual compounding (default)</li> <li>• 3 = Compounding three times per year</li> <li>• 4 = Quarterly compounding</li> <li>• 6 = Bimonthly compounding</li> <li>• 12 = Monthly compounding</li> </ul>
<b>Basis</b>	(Optional) Day-count basis values for zero rates: <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> </ul>

- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

## Description

`F = getZeroRates(CurveObj, InpDates, 'Parameter1', Value1, 'Parameter2', Value2, ...)` returns zero rates for the input dates. You must enter the optional arguments for **Basis** and **Compounding** as parameter/value pairs.

## Examples

### Get Zero Rates For Input Dates For an IRDataCurve

This example shows how to get zero rates for input dates for an `IRDataCurve`.

```
Data = [2.09 2.47 2.71 3.12 3.43 3.85 4.57 4.58]/100;
Dates = daysadd(today,[360 2*360 3*360 5*360 7*360 10*360 20*360 30*360],1);
irdc = IRDataCurve('Zero',today,Dates,Data);
getZeroRates(irdc, today+30:30:today+720)
```

ans =

0.0174  
0.0177  
0.0180  
0.0184  
0.0187  
0.0190  
0.0193  
0.0196  
0.0199  
0.0202  
0.0205  
0.0208  
0.0212  
0.0215  
0.0218  
0.0221  
0.0224  
0.0227  
0.0230  
0.0233  
0.0237  
0.0240  
0.0243  
0.0246

### More About

- “@IRDataCurve”



# getZeroRates

Get zero rates for input dates for `IRFunctionCurve`

## Class

@`IRFunctionCurve`

## Syntax

```
F = getZeroRates(CurveObj, InpDates)
```

```
F = getZeroRates(CurveObj, InpDates, 'Parameter1',  
Value1, 'Parameter2', Value2, ...)
```

## Arguments

<b>CurveObj</b>	Interest-rate curve object that is constructed using <code>IRFunctionCurve</code> .
<b>InpDates</b>	Vector of input dates using MATLAB date format. The input dates must be after the settle date.
<b>Compounding</b>	(Optional) Scalar that sets the compounding frequency per year for zero rates are: <ul style="list-style-type: none"> <li>• -1 = Continuous compounding</li> <li>• 1 = Annual compounding</li> <li>• 2 = Semiannual compounding (default)</li> <li>• 3 = Compounding three times per year</li> <li>• 4 = Quarterly compounding</li> <li>• 6 = Bimonthly compounding</li> <li>• 12 = Monthly compounding</li> </ul>
<b>Basis</b>	(Optional) Day-count basis value for zero rates: <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> </ul>

- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (BMA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ICMA)
- 9 = actual/360 (ICMA)
- 10 = actual/365 (ICMA)
- 11 = 30/360E (ICMA)
- 12 = actual/actual (ISDA)
- 13 = BUS/252

For more information, see **basis**.

## Description

`F = getZeroRates(CurveObj, InpDates, 'Parameter1', Value1, 'Parameter2', Value2, ...)` returns zero rates for the input dates. You must enter the optional arguments for **Basis** and **Compounding** as parameter/value pairs.

## Examples

### Get Zero Rates For Input Dates For an IRFunctionCurve

This example shows how to get zero rates for input dates for an `IRFunctionCurve`.

```
irfc = IRFunctionCurve('Forward',today,@(t) polyval([-0.0001 0.003 0.02],t));  
getZeroRates(irfc, today+30:30:today+720)
```

```
ans =
```

```
0.0201
```

0.0202  
0.0204  
0.0205  
0.0206  
0.0207  
0.0209  
0.0210  
0.0211  
0.0212  
0.0213  
0.0214  
0.0216  
0.0217  
0.0218  
0.0219  
0.0220  
0.0221  
0.0223  
0.0224  
0.0225  
0.0226  
0.0227  
0.0228

## More About

- “@IRFunctionCurve”

## IRBootstrapOptions

Construct specific options for bootstrapping interest-rate curve object

### Class

@IRBootstrapOptions

### Syntax

```
mybootoptions = IRBootstrapOptions('Param1', Value1)
```

### Arguments

ConvexityAdjustment	<p>(Optional) Controls the convexity adjustment to interest-rate futures. This can be specified as a function handle that takes one numeric input (time-to-maturity) and returns one numeric output, <code>ConvexityAdjustment</code>. For more information on defining a function handle, see the MATLAB Programming Fundamentals documentation.</p> <p>Alternatively, you can define <code>ConvexityAdjustment</code> as an N-by-1 vector of values, where N is the number of interest-rate futures.</p> <p>In either case, the <code>ConvexityAdjustment</code> is subtracted from the futures rate.</p>
---------------------	---

### Description

`mybootoptions = IRBootstrapOptions('Param1', Value1)` constructs an `IRBootstrapOptionsObj` structure. The `IRBootstrapOptionsObj` is used with the `bootstrap` method.

## Examples

```
mybootoptions = IRBootstrapOptions('ConvexityAdjustment', repmat(.005,10,1))
```

```
mybootoptions =
```

```
IRBootstrapOptions with properties:  
ConvexityAdjustment: [10x1 double]
```

## More About

- “@IRDataCurve”

## IRDataCurve

Construct interest-rate curve object from dates and data

### Class

@IRDataCurve

### Syntax

```
CurveObj = IRDataCurve(Type, Settle, Dates, Data)
```

```
CurveObj = IRDataCurve(Type, Settle, Dates, Data, 'Parameter1',  
Value1, 'Parameter2', Value2, ...)
```

### Arguments

Type	Type of interest-rate curve. Acceptable values are <b>forward</b> , <b>zero</b> , or <b>discount</b> .
Settle	Scalar for the <b>Settle</b> date of the curve.
Dates	Dates corresponding to rate data.
Data	Interest-rate data for the curve object.
Compounding	(Optional) Scalar that sets the compounding frequency per year for the <b>IRDataCurve</b> object: <ul style="list-style-type: none"> <li>• -1 = Continuous compounding</li> <li>• 1 = Annual compounding</li> <li>• 2 = Semiannual compounding (default)</li> <li>• 3 = Compounding three times per year</li> <li>• 4 = Quarterly compounding</li> <li>• 6 = Bimonthly compounding</li> </ul>

	<ul style="list-style-type: none"> <li>• 12 = Monthly compounding</li> </ul>
<b>Basis</b>	<p>(Optional) Day-count basis of the interest-rate curve. A scalar of integers.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
<b>InterpMethod</b>	<p>(Optional) Values are:</p> <ul style="list-style-type: none"> <li>• 'linear' — Linear interpolation (default).</li> <li>• 'constant' — Piecewise constant interpolation.</li> <li>• 'pchip' — Piecewise cubic Hermite interpolation.</li> <li>• 'spline' — Cubic spline interpolation.</li> </ul>

## Description

CurveObj = IRDataCurve(Type, Settle, Dates, Data, 'Parameter1', Value1, 'Parameter2', Value2, ...) constructs an interest-rate curve with the specified Dates and Data. You must enter the optional arguments for Basis, Compounding, and InterpMethod as parameter/value pairs.

Alternatively, an `IRDataCurve` object can be bootstrapped from market data using the `bootstrap` method.

After an `IRDataCurve` curve object is constructed, you can use the following methods to determine the forward rates, zero rates, and discount factors. In addition, you can use the `toRateSpec` method to convert the interest-rate curve object to a `RateSpec` structure.

Method	Description
<code>getForwardRates</code>	Returns forward rates for input dates.
<code>getZeroRates</code>	Returns zero rates for input dates.
<code>getDiscountFactors</code>	Returns discount factors for input dates.
<code>getParYields</code>	Returns par yields for input dates.
<code>toRateSpec</code>	Converts to be a <code>RateSpec</code> object; this structure is identical to the <code>RateSpec</code> produced by the Financial Instruments Toolbox function <code>intenvset</code> .
<code>bootstrap</code>	Bootstraps an interest rate curve from market data.

## Examples

```
Data = [2.09 2.47 2.71 3.12 3.43 3.85 4.57 4.58]/100;
Dates = daysadd(today,[360 2*360 3*360 5*360 7*360 10*360 20*360 30*360],1);
irdc = IRDataCurve('Zero',today,Dates,Data)
```

```
irdc =
```

```
Properties:
    Dates: [8x1 double]
    Data: [8x1 double]
    InterpMethod: 'linear'
    Type: 'Zero'
    Settle: 733599
    Compounding: 2
    Basis: 0
```

## More About

- “@IRCurve”



# IRFitOptions

Construct specific options for fitting interest-rate curve object

## Class

@IRFitOptions

## Syntax

```
myfitoptions = IRFitOptions(InitialGuess)
```

```
myfitoptions = IRFitOptions(InitialGuess, 'Parameter1', Value1)
```

## Arguments

InitialGuess	Initial guess for the parameters of the curve function. Vector of values for the starting point of the optimization.
FitType	(Optional) Price, Yield, or DurationWeightedPrice determines which is minimized in the curve fitting process. The default is DurationWeightedPrice.
UpperBound	(Optional) Lower bound for the parameters of the curve function.
LowerBound	(Optional) Upper bound for the parameters of the curve function.
OptOptions	(Optional) Optimization solver options constructed with <code>optimoptions</code> from the Optimization Toolbox ( <code>optimset</code> is also supported).

## Description

`myfitoptions = IRFitOptions('Param1', Value1)` constructs the `IRFitOptions` structure with an initial guess or with an initial guess and bounds. You must enter the optional arguments for `FitType`, `UpperBound`, `LowerBound`, and `OptOptions` as parameter/value pairs.

---

**Note:** IRFitOptions constructor must be used with fitFunction method when building a custom fitting function.

---

## Examples

```
myfitoptions = IRFitOptions([7 2 1 0], 'FitType', 'yield')
```

```
myfitoptions =
```

```
Properties:
    FitType: 'yield'
    InitialGuess: [7 2 1 0]
    UpperBound: []
    LowerBound: []
    OptOptions: []
```

## More About

- “@IRFunctionCurve”

# IRFunctionCurve

Construct interest-rate curve object from function handle or function and fit to market data

## Class

@IRFunctionCurve

## Syntax

```
CurveObj = IRFunctionCurve(Type, Settle, FunctionHandle)
```

```
CurveObj = IRFunctionCurve(Type, Settle, FunctionHandle,  
'Parameter1', Value1, 'Parameter2', Value2, ...)
```

## Arguments

Type	Type of interest-rate curve: <b>zero</b> , <b>forward</b> , or <b>discount</b> .
Settle	Scalar for the <b>Settle</b> date of the curve.
Compounding	(Optional) Scalar that sets the compounding frequency per year for the <b>IRFunctionCurve</b> object: <ul style="list-style-type: none"> <li>• -1 = Continuous compounding</li> <li>• 1 = Annual compounding</li> <li>• 2 = Semiannual compounding (default)</li> <li>• 3 = Compounding three times per year</li> <li>• 4 = Quarterly compounding</li> <li>• 6 = Bimonthly compounding</li> <li>• 12 = Monthly compounding</li> </ul>
Basis	(Optional) Day-count basis of the bond. A scalar of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> </ul>

	<ul style="list-style-type: none"> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
FunctionHandle	Function handle that defines the interest-rate curve. The function handle requires one numeric input (time-to-maturity) and returns one numeric output (interest rate or discount factor). For more information on defining a function handle, see the MATLAB Programming Fundamentals documentation.
Parameters	Fitted parameters for function.

## Description

`CurveObj = IRFunctionCurve(Type, Settle, FunctionHandle, 'Parameter1', Value1, 'Parameter2', Value2, ...)` constructs an interest-rate curve object directly by specifying a function handle. You must enter the optional arguments for **Basis** and **Compounding** as parameter/value pairs.

After you use the `IRFunctionCurve` constructor to create an `IRFunctionCurve` object, you can fit the bond using the following methods.

Method	Description
<code>getForwardRates</code>	Returns forward rates for input dates.

Method	Description
getZeroRates	Returns zero rates for input dates.
getDiscountFactors	Returns discount factors for input dates.
getParYields	Returns par yields for input dates.
toRateSpec	Converts to be a <code>RateSpec</code> object.  This <code>RateSpec</code> structure is identical to the <code>RateSpec</code> produced by the Financial Instruments Toolbox function <code>intenvset</code> .

Alternatively, you can construct an `IRFunctionCurve` object using the following static methods.

Static Method	Description
fitNelsonSiegel	Fits a Nelson-Siegel function to market data.
fitSvensson	Fits a Svensson function to market data.
fitSmoothingSpline	Fits a smoothing spline function to market data.
fitFunction	Fits a custom function to market data.

## Examples

```
irfc = IRFunctionCurve('Forward',today,@(t) polyval([-0.0001 0.003 0.02],t))
```

```
irfc =
```

```
Properties:
```

```
FunctionHandle: @(t)polyval([-0.0001,0.003,0.02],t)
```

```
Type: 'Forward'
```

```
Settle: 733599
```

```
Compounding: 2
```

```
Basis: 0
```

## More About

- “@IRCurve”

## liborduration

Duration of LIBOR-based interest-rate swap

### Syntax

```
[PayFixDuration GetFixDuration] = liborduration(SwapFixRate,  
Tenor, Settle)
```

### Arguments

SwapFixRate	Scalar or column vector of swap fixed rates in decimal.
Tenor	Scalar or column vector indicating life of the swap in years. Fractional numbers are rounded upward.
Settle	Scalar or column vector of settlement dates.

### Description

[PayFixDuration GetFixDuration] = liborduration(SwapFixRate, Tenor, Settle) computes the duration of LIBOR-based interest-rate swaps.

PayFixDuration is the modified duration, in years, realized when entering pay-fix side of the swap.

GetFixDuration is the modified duration, in years, realized when entering receive-fix side of the swap.

### Examples

#### Compute the Duration of LIBOR-Based Interest-Rate Swaps

This example shows how to compute the duration of LIBOR-based interest-rate swaps using the following data.

```
SwapFixRate = 0.0383;
```

```
Tenor = 7;  
Settle = datenum('11-Oct-2002');  
  
[PayFixDuration GetFixDuration] = liborduration(SwapFixRate,...  
Tenor, Settle)
```

```
PayFixDuration =
```

```
-4.7567
```

```
GetFixDuration =
```

```
4.7567
```

## See Also

[liborfloat2fixed](#) | [liborprice](#)

## liborfloat2fixed

Compute par fixed-rate of swap given 3-month LIBOR data

### Syntax

```
[FixedSpec, ForwardDates, ForwardRates] =
liborfloat2fixed(ThreeMonthRates, Settle, Tenor, StartDate,
Interpolation, ConvexAdj, RateParam, InArrears, Sigma,
FixedCompound, FixedBasis)
```

### Arguments

ThreeMonthRates	Three-month Eurodollar futures data or forward rate agreement data. (A forward rate agreement stipulates that a certain interest rate applies to a certain principal amount for a given future time period.) An n-by-3 matrix in the form of [month year IMMQuote]. The floating rate is assumed to compound quarterly and to accrue on an actual/360 basis.
Settle	Settlement date of the swap. Scalar.
Tenor	Life of the swap. Scalar.
StartDate	(Optional) Scalar value to denote reference date for valuation of (forward) swap. This in effect allows forward swap valuation. Default = Settle.
Interpolation	(Optional) Interpolation method to determine applicable forward rate for months when no Eurodollar data is available. Default is 'linear' or 1. Other possible values are 'Nearest' or 0, and 'Cubic' or 2.
ConvexAdj	(Optional) Default = 0 (off). 1 = on. Denotes whether futures/forward convexity adjustment is required. Pertains to forward rate adjustments when those rates are taken from Eurodollar futures data.
RateParam	(Optional) Short-rate model's parameters (Hull-White) [a S], where the short-rate process is: $dr = [\theta(t) - ar]dt + Sdz.$



	Default = [0.05 0.015].
InArrears	(Optional) Default = 0 (off). Set to 1 for on. If on, the routine does an automatic a convexity adjustment to forward rates.
Sigma	(Optional) Overall annual volatility of caplets.
FixedCompound	(Optional) Scalar value. Compounding or frequency of payment on the fixed side. Also, the reset frequency. Default = 4 (quarterly). Other values are 1, 2, and 12.
FixedBasis	<p>(Optional) Scalar value. Basis of the fixed side.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> </ul> <p>For more information, see <b>basis</b>.</p>

## Description

[FixedSpec, ForwardDates, ForwardRates] =  
liborfloat2fixed(ThreeMonthRates, Settle, Tenor, StartDate,  
Interpolation, ConvexAdj, RateParam, InArrears, Sigma,  
FixedCompound, FixedBasis) computes forward rates, dates, and the swap fixed  
rate.

FixedSpec specifies the structure of the fixed-rate side of the swap:

- **Coupon:** Par-swap rate
- **Settle:** Start date
- **Maturity:** End date
- **Period:** Frequency of payment
- **Basis:** Accrual basis

**ForwardDates** are dates corresponding to **ForwardRates** (all third Wednesdays of the month, spread 3 months apart). The first element is the third Wednesday immediately after **Settle**.

**ForwardRates** are forward rates corresponding to the forward dates, quarterly compounded, and on the actual/360 basis.

---

**Note** To preserve input integrity, **Tenor** is rounded upward to the closest integer. Currently traded tenors are 2, 5, and 10 years.

---

The function assumes that floating-rate observations occur quarterly on the third Wednesday of a delivery month. The first delivery month is the month of the first third Wednesday after **Settle**. Floating-side payments occur on the third-month anniversaries of observation dates.

## Examples

### Compute the Par Fixed-Rate of a Swap Given 3-Month LIBOR Data

This example shows how to compute the par fixed-rate of a swap given 3-month LIBOR data. Use the supplied `EDdata.xls` file as input to a `liborfloat2fixed` computation.

```
[EDFutData, textdata] = xlsread('EDdata.xls');
Settle                = datenum('15-Oct-2002');
Tenor                 = 2;

[FixedSpec, ForwardDates, ForwardRates] = ...
    liborfloat2fixed(EDFutData(:,1:3), Settle, Tenor)

FixedSpec =
```

Coupon: 0.0222  
Settle: '16-Oct-2002'  
Maturity: '16-Oct-2004'  
Period: 4  
Basis: 1

ForwardDates =

731505  
731596  
731687  
731778  
731869  
731967  
732058  
732149

ForwardRates =

0.0177  
0.0166  
0.0170  
0.0188  
0.0214  
0.0248  
0.0279  
0.0305

## See Also

[liborduration](#) | [liborprice](#)

## liborprice

Price swap given swap rate

### Syntax

```
Price = liborprice(ThreeMonthRates, Settle, Tenor,
SwapRate, StartDate, Interpolation, ConvexAdj, RateParam,
InArrears, Sigma, FixedCompound, FixedBasis)
```

### Arguments

ThreeMonthRates	Three-month Eurodollar futures data or forward rate agreement data. (A forward rate agreement stipulates that a certain interest rate applies to a certain principal amount for a given future time period.) An n-by-3 matrix in the form of [month year IMMQuote]. The floating rate is assumed to compound quarterly and to accrue on an actual/360 basis.
Settle	Settlement date of swap. Scalar.
Tenor	Life of the swap. Scalar.
SwapRate	Swap rate in decimal.
StartDate	(Optional) Scalar value to denote reference date for valuation of (forward) swap. This in effect allows forward swap valuation. Default = <b>Settle</b> .
Interpolation	(Optional) Interpolation method to determine applicable forward rate for months when no Eurodollar data is available. Default is 'linear' or 1. Other possible values are 'Nearest' or 0, and 'Cubic' or 2.
ConvexAdj	(Optional) Default = 0 (off). 1 = on. Denotes whether futures/forward convexity adjustment is required. Pertains to forward rate adjustments when those rates are taken from Eurodollar futures data.

RateParam	<p>(Optional) Short-rate model's parameters (Hull-White) [a S], where the short-rate process is:</p> $dr = [\theta(t) - ar]dt + Sdz.$ <p>Default = [0.05 0.015].</p>
InArrears	(Optional) Default = 0 (off). Set to 1 for on. If on, the routine does an automatic convexity adjustment to forward rates.
Sigma	(Optional) Overall annual volatility of caplets.
FixedCompound	(Optional) Scalar value. Compounding or frequency of payment on the fixed side. Also, the reset frequency. Default = 4 (quarterly). Other values are 1, 2, and 12.
FixedBasis	<p>(Optional) Scalar value. Basis of the fixed side.</p> <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> </ul> <p>For more information, see <b>basis</b>.</p>

## Description

Price = liborprice(ThreeMonthRates, Settle, Tenor, SwapRate, StartDate, Interpolation, ConvexAdj, RateParam, InArrears, Sigma,

`FixedCompound`, `FixedBasis`) computes the price per \$100 notional value of a swap given the swap rate. A positive result indicates that fixed side is more valuable than the floating side.

`Price` is the present value of the difference between floating and fixed-rate sides of the swap per \$100 notional.

## Examples

### Compute the Price Per \$100 Notional Value of a Swap Given the Swap Rate

This example shows that a swap paying the par swap rate has a value of 0.

```
% load the input data
[EDFutData, textdata] = xlsread('EDdata.xls');
Settle = datenum('15-Oct-2002');
Tenor = 2;

% compute the fixed rate from the Eurodollar data
FixedSpec = liborfloat2fixed(EDFutData(:,1:3), Settle, Tenor)

% compute the price of a par swap
Price = liborprice(EDFutData(:,1:3), Settle, Tenor, FixedSpec.Coupon)
```

```
FixedSpec =
```

```
    Coupon: 0.0222
    Settle: '16-Oct-2002'
    Maturity: '16-Oct-2004'
    Period: 4
    Basis: 1
```

```
Price =
```

```
2.7756e-15
```

Price is effectively equal to 0.

### See Also

`liborduration` | `liborfloat2fixed`

# mbscfamounts

Cash flow and time mapping for mortgage pool

## Syntax

```
[CFlowAmounts, CFlowDates, TFactors, Factors, Payment, Principal, Interest, Prepayment] = mbscfamounts(Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, PrepaySpeed, PrepayMatrix)
```

## Arguments

Settle	Settlement date. A serial date number or date string. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. A serial date number or date string.
IssueDate	Issue date. A serial date number or date string.
GrossRate	Gross coupon rate (including fees), in decimal.
CouponRate	(Optional) Net coupon rate, in decimal. Default = <b>GrossRate</b> .
Delay	(Optional) Delay in days. Default is 0 (no delay).
PrepaySpeed	(Optional) Relation of the conditional payment rate (CPR) to the benchmark model. Default = 0. If you input a customized prepayment matrix, set <b>PrepaySpeed</b> to [ ].
PrepayMatrix	(Optional) Used only when <b>PrepaySpeed</b> is unspecified. Customized prepayment vector. A NaN-padded matrix of size <b>max(TermRemaining)</b> -by-NMBS. Each column corresponds to each mortgage-backed security, and each row corresponds to each month after settlement.

All inputs (except **PrepayMatrix**) are number of mortgage-backed securities (NMBS)-by-1 vectors.

## Description

[CFlowAmounts, CFlowDates, TFactors, Factors, Payment, Principal, Interest, Prepayment] = mbscfamounts(Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, PrepaySpeed, PrepayMatrix) computes cash flows between settle and maturity dates, the corresponding time factors in months from settle, and the mortgage factor (the fraction of loan principal outstanding).

CFlowAmounts is a vector of cash flows starting from Settle through end of the last month (Maturity).

CFlowDates indicates when cash flows occur, including at Settle. A negative number at Settle indicates accrued interest is due.

TFactors is a vector of times in months from Settle, corresponding to each cash flow.

Factors is a vector of mortgage factors (the fraction of the balance still outstanding at the end of each month).

Payment is a NMBS-by-P matrix of total monthly payment.

Principal is a NMBS-by-P matrix of principal portion of the payment

Interest is a NMBS-by-P matrix of interest portion of the payment.

Prepayment is a NMBS-by-P matrix of unscheduled payment of principal.

## Examples

### Calculate Cash Flow Amounts and Dates, Time Factors, and Mortgage Factors for a Single Mortgage

Given a mortgage with the following characteristics, compute the cash flow amounts and dates, the time factors, and the mortgage factors.

Define the mortgage characteristics.

```
Settle      = datenum('17-April-2002');
Maturity    = datenum('1-Jan-2030');
IssueDate   = datenum('1-Jan-2000');
GrossRate   = 0.08125;
CouponRate  = 0.075;
Delay       = 14;
```



```
PrepaySpeed = 100;
```

Use `mbscfamounts` to evaluate the mortgage.

```
[CFlowAmounts, CFlowDates, TFactors, Factors] = ...  
mbscfamounts(Settle, Maturity, IssueDate, GrossRate, ...  
CouponRate, Delay, PrepaySpeed)
```

```
CFlowAmounts =
```

```
Columns 1 through 7
```

```
-0.0033    0.0118    0.0120    0.0121    0.0120    0.0119    0.0119
```

```
Columns 8 through 14
```

```
0.0118    0.0117    0.0117    0.0116    0.0115    0.0115    0.0114
```

```
Columns 15 through 21
```

```
0.0114    0.0113    0.0112    0.0112    0.0111    0.0110    0.0110
```

```
Columns 22 through 28
```

```
0.0109    0.0109    0.0108    0.0107    0.0107    0.0106    0.0106
```

```
Columns 29 through 35
```

```
0.0105    0.0105    0.0104    0.0103    0.0103    0.0102    0.0102
```

```
Columns 36 through 42
```

```
0.0101    0.0101    0.0100    0.0099    0.0099    0.0098    0.0098
```

```
Columns 43 through 49
```

```
0.0097    0.0097    0.0096    0.0096    0.0095    0.0095    0.0094
```

```
Columns 50 through 56
```

```
0.0094    0.0093    0.0093    0.0092    0.0092    0.0091    0.0090
```

```
Columns 57 through 63
```

0.0090	0.0089	0.0089	0.0088	0.0088	0.0087	0.0087
Columns 64 through 70						
0.0087	0.0086	0.0086	0.0085	0.0085	0.0084	0.0084
Columns 71 through 77						
0.0083	0.0083	0.0082	0.0082	0.0081	0.0081	0.0080
Columns 78 through 84						
0.0080	0.0079	0.0079	0.0079	0.0078	0.0078	0.0077
Columns 85 through 91						
0.0077	0.0076	0.0076	0.0075	0.0075	0.0075	0.0074
Columns 92 through 98						
0.0074	0.0073	0.0073	0.0073	0.0072	0.0072	0.0071
Columns 99 through 105						
0.0071	0.0070	0.0070	0.0070	0.0069	0.0069	0.0068
Columns 106 through 112						
0.0068	0.0068	0.0067	0.0067	0.0066	0.0066	0.0066
Columns 113 through 119						
0.0065	0.0065	0.0065	0.0064	0.0064	0.0063	0.0063
Columns 120 through 126						
0.0063	0.0062	0.0062	0.0062	0.0061	0.0061	0.0061
Columns 127 through 133						
0.0060	0.0060	0.0059	0.0059	0.0059	0.0058	0.0058
Columns 134 through 140						

---

0.0058	0.0057	0.0057	0.0057	0.0056	0.0056	0.0056
Columns 141 through 147						
0.0055	0.0055	0.0055	0.0054	0.0054	0.0054	0.0053
Columns 148 through 154						
0.0053	0.0053	0.0052	0.0052	0.0052	0.0052	0.0051
Columns 155 through 161						
0.0051	0.0051	0.0050	0.0050	0.0050	0.0049	0.0049
Columns 162 through 168						
0.0049	0.0048	0.0048	0.0048	0.0048	0.0047	0.0047
Columns 169 through 175						
0.0047	0.0046	0.0046	0.0046	0.0046	0.0045	0.0045
Columns 176 through 182						
0.0045	0.0044	0.0044	0.0044	0.0044	0.0043	0.0043
Columns 183 through 189						
0.0043	0.0043	0.0042	0.0042	0.0042	0.0041	0.0041
Columns 190 through 196						
0.0041	0.0041	0.0040	0.0040	0.0040	0.0040	0.0039
Columns 197 through 203						
0.0039	0.0039	0.0039	0.0038	0.0038	0.0038	0.0038
Columns 204 through 210						
0.0037	0.0037	0.0037	0.0037	0.0036	0.0036	0.0036
Columns 211 through 217						

0.0036	0.0035	0.0035	0.0035	0.0035	0.0035	0.0034
Columns 218 through 224						
0.0034	0.0034	0.0034	0.0033	0.0033	0.0033	0.0033
Columns 225 through 231						
0.0033	0.0032	0.0032	0.0032	0.0032	0.0031	0.0031
Columns 232 through 238						
0.0031	0.0031	0.0031	0.0030	0.0030	0.0030	0.0030
Columns 239 through 245						
0.0030	0.0029	0.0029	0.0029	0.0029	0.0029	0.0028
Columns 246 through 252						
0.0028	0.0028	0.0028	0.0028	0.0027	0.0027	0.0027
Columns 253 through 259						
0.0027	0.0027	0.0026	0.0026	0.0026	0.0026	0.0026
Columns 260 through 266						
0.0025	0.0025	0.0025	0.0025	0.0025	0.0024	0.0024
Columns 267 through 273						
0.0024	0.0024	0.0024	0.0024	0.0023	0.0023	0.0023
Columns 274 through 280						
0.0023	0.0023	0.0023	0.0022	0.0022	0.0022	0.0022
Columns 281 through 287						
0.0022	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021
Columns 288 through 294						

---

0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Columns 295 through 301						
0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0018
Columns 302 through 308						
0.0018	0.0018	0.0018	0.0018	0.0018	0.0017	0.0017
Columns 309 through 315						
0.0017	0.0017	0.0017	0.0017	0.0017	0.0016	0.0016
Columns 316 through 322						
0.0016	0.0016	0.0016	0.0016	0.0016	0.0015	0.0015
Columns 323 through 329						
0.0015	0.0015	0.0015	0.0015	0.0015	0.0014	0.0014
Columns 330 through 334						
0.0014	0.0014	0.0014	0.0014	0.0014		

CFLowDates =

Columns 1 through 6						
731323	731337	731368	731398	731429	731460	
Columns 7 through 12						
731490	731521	731551	731582	731613	731641	
Columns 13 through 18						
731672	731702	731733	731763	731794	731825	
Columns 19 through 24						
731855	731886	731916	731947	731978	732007	

Columns 25 through 30

732038	732068	732099	732129	732160	732191
--------	--------	--------	--------	--------	--------

Columns 31 through 36

732221	732252	732282	732313	732344	732372
--------	--------	--------	--------	--------	--------

Columns 37 through 42

732403	732433	732464	732494	732525	732556
--------	--------	--------	--------	--------	--------

Columns 43 through 48

732586	732617	732647	732678	732709	732737
--------	--------	--------	--------	--------	--------

Columns 49 through 54

732768	732798	732829	732859	732890	732921
--------	--------	--------	--------	--------	--------

Columns 55 through 60

732951	732982	733012	733043	733074	733102
--------	--------	--------	--------	--------	--------

Columns 61 through 66

733133	733163	733194	733224	733255	733286
--------	--------	--------	--------	--------	--------

Columns 67 through 72

733316	733347	733377	733408	733439	733468
--------	--------	--------	--------	--------	--------

Columns 73 through 78

733499	733529	733560	733590	733621	733652
--------	--------	--------	--------	--------	--------

Columns 79 through 84

733682	733713	733743	733774	733805	733833
--------	--------	--------	--------	--------	--------

Columns 85 through 90

733864	733894	733925	733955	733986	734017
--------	--------	--------	--------	--------	--------

Columns 91 through 96

734047	734078	734108	734139	734170	734198
--------	--------	--------	--------	--------	--------

Columns 97 through 102

734229	734259	734290	734320	734351	734382
--------	--------	--------	--------	--------	--------

Columns 103 through 108

734412	734443	734473	734504	734535	734563
--------	--------	--------	--------	--------	--------

Columns 109 through 114

734594	734624	734655	734685	734716	734747
--------	--------	--------	--------	--------	--------

Columns 115 through 120

734777	734808	734838	734869	734900	734929
--------	--------	--------	--------	--------	--------

Columns 121 through 126

734960	734990	735021	735051	735082	735113
--------	--------	--------	--------	--------	--------

Columns 127 through 132

735143	735174	735204	735235	735266	735294
--------	--------	--------	--------	--------	--------

Columns 133 through 138

735325	735355	735386	735416	735447	735478
--------	--------	--------	--------	--------	--------

Columns 139 through 144

735508	735539	735569	735600	735631	735659
--------	--------	--------	--------	--------	--------

Columns 145 through 150

735690	735720	735751	735781	735812	735843
--------	--------	--------	--------	--------	--------

Columns 151 through 156

735873	735904	735934	735965	735996	736024
--------	--------	--------	--------	--------	--------

Columns 157 through 162

736055	736085	736116	736146	736177	736208
--------	--------	--------	--------	--------	--------

Columns 163 through 168

736238	736269	736299	736330	736361	736390
--------	--------	--------	--------	--------	--------

Columns 169 through 174

736421	736451	736482	736512	736543	736574
--------	--------	--------	--------	--------	--------

Columns 175 through 180

736604	736635	736665	736696	736727	736755
--------	--------	--------	--------	--------	--------

Columns 181 through 186

736786	736816	736847	736877	736908	736939
--------	--------	--------	--------	--------	--------

Columns 187 through 192

736969	737000	737030	737061	737092	737120
--------	--------	--------	--------	--------	--------

Columns 193 through 198

737151	737181	737212	737242	737273	737304
--------	--------	--------	--------	--------	--------

Columns 199 through 204

737334	737365	737395	737426	737457	737485
--------	--------	--------	--------	--------	--------

Columns 205 through 210

737516	737546	737577	737607	737638	737669
--------	--------	--------	--------	--------	--------

Columns 211 through 216

737699	737730	737760	737791	737822	737851
--------	--------	--------	--------	--------	--------

Columns 217 through 222

737882	737912	737943	737973	738004	738035
--------	--------	--------	--------	--------	--------



Columns 223 through 228

738065 738096 738126 738157 738188 738216

Columns 229 through 234

738247 738277 738308 738338 738369 738400

Columns 235 through 240

738430 738461 738491 738522 738553 738581

Columns 241 through 246

738612 738642 738673 738703 738734 738765

Columns 247 through 252

738795 738826 738856 738887 738918 738946

Columns 253 through 258

738977 739007 739038 739068 739099 739130

Columns 259 through 264

739160 739191 739221 739252 739283 739312

Columns 265 through 270

739343 739373 739404 739434 739465 739496

Columns 271 through 276

739526 739557 739587 739618 739649 739677

Columns 277 through 282

739708 739738 739769 739799 739830 739861

Columns 283 through 288

739891 739922 739952 739983 740014 740042

Columns 289 through 294

740073	740103	740134	740164	740195	740226
--------	--------	--------	--------	--------	--------

Columns 295 through 300

740256	740287	740317	740348	740379	740407
--------	--------	--------	--------	--------	--------

Columns 301 through 306

740438	740468	740499	740529	740560	740591
--------	--------	--------	--------	--------	--------

Columns 307 through 312

740621	740652	740682	740713	740744	740773
--------	--------	--------	--------	--------	--------

Columns 313 through 318

740804	740834	740865	740895	740926	740957
--------	--------	--------	--------	--------	--------

Columns 319 through 324

740987	741018	741048	741079	741110	741138
--------	--------	--------	--------	--------	--------

Columns 325 through 330

741169	741199	741230	741260	741291	741322
--------	--------	--------	--------	--------	--------

Columns 331 through 334

741352	741383	741413	741444
--------	--------	--------	--------

TFactors =

Columns 1 through 7

0	0.9333	1.9333	2.9333	3.9333	4.9333	5.9333
---	--------	--------	--------	--------	--------	--------

Columns 8 through 14

6.9333	7.9333	8.9333	9.9333	10.9333	11.9333	12.9333
--------	--------	--------	--------	---------	---------	---------

Columns 15 through 21

13.9333 14.9333 15.9333 16.9333 17.9333 18.9333 19.9333

Columns 22 through 28

20.9333 21.9333 22.9333 23.9333 24.9333 25.9333 26.9333

Columns 29 through 35

27.9333 28.9333 29.9333 30.9333 31.9333 32.9333 33.9333

Columns 36 through 42

34.9333 35.9333 36.9333 37.9333 38.9333 39.9333 40.9333

Columns 43 through 49

41.9333 42.9333 43.9333 44.9333 45.9333 46.9333 47.9333

Columns 50 through 56

48.9333 49.9333 50.9333 51.9333 52.9333 53.9333 54.9333

Columns 57 through 63

55.9333 56.9333 57.9333 58.9333 59.9333 60.9333 61.9333

Columns 64 through 70

62.9333 63.9333 64.9333 65.9333 66.9333 67.9333 68.9333

Columns 71 through 77

69.9333 70.9333 71.9333 72.9333 73.9333 74.9333 75.9333

Columns 78 through 84

76.9333 77.9333 78.9333 79.9333 80.9333 81.9333 82.9333

Columns 85 through 91

83.9333 84.9333 85.9333 86.9333 87.9333 88.9333 89.9333

Columns 92 through 98

90.9333 91.9333 92.9333 93.9333 94.9333 95.9333 96.9333

Columns 99 through 105

97.9333 98.9333 99.9333 100.9333 101.9333 102.9333 103.9333

Columns 106 through 112

104.9333 105.9333 106.9333 107.9333 108.9333 109.9333 110.9333

Columns 113 through 119

111.9333 112.9333 113.9333 114.9333 115.9333 116.9333 117.9333

Columns 120 through 126

118.9333 119.9333 120.9333 121.9333 122.9333 123.9333 124.9333

Columns 127 through 133

125.9333 126.9333 127.9333 128.9333 129.9333 130.9333 131.9333

Columns 134 through 140

132.9333 133.9333 134.9333 135.9333 136.9333 137.9333 138.9333

Columns 141 through 147

139.9333 140.9333 141.9333 142.9333 143.9333 144.9333 145.9333

Columns 148 through 154

146.9333 147.9333 148.9333 149.9333 150.9333 151.9333 152.9333

Columns 155 through 161

153.9333 154.9333 155.9333 156.9333 157.9333 158.9333 159.9333

Columns 162 through 168

160.9333 161.9333 162.9333 163.9333 164.9333 165.9333 166.9333

Columns 169 through 175

167.9333 168.9333 169.9333 170.9333 171.9333 172.9333 173.9333

Columns 176 through 182

174.9333 175.9333 176.9333 177.9333 178.9333 179.9333 180.9333

Columns 183 through 189

181.9333 182.9333 183.9333 184.9333 185.9333 186.9333 187.9333

Columns 190 through 196

188.9333 189.9333 190.9333 191.9333 192.9333 193.9333 194.9333

Columns 197 through 203

195.9333 196.9333 197.9333 198.9333 199.9333 200.9333 201.9333

Columns 204 through 210

202.9333 203.9333 204.9333 205.9333 206.9333 207.9333 208.9333

Columns 211 through 217

209.9333 210.9333 211.9333 212.9333 213.9333 214.9333 215.9333

Columns 218 through 224

216.9333 217.9333 218.9333 219.9333 220.9333 221.9333 222.9333

Columns 225 through 231

223.9333 224.9333 225.9333 226.9333 227.9333 228.9333 229.9333

Columns 232 through 238

230.9333 231.9333 232.9333 233.9333 234.9333 235.9333 236.9333

Columns 239 through 245

237.9333 238.9333 239.9333 240.9333 241.9333 242.9333 243.9333

Columns 246 through 252

244.9333 245.9333 246.9333 247.9333 248.9333 249.9333 250.9333

Columns 253 through 259

251.9333 252.9333 253.9333 254.9333 255.9333 256.9333 257.9333

Columns 260 through 266

258.9333 259.9333 260.9333 261.9333 262.9333 263.9333 264.9333

Columns 267 through 273

265.9333 266.9333 267.9333 268.9333 269.9333 270.9333 271.9333

Columns 274 through 280

272.9333 273.9333 274.9333 275.9333 276.9333 277.9333 278.9333

Columns 281 through 287

279.9333 280.9333 281.9333 282.9333 283.9333 284.9333 285.9333

Columns 288 through 294

286.9333 287.9333 288.9333 289.9333 290.9333 291.9333 292.9333

Columns 295 through 301

293.9333 294.9333 295.9333 296.9333 297.9333 298.9333 299.9333

Columns 302 through 308

300.9333 301.9333 302.9333 303.9333 304.9333 305.9333 306.9333

Columns 309 through 315

307.9333 308.9333 309.9333 310.9333 311.9333 312.9333 313.9333

Columns 316 through 322

314.9333 315.9333 316.9333 317.9333 318.9333 319.9333 320.9333

Columns 323 through 329

321.9333 322.9333 323.9333 324.9333 325.9333 326.9333 327.9333

Columns 330 through 334

328.9333 329.9333 330.9333 331.9333 332.9333

Factors =

Columns 1 through 7

1.0000 0.9944 0.9887 0.9828 0.9769 0.9711 0.9653

Columns 8 through 14

0.9595 0.9538 0.9481 0.9424 0.9368 0.9311 0.9255

Columns 15 through 21

0.9199 0.9144 0.9089 0.9034 0.8979 0.8925 0.8871

Columns 22 through 28

0.8817 0.8763 0.8710 0.8657 0.8604 0.8552 0.8499

Columns 29 through 35

0.8447 0.8396 0.8344 0.8293 0.8242 0.8191 0.8140

Columns 36 through 42

0.8090 0.8040 0.7990 0.7941 0.7892 0.7842 0.7794

Columns 43 through 49

0.7745 0.7697 0.7649 0.7601 0.7553 0.7506 0.7458

Columns 50 through 56

0.7411 0.7365 0.7318 0.7272 0.7226 0.7180 0.7134

Columns 57 through 63

0.7089	0.7044	0.6999	0.6954	0.6910	0.6865	0.6821
Columns 64 through 70						
0.6777	0.6734	0.6690	0.6647	0.6604	0.6561	0.6519
Columns 71 through 77						
0.6476	0.6434	0.6392	0.6350	0.6309	0.6267	0.6226
Columns 78 through 84						
0.6185	0.6144	0.6104	0.6063	0.6023	0.5983	0.5943
Columns 85 through 91						
0.5903	0.5864	0.5825	0.5785	0.5747	0.5708	0.5669
Columns 92 through 98						
0.5631	0.5593	0.5555	0.5517	0.5479	0.5442	0.5405
Columns 99 through 105						
0.5368	0.5331	0.5294	0.5257	0.5221	0.5185	0.5149
Columns 106 through 112						
0.5113	0.5077	0.5042	0.5006	0.4971	0.4936	0.4901
Columns 113 through 119						
0.4866	0.4832	0.4797	0.4763	0.4729	0.4695	0.4661
Columns 120 through 126						
0.4628	0.4594	0.4561	0.4528	0.4495	0.4462	0.4430
Columns 127 through 133						
0.4397	0.4365	0.4333	0.4301	0.4269	0.4237	0.4205
Columns 134 through 140						



---

0.4174	0.4143	0.4111	0.4080	0.4049	0.4019	0.3988
Columns 141 through 147						
0.3958	0.3927	0.3897	0.3867	0.3837	0.3808	0.3778
Columns 148 through 154						
0.3748	0.3719	0.3690	0.3661	0.3632	0.3603	0.3574
Columns 155 through 161						
0.3546	0.3517	0.3489	0.3461	0.3433	0.3405	0.3377
Columns 162 through 168						
0.3350	0.3322	0.3295	0.3267	0.3240	0.3213	0.3186
Columns 169 through 175						
0.3160	0.3133	0.3106	0.3080	0.3054	0.3027	0.3001
Columns 176 through 182						
0.2975	0.2950	0.2924	0.2898	0.2873	0.2847	0.2822
Columns 183 through 189						
0.2797	0.2772	0.2747	0.2722	0.2698	0.2673	0.2649
Columns 190 through 196						
0.2624	0.2600	0.2576	0.2552	0.2528	0.2504	0.2480
Columns 197 through 203						
0.2457	0.2433	0.2410	0.2386	0.2363	0.2340	0.2317
Columns 204 through 210						
0.2294	0.2271	0.2249	0.2226	0.2204	0.2181	0.2159
Columns 211 through 217						

0.2137	0.2115	0.2093	0.2071	0.2049	0.2027	0.2005
Columns 218 through 224						
0.1984	0.1962	0.1941	0.1920	0.1899	0.1877	0.1856
Columns 225 through 231						
0.1836	0.1815	0.1794	0.1773	0.1753	0.1732	0.1712
Columns 232 through 238						
0.1692	0.1671	0.1651	0.1631	0.1611	0.1591	0.1572
Columns 239 through 245						
0.1552	0.1532	0.1513	0.1493	0.1474	0.1455	0.1436
Columns 246 through 252						
0.1416	0.1397	0.1378	0.1359	0.1341	0.1322	0.1303
Columns 253 through 259						
0.1285	0.1266	0.1248	0.1229	0.1211	0.1193	0.1175
Columns 260 through 266						
0.1157	0.1139	0.1121	0.1103	0.1085	0.1068	0.1050
Columns 267 through 273						
0.1032	0.1015	0.0998	0.0980	0.0963	0.0946	0.0929
Columns 274 through 280						
0.0912	0.0895	0.0878	0.0861	0.0844	0.0827	0.0811
Columns 281 through 287						
0.0794	0.0778	0.0761	0.0745	0.0728	0.0712	0.0696
Columns 288 through 294						

```

    0.0680    0.0664    0.0648    0.0632    0.0616    0.0600    0.0584
Columns 295 through 301
    0.0568    0.0553    0.0537    0.0522    0.0506    0.0491    0.0476
Columns 302 through 308
    0.0460    0.0445    0.0430    0.0415    0.0400    0.0385    0.0370
Columns 309 through 315
    0.0355    0.0340    0.0325    0.0311    0.0296    0.0281    0.0267
Columns 316 through 322
    0.0252    0.0238    0.0223    0.0209    0.0195    0.0180    0.0166
Columns 323 through 329
    0.0152    0.0138    0.0124    0.0110    0.0096    0.0082    0.0068
Columns 330 through 334
    0.0055    0.0041    0.0027    0.0014         0

```

The result is contained in four 334-element row vectors.

### **Compute Cash Flow Amounts and Dates, Time Factors, and Mortgage Factors for a Mortgage Portfolio**

Given a portfolio of mortgage-backed securities, use `mbscfamounts` to compute the cash flows and other factors from the portfolio.

Define characteristics for a mortgage portfolio.

```

Settle      = datenum(['13-Jan-2000'; '17-Apr-2002'; '17-May-2002']);
Maturity    = datenum('1-Jan-2030');
IssueDate   = datenum('1-Jan-2000');
GrossRate   = 0.08125;
CouponRate  = [0.075; 0.07875; 0.0775];
Delay       = 14;
PrepaySpeed = 100;

```

Use `mbscfamonts` to evaluate the mortgage.

```
[CFlowAmounts, CFlowDates, TFactors, Factors] = ...
mbscfamonts(Settle, Maturity, IssueDate, GrossRate, ...
CouponRate, Delay, PrepaySpeed)
```

CFlowAmounts =

Columns 1 through 7

-0.0025	0.0071	0.0072	0.0074	0.0076	0.0077	0.0079
-0.0035	0.0121	0.0123	0.0124	0.0123	0.0122	0.0122
-0.0034	0.0122	0.0123	0.0123	0.0122	0.0121	0.0121

Columns 8 through 14

0.0080	0.0082	0.0084	0.0085	0.0087	0.0088	0.0090
0.0121	0.0120	0.0120	0.0119	0.0118	0.0118	0.0117
0.0120	0.0119	0.0119	0.0118	0.0117	0.0117	0.0116

Columns 15 through 21

0.0091	0.0093	0.0094	0.0095	0.0097	0.0098	0.0099
0.0116	0.0116	0.0115	0.0115	0.0114	0.0113	0.0113
0.0116	0.0115	0.0114	0.0114	0.0113	0.0112	0.0112

Columns 22 through 28

0.0101	0.0102	0.0103	0.0104	0.0106	0.0107	0.0108
0.0112	0.0111	0.0111	0.0110	0.0110	0.0109	0.0108
0.0111	0.0111	0.0110	0.0109	0.0109	0.0108	0.0108

Columns 29 through 35

0.0109	0.0110	0.0111	0.0110	0.0110	0.0109	0.0109
0.0108	0.0107	0.0107	0.0106	0.0105	0.0105	0.0104
0.0107	0.0106	0.0106	0.0105	0.0105	0.0104	0.0103

Columns 36 through 42

0.0108	0.0107	0.0107	0.0106	0.0106	0.0105	0.0104
0.0104	0.0103	0.0103	0.0102	0.0101	0.0101	0.0100
0.0103	0.0102	0.0102	0.0101	0.0101	0.0100	0.0099

Columns 43 through 49

0.0104	0.0103	0.0103	0.0102	0.0102	0.0101	0.0101
0.0100	0.0099	0.0099	0.0098	0.0098	0.0097	0.0096
0.0099	0.0098	0.0098	0.0097	0.0097	0.0096	0.0096

Columns 50 through 56

0.0100	0.0099	0.0099	0.0098	0.0098	0.0097	0.0097
0.0096	0.0095	0.0095	0.0094	0.0094	0.0093	0.0093
0.0095	0.0095	0.0094	0.0094	0.0093	0.0092	0.0092

Columns 57 through 63

0.0096	0.0096	0.0095	0.0095	0.0094	0.0094	0.0093
0.0092	0.0092	0.0091	0.0091	0.0090	0.0090	0.0089
0.0091	0.0091	0.0090	0.0090	0.0089	0.0089	0.0088

Columns 64 through 70

0.0093	0.0092	0.0091	0.0091	0.0090	0.0090	0.0089
0.0089	0.0088	0.0088	0.0087	0.0087	0.0086	0.0086
0.0088	0.0087	0.0087	0.0086	0.0086	0.0085	0.0085

Columns 71 through 77

0.0089	0.0088	0.0088	0.0088	0.0087	0.0087	0.0086
0.0085	0.0085	0.0084	0.0084	0.0083	0.0083	0.0082
0.0085	0.0084	0.0084	0.0083	0.0083	0.0082	0.0082

Columns 78 through 84

0.0086	0.0085	0.0085	0.0084	0.0084	0.0083	0.0083
0.0082	0.0081	0.0081	0.0080	0.0080	0.0080	0.0079
0.0081	0.0081	0.0080	0.0080	0.0079	0.0079	0.0078

Columns 85 through 91

0.0082	0.0082	0.0081	0.0081	0.0080	0.0080	0.0080
0.0079	0.0078	0.0078	0.0077	0.0077	0.0076	0.0076
0.0078	0.0078	0.0077	0.0077	0.0076	0.0076	0.0075

Columns 92 through 98

0.0079	0.0079	0.0078	0.0078	0.0077	0.0077	0.0076
0.0076	0.0075	0.0075	0.0074	0.0074	0.0073	0.0073
0.0075	0.0075	0.0074	0.0074	0.0073	0.0073	0.0072

Columns 99 through 105

0.0076	0.0076	0.0075	0.0075	0.0074	0.0074	0.0074
0.0073	0.0072	0.0072	0.0071	0.0071	0.0070	0.0070
0.0072	0.0072	0.0071	0.0071	0.0070	0.0070	0.0070

Columns 106 through 112

0.0073	0.0073	0.0072	0.0072	0.0071	0.0071	0.0071
0.0070	0.0069	0.0069	0.0068	0.0068	0.0068	0.0067
0.0069	0.0069	0.0068	0.0068	0.0068	0.0067	0.0067

Columns 113 through 119

0.0070	0.0070	0.0069	0.0069	0.0069	0.0068	0.0068
0.0067	0.0066	0.0066	0.0066	0.0065	0.0065	0.0065
0.0066	0.0066	0.0066	0.0065	0.0065	0.0064	0.0064

Columns 120 through 126

0.0067	0.0067	0.0067	0.0066	0.0066	0.0066	0.0065
0.0064	0.0064	0.0063	0.0063	0.0063	0.0062	0.0062
0.0064	0.0063	0.0063	0.0063	0.0062	0.0062	0.0061

Columns 127 through 133

0.0065	0.0064	0.0064	0.0064	0.0063	0.0063	0.0063
0.0062	0.0061	0.0061	0.0060	0.0060	0.0060	0.0059
0.0061	0.0061	0.0060	0.0060	0.0060	0.0059	0.0059

Columns 134 through 140

0.0062	0.0062	0.0062	0.0061	0.0061	0.0060	0.0060
0.0059	0.0059	0.0058	0.0058	0.0058	0.0057	0.0057
0.0059	0.0058	0.0058	0.0058	0.0057	0.0057	0.0057

Columns 141 through 147

0.0060	0.0059	0.0059	0.0059	0.0058	0.0058	0.0058
0.0057	0.0056	0.0056	0.0056	0.0055	0.0055	0.0055

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0.0056	0.0056	0.0056	0.0055	0.0055	0.0055	0.0054
Columns 148 through 154						
0.0057	0.0057	0.0057	0.0056	0.0056	0.0056	0.0055
0.0054	0.0054	0.0054	0.0053	0.0053	0.0053	0.0052
0.0054	0.0054	0.0053	0.0053	0.0053	0.0052	0.0052
Columns 155 through 161						
0.0055	0.0055	0.0054	0.0054	0.0054	0.0053	0.0053
0.0052	0.0052	0.0051	0.0051	0.0051	0.0050	0.0050
0.0052	0.0051	0.0051	0.0051	0.0050	0.0050	0.0050
Columns 162 through 168						
0.0053	0.0052	0.0052	0.0052	0.0052	0.0051	0.0051
0.0050	0.0050	0.0049	0.0049	0.0049	0.0048	0.0048
0.0049	0.0049	0.0049	0.0049	0.0048	0.0048	0.0048
Columns 169 through 175						
0.0051	0.0050	0.0050	0.0050	0.0049	0.0049	0.0049
0.0048	0.0047	0.0047	0.0047	0.0047	0.0046	0.0046
0.0047	0.0047	0.0047	0.0046	0.0046	0.0046	0.0046
Columns 176 through 182						
0.0049	0.0048	0.0048	0.0048	0.0047	0.0047	0.0047
0.0046	0.0045	0.0045	0.0045	0.0045	0.0044	0.0044
0.0045	0.0045	0.0045	0.0044	0.0044	0.0044	0.0044
Columns 183 through 189						
0.0047	0.0046	0.0046	0.0046	0.0045	0.0045	0.0045
0.0044	0.0043	0.0043	0.0043	0.0043	0.0042	0.0042
0.0043	0.0043	0.0043	0.0043	0.0042	0.0042	0.0042
Columns 190 through 196						
0.0045	0.0044	0.0044	0.0044	0.0043	0.0043	0.0043
0.0042	0.0041	0.0041	0.0041	0.0041	0.0040	0.0040
0.0041	0.0041	0.0041	0.0041	0.0040	0.0040	0.0040

Columns 197 through 203

0.0043	0.0042	0.0042	0.0042	0.0042	0.0041	0.0041
0.0040	0.0040	0.0039	0.0039	0.0039	0.0039	0.0038
0.0040	0.0039	0.0039	0.0039	0.0039	0.0038	0.0038

Columns 204 through 210

0.0041	0.0041	0.0040	0.0040	0.0040	0.0040	0.0039
0.0038	0.0038	0.0038	0.0037	0.0037	0.0037	0.0037
0.0038	0.0038	0.0037	0.0037	0.0037	0.0037	0.0036

Columns 211 through 217

0.0039	0.0039	0.0039	0.0038	0.0038	0.0038	0.0038
0.0036	0.0036	0.0036	0.0036	0.0035	0.0035	0.0035
0.0036	0.0036	0.0036	0.0035	0.0035	0.0035	0.0035

Columns 218 through 224

0.0037	0.0037	0.0037	0.0037	0.0036	0.0036	0.0036
0.0035	0.0034	0.0034	0.0034	0.0034	0.0034	0.0033
0.0034	0.0034	0.0034	0.0034	0.0034	0.0033	0.0033

Columns 225 through 231

0.0036	0.0036	0.0035	0.0035	0.0035	0.0035	0.0034
0.0033	0.0033	0.0033	0.0032	0.0032	0.0032	0.0032
0.0033	0.0033	0.0032	0.0032	0.0032	0.0032	0.0032

Columns 232 through 238

0.0034	0.0034	0.0034	0.0033	0.0033	0.0033	0.0033
0.0032	0.0031	0.0031	0.0031	0.0031	0.0030	0.0030
0.0031	0.0031	0.0031	0.0031	0.0030	0.0030	0.0030

Columns 239 through 245

0.0033	0.0032	0.0032	0.0032	0.0032	0.0032	0.0031
0.0030	0.0030	0.0030	0.0029	0.0029	0.0029	0.0029
0.0030	0.0030	0.0029	0.0029	0.0029	0.0029	0.0029

Columns 246 through 252



0.0031	0.0031	0.0031	0.0031	0.0030	0.0030	0.0030
0.0029	0.0028	0.0028	0.0028	0.0028	0.0028	0.0027
0.0028	0.0028	0.0028	0.0028	0.0028	0.0027	0.0027

Columns 253 through 259

0.0030	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029
0.0027	0.0027	0.0027	0.0027	0.0026	0.0026	0.0026
0.0027	0.0027	0.0027	0.0026	0.0026	0.0026	0.0026

Columns 260 through 266

0.0028	0.0028	0.0028	0.0028	0.0028	0.0027	0.0027
0.0026	0.0026	0.0025	0.0025	0.0025	0.0025	0.0025
0.0026	0.0025	0.0025	0.0025	0.0025	0.0025	0.0024

Columns 267 through 273

0.0027	0.0027	0.0027	0.0026	0.0026	0.0026	0.0026
0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0023
0.0024	0.0024	0.0024	0.0024	0.0024	0.0023	0.0023

Columns 274 through 280

0.0026	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
0.0023	0.0023	0.0023	0.0023	0.0022	0.0022	0.0022
0.0023	0.0023	0.0023	0.0022	0.0022	0.0022	0.0022

Columns 281 through 287

0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0023
0.0022	0.0022	0.0022	0.0021	0.0021	0.0021	0.0021
0.0022	0.0022	0.0021	0.0021	0.0021	0.0021	0.0021

Columns 288 through 294

0.0023	0.0023	0.0023	0.0023	0.0023	0.0022	0.0022
0.0021	0.0021	0.0020	0.0020	0.0020	0.0020	0.0020
0.0021	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020

Columns 295 through 301

0.0022	0.0022	0.0022	0.0022	0.0021	0.0021	0.0021
0.0020	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019

0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0018
Columns 302 through 308						
0.0021	0.0021	0.0021	0.0020	0.0020	0.0020	0.0020
0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0017
0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0017
Columns 309 through 315						
0.0020	0.0020	0.0019	0.0019	0.0019	0.0019	0.0019
0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0016
0.0017	0.0017	0.0017	0.0017	0.0017	0.0016	0.0016
Columns 316 through 322						
0.0019	0.0019	0.0018	0.0018	0.0018	0.0018	0.0018
0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0015
0.0016	0.0016	0.0016	0.0016	0.0016	0.0015	0.0015
Columns 323 through 329						
0.0018	0.0018	0.0017	0.0017	0.0017	0.0017	0.0017
0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0014
0.0015	0.0015	0.0015	0.0015	0.0015	0.0014	0.0014
Columns 330 through 336						
0.0017	0.0017	0.0016	0.0016	0.0016	0.0016	0.0016
0.0014	0.0014	0.0014	0.0014	0.0014	NaN	NaN
0.0014	0.0014	0.0014	0.0014	NaN	NaN	NaN
Columns 337 through 343						
0.0016	0.0016	0.0015	0.0015	0.0015	0.0015	0.0015
NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN
Columns 344 through 350						
0.0015	0.0015	0.0014	0.0014	0.0014	0.0014	0.0014
NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN

Columns 351 through 357

0.0014	0.0014	0.0014	0.0013	0.0013	0.0013	0.0013
NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN

Columns 358 through 361

0.0013	0.0013	0.0013	0.0013
NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN

CFlowDates =

Columns 1 through 6

730498	730517	730546	730577	730607	730638
731323	731337	731368	731398	731429	731460
731353	731368	731398	731429	731460	731490

Columns 7 through 12

730668	730699	730730	730760	730791	730821
731490	731521	731551	731582	731613	731641
731521	731551	731582	731613	731641	731672

Columns 13 through 18

730852	730883	730911	730942	730972	731003
731672	731702	731733	731763	731794	731825
731702	731733	731763	731794	731825	731855

Columns 19 through 24

731033	731064	731095	731125	731156	731186
731855	731886	731916	731947	731978	732007
731886	731916	731947	731978	732007	732038

Columns 25 through 30

731217	731248	731276	731307	731337	731368
732038	732068	732099	732129	732160	732191
732068	732099	732129	732160	732191	732221

## Columns 31 through 36

731398	731429	731460	731490	731521	731551
732221	732252	732282	732313	732344	732372
732252	732282	732313	732344	732372	732403

## Columns 37 through 42

731582	731613	731641	731672	731702	731733
732403	732433	732464	732494	732525	732556
732433	732464	732494	732525	732556	732586

## Columns 43 through 48

731763	731794	731825	731855	731886	731916
732586	732617	732647	732678	732709	732737
732617	732647	732678	732709	732737	732768

## Columns 49 through 54

731947	731978	732007	732038	732068	732099
732768	732798	732829	732859	732890	732921
732798	732829	732859	732890	732921	732951

## Columns 55 through 60

732129	732160	732191	732221	732252	732282
732951	732982	733012	733043	733074	733102
732982	733012	733043	733074	733102	733133

## Columns 61 through 66

732313	732344	732372	732403	732433	732464
733133	733163	733194	733224	733255	733286
733163	733194	733224	733255	733286	733316

## Columns 67 through 72

732494	732525	732556	732586	732617	732647
733316	733347	733377	733408	733439	733468
733347	733377	733408	733439	733468	733499

## Columns 73 through 78

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732678	732709	732737	732768	732798	732829
733499	733529	733560	733590	733621	733652
733529	733560	733590	733621	733652	733682

Columns 79 through 84

732859	732890	732921	732951	732982	733012
733682	733713	733743	733774	733805	733833
733713	733743	733774	733805	733833	733864

Columns 85 through 90

733043	733074	733102	733133	733163	733194
733864	733894	733925	733955	733986	734017
733894	733925	733955	733986	734017	734047

Columns 91 through 96

733224	733255	733286	733316	733347	733377
734047	734078	734108	734139	734170	734198
734078	734108	734139	734170	734198	734229

Columns 97 through 102

733408	733439	733468	733499	733529	733560
734229	734259	734290	734320	734351	734382
734259	734290	734320	734351	734382	734412

Columns 103 through 108

733590	733621	733652	733682	733713	733743
734412	734443	734473	734504	734535	734563
734443	734473	734504	734535	734563	734594

Columns 109 through 114

733774	733805	733833	733864	733894	733925
734594	734624	734655	734685	734716	734747
734624	734655	734685	734716	734747	734777

Columns 115 through 120

733955	733986	734017	734047	734078	734108
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734777	734808	734838	734869	734900	734929
734808	734838	734869	734900	734929	734960

Columns 121 through 126

734139	734170	734198	734229	734259	734290
734960	734990	735021	735051	735082	735113
734990	735021	735051	735082	735113	735143

Columns 127 through 132

734320	734351	734382	734412	734443	734473
735143	735174	735204	735235	735266	735294
735174	735204	735235	735266	735294	735325

Columns 133 through 138

734504	734535	734563	734594	734624	734655
735325	735355	735386	735416	735447	735478
735355	735386	735416	735447	735478	735508

Columns 139 through 144

734685	734716	734747	734777	734808	734838
735508	735539	735569	735600	735631	735659
735539	735569	735600	735631	735659	735690

Columns 145 through 150

734869	734900	734929	734960	734990	735021
735690	735720	735751	735781	735812	735843
735720	735751	735781	735812	735843	735873

Columns 151 through 156

735051	735082	735113	735143	735174	735204
735873	735904	735934	735965	735996	736024
735904	735934	735965	735996	736024	736055

Columns 157 through 162

735235	735266	735294	735325	735355	735386
736055	736085	736116	736146	736177	736208
736085	736116	736146	736177	736208	736238

## Columns 163 through 168

735416	735447	735478	735508	735539	735569
736238	736269	736299	736330	736361	736390
736269	736299	736330	736361	736390	736421

## Columns 169 through 174

735600	735631	735659	735690	735720	735751
736421	736451	736482	736512	736543	736574
736451	736482	736512	736543	736574	736604

## Columns 175 through 180

735781	735812	735843	735873	735904	735934
736604	736635	736665	736696	736727	736755
736635	736665	736696	736727	736755	736786

## Columns 181 through 186

735965	735996	736024	736055	736085	736116
736786	736816	736847	736877	736908	736939
736816	736847	736877	736908	736939	736969

## Columns 187 through 192

736146	736177	736208	736238	736269	736299
736969	737000	737030	737061	737092	737120
737000	737030	737061	737092	737120	737151

## Columns 193 through 198

736330	736361	736390	736421	736451	736482
737151	737181	737212	737242	737273	737304
737181	737212	737242	737273	737304	737334

## Columns 199 through 204

736512	736543	736574	736604	736635	736665
737334	737365	737395	737426	737457	737485
737365	737395	737426	737457	737485	737516

## Columns 205 through 210

736696	736727	736755	736786	736816	736847
737516	737546	737577	737607	737638	737669
737546	737577	737607	737638	737669	737699

Columns 211 through 216

736877	736908	736939	736969	737000	737030
737699	737730	737760	737791	737822	737851
737730	737760	737791	737822	737851	737882

Columns 217 through 222

737061	737092	737120	737151	737181	737212
737882	737912	737943	737973	738004	738035
737912	737943	737973	738004	738035	738065

Columns 223 through 228

737242	737273	737304	737334	737365	737395
738065	738096	738126	738157	738188	738216
738096	738126	738157	738188	738216	738247

Columns 229 through 234

737426	737457	737485	737516	737546	737577
738247	738277	738308	738338	738369	738400
738277	738308	738338	738369	738400	738430

Columns 235 through 240

737607	737638	737669	737699	737730	737760
738430	738461	738491	738522	738553	738581
738461	738491	738522	738553	738581	738612

Columns 241 through 246

737791	737822	737851	737882	737912	737943
738612	738642	738673	738703	738734	738765
738642	738673	738703	738734	738765	738795

Columns 247 through 252

737973	738004	738035	738065	738096	738126
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738795	738826	738856	738887	738918	738946
738826	738856	738887	738918	738946	738977

Columns 253 through 258

738157	738188	738216	738247	738277	738308
738977	739007	739038	739068	739099	739130
739007	739038	739068	739099	739130	739160

Columns 259 through 264

738338	738369	738400	738430	738461	738491
739160	739191	739221	739252	739283	739312
739191	739221	739252	739283	739312	739343

Columns 265 through 270

738522	738553	738581	738612	738642	738673
739343	739373	739404	739434	739465	739496
739373	739404	739434	739465	739496	739526

Columns 271 through 276

738703	738734	738765	738795	738826	738856
739526	739557	739587	739618	739649	739677
739557	739587	739618	739649	739677	739708

Columns 277 through 282

738887	738918	738946	738977	739007	739038
739708	739738	739769	739799	739830	739861
739738	739769	739799	739830	739861	739891

Columns 283 through 288

739068	739099	739130	739160	739191	739221
739891	739922	739952	739983	740014	740042
739922	739952	739983	740014	740042	740073

Columns 289 through 294

739252	739283	739312	739343	739373	739404
740073	740103	740134	740164	740195	740226
740103	740134	740164	740195	740226	740256

Columns 295 through 300

739434	739465	739496	739526	739557	739587
740256	740287	740317	740348	740379	740407
740287	740317	740348	740379	740407	740438

Columns 301 through 306

739618	739649	739677	739708	739738	739769
740438	740468	740499	740529	740560	740591
740468	740499	740529	740560	740591	740621

Columns 307 through 312

739799	739830	739861	739891	739922	739952
740621	740652	740682	740713	740744	740773
740652	740682	740713	740744	740773	740804

Columns 313 through 318

739983	740014	740042	740073	740103	740134
740804	740834	740865	740895	740926	740957
740834	740865	740895	740926	740957	740987

Columns 319 through 324

740164	740195	740226	740256	740287	740317
740987	741018	741048	741079	741110	741138
741018	741048	741079	741110	741138	741169

Columns 325 through 330

740348	740379	740407	740438	740468	740499
741169	741199	741230	741260	741291	741322
741199	741230	741260	741291	741322	741352

Columns 331 through 336

740529	740560	740591	740621	740652	740682
741352	741383	741413	741444	NaN	NaN
741383	741413	741444	NaN	NaN	NaN

Columns 337 through 342

740713	740744	740773	740804	740834	740865
NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN

Columns 343 through 348

740895	740926	740957	740987	741018	741048
NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN

Columns 349 through 354

741079	741110	741138	741169	741199	741230
NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN

Columns 355 through 360

741260	741291	741322	741352	741383	741413
NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN

Column 361

741444
NaN
NaN

TFactors =

Columns 1 through 7

0	1.0667	2.0667	3.0667	4.0667	5.0667	6.0667
0	0.9333	1.9333	2.9333	3.9333	4.9333	5.9333
0	0.9333	1.9333	2.9333	3.9333	4.9333	5.9333

Columns 8 through 14

7.0667	8.0667	9.0667	10.0667	11.0667	12.0667	13.0667
6.9333	7.9333	8.9333	9.9333	10.9333	11.9333	12.9333
6.9333	7.9333	8.9333	9.9333	10.9333	11.9333	12.9333

## Columns 15 through 21

14.0667	15.0667	16.0667	17.0667	18.0667	19.0667	20.0667
13.9333	14.9333	15.9333	16.9333	17.9333	18.9333	19.9333
13.9333	14.9333	15.9333	16.9333	17.9333	18.9333	19.9333

## Columns 22 through 28

21.0667	22.0667	23.0667	24.0667	25.0667	26.0667	27.0667
20.9333	21.9333	22.9333	23.9333	24.9333	25.9333	26.9333
20.9333	21.9333	22.9333	23.9333	24.9333	25.9333	26.9333

## Columns 29 through 35

28.0667	29.0667	30.0667	31.0667	32.0667	33.0667	34.0667
27.9333	28.9333	29.9333	30.9333	31.9333	32.9333	33.9333
27.9333	28.9333	29.9333	30.9333	31.9333	32.9333	33.9333

## Columns 36 through 42

35.0667	36.0667	37.0667	38.0667	39.0667	40.0667	41.0667
34.9333	35.9333	36.9333	37.9333	38.9333	39.9333	40.9333
34.9333	35.9333	36.9333	37.9333	38.9333	39.9333	40.9333

## Columns 43 through 49

42.0667	43.0667	44.0667	45.0667	46.0667	47.0667	48.0667
41.9333	42.9333	43.9333	44.9333	45.9333	46.9333	47.9333
41.9333	42.9333	43.9333	44.9333	45.9333	46.9333	47.9333

## Columns 50 through 56

49.0667	50.0667	51.0667	52.0667	53.0667	54.0667	55.0667
48.9333	49.9333	50.9333	51.9333	52.9333	53.9333	54.9333
48.9333	49.9333	50.9333	51.9333	52.9333	53.9333	54.9333

## Columns 57 through 63

56.0667	57.0667	58.0667	59.0667	60.0667	61.0667	62.0667
55.9333	56.9333	57.9333	58.9333	59.9333	60.9333	61.9333
55.9333	56.9333	57.9333	58.9333	59.9333	60.9333	61.9333

## Columns 64 through 70

63.0667 64.0667 65.0667 66.0667 67.0667 68.0667 69.0667  
62.9333 63.9333 64.9333 65.9333 66.9333 67.9333 68.9333  
62.9333 63.9333 64.9333 65.9333 66.9333 67.9333 68.9333

Columns 71 through 77

70.0667 71.0667 72.0667 73.0667 74.0667 75.0667 76.0667  
69.9333 70.9333 71.9333 72.9333 73.9333 74.9333 75.9333  
69.9333 70.9333 71.9333 72.9333 73.9333 74.9333 75.9333

Columns 78 through 84

77.0667 78.0667 79.0667 80.0667 81.0667 82.0667 83.0667  
76.9333 77.9333 78.9333 79.9333 80.9333 81.9333 82.9333  
76.9333 77.9333 78.9333 79.9333 80.9333 81.9333 82.9333

Columns 85 through 91

84.0667 85.0667 86.0667 87.0667 88.0667 89.0667 90.0667  
83.9333 84.9333 85.9333 86.9333 87.9333 88.9333 89.9333  
83.9333 84.9333 85.9333 86.9333 87.9333 88.9333 89.9333

Columns 92 through 98

91.0667 92.0667 93.0667 94.0667 95.0667 96.0667 97.0667  
90.9333 91.9333 92.9333 93.9333 94.9333 95.9333 96.9333  
90.9333 91.9333 92.9333 93.9333 94.9333 95.9333 96.9333

Columns 99 through 105

98.0667 99.0667 100.0667 101.0667 102.0667 103.0667 104.0667  
97.9333 98.9333 99.9333 100.9333 101.9333 102.9333 103.9333  
97.9333 98.9333 99.9333 100.9333 101.9333 102.9333 103.9333

Columns 106 through 112

105.0667 106.0667 107.0667 108.0667 109.0667 110.0667 111.0667  
104.9333 105.9333 106.9333 107.9333 108.9333 109.9333 110.9333  
104.9333 105.9333 106.9333 107.9333 108.9333 109.9333 110.9333

Columns 113 through 119

112.0667 113.0667 114.0667 115.0667 116.0667 117.0667 118.0667  
111.9333 112.9333 113.9333 114.9333 115.9333 116.9333 117.9333

111.9333 112.9333 113.9333 114.9333 115.9333 116.9333 117.9333

Columns 120 through 126

119.0667 120.0667 121.0667 122.0667 123.0667 124.0667 125.0667  
118.9333 119.9333 120.9333 121.9333 122.9333 123.9333 124.9333  
118.9333 119.9333 120.9333 121.9333 122.9333 123.9333 124.9333

Columns 127 through 133

126.0667 127.0667 128.0667 129.0667 130.0667 131.0667 132.0667  
125.9333 126.9333 127.9333 128.9333 129.9333 130.9333 131.9333  
125.9333 126.9333 127.9333 128.9333 129.9333 130.9333 131.9333

Columns 134 through 140

133.0667 134.0667 135.0667 136.0667 137.0667 138.0667 139.0667  
132.9333 133.9333 134.9333 135.9333 136.9333 137.9333 138.9333  
132.9333 133.9333 134.9333 135.9333 136.9333 137.9333 138.9333

Columns 141 through 147

140.0667 141.0667 142.0667 143.0667 144.0667 145.0667 146.0667  
139.9333 140.9333 141.9333 142.9333 143.9333 144.9333 145.9333  
139.9333 140.9333 141.9333 142.9333 143.9333 144.9333 145.9333

Columns 148 through 154

147.0667 148.0667 149.0667 150.0667 151.0667 152.0667 153.0667  
146.9333 147.9333 148.9333 149.9333 150.9333 151.9333 152.9333  
146.9333 147.9333 148.9333 149.9333 150.9333 151.9333 152.9333

Columns 155 through 161

154.0667 155.0667 156.0667 157.0667 158.0667 159.0667 160.0667  
153.9333 154.9333 155.9333 156.9333 157.9333 158.9333 159.9333  
153.9333 154.9333 155.9333 156.9333 157.9333 158.9333 159.9333

Columns 162 through 168

161.0667 162.0667 163.0667 164.0667 165.0667 166.0667 167.0667  
160.9333 161.9333 162.9333 163.9333 164.9333 165.9333 166.9333  
160.9333 161.9333 162.9333 163.9333 164.9333 165.9333 166.9333

Columns 169 through 175

168.0667	169.0667	170.0667	171.0667	172.0667	173.0667	174.0667
167.9333	168.9333	169.9333	170.9333	171.9333	172.9333	173.9333
167.9333	168.9333	169.9333	170.9333	171.9333	172.9333	173.9333

Columns 176 through 182

175.0667	176.0667	177.0667	178.0667	179.0667	180.0667	181.0667
174.9333	175.9333	176.9333	177.9333	178.9333	179.9333	180.9333
174.9333	175.9333	176.9333	177.9333	178.9333	179.9333	180.9333

Columns 183 through 189

182.0667	183.0667	184.0667	185.0667	186.0667	187.0667	188.0667
181.9333	182.9333	183.9333	184.9333	185.9333	186.9333	187.9333
181.9333	182.9333	183.9333	184.9333	185.9333	186.9333	187.9333

Columns 190 through 196

189.0667	190.0667	191.0667	192.0667	193.0667	194.0667	195.0667
188.9333	189.9333	190.9333	191.9333	192.9333	193.9333	194.9333
188.9333	189.9333	190.9333	191.9333	192.9333	193.9333	194.9333

Columns 197 through 203

196.0667	197.0667	198.0667	199.0667	200.0667	201.0667	202.0667
195.9333	196.9333	197.9333	198.9333	199.9333	200.9333	201.9333
195.9333	196.9333	197.9333	198.9333	199.9333	200.9333	201.9333

Columns 204 through 210

203.0667	204.0667	205.0667	206.0667	207.0667	208.0667	209.0667
202.9333	203.9333	204.9333	205.9333	206.9333	207.9333	208.9333
202.9333	203.9333	204.9333	205.9333	206.9333	207.9333	208.9333

Columns 211 through 217

210.0667	211.0667	212.0667	213.0667	214.0667	215.0667	216.0667
209.9333	210.9333	211.9333	212.9333	213.9333	214.9333	215.9333
209.9333	210.9333	211.9333	212.9333	213.9333	214.9333	215.9333

Columns 218 through 224

217.0667	218.0667	219.0667	220.0667	221.0667	222.0667	223.0667
216.9333	217.9333	218.9333	219.9333	220.9333	221.9333	222.9333
216.9333	217.9333	218.9333	219.9333	220.9333	221.9333	222.9333

Columns 225 through 231

224.0667	225.0667	226.0667	227.0667	228.0667	229.0667	230.0667
223.9333	224.9333	225.9333	226.9333	227.9333	228.9333	229.9333
223.9333	224.9333	225.9333	226.9333	227.9333	228.9333	229.9333

Columns 232 through 238

231.0667	232.0667	233.0667	234.0667	235.0667	236.0667	237.0667
230.9333	231.9333	232.9333	233.9333	234.9333	235.9333	236.9333
230.9333	231.9333	232.9333	233.9333	234.9333	235.9333	236.9333

Columns 239 through 245

238.0667	239.0667	240.0667	241.0667	242.0667	243.0667	244.0667
237.9333	238.9333	239.9333	240.9333	241.9333	242.9333	243.9333
237.9333	238.9333	239.9333	240.9333	241.9333	242.9333	243.9333

Columns 246 through 252

245.0667	246.0667	247.0667	248.0667	249.0667	250.0667	251.0667
244.9333	245.9333	246.9333	247.9333	248.9333	249.9333	250.9333
244.9333	245.9333	246.9333	247.9333	248.9333	249.9333	250.9333

Columns 253 through 259

252.0667	253.0667	254.0667	255.0667	256.0667	257.0667	258.0667
251.9333	252.9333	253.9333	254.9333	255.9333	256.9333	257.9333
251.9333	252.9333	253.9333	254.9333	255.9333	256.9333	257.9333

Columns 260 through 266

259.0667	260.0667	261.0667	262.0667	263.0667	264.0667	265.0667
258.9333	259.9333	260.9333	261.9333	262.9333	263.9333	264.9333
258.9333	259.9333	260.9333	261.9333	262.9333	263.9333	264.9333

Columns 267 through 273

266.0667	267.0667	268.0667	269.0667	270.0667	271.0667	272.0667
265.9333	266.9333	267.9333	268.9333	269.9333	270.9333	271.9333



265.9333 266.9333 267.9333 268.9333 269.9333 270.9333 271.9333

Columns 274 through 280

273.0667 274.0667 275.0667 276.0667 277.0667 278.0667 279.0667  
272.9333 273.9333 274.9333 275.9333 276.9333 277.9333 278.9333  
272.9333 273.9333 274.9333 275.9333 276.9333 277.9333 278.9333

Columns 281 through 287

280.0667 281.0667 282.0667 283.0667 284.0667 285.0667 286.0667  
279.9333 280.9333 281.9333 282.9333 283.9333 284.9333 285.9333  
279.9333 280.9333 281.9333 282.9333 283.9333 284.9333 285.9333

Columns 288 through 294

287.0667 288.0667 289.0667 290.0667 291.0667 292.0667 293.0667  
286.9333 287.9333 288.9333 289.9333 290.9333 291.9333 292.9333  
286.9333 287.9333 288.9333 289.9333 290.9333 291.9333 292.9333

Columns 295 through 301

294.0667 295.0667 296.0667 297.0667 298.0667 299.0667 300.0667  
293.9333 294.9333 295.9333 296.9333 297.9333 298.9333 299.9333  
293.9333 294.9333 295.9333 296.9333 297.9333 298.9333 299.9333

Columns 302 through 308

301.0667 302.0667 303.0667 304.0667 305.0667 306.0667 307.0667  
300.9333 301.9333 302.9333 303.9333 304.9333 305.9333 306.9333  
300.9333 301.9333 302.9333 303.9333 304.9333 305.9333 306.9333

Columns 309 through 315

308.0667 309.0667 310.0667 311.0667 312.0667 313.0667 314.0667  
307.9333 308.9333 309.9333 310.9333 311.9333 312.9333 313.9333  
307.9333 308.9333 309.9333 310.9333 311.9333 312.9333 313.9333

Columns 316 through 322

315.0667 316.0667 317.0667 318.0667 319.0667 320.0667 321.0667  
314.9333 315.9333 316.9333 317.9333 318.9333 319.9333 320.9333  
314.9333 315.9333 316.9333 317.9333 318.9333 319.9333 320.9333

Columns 323 through 329

322.0667	323.0667	324.0667	325.0667	326.0667	327.0667	328.0667
321.9333	322.9333	323.9333	324.9333	325.9333	326.9333	327.9333
321.9333	322.9333	323.9333	324.9333	325.9333	326.9333	327.9333

Columns 330 through 336

329.0667	330.0667	331.0667	332.0667	333.0667	334.0667	335.0667
328.9333	329.9333	330.9333	331.9333	332.9333	NaN	NaN
328.9333	329.9333	330.9333	331.9333	NaN	NaN	NaN

Columns 337 through 343

336.0667	337.0667	338.0667	339.0667	340.0667	341.0667	342.0667
NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN

Columns 344 through 350

343.0667	344.0667	345.0667	346.0667	347.0667	348.0667	349.0667
NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN

Columns 351 through 357

350.0667	351.0667	352.0667	353.0667	354.0667	355.0667	356.0667
NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN

Columns 358 through 361

357.0667	358.0667	359.0667	360.0667
NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN

Factors =

Columns 1 through 7

1.0000	0.9992	0.9982	0.9970	0.9957	0.9942	0.9925
1.0000	0.9944	0.9887	0.9828	0.9769	0.9711	0.9653
1.0000	0.9942	0.9883	0.9824	0.9766	0.9707	0.9649

## Columns 8 through 14

0.9907	0.9887	0.9865	0.9841	0.9816	0.9789	0.9761
0.9595	0.9538	0.9481	0.9424	0.9368	0.9311	0.9255
0.9592	0.9534	0.9477	0.9420	0.9364	0.9307	0.9251

## Columns 15 through 21

0.9731	0.9699	0.9666	0.9631	0.9594	0.9556	0.9517
0.9199	0.9144	0.9089	0.9034	0.8979	0.8925	0.8871
0.9195	0.9140	0.9085	0.9030	0.8975	0.8921	0.8866

## Columns 22 through 28

0.9475	0.9433	0.9389	0.9343	0.9296	0.9247	0.9197
0.8817	0.8763	0.8710	0.8657	0.8604	0.8552	0.8499
0.8813	0.8759	0.8706	0.8653	0.8600	0.8547	0.8495

## Columns 29 through 35

0.9146	0.9093	0.9039	0.8985	0.8932	0.8878	0.8825
0.8447	0.8396	0.8344	0.8293	0.8242	0.8191	0.8140
0.8443	0.8391	0.8339	0.8288	0.8237	0.8186	0.8136

## Columns 36 through 42

0.8772	0.8720	0.8668	0.8616	0.8564	0.8512	0.8461
0.8090	0.8040	0.7990	0.7941	0.7892	0.7842	0.7794
0.8085	0.8035	0.7985	0.7936	0.7887	0.7837	0.7789

## Columns 43 through 49

0.8410	0.8359	0.8309	0.8258	0.8208	0.8159	0.8109
0.7745	0.7697	0.7649	0.7601	0.7553	0.7506	0.7458
0.7740	0.7692	0.7643	0.7595	0.7548	0.7500	0.7453

## Columns 50 through 56

0.8060	0.8011	0.7962	0.7913	0.7865	0.7817	0.7769
0.7411	0.7365	0.7318	0.7272	0.7226	0.7180	0.7134
0.7406	0.7359	0.7313	0.7267	0.7220	0.7175	0.7129

## Columns 57 through 63

0.7722	0.7674	0.7627	0.7580	0.7533	0.7487	0.7441
0.7089	0.7044	0.6999	0.6954	0.6910	0.6865	0.6821
0.7084	0.7038	0.6993	0.6949	0.6904	0.6860	0.6816

Columns 64 through 70

0.7395	0.7349	0.7303	0.7258	0.7213	0.7168	0.7123
0.6777	0.6734	0.6690	0.6647	0.6604	0.6561	0.6519
0.6772	0.6728	0.6684	0.6641	0.6598	0.6555	0.6513

Columns 71 through 77

0.7079	0.7035	0.6991	0.6947	0.6903	0.6860	0.6817
0.6476	0.6434	0.6392	0.6350	0.6309	0.6267	0.6226
0.6470	0.6428	0.6386	0.6344	0.6302	0.6261	0.6220

Columns 78 through 84

0.6774	0.6731	0.6688	0.6646	0.6604	0.6562	0.6520
0.6185	0.6144	0.6104	0.6063	0.6023	0.5983	0.5943
0.6179	0.6138	0.6097	0.6057	0.6016	0.5976	0.5936

Columns 85 through 91

0.6478	0.6437	0.6396	0.6355	0.6314	0.6274	0.6233
0.5903	0.5864	0.5825	0.5785	0.5747	0.5708	0.5669
0.5897	0.5857	0.5818	0.5779	0.5740	0.5701	0.5663

Columns 92 through 98

0.6193	0.6153	0.6113	0.6074	0.6035	0.5995	0.5956
0.5631	0.5593	0.5555	0.5517	0.5479	0.5442	0.5405
0.5624	0.5586	0.5548	0.5510	0.5473	0.5435	0.5398

Columns 99 through 105

0.5917	0.5879	0.5840	0.5802	0.5764	0.5726	0.5688
0.5368	0.5331	0.5294	0.5257	0.5221	0.5185	0.5149
0.5361	0.5324	0.5287	0.5250	0.5214	0.5178	0.5142

Columns 106 through 112

0.5651	0.5614	0.5576	0.5539	0.5503	0.5466	0.5429
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0.5113	0.5077	0.5042	0.5006	0.4971	0.4936	0.4901
0.5106	0.5070	0.5034	0.4999	0.4964	0.4929	0.4894

Columns 113 through 119

0.5393	0.5357	0.5321	0.5285	0.5250	0.5214	0.5179
0.4866	0.4832	0.4797	0.4763	0.4729	0.4695	0.4661
0.4859	0.4824	0.4790	0.4756	0.4722	0.4688	0.4654

Columns 120 through 126

0.5144	0.5109	0.5074	0.5040	0.5005	0.4971	0.4937
0.4628	0.4594	0.4561	0.4528	0.4495	0.4462	0.4430
0.4620	0.4587	0.4554	0.4520	0.4487	0.4455	0.4422

Columns 127 through 133

0.4903	0.4869	0.4835	0.4802	0.4769	0.4735	0.4702
0.4397	0.4365	0.4333	0.4301	0.4269	0.4237	0.4205
0.4389	0.4357	0.4325	0.4293	0.4261	0.4229	0.4197

Columns 134 through 140

0.4670	0.4637	0.4604	0.4572	0.4540	0.4508	0.4476
0.4174	0.4143	0.4111	0.4080	0.4049	0.4019	0.3988
0.4166	0.4134	0.4103	0.4072	0.4041	0.4011	0.3980

Columns 141 through 147

0.4444	0.4412	0.4381	0.4349	0.4318	0.4287	0.4256
0.3958	0.3927	0.3897	0.3867	0.3837	0.3808	0.3778
0.3949	0.3919	0.3889	0.3859	0.3829	0.3799	0.3769

Columns 148 through 154

0.4226	0.4195	0.4165	0.4134	0.4104	0.4074	0.4044
0.3748	0.3719	0.3690	0.3661	0.3632	0.3603	0.3574
0.3740	0.3711	0.3681	0.3652	0.3623	0.3594	0.3566

Columns 155 through 161

0.4014	0.3985	0.3955	0.3926	0.3897	0.3868	0.3839
0.3546	0.3517	0.3489	0.3461	0.3433	0.3405	0.3377
0.3537	0.3509	0.3480	0.3452	0.3424	0.3396	0.3368

Columns 162 through 168

0.3810	0.3781	0.3753	0.3724	0.3696	0.3668	0.3640
0.3350	0.3322	0.3295	0.3267	0.3240	0.3213	0.3186
0.3341	0.3313	0.3286	0.3258	0.3231	0.3204	0.3177

Columns 169 through 175

0.3612	0.3584	0.3557	0.3529	0.3502	0.3475	0.3448
0.3160	0.3133	0.3106	0.3080	0.3054	0.3027	0.3001
0.3151	0.3124	0.3097	0.3071	0.3045	0.3018	0.2992

Columns 176 through 182

0.3421	0.3394	0.3367	0.3340	0.3314	0.3287	0.3261
0.2975	0.2950	0.2924	0.2898	0.2873	0.2847	0.2822
0.2966	0.2940	0.2915	0.2889	0.2863	0.2838	0.2813

Columns 183 through 189

0.3235	0.3209	0.3183	0.3157	0.3132	0.3106	0.3081
0.2797	0.2772	0.2747	0.2722	0.2698	0.2673	0.2649
0.2788	0.2763	0.2738	0.2713	0.2688	0.2663	0.2639

Columns 190 through 196

0.3055	0.3030	0.3005	0.2980	0.2955	0.2931	0.2906
0.2624	0.2600	0.2576	0.2552	0.2528	0.2504	0.2480
0.2615	0.2590	0.2566	0.2542	0.2518	0.2494	0.2470

Columns 197 through 203

0.2881	0.2857	0.2833	0.2809	0.2784	0.2760	0.2737
0.2457	0.2433	0.2410	0.2386	0.2363	0.2340	0.2317
0.2447	0.2423	0.2400	0.2376	0.2353	0.2330	0.2307

Columns 204 through 210

0.2713	0.2689	0.2666	0.2642	0.2619	0.2596	0.2573
0.2294	0.2271	0.2249	0.2226	0.2204	0.2181	0.2159
0.2284	0.2261	0.2239	0.2216	0.2193	0.2171	0.2149

Columns 211 through 217

0.2550	0.2527	0.2504	0.2481	0.2458	0.2436	0.2414
0.2137	0.2115	0.2093	0.2071	0.2049	0.2027	0.2005
0.2126	0.2104	0.2082	0.2060	0.2038	0.2017	0.1995

Columns 218 through 224

0.2391	0.2369	0.2347	0.2325	0.2303	0.2281	0.2259
0.1984	0.1962	0.1941	0.1920	0.1899	0.1877	0.1856
0.1973	0.1952	0.1931	0.1909	0.1888	0.1867	0.1846

Columns 225 through 231

0.2238	0.2216	0.2195	0.2173	0.2152	0.2131	0.2110
0.1836	0.1815	0.1794	0.1773	0.1753	0.1732	0.1712
0.1825	0.1804	0.1783	0.1763	0.1742	0.1722	0.1701

Columns 232 through 238

0.2089	0.2068	0.2047	0.2027	0.2006	0.1986	0.1965
0.1692	0.1671	0.1651	0.1631	0.1611	0.1591	0.1572
0.1681	0.1661	0.1640	0.1620	0.1600	0.1581	0.1561

Columns 239 through 245

0.1945	0.1925	0.1904	0.1884	0.1864	0.1844	0.1825
0.1552	0.1532	0.1513	0.1493	0.1474	0.1455	0.1436
0.1541	0.1521	0.1502	0.1482	0.1463	0.1444	0.1424

Columns 246 through 252

0.1805	0.1785	0.1766	0.1746	0.1727	0.1707	0.1688
0.1416	0.1397	0.1378	0.1359	0.1341	0.1322	0.1303
0.1405	0.1386	0.1367	0.1348	0.1329	0.1311	0.1292

Columns 253 through 259

0.1669	0.1650	0.1631	0.1612	0.1593	0.1575	0.1556
0.1285	0.1266	0.1248	0.1229	0.1211	0.1193	0.1175
0.1273	0.1255	0.1236	0.1218	0.1200	0.1181	0.1163

Columns 260 through 266

0.1537	0.1519	0.1500	0.1482	0.1464	0.1446	0.1427
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0.1157	0.1139	0.1121	0.1103	0.1085	0.1068	0.1050
0.1145	0.1127	0.1109	0.1091	0.1074	0.1056	0.1038

Columns 267 through 273

0.1409	0.1391	0.1374	0.1356	0.1338	0.1320	0.1303
0.1032	0.1015	0.0998	0.0980	0.0963	0.0946	0.0929
0.1021	0.1003	0.0986	0.0968	0.0951	0.0934	0.0917

Columns 274 through 280

0.1285	0.1268	0.1250	0.1233	0.1216	0.1199	0.1182
0.0912	0.0895	0.0878	0.0861	0.0844	0.0827	0.0811
0.0900	0.0883	0.0866	0.0849	0.0832	0.0815	0.0798

Columns 281 through 287

0.1165	0.1148	0.1131	0.1114	0.1097	0.1080	0.1064
0.0794	0.0778	0.0761	0.0745	0.0728	0.0712	0.0696
0.0782	0.0765	0.0749	0.0732	0.0716	0.0700	0.0684

Columns 288 through 294

0.1047	0.1031	0.1014	0.0998	0.0982	0.0966	0.0950
0.0680	0.0664	0.0648	0.0632	0.0616	0.0600	0.0584
0.0667	0.0651	0.0635	0.0619	0.0603	0.0587	0.0572

Columns 295 through 301

0.0933	0.0917	0.0902	0.0886	0.0870	0.0854	0.0838
0.0568	0.0553	0.0537	0.0522	0.0506	0.0491	0.0476
0.0556	0.0540	0.0525	0.0509	0.0494	0.0478	0.0463

Columns 302 through 308

0.0823	0.0807	0.0792	0.0776	0.0761	0.0746	0.0730
0.0460	0.0445	0.0430	0.0415	0.0400	0.0385	0.0370
0.0448	0.0432	0.0417	0.0402	0.0387	0.0372	0.0357

Columns 309 through 315

0.0715	0.0700	0.0685	0.0670	0.0655	0.0640	0.0625
0.0355	0.0340	0.0325	0.0311	0.0296	0.0281	0.0267
0.0342	0.0327	0.0312	0.0298	0.0283	0.0268	0.0254



Columns 316 through 322

0.0610	0.0596	0.0581	0.0566	0.0552	0.0537	0.0523
0.0252	0.0238	0.0223	0.0209	0.0195	0.0180	0.0166
0.0239	0.0225	0.0210	0.0196	0.0181	0.0167	0.0153

Columns 323 through 329

0.0508	0.0494	0.0480	0.0466	0.0451	0.0437	0.0423
0.0152	0.0138	0.0124	0.0110	0.0096	0.0082	0.0068
0.0139	0.0125	0.0111	0.0097	0.0083	0.0069	0.0055

Columns 330 through 336

0.0409	0.0395	0.0381	0.0368	0.0354	0.0340	0.0326
0.0055	0.0041	0.0027	0.0014	0	NaN	NaN
0.0041	0.0027	0.0014	0	NaN	NaN	NaN

Columns 337 through 343

0.0313	0.0299	0.0286	0.0272	0.0259	0.0245	0.0232
NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN

Columns 344 through 350

0.0219	0.0205	0.0192	0.0179	0.0166	0.0153	0.0140
NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN

Columns 351 through 357

0.0127	0.0114	0.0101	0.0088	0.0076	0.0063	0.0050
NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN

Columns 358 through 361

0.0038	0.0025	0.0012	0
NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN

Each output is a 3-by-361 element matrix padded with NaN's wherever elements are missing.

### Calculate Payment, Principal, Interest, and Prepayment for a Single Mortgage

Given a mortgage with the following characteristics, compute payments, principal, interest, and prepayment.

Define the mortgage characteristics.

```
Settle      = datenum('17-April-2002');
Maturity    = datenum('1-Jan-2030');
IssueDate   = datenum('1-Jan-2000');
GrossRate   = 0.08125;
CouponRate  = 0.075;
Delay       = 14;
PrepaySpeed = 100;
```

Use `mbscfamonts` to evaluate the mortgage.

```
[Payment, Principal, Interest, Prepayment] = ...
mbscfamonts(Settle, Maturity, IssueDate, GrossRate, ...
CouponRate, Delay, PrepaySpeed)
```

Payment =

Columns 1 through 7

```
-0.0033    0.0118    0.0120    0.0121    0.0120    0.0119    0.0119
```

Columns 8 through 14

```
0.0118    0.0117    0.0117    0.0116    0.0115    0.0115    0.0114
```

Columns 15 through 21

```
0.0114    0.0113    0.0112    0.0112    0.0111    0.0110    0.0110
```

Columns 22 through 28

```
0.0109    0.0109    0.0108    0.0107    0.0107    0.0106    0.0106
```

Columns 29 through 35

---

0.0105	0.0105	0.0104	0.0103	0.0103	0.0102	0.0102
Columns 36 through 42						
0.0101	0.0101	0.0100	0.0099	0.0099	0.0098	0.0098
Columns 43 through 49						
0.0097	0.0097	0.0096	0.0096	0.0095	0.0095	0.0094
Columns 50 through 56						
0.0094	0.0093	0.0093	0.0092	0.0092	0.0091	0.0090
Columns 57 through 63						
0.0090	0.0089	0.0089	0.0088	0.0088	0.0087	0.0087
Columns 64 through 70						
0.0087	0.0086	0.0086	0.0085	0.0085	0.0084	0.0084
Columns 71 through 77						
0.0083	0.0083	0.0082	0.0082	0.0081	0.0081	0.0080
Columns 78 through 84						
0.0080	0.0079	0.0079	0.0079	0.0078	0.0078	0.0077
Columns 85 through 91						
0.0077	0.0076	0.0076	0.0075	0.0075	0.0075	0.0074
Columns 92 through 98						
0.0074	0.0073	0.0073	0.0073	0.0072	0.0072	0.0071
Columns 99 through 105						
0.0071	0.0070	0.0070	0.0070	0.0069	0.0069	0.0068
Columns 106 through 112						

0.0068	0.0068	0.0067	0.0067	0.0066	0.0066	0.0066
Columns 113 through 119						
0.0065	0.0065	0.0065	0.0064	0.0064	0.0063	0.0063
Columns 120 through 126						
0.0063	0.0062	0.0062	0.0062	0.0061	0.0061	0.0061
Columns 127 through 133						
0.0060	0.0060	0.0059	0.0059	0.0059	0.0058	0.0058
Columns 134 through 140						
0.0058	0.0057	0.0057	0.0057	0.0056	0.0056	0.0056
Columns 141 through 147						
0.0055	0.0055	0.0055	0.0054	0.0054	0.0054	0.0053
Columns 148 through 154						
0.0053	0.0053	0.0052	0.0052	0.0052	0.0052	0.0051
Columns 155 through 161						
0.0051	0.0051	0.0050	0.0050	0.0050	0.0049	0.0049
Columns 162 through 168						
0.0049	0.0048	0.0048	0.0048	0.0048	0.0047	0.0047
Columns 169 through 175						
0.0047	0.0046	0.0046	0.0046	0.0046	0.0045	0.0045
Columns 176 through 182						
0.0045	0.0044	0.0044	0.0044	0.0044	0.0043	0.0043
Columns 183 through 189						

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0.0043	0.0043	0.0042	0.0042	0.0042	0.0041	0.0041
Columns 190 through 196						
0.0041	0.0041	0.0040	0.0040	0.0040	0.0040	0.0039
Columns 197 through 203						
0.0039	0.0039	0.0039	0.0038	0.0038	0.0038	0.0038
Columns 204 through 210						
0.0037	0.0037	0.0037	0.0037	0.0036	0.0036	0.0036
Columns 211 through 217						
0.0036	0.0035	0.0035	0.0035	0.0035	0.0035	0.0034
Columns 218 through 224						
0.0034	0.0034	0.0034	0.0033	0.0033	0.0033	0.0033
Columns 225 through 231						
0.0033	0.0032	0.0032	0.0032	0.0032	0.0031	0.0031
Columns 232 through 238						
0.0031	0.0031	0.0031	0.0030	0.0030	0.0030	0.0030
Columns 239 through 245						
0.0030	0.0029	0.0029	0.0029	0.0029	0.0029	0.0028
Columns 246 through 252						
0.0028	0.0028	0.0028	0.0028	0.0027	0.0027	0.0027
Columns 253 through 259						
0.0027	0.0027	0.0026	0.0026	0.0026	0.0026	0.0026
Columns 260 through 266						

0.0025	0.0025	0.0025	0.0025	0.0025	0.0024	0.0024
Columns 267 through 273						
0.0024	0.0024	0.0024	0.0024	0.0023	0.0023	0.0023
Columns 274 through 280						
0.0023	0.0023	0.0023	0.0022	0.0022	0.0022	0.0022
Columns 281 through 287						
0.0022	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021
Columns 288 through 294						
0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Columns 295 through 301						
0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0018
Columns 302 through 308						
0.0018	0.0018	0.0018	0.0018	0.0018	0.0017	0.0017
Columns 309 through 315						
0.0017	0.0017	0.0017	0.0017	0.0017	0.0016	0.0016
Columns 316 through 322						
0.0016	0.0016	0.0016	0.0016	0.0016	0.0015	0.0015
Columns 323 through 329						
0.0015	0.0015	0.0015	0.0015	0.0015	0.0014	0.0014
Columns 330 through 334						
0.0014	0.0014	0.0014	0.0014	0.0014		

Principal =

Columns 1 through 6

731323	731337	731368	731398	731429	731460
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Columns 7 through 12

731490	731521	731551	731582	731613	731641
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Columns 13 through 18

731672	731702	731733	731763	731794	731825
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Columns 19 through 24

731855	731886	731916	731947	731978	732007
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Columns 25 through 30

732038	732068	732099	732129	732160	732191
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Columns 31 through 36

732221	732252	732282	732313	732344	732372
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Columns 37 through 42

732403	732433	732464	732494	732525	732556
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Columns 43 through 48

732586	732617	732647	732678	732709	732737
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Columns 49 through 54

732768	732798	732829	732859	732890	732921
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Columns 55 through 60

732951	732982	733012	733043	733074	733102
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Columns 61 through 66

733133	733163	733194	733224	733255	733286
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Columns 67 through 72

733316	733347	733377	733408	733439	733468
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Columns 73 through 78

733499	733529	733560	733590	733621	733652
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Columns 79 through 84

733682	733713	733743	733774	733805	733833
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Columns 85 through 90

733864	733894	733925	733955	733986	734017
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Columns 91 through 96

734047	734078	734108	734139	734170	734198
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Columns 97 through 102

734229	734259	734290	734320	734351	734382
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Columns 103 through 108

734412	734443	734473	734504	734535	734563
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Columns 109 through 114

734594	734624	734655	734685	734716	734747
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Columns 115 through 120

734777	734808	734838	734869	734900	734929
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Columns 121 through 126

734960	734990	735021	735051	735082	735113
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Columns 127 through 132

735143	735174	735204	735235	735266	735294
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Columns 133 through 138

735325 735355 735386 735416 735447 735478

Columns 139 through 144

735508 735539 735569 735600 735631 735659

Columns 145 through 150

735690 735720 735751 735781 735812 735843

Columns 151 through 156

735873 735904 735934 735965 735996 736024

Columns 157 through 162

736055 736085 736116 736146 736177 736208

Columns 163 through 168

736238 736269 736299 736330 736361 736390

Columns 169 through 174

736421 736451 736482 736512 736543 736574

Columns 175 through 180

736604 736635 736665 736696 736727 736755

Columns 181 through 186

736786 736816 736847 736877 736908 736939

Columns 187 through 192

736969 737000 737030 737061 737092 737120

Columns 193 through 198

737151 737181 737212 737242 737273 737304

Columns 199 through 204

737334	737365	737395	737426	737457	737485
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Columns 205 through 210

737516	737546	737577	737607	737638	737669
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Columns 211 through 216

737699	737730	737760	737791	737822	737851
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Columns 217 through 222

737882	737912	737943	737973	738004	738035
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Columns 223 through 228

738065	738096	738126	738157	738188	738216
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Columns 229 through 234

738247	738277	738308	738338	738369	738400
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Columns 235 through 240

738430	738461	738491	738522	738553	738581
--------	--------	--------	--------	--------	--------

Columns 241 through 246

738612	738642	738673	738703	738734	738765
--------	--------	--------	--------	--------	--------

Columns 247 through 252

738795	738826	738856	738887	738918	738946
--------	--------	--------	--------	--------	--------

Columns 253 through 258

738977	739007	739038	739068	739099	739130
--------	--------	--------	--------	--------	--------

Columns 259 through 264

739160	739191	739221	739252	739283	739312
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Columns 265 through 270

739343 739373 739404 739434 739465 739496

Columns 271 through 276

739526 739557 739587 739618 739649 739677

Columns 277 through 282

739708 739738 739769 739799 739830 739861

Columns 283 through 288

739891 739922 739952 739983 740014 740042

Columns 289 through 294

740073 740103 740134 740164 740195 740226

Columns 295 through 300

740256 740287 740317 740348 740379 740407

Columns 301 through 306

740438 740468 740499 740529 740560 740591

Columns 307 through 312

740621 740652 740682 740713 740744 740773

Columns 313 through 318

740804 740834 740865 740895 740926 740957

Columns 319 through 324

740987 741018 741048 741079 741110 741138

Columns 325 through 330

741169 741199 741230 741260 741291 741322

Columns 331 through 334

741352      741383      741413      741444

Interest =

Columns 1 through 7

0    0.9333    1.9333    2.9333    3.9333    4.9333    5.9333

Columns 8 through 14

6.9333    7.9333    8.9333    9.9333    10.9333    11.9333    12.9333

Columns 15 through 21

13.9333    14.9333    15.9333    16.9333    17.9333    18.9333    19.9333

Columns 22 through 28

20.9333    21.9333    22.9333    23.9333    24.9333    25.9333    26.9333

Columns 29 through 35

27.9333    28.9333    29.9333    30.9333    31.9333    32.9333    33.9333

Columns 36 through 42

34.9333    35.9333    36.9333    37.9333    38.9333    39.9333    40.9333

Columns 43 through 49

41.9333    42.9333    43.9333    44.9333    45.9333    46.9333    47.9333

Columns 50 through 56

48.9333    49.9333    50.9333    51.9333    52.9333    53.9333    54.9333

Columns 57 through 63

55.9333    56.9333    57.9333    58.9333    59.9333    60.9333    61.9333

Columns 64 through 70

62.9333 63.9333 64.9333 65.9333 66.9333 67.9333 68.9333

Columns 71 through 77

69.9333 70.9333 71.9333 72.9333 73.9333 74.9333 75.9333

Columns 78 through 84

76.9333 77.9333 78.9333 79.9333 80.9333 81.9333 82.9333

Columns 85 through 91

83.9333 84.9333 85.9333 86.9333 87.9333 88.9333 89.9333

Columns 92 through 98

90.9333 91.9333 92.9333 93.9333 94.9333 95.9333 96.9333

Columns 99 through 105

97.9333 98.9333 99.9333 100.9333 101.9333 102.9333 103.9333

Columns 106 through 112

104.9333 105.9333 106.9333 107.9333 108.9333 109.9333 110.9333

Columns 113 through 119

111.9333 112.9333 113.9333 114.9333 115.9333 116.9333 117.9333

Columns 120 through 126

118.9333 119.9333 120.9333 121.9333 122.9333 123.9333 124.9333

Columns 127 through 133

125.9333 126.9333 127.9333 128.9333 129.9333 130.9333 131.9333

Columns 134 through 140

132.9333 133.9333 134.9333 135.9333 136.9333 137.9333 138.9333

Columns 141 through 147

139.9333 140.9333 141.9333 142.9333 143.9333 144.9333 145.9333

Columns 148 through 154

146.9333 147.9333 148.9333 149.9333 150.9333 151.9333 152.9333

Columns 155 through 161

153.9333 154.9333 155.9333 156.9333 157.9333 158.9333 159.9333

Columns 162 through 168

160.9333 161.9333 162.9333 163.9333 164.9333 165.9333 166.9333

Columns 169 through 175

167.9333 168.9333 169.9333 170.9333 171.9333 172.9333 173.9333

Columns 176 through 182

174.9333 175.9333 176.9333 177.9333 178.9333 179.9333 180.9333

Columns 183 through 189

181.9333 182.9333 183.9333 184.9333 185.9333 186.9333 187.9333

Columns 190 through 196

188.9333 189.9333 190.9333 191.9333 192.9333 193.9333 194.9333

Columns 197 through 203

195.9333 196.9333 197.9333 198.9333 199.9333 200.9333 201.9333

Columns 204 through 210

202.9333 203.9333 204.9333 205.9333 206.9333 207.9333 208.9333

Columns 211 through 217

209.9333 210.9333 211.9333 212.9333 213.9333 214.9333 215.9333

---

Columns 218 through 224

216.9333	217.9333	218.9333	219.9333	220.9333	221.9333	222.9333
----------	----------	----------	----------	----------	----------	----------

Columns 225 through 231

223.9333	224.9333	225.9333	226.9333	227.9333	228.9333	229.9333
----------	----------	----------	----------	----------	----------	----------

Columns 232 through 238

230.9333	231.9333	232.9333	233.9333	234.9333	235.9333	236.9333
----------	----------	----------	----------	----------	----------	----------

Columns 239 through 245

237.9333	238.9333	239.9333	240.9333	241.9333	242.9333	243.9333
----------	----------	----------	----------	----------	----------	----------

Columns 246 through 252

244.9333	245.9333	246.9333	247.9333	248.9333	249.9333	250.9333
----------	----------	----------	----------	----------	----------	----------

Columns 253 through 259

251.9333	252.9333	253.9333	254.9333	255.9333	256.9333	257.9333
----------	----------	----------	----------	----------	----------	----------

Columns 260 through 266

258.9333	259.9333	260.9333	261.9333	262.9333	263.9333	264.9333
----------	----------	----------	----------	----------	----------	----------

Columns 267 through 273

265.9333	266.9333	267.9333	268.9333	269.9333	270.9333	271.9333
----------	----------	----------	----------	----------	----------	----------

Columns 274 through 280

272.9333	273.9333	274.9333	275.9333	276.9333	277.9333	278.9333
----------	----------	----------	----------	----------	----------	----------

Columns 281 through 287

279.9333	280.9333	281.9333	282.9333	283.9333	284.9333	285.9333
----------	----------	----------	----------	----------	----------	----------

Columns 288 through 294

286.9333	287.9333	288.9333	289.9333	290.9333	291.9333	292.9333
----------	----------	----------	----------	----------	----------	----------

Columns 295 through 301

293.9333 294.9333 295.9333 296.9333 297.9333 298.9333 299.9333

Columns 302 through 308

300.9333 301.9333 302.9333 303.9333 304.9333 305.9333 306.9333

Columns 309 through 315

307.9333 308.9333 309.9333 310.9333 311.9333 312.9333 313.9333

Columns 316 through 322

314.9333 315.9333 316.9333 317.9333 318.9333 319.9333 320.9333

Columns 323 through 329

321.9333 322.9333 323.9333 324.9333 325.9333 326.9333 327.9333

Columns 330 through 334

328.9333 329.9333 330.9333 331.9333 332.9333

Prepayment =

Columns 1 through 7

1.0000 0.9944 0.9887 0.9828 0.9769 0.9711 0.9653

Columns 8 through 14

0.9595 0.9538 0.9481 0.9424 0.9368 0.9311 0.9255

Columns 15 through 21

0.9199 0.9144 0.9089 0.9034 0.8979 0.8925 0.8871

Columns 22 through 28

0.8817 0.8763 0.8710 0.8657 0.8604 0.8552 0.8499

Columns 29 through 35



---

0.8447	0.8396	0.8344	0.8293	0.8242	0.8191	0.8140
Columns 36 through 42						
0.8090	0.8040	0.7990	0.7941	0.7892	0.7842	0.7794
Columns 43 through 49						
0.7745	0.7697	0.7649	0.7601	0.7553	0.7506	0.7458
Columns 50 through 56						
0.7411	0.7365	0.7318	0.7272	0.7226	0.7180	0.7134
Columns 57 through 63						
0.7089	0.7044	0.6999	0.6954	0.6910	0.6865	0.6821
Columns 64 through 70						
0.6777	0.6734	0.6690	0.6647	0.6604	0.6561	0.6519
Columns 71 through 77						
0.6476	0.6434	0.6392	0.6350	0.6309	0.6267	0.6226
Columns 78 through 84						
0.6185	0.6144	0.6104	0.6063	0.6023	0.5983	0.5943
Columns 85 through 91						
0.5903	0.5864	0.5825	0.5785	0.5747	0.5708	0.5669
Columns 92 through 98						
0.5631	0.5593	0.5555	0.5517	0.5479	0.5442	0.5405
Columns 99 through 105						
0.5368	0.5331	0.5294	0.5257	0.5221	0.5185	0.5149
Columns 106 through 112						

0.5113	0.5077	0.5042	0.5006	0.4971	0.4936	0.4901
Columns 113 through 119						
0.4866	0.4832	0.4797	0.4763	0.4729	0.4695	0.4661
Columns 120 through 126						
0.4628	0.4594	0.4561	0.4528	0.4495	0.4462	0.4430
Columns 127 through 133						
0.4397	0.4365	0.4333	0.4301	0.4269	0.4237	0.4205
Columns 134 through 140						
0.4174	0.4143	0.4111	0.4080	0.4049	0.4019	0.3988
Columns 141 through 147						
0.3958	0.3927	0.3897	0.3867	0.3837	0.3808	0.3778
Columns 148 through 154						
0.3748	0.3719	0.3690	0.3661	0.3632	0.3603	0.3574
Columns 155 through 161						
0.3546	0.3517	0.3489	0.3461	0.3433	0.3405	0.3377
Columns 162 through 168						
0.3350	0.3322	0.3295	0.3267	0.3240	0.3213	0.3186
Columns 169 through 175						
0.3160	0.3133	0.3106	0.3080	0.3054	0.3027	0.3001
Columns 176 through 182						
0.2975	0.2950	0.2924	0.2898	0.2873	0.2847	0.2822
Columns 183 through 189						

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0.2797	0.2772	0.2747	0.2722	0.2698	0.2673	0.2649
Columns 190 through 196						
0.2624	0.2600	0.2576	0.2552	0.2528	0.2504	0.2480
Columns 197 through 203						
0.2457	0.2433	0.2410	0.2386	0.2363	0.2340	0.2317
Columns 204 through 210						
0.2294	0.2271	0.2249	0.2226	0.2204	0.2181	0.2159
Columns 211 through 217						
0.2137	0.2115	0.2093	0.2071	0.2049	0.2027	0.2005
Columns 218 through 224						
0.1984	0.1962	0.1941	0.1920	0.1899	0.1877	0.1856
Columns 225 through 231						
0.1836	0.1815	0.1794	0.1773	0.1753	0.1732	0.1712
Columns 232 through 238						
0.1692	0.1671	0.1651	0.1631	0.1611	0.1591	0.1572
Columns 239 through 245						
0.1552	0.1532	0.1513	0.1493	0.1474	0.1455	0.1436
Columns 246 through 252						
0.1416	0.1397	0.1378	0.1359	0.1341	0.1322	0.1303
Columns 253 through 259						
0.1285	0.1266	0.1248	0.1229	0.1211	0.1193	0.1175
Columns 260 through 266						

0.1157	0.1139	0.1121	0.1103	0.1085	0.1068	0.1050
Columns 267 through 273						
0.1032	0.1015	0.0998	0.0980	0.0963	0.0946	0.0929
Columns 274 through 280						
0.0912	0.0895	0.0878	0.0861	0.0844	0.0827	0.0811
Columns 281 through 287						
0.0794	0.0778	0.0761	0.0745	0.0728	0.0712	0.0696
Columns 288 through 294						
0.0680	0.0664	0.0648	0.0632	0.0616	0.0600	0.0584
Columns 295 through 301						
0.0568	0.0553	0.0537	0.0522	0.0506	0.0491	0.0476
Columns 302 through 308						
0.0460	0.0445	0.0430	0.0415	0.0400	0.0385	0.0370
Columns 309 through 315						
0.0355	0.0340	0.0325	0.0311	0.0296	0.0281	0.0267
Columns 316 through 322						
0.0252	0.0238	0.0223	0.0209	0.0195	0.0180	0.0166
Columns 323 through 329						
0.0152	0.0138	0.0124	0.0110	0.0096	0.0082	0.0068
Columns 330 through 334						
0.0055	0.0041	0.0027	0.0014	0		

## References

[1] *PSA Uniform Practices*, SF-4

### See Also

mbspassthrough | mbsnoprepay | cmoseqcf | cmoschedcf | cmosched

## mbsconvp

Convexity of mortgage pool given price

### Syntax

Convexity = mbsconvp(Price, Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, PrepaySpeed, PrepayMatrix)

### Arguments

Price	Clean price for every \$100 face value.
Settle	Settlement date. A serial date number or date string. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. A serial date number or date string.
IssueDate	Issue date. A serial date number or date string.
GrossRate	Gross coupon rate (including fees), in decimal.
CouponRate	Net coupon rate, in decimal. Default = <b>GrossRate</b> .
Delay	Delay in days.
PrepaySpeed	(Optional) Relation of the conditional payment rate (CPR) to the benchmark model. Default = 0. Set <b>PrepaySpeed</b> to [ ] if you input a customized prepayment matrix.
PrepayMatrix	(Optional) Used only when <b>PrepaySpeed</b> is unspecified. Customized prepayment vector. A NaN-padded matrix of size <code>max(TermRemaining)</code> -by-NMBS. Each column corresponds to each mortgage-backed security, and each row corresponds to each month after settlement.

All inputs (except **PrepayMatrix**) are number of mortgage-backed securities (NMBS) by 1 vectors.

## Description

Convexity = mbsconvp(Price, Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, PrepaySpeed, PrepayMatrix) computes mortgage-backed security convexity, given time information, price at settlement, and optionally, a prepayment model.

---

**Note** If you specify the PSA or FHA model, it will be seasoned with how long the debt has been outstanding (the loan's age).

---

## Examples

### Compute a Mortgage-Backed Security Convexity

This example shows how to compute a mortgage-backed security convexity, given a mortgage-backed security with the following characteristics.

```
Price      = 101;
Settle     = '15-Apr-2002';
Maturity   = '1 Jan 2030';
IssueDate  = '1-Jan-2000';
GrossRate  = 0.08125;
CouponRate = 0.075;
Delay      = 14;
Speed      = 100;
```

```
Convexity = mbsconvp(Price, Settle, Maturity, IssueDate, ...
GrossRate, CouponRate, Delay, Speed)
```

```
Convexity =
    71.6299
```

## References

[1] *PSA Uniform Practices*, SF-49

**See Also**

`mbsconvy` | `mbsdurp` | `mbspassthrough` | `mbsnoprepay` | `mbsdury`



# mbsconvy

Convexity of mortgage pool given yield

## Syntax

Convexity = mbsconvy(Yield, Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, PrepaySpeed, PrepayMatrix)

## Arguments

Yield	Mortgage yield, compounded monthly (in decimal).
Settle	Settlement date. A serial date number or date string. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. A serial date number or date string.
IssueDate	Issue date. A serial date number or date string.
GrossRate	Gross coupon rate (including fees), in decimal.
CouponRate	Net coupon rate, in decimal. Default = <b>GrossRate</b> .
Delay	Delay in days.
PrepaySpeed	(Optional) Relation of the conditional payment rate (CPR) to the benchmark model. Default = 0. Set <b>PrepaySpeed</b> to [ ] if you input a customized prepayment matrix.
PrepayMatrix	(Optional) Used only when <b>PrepaySpeed</b> is unspecified. Customized prepayment vector. A NaN-padded matrix of size $\max(\text{TermRemaining})$ -by-NMBS. Each column corresponds to each mortgage-backed security, and each row corresponds to each month after settlement.

All inputs (except **PrepayMatrix**) are number of mortgage-backed securities (NMBS) by 1 vectors.

## Description

Convexity = mbsconvy(Yield, Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, PrepaySpeed, PrepayMatrix) computes mortgage-backed security convexity, given time information, semiannual mortgage yield, and optionally, a prepayment model.

---

**Note** If you specify the PSA or FHA model, it will be seasoned with how long the debt has been outstanding (the loan's age).

---

## Examples

### Compute the Convexity of a Mortgage Pool Given Yield

This example shows how to compute the convexity of mortgage pool given yield for a mortgage-backed security with the following characteristics.

```
Yield      = 0.07125;
Settle     = '15-Apr-2002';
Maturity   = '1 Jan 2030';
IssueDate  = '1-Jan-2000';
GrossRate  = 0.08125;
Speed      = 100;
CouponRate = 0.075;
Delay      = 14;
```

```
Convexity = mbsconvy(Yield, Settle, Maturity, IssueDate, ...
GrossRate, CouponRate, Delay, Speed)
```

```
Convexity =
    72.8263
```

## References

[1] *PSA Uniform Practices*, SF-49

## **See Also**

mbsconvp | mbsdurp | mbsdury

## mbsdurp

Duration of mortgage pool given price

### Syntax

```
[YearDuration, ModDuration] = mbsdurp(Price, Settle, Maturity,
IssueDate, GrossRate, CouponRate, Delay, PrepaySpeed,
PrepayMatrix)
```

### Arguments

Price	Clean price for every \$100 face value.
Settle	Settlement date. A serial date number or date string. <b>Settle</b> must be earlier than or equal to <b>Maturity</b> .
Maturity	Maturity date. A serial date number or date string.
IssueDate	Issue date. A serial date number or date string.
GrossRate	Gross coupon rate (including fees), in decimal.
CouponRate	(Optional) Net coupon rate, in decimal. Default = <b>GrossRate</b> .
Delay	(Optional) Delay in days.
PrepaySpeed	(Optional) Relation of the conditional payment rate (CPR) to the benchmark model. Default = 0. Set <b>PrepaySpeed</b> to [ ] if you input a customized prepayment matrix.
PrepayMatrix	(Optional) Used only when <b>PrepaySpeed</b> is unspecified. Customized prepayment vector. A NaN-padded matrix of size <b>max(TermRemaining)</b> -by-NMBS. Each column corresponds to each mortgage-backed security, and each row corresponds to each month after settlement.

All inputs (except **PrepayMatrix**) are number of mortgage-backed securities (NMBS) by 1 vectors.

## Description

[YearDuration, ModDuration] = mbsdurp(Price, Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, PrepaySpeed, PrepayMatrix) computes the mortgage-backed security Macaulay (YearDuration) in years and modified (ModDuration) durations in years, given time information, price at settlement, and optionally, a prepayment model.

---

**Note** If you specify the PSA or FHA model, it will be seasoned with how long the debt has been outstanding (the loan's age).

---

## Examples

### Find the Duration of a Mortgage Pool

This example shows how to find the duration of mortgage pool given a mortgage-backed security with the following characteristics.

```
Price = 101;  
Settle = datenum('15-Apr-2002');  
Maturity = datenum('1 Jan 2030');  
IssueDate = datenum('1-Jan-2000');  
GrossRate = 0.08125;  
CouponRate = 0.075;;  
Delay = 14;  
Speed = 100;
```

```
[YearDuration, ModDuration] = mbsdurp(Price, Settle, Maturity,...  
IssueDate, GrossRate, CouponRate, Delay, Speed)
```

```
YearDuration =
```

```
6.4380
```

```
ModDuration =
```

```
6.2080
```

## References

[1] *PSA Uniform Practices*, SF-49

### See Also

`mbsconvp` | `mbsconvy` | `mbsdury`

# mbsdury

Duration of mortgage pool given yield

## Syntax

```
[YearDuration, ModDuration] = mbsdury(Yield, Settle, Maturity,
IssueDate, GrossRate, CouponRate, Delay, PrepaySpeed,
PrepayMatrix)
```

## Arguments

Yield	Mortgage yield, compounded monthly, in decimal.
Settle	Settlement date. A serial date number or date string. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. A serial date number or date string.
IssueDate	Issue date. A serial date number or date string.
GrossRate	Gross coupon rate (including fees), in decimal.
CouponRate	Net coupon rate, in decimal. Default = <b>GrossRate</b> .
Delay	Delay in days.
PrepaySpeed	(Optional) Relation of the conditional payment rate (CPR) to the benchmark model. Default = 0. Set <b>PrepaySpeed</b> to [ ] if you input a customized prepayment matrix.
PrepayMatrix	(Optional) Used only when <b>PrepaySpeed</b> is unspecified. Customized prepayment vector. A NaN-padded matrix of size <b>max(TermRemaining)</b> -by-NMBS. Each column corresponds to each mortgage-backed security, and each row corresponds to each month after settlement.

All inputs (except **PrepayMatrix**) are number of mortgage-backed securities (NMBS) by 1 vectors.

## Description

[YearDuration, ModDuration] = mbsdury(Yield, Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, PrepaySpeed, PrepayMatrix) computes the mortgage-backed security Macaulay (YearDuration) and Modified (ModDuration) durations, given time information, yield to maturity, and optionally, a prepayment model.

---

**Note** If you specify the PSA or FHA model, it will be seasoned with how long the debt has been outstanding (the loan's age).

---

## Examples

### Find the Duration of a Mortgage Pool Given the Yield

This example shows how to find the duration of mortgage pool given a mortgage-backed security with the following characteristics.

```
Yield = 0.07298413;  
Settle = '15-Apr-2002';  
Maturity = '1 Jan 2030';  
IssueDate = '1-Jan-2000';  
GrossRate = 0.08125;  
Speed = 100;  
CouponRate = 0.075;  
Delay = 14;
```

```
[YearDuration, ModDuration] = mbsdury(Yield, Settle, Maturity,...  
IssueDate, GrossRate, CouponRate, Delay, Speed)
```

```
YearDuration =
```

```
6.4380
```

```
ModDuration =
```

```
6.2080
```



## References

[1] *PSA Uniform Practices*, SF-49

### See Also

mbsconvp | mbsconvy | mbsdurp

## mbsnoprepay

End-of-month mortgage cash flows and balances without prepayment

### Syntax

```
[Balance, Interest, Payment, Principal] =  
mbsnoprepay(OriginalBalance, GrossRate, Term)
```

### Arguments

OriginalBalance	Original face value in dollars.
GrossRate	Gross coupon rate (including fees), in decimal.
Term	Term of the mortgage in months.

All inputs are number of mortgage-backed securities (NMBS)-by-1 vectors.

### Description

[Balance, Interest, Payment, Principal] = mbsnoprepay(OriginalBalance, GrossRate, Term) computes end-of-month mortgage balance, interest payments, principal payments, and cash flow payments with zero prepayment rate.

The function returns amortizing cash flows and balances over a specified term with no prepayment. When the lengths of pass-throughs are not the same, MATLAB software pads the shorter ones with NaN.

**Balance** lists the end-of-month balances over the life of the pass-through.

**Interest** lists all end-of-month interest payments over the life of the pass-through.

**Payment** lists all end-of-month payments over the life of the pass-through.

**Principal** lists all scheduled end-of-month principal payments over the life of the pass-through.

All outputs are Term-by-1 vectors.

## Examples

Given mortgage pools with the following characteristics, compute an amortization schedule.

```
OriginalBalance = 400000000;  
CouponRate = 0.08125;  
Term = [357; 355]; % Three- and five-month old mortgage pools.
```

```
[Balance, Interest, Payment, Principal] = ...  
mbsnoprepay(OriginalBalance, CouponRate, Term);
```

## mbsoas2price

Price given option-adjusted spread

### Syntax

```
Price = mbsoas2price(ZeroCurve, OAS, Settle, Maturity, IssueDate,
GrossRate, CouponRate, Delay, Interpolation, PrepaySpeed,
PrepayMatrix)
```

### Arguments

ZeroCurve	A matrix of three columns: <ul style="list-style-type: none"> <li>• Column 1: Serial date numbers.</li> <li>• Column 2: Spot rates with maturities corresponding to the dates in Column 1, in decimal (for example, 0.075).</li> <li>• Column 3: Compounding of the rates in Column 2. (This is the agency spot rate on the settlement date.)</li> </ul>
OAS	Option-adjusted spreads in basis points.
Settle	Settlement date (scalar only). A serial date number or date string. Date when option-adjusted spread is calculated. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. Scalar or vector in serial date number or date string format.
IssueDate	Issue date. A serial date number or date string.
GrossRate	Gross coupon rate (including fees), in decimal.
CouponRate	(Optional) Net coupon rate, in decimal. Default = <b>GrossRate</b> .
Delay	(Optional) Delay (in days) between payment from homeowner and receipt by bondholder. Default = 0 (no delay between payment and receipt).
Interpolation	Interpolation method. Computes the corresponding spot rates for the bond's cash flow. Available methods are (0) nearest, (1)

	linear, and (2) cubic spline. Default = 1. See <code>interp1</code> for more information.
<code>PrepaySpeed</code>	(Optional) Relation of the conditional payment rate (CPR) to the benchmark model. Default = end of month's CPR. Set <code>PrepaySpeed</code> to <code>[]</code> if you input a customized prepayment matrix.
<code>PrepayMatrix</code>	(Optional) Customized prepayment matrix. A matrix of size <code>max(TermRemaining)</code> -by-NMBS. Missing values are padded with NaNs. Each column corresponds to a mortgage-backed security, and each row corresponds to each month after settlement.

All inputs (except `PrepayMatrix`) are number of mortgage-backed securities (NMBS) by 1 vectors.

## Description

`Price = mbsoas2price(ZeroCurve, OAS, Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, Interpolation, PrepaySpeed, PrepayMatrix)` computes the clean price of a pass-through security for each \$100 face value of outstanding principal.

## Examples

### Compute the Theoretical Price of a Mortgage Pool

Given an option-adjusted spread, a spot curve, and a prepayment assumption, compute theoretical price of a mortgage pool. First, create the bonds matrix:

```
Bonds = [datenum('11/21/2002') 0      100 0 2 1;
          datenum('02/20/2003') 0      100 0 2 1;
          datenum('07/31/2004') 0.03   100 2 3 1;
          datenum('08/15/2007') 0.035  100 2 3 1;
          datenum('08/15/2012') 0.04875 100 2 3 1;
          datenum('02/15/2031') 0.05375 100 2 3 1];
```

Choose a settlement date.

```
Settle = datenum('20-Aug-2002');
```

Assume the following clean prices for the bonds:

```
Prices = [ 98.97467;  
          98.58044;  
          100.10534;  
          98.18054;  
          101.38136;  
          99.25411];
```

Use the following formula to compute spot compounding for the bonds:

```
SpotCompounding = 2*ones(size(Prices));
```

Compute the zero curve.

```
[ZeroRatesP, CurveDatesP] = zbtprice(Bonds, Prices, Settle);  
ZeroCurve = [CurveDatesP, ZeroRatesP, SpotCompounding]
```

```
ZeroCurve =
```

```
1.0e+05 *  
  
7.3154    0.0000    0.0000  
7.3163    0.0000    0.0000  
7.3216    0.0000    0.0000  
7.3327    0.0000    0.0000  
7.3510    0.0000    0.0000  
7.4185    0.0000    0.0000
```

Assign the following parameters:

```
OAS          = [26.0502; 28.6348; 31.2222];  
Maturity     = datenum('02-Jan-2030');  
IssueDate    = datenum('02-Jan-2000');  
GrossRate    = 0.08125;  
CouponRate   = 0.075;  
Delay        = 14;  
Interpolation = 1;  
PrepaySpeed  = [0 50 100];
```

Calculate the theoretical price from the option-adjusted spread.

```
Price = mbsoas2price(ZeroCurve, OAS, Settle, Maturity, ...
```

IssueDate, GrossRate, CouponRate, Delay, Interpolation, ...  
PrepaySpeed)

Price =

95.0006  
95.0006  
95.0006

### **See Also**

[mbsprice2oas](#) | [mbsyield2oas](#) | [mbssoas2yield](#)

## mbsoas2yield

Yield given option-adjusted spread

### Syntax

```
[MYield, BEMBSYield] = mbsoas2yield(ZeroCurve, OAS, Settle,
Maturity, IssueDate, GrossRate, CouponRate, Delay, Interpolation,
PrepaySpeed, PrepayMatrix)
```

### Arguments

ZeroCurve	A matrix of three columns: <ul style="list-style-type: none"> <li>• Column 1: Serial date numbers.</li> <li>• Column 2: Spot rates with maturities corresponding to the dates in Column 1, in decimal (for example, 0.075).</li> <li>• Column 3: Compounding of the rates in Column 2. (This is the agency spot rate on the settlement date.)</li> </ul>
OAS	Option-adjusted spreads in basis points.
Settle	Settlement date (scalar only). A serial date number or date string. Date when option-adjusted spread is calculated. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. Scalar or vector in serial date number or date string format.
IssueDate	Issue date. A serial date number or date string.
GrossRate	Gross coupon rate (including fees), in decimal.
CouponRate	(Optional) Net coupon rate, in decimal. Default = <b>GrossRate</b> .
Delay	(Optional) Delay (in days) between payment from homeowner and receipt by bondholder. Default = 0 (no delay between payment and receipt).
Interpolation	Interpolation method. Computes the corresponding spot rates for the bond's cash flow. Available methods are (0) nearest, (1)



	linear, and (2) cubic spline. Default = 1. See <code>interp1</code> for more information.
<code>PrepaySpeed</code>	(Optional) Relation of the conditional payment rate (CPR) to the benchmark model. Default = end of month's CPR. Set <code>PrepaySpeed</code> to <code>[]</code> if you input a customized prepayment matrix.
<code>PrepayMatrix</code>	(Optional) Customized prepayment matrix. A matrix of size <code>max(TermRemaining)</code> -by-NMBS. Missing values are padded with NaNs. Each column corresponds to a mortgage-backed security, and each row corresponds to each month after settlement.

All inputs (except `PrepayMatrix`) are number of mortgage-backed securities (NMBS) by 1 vectors.

## Description

`[MYield, BEMBSYield] = mbsoas2yield(ZeroCurve, OAS, Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, Interpolation, PrepaySpeed, PrepayMatrix)` computes the mortgage and bond-equivalent yields of a pass-through security.

`MYield` is the yield to maturity of the mortgage-backed security (the mortgage yield). This yield is compounded monthly (12 times per year). For example:

0.075 (7.5%)

`BEMBSYield` is the corresponding bond equivalent yield of the mortgage-backed security. This yield is compounded semiannually (two times per year). For example:

0.0761 (7.61%)

## Examples

### Compute the Theoretical Yield to Maturity of a Mortgage Pool

Given an option-adjusted spread, a spot curve, and a prepayment assumption, compute the theoretical yield to maturity of a mortgage pool. First, create the bonds matrix:

```
Bonds = [datenum('11/21/2002') 0      100 0 2 1;
          datenum('02/20/2003') 0      100 0 2 1;
          datenum('07/31/2004') 0.03   100 2 3 1;
          datenum('08/15/2007') 0.035  100 2 3 1;
          datenum('08/15/2012') 0.04875 100 2 3 1;
          datenum('02/15/2031') 0.05375 100 2 3 1];
```

Choose a settlement date.

```
Settle = datenum('20-Aug-2002');
```

Assume the following clean prices for the bonds:

```
Prices = [ 98.97467;
           98.58044;
           100.10534;
           98.18054;
           101.38136;
           99.25411];
```

Use the following formula to compute spot compounding for the bonds:

```
SpotCompounding = 2*ones(size(Prices));
```

Compute the zero curve.

```
[ZeroRatesP, CurveDatesP] = zbtprice(Bonds, Prices, Settle);
ZeroCurve = [CurveDatesP, ZeroRatesP, SpotCompounding]
```

```
ZeroCurve =
```

```
1.0e+05 *
    7.3154    0.0000    0.0000
    7.3163    0.0000    0.0000
    7.3216    0.0000    0.0000
    7.3327    0.0000    0.0000
    7.3510    0.0000    0.0000
    7.4185    0.0000    0.0000
```

Assign the following parameters:

```
OAS = [26.0502; 28.6348; 31.2222];
```

```
Maturity      = datenum('02-Jan-2030');
IssueDate     = datenum('02-Jan-2000');
GrossRate     = 0.08125;
CouponRate    = 0.075;
Delay         = 14;
Interpolation = 1;
PrepaySpeed   = [0 50 100];
```

Compute the mortgage yield and bond equivalent mortgage yield.

```
[MYield BEMBSYield] = mbssoas2yield(ZeroCurve, OAS, Settle, ...
Maturity, IssueDate, GrossRate, CouponRate, Delay, ...
Interpolation, PrepaySpeed)
```

```
MYield =
```

```
    0.0802
    0.0814
    0.0828
```

```
BEMBSYield =
```

```
    0.0816
    0.0828
    0.0842
```

## See Also

[mbsprice2oas](#) | [mbsyield2oas](#) | [mbssoas2price](#)

## mbspassthrough

Mortgage pool cash flows and balances with prepayment

### Syntax

```
[Balance, Payment, Principal, Interest, Prepayment] =
mbspassthrough(OriginalBalance, GrossRate, OriginalTerm,
TermRemaining, PrepaySpeed, PrepayMatrix)
```

### Arguments

OriginalBalance	Original balance value in dollars (balance at the beginning of each TermRemaining).
GrossRate	Gross coupon rate (including fees), in decimal.
OriginalTerm	Term of the mortgage in months.
TermRemaining	(Optional) Number of full months between settlement and maturity.
PrepaySpeed	(Optional) Relation of the conditional payment rate (CPR) to the benchmark model. Default = 0 (no prepayment). Set PrepaySpeed to [] if you input a customized prepayment matrix.
PrepayMatrix	(Optional) Used only when PrepaySpeed is unspecified. Customized prepayment vector. A NaN-padded matrix of size max(TermRemaining)-by-NMBS. Each column corresponds to each mortgage-backed security, and each row corresponds to each month after settlement.

All inputs (except PrepayMatrix) are number of mortgage-backed securities (NMBS) by 1 vectors.

## Description

```
[Balance, Payment, Principal, Prepayment, Interest] =
mbspassthrough(OriginalBalance, GrossRate, OriginalTerm,
TermRemaining, PrepaySpeed, PrepayMatrix)
```

All outputs are `TermRemaining-by-1` vectors of end-of-month values.

`Balance` is a matrix for the principal balance at end of month.

`Payment` is a matrix for the total monthly payment.

`Principal` is a matrix for the principal portion of the payment.

`Interest` is a matrix for the interest portion of the payment.

`Prepayment` is a matrix that indicates any unscheduled principal payment.

By default, the securities are seasoned. The applicable CPR depends upon `TermRemaining` based on a 30-year prepayment model (PSA or FHA). You may supply a different CPR vector of size `TermRemaining-by-1`.

## Examples

### Compute the Cash Flow of Principal, Interest, and Prepayment of a Pass-Through Security

This example shows how to compute the cash flows and balances of a 3-month old mortgage pool with original term of 360 months, assuming a prepayment speed of 100.

```
OriginalBalance = 100000;
GrossRate = 0.08125;
OriginalTerm = 360;
TermRemaining = 357;
PrepaySpeed = 100;
```

```
[Balance, Payment, Principal, Interest, Prepayment] =...
mbspassthrough(OriginalBalance, GrossRate, OriginalTerm,...
TermRemaining, PrepaySpeed)
```

Balance =

```
1.0e+04 *
```

9.9866  
9.9715  
9.9548  
9.9363  
9.9161  
9.8942  
9.8707  
9.8454  
9.8185  
9.7900  
9.7598  
9.7280  
9.6946  
9.6596  
9.6230  
9.5848  
9.5450  
9.5037  
9.4609  
9.4166  
9.3708  
9.3235  
9.2748  
9.2247  
9.1731  
9.1202  
9.0659  
9.0119  
8.9582  
8.9047  
8.8515  
8.7985  
8.7458  
8.6934  
8.6412  
8.5893  
8.5376  
8.4862  
8.4351  
8.3842  
8.3335  
8.2831  
8.2329

8.1830  
8.1333  
8.0839  
8.0347  
7.9858  
7.9371  
7.8886  
7.8404  
7.7924  
7.7446  
7.6971  
7.6498  
7.6027  
7.5559  
7.5093  
7.4629  
7.4168  
7.3708  
7.3251  
7.2797  
7.2344  
7.1894  
7.1445  
7.0999  
7.0556  
7.0114  
6.9674  
6.9237  
6.8802  
6.8368  
6.7937  
6.7508  
6.7082  
6.6657  
6.6234  
6.5813  
6.5395  
6.4978  
6.4563  
6.4151  
6.3740  
6.3331  
6.2925  
6.2520

6.2117  
6.1716  
6.1317  
6.0920  
6.0525  
6.0132  
5.9741  
5.9351  
5.8964  
5.8578  
5.8194  
5.7812  
5.7432  
5.7054  
5.6678  
5.6303  
5.5930  
5.5559  
5.5189  
5.4822  
5.4456  
5.4092  
5.3730  
5.3369  
5.3010  
5.2653  
5.2298  
5.1944  
5.1592  
5.1241  
5.0893  
5.0545  
5.0200  
4.9856  
4.9514  
4.9174  
4.8835  
4.8497  
4.8162  
4.7827  
4.7495  
4.7164  
4.6834  
4.6507



4.6180  
4.5855  
4.5532  
4.5211  
4.4890  
4.4572  
4.4254  
4.3939  
4.3624  
4.3312  
4.3000  
4.2691  
4.2382  
4.2075  
4.1770  
4.1466  
4.1163  
4.0862  
4.0562  
4.0264  
3.9967  
3.9671  
3.9377  
3.9084  
3.8792  
3.8502  
3.8213  
3.7926  
3.7640  
3.7355  
3.7071  
3.6789  
3.6508  
3.6229  
3.5950  
3.5673  
3.5398  
3.5123  
3.4850  
3.4578  
3.4307  
3.4038  
3.3770  
3.3503

3.3237  
3.2972  
3.2709  
3.2447  
3.2186  
3.1926  
3.1668  
3.1410  
3.1154  
3.0899  
3.0645  
3.0393  
3.0141  
2.9891  
2.9641  
2.9393  
2.9146  
2.8900  
2.8655  
2.8412  
2.8169  
2.7928  
2.7687  
2.7448  
2.7210  
2.6972  
2.6736  
2.6501  
2.6267  
2.6034  
2.5802  
2.5571  
2.5342  
2.5113  
2.4885  
2.4658  
2.4432  
2.4208  
2.3984  
2.3761  
2.3539  
2.3318  
2.3099  
2.2880

2.2662  
2.2445  
2.2229  
2.2014  
2.1800  
2.1587  
2.1374  
2.1163  
2.0953  
2.0743  
2.0535  
2.0327  
2.0120  
1.9915  
1.9710  
1.9506  
1.9303  
1.9100  
1.8899  
1.8698  
1.8499  
1.8300  
1.8102  
1.7905  
1.7709  
1.7513  
1.7319  
1.7125  
1.6932  
1.6740  
1.6549  
1.6359  
1.6169  
1.5980  
1.5792  
1.5605  
1.5419  
1.5233  
1.5048  
1.4864  
1.4681  
1.4498  
1.4317  
1.4136

1.3956  
1.3776  
1.3597  
1.3419  
1.3242  
1.3066  
1.2890  
1.2715  
1.2541  
1.2367  
1.2194  
1.2022  
1.1851  
1.1680  
1.1510  
1.1341  
1.1172  
1.1004  
1.0837  
1.0671  
1.0505  
1.0340  
1.0175  
1.0011  
0.9848  
0.9685  
0.9524  
0.9362  
0.9202  
0.9042  
0.8883  
0.8724  
0.8566  
0.8409  
0.8252  
0.8096  
0.7940  
0.7786  
0.7631  
0.7478  
0.7325  
0.7172  
0.7020  
0.6869

0.6719  
0.6569  
0.6419  
0.6270  
0.6122  
0.5974  
0.5827  
0.5680  
0.5535  
0.5389  
0.5244  
0.5100  
0.4956  
0.4813  
0.4670  
0.4528  
0.4387  
0.4246  
0.4105  
0.3965  
0.3826  
0.3687  
0.3548  
0.3411  
0.3273  
0.3136  
0.3000  
0.2864  
0.2729  
0.2594  
0.2460  
0.2326  
0.2193  
0.2060  
0.1928  
0.1796  
0.1665  
0.1534  
0.1403  
0.1273  
0.1144  
0.1015  
0.0887  
0.0759

0.0631  
0.0504  
0.0377  
0.0251  
0.0125  
0

Payment =

743.9671  
743.4693  
742.8468  
742.0999  
741.2285  
740.2329  
739.1132  
737.8699  
736.5034  
735.0139  
733.4021  
731.6684  
729.8136  
727.8383  
725.7432  
723.5292  
721.1972  
718.7479  
716.1826  
713.5021  
710.7075  
707.8002  
704.7812  
701.6518  
698.4134  
695.0674  
691.6152  
688.0582  
684.5195  
680.9990  
677.4966  
674.0122  
670.5458  
667.0971

663.6663  
660.2530  
656.8573  
653.4791  
650.1182  
646.7747  
643.4483  
640.1390  
636.8468  
633.5715  
630.3130  
627.0713  
623.8463  
620.6378  
617.4459  
614.2704  
611.1112  
607.9682  
604.8414  
601.7307  
598.6360  
595.5572  
592.4942  
589.4470  
586.4155  
583.3996  
580.3991  
577.4141  
574.4445  
571.4901  
568.5509  
565.6269  
562.7178  
559.8238  
556.9446  
554.0802  
551.2306  
548.3956  
545.5752  
542.7693  
539.9778  
537.2007  
534.4379  
531.6893

528.9548  
526.2343  
523.5279  
520.8354  
518.1567  
515.4919  
512.8407  
510.2031  
507.5791  
504.9687  
502.3716  
499.7879  
497.2175  
494.6603  
492.1162  
489.5853  
487.0673  
484.5623  
482.0702  
479.5909  
477.1244  
474.6705  
472.2293  
469.8006  
467.3844  
464.9807  
462.5893  
460.2102  
457.8433  
455.4886  
453.1460  
450.8155  
448.4969  
446.1903  
443.8955  
441.6126  
439.3414  
437.0818  
434.8339  
432.5976  
430.3727  
428.1593  
425.9573  
423.7666



421.5871  
419.4189  
417.2618  
415.1158  
412.9809  
410.8569  
408.7439  
406.6417  
404.5503  
402.4697  
400.3998  
398.3406  
396.2919  
394.2538  
392.2261  
390.2089  
388.2020  
386.2055  
384.2192  
382.2432  
380.2773  
378.3215  
376.3758  
374.4401  
372.5144  
370.5985  
368.6925  
366.7963  
364.9099  
363.0332  
361.1661  
359.3086  
357.4607  
355.6223  
353.7933  
351.9737  
350.1635  
348.3626  
346.5710  
344.7886  
343.0153  
341.2512  
339.4961  
337.7501

336.0130  
334.2849  
332.5657  
330.8553  
329.1537  
327.4609  
325.7767  
324.1013  
322.4344  
320.7761  
319.1264  
317.4851  
315.8523  
314.2278  
312.6117  
311.0040  
309.4045  
307.8132  
306.2301  
304.6552  
303.0883  
301.5295  
299.9788  
298.4360  
296.9011  
295.3742  
293.8550  
292.3437  
290.8402  
289.3444  
287.8563  
286.3759  
284.9030  
283.4378  
281.9800  
280.5298  
279.0871  
277.6517  
276.2237  
274.8031  
273.3898  
271.9838  
270.5849  
269.1933

267.8088  
266.4315  
265.0612  
263.6980  
262.3418  
260.9926  
259.6503  
258.3149  
256.9864  
255.6647  
254.3498  
253.0417  
251.7403  
250.4456  
249.1576  
247.8761  
246.6013  
245.3330  
244.0713  
242.8160  
241.5672  
240.3248  
239.0888  
237.8592  
236.6359  
235.4189  
234.2081  
233.0036  
231.8052  
230.6131  
229.4270  
228.2471  
227.0732  
225.9054  
224.7435  
223.5877  
222.4377  
221.2937  
220.1556  
219.0234  
217.8969  
216.7763  
215.6614  
214.5522

213.4488  
212.3510  
211.2589  
210.1724  
209.0915  
208.0161  
206.9463  
205.8820  
204.8231  
203.7697  
202.7217  
201.6791  
200.6419  
199.6100  
198.5834  
197.5621  
196.5460  
195.5352  
194.5295  
193.5290  
192.5337  
191.5435  
190.5584  
189.5784  
188.6034  
187.6334  
186.6684  
185.7083  
184.7532  
183.8030  
182.8577  
181.9173  
180.9817  
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## See Also

mbswal

## mbsprice

Mortgage-backed security price given yield

### Syntax

```
[Price, AccrInt] = mbsprice(Yield, Settle, Maturity, IssueDate,
GrossRate, CouponRate, Delay, PrepaySpeed, PrepayMatrix)
```

### Arguments

Yield	Mortgage yield, compounded monthly (in decimal).
Settle	Settlement date. A serial date number or date string. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. A serial date number or date string.
IssueDate	Issue date. A serial date number or date string.
GrossRate	Gross coupon rate (including fees), in decimal.
CouponRate	(Optional) Net coupon rate, in decimal. Default = <b>GrossRate</b> .
Delay	(Optional) Delay (in days) between payment from homeowner and receipt by bondholder. Default = 0 (no delay between payment and receipt).
PrepaySpeed	(Optional) Relation of the conditional payment rate (CPR) to the benchmark model. Default = 0 (no prepayment). Set <b>PrepaySpeed</b> to [ ] if you input a customized prepayment matrix.
PrepayMatrix	(Optional) Customized prepayment matrix. A matrix of size <code>max(TermRemaining)</code> -by-NMBS. Missing values are padded with NaNs. Each column corresponds to a mortgage-backed security, and each row corresponds to each month after settlement.

All inputs (except **PrepayMatrix**) are number of mortgage-backed securities (NMBS) by 1 vectors.



## Description

[Price, AccrInt] = mbsprice(Yield, Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, PrepaySpeed, PrepayMatrix) computes a mortgage-backed security price, given time information, mortgage yield at settlement, and optionally, a prepayment model.

All outputs are scalar values.

Price is the clean price for every \$100 face value of the securities.

AccrInt is the accrued interest of the mortgage-backed securities.

## Examples

### Determine the Mortgage-Backed Security Price Given the Yield

This example shows how to determine the mortgage-backed security price given a mortgage-backed security with the following characteristics.

```
Yield = 0.0725;  
Settle = datenum('15-Apr-2002');  
Maturity = datenum('1 Jan 2030');  
IssueDate = datenum('1-Jan-2000');  
GrossRate = 0.08125;  
CouponRate = 0.075;  
Delay = 14;  
Speed = 100;
```

```
[Price AccrInt] = mbsprice(Yield, Settle, Maturity, IssueDate,...  
GrossRate, CouponRate, Delay, Speed)
```

```
Price =
```

```
101.3147
```

```
AccrInt =
```

```
0.2917
```

## References

[1] *PSA Uniform Practices*, SF-49

### See Also

mbsyield

# mbsprice2oas

Option-adjusted spread given price

## Syntax

```
OAS = mbsprice2oas(ZeroCurve, Price, Settle, Maturity, IssueDate,
GrossRate, CouponRate, Delay, Interpolation PrepaySpeed,
PrepayMatrix)
```

## Arguments

ZeroCurve	A matrix of three columns: <ul style="list-style-type: none"> <li>• Column 1: Serial date numbers.</li> <li>• Column 2: Spot rates with maturities corresponding to the dates in Column 1, in decimal (for example, 0.075).</li> <li>• Column 3: Compounding of the rates in Column 2. Values are 1 (annual), 2 (semiannual), 3 (three times per year), 4 (quarterly), 6 (bimonthly), 12 (monthly), and -1 (continuous).</li> </ul>
Price	Clean price for every \$100 face value of bond issue.
Settle	Settlement date (scalar only). A serial date number or date string. Date when option-adjusted spread is calculated. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. Scalar or vector in serial date number or date string format.
IssueDate	Issue date. A serial date number or date string.
GrossRate	Gross coupon rate (including fees), in decimal.
CouponRate	(Optional) Net coupon rate, in decimal. Default = <b>GrossRate</b> .
Delay	(Optional) Delay (in days) between payment from homeowner and receipt by bondholder. Default = 0 (no delay between payment and receipt).

Interpolation	Interpolation method. Computes the corresponding spot rates for the bond's cash flow. Available methods are (0) nearest, (1) linear, and (2) cubic spline. Default = 1. See <code>interp1</code> for more information.
PrepaySpeed	(Optional) Relation of the conditional payment rate (CPR) to the benchmark model. Default = end of month's CPR. Set <code>PrepaySpeed</code> to <code>[]</code> if you input a customized prepayment matrix.
PrepayMatrix	(Optional) Customized prepayment matrix. A matrix of size <code>max(TermRemaining)</code> -by-NMBS. Missing values are padded with NaNs. Each column corresponds to a mortgage-backed security, and each row corresponds to each month after settlement.

All inputs (except `PrepayMatrix`) are number of mortgage-backed securities (NMBS) by 1 vectors.

## Description

OAS = `mbsprice2oas(ZeroCurve, Price, Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, Interpolation, PrepaySpeed, PrepayMatrix)` computes the monthly option-adjusted spread in basis points.

## Examples

### Calculate the Option-Adjusted Spread of a 30-Year Fixed-Rate Mortgage

Calculate the option-adjusted spread of a 30-year fixed-rate mortgage with about a 28-year weighted average maturity remaining, given assumptions of 0, 50, and 100 PSA prepayments. First, create the bonds matrix:

```
Bonds = [datenum('11/21/2002') 0      100 0 2 1;
          datenum('02/20/2003') 0      100 0 2 1;
          datenum('07/31/2004') 0.03   100 2 3 1;
          datenum('08/15/2007') 0.035  100 2 3 1;
          datenum('08/15/2012') 0.04875 100 2 3 1;
          datenum('02/15/2031') 0.05375 100 2 3 1];
```

Choose a settlement date.

```
Settle = datenum('20-Aug-2002');
```

Assume the following clean prices for the bonds:

```
Prices = [ 98.97467;
           98.58044;
           100.10534;
           98.18054;
           101.38136;
           99.25411];
```

Use the following formula to compute spot compounding for the bonds:

```
SpotCompounding = 2*ones(size(Prices));
```

Compute the zero curve.

```
[ZeroRatesP, CurveDatesP] = zbtprice(Bonds, Prices, Settle);
ZeroCurve = [CurveDatesP, ZeroRatesP, SpotCompounding]
```

```
ZeroCurve =
```

```
1.0e+05 *
    7.3154    0.0000    0.0000
    7.3163    0.0000    0.0000
    7.3216    0.0000    0.0000
    7.3327    0.0000    0.0000
    7.3510    0.0000    0.0000
    7.4185    0.0000    0.0000
```

Assign the following parameters:

```
Price          = 95;
Maturity       = datenum('02-Jan-2030');
IssueDate     = datenum('02-Jan-2000');
GrossRate     = 0.08125;
CouponRate    = 0.075;
Delay         = 14;
Interpolation = 1;
PrepaySpeed   = [0; 50; 100];
```

```
Interpolation = 1;
```

Compute the option-adjusted spread.

```
OAS = mbsprice2oas(ZeroCurve, Price, Settle, Maturity, ...  
IssueDate, GrossRate, CouponRate, Delay, Interpolation, ...  
PrepaySpeed)
```

```
OAS =
```

```
26.0508  
28.6355  
31.2232
```

## See Also

[mbssoas2price](#) | [mbssoas2yield](#) | [mbsyield2oas](#)

# mbsprice2speed

Implied PSA prepayment speeds given price

## Syntax

```
[ImpSpdOnPrc, ImpSpdOnDur, ImpSpdOnCnv] = mbsprice2speed(Price,
Settle, Maturity, IssueDate, GrossRate, PrepayMatrix, CouponRate,
Delay)
```

## Arguments

<b>Price</b>	Clean price for every \$100 face value.
<b>Settle</b>	Settlement date. A serial date number or date string. <b>Settle</b> must be earlier than <b>Maturity</b> .
<b>Maturity</b>	Maturity date. A serial date number or date string.
<b>IssueDate</b>	Issue date. A serial date number or date string.
<b>GrossRate</b>	Gross coupon rate (including fees), in decimal.
<b>PrepayMatrix</b>	Customized prepayment matrix. A matrix of size $\max(\text{TermRemaining})$ -by-NMBS. Missing values are padded with NaNs. Each column corresponds to a mortgage-backed security, and each row corresponds to each month after settlement.
<b>CouponRate</b>	(Optional) Net coupon rate, in decimal. Default = <b>GrossRate</b> .
<b>Delay</b>	(Optional) Delay (in days) between payment from homeowner and receipt by bondholder. Default = 0 (no delay between payment and receipt).

All inputs (except **PrepayMatrix**) are number of mortgage-backed securities (NMBS)-by-1 vectors.

## Description

```
[ImpSpdOnPrc, ImpSpdOnDur, ImpSpdOnCnv] = mbsprice2speed(Price,
Settle, Maturity, IssueDate, GrossRate, PrepayMatrix, CouponRate,
```

`Delay`) computes PSA prepayment speeds implied by pool prices and projected (user-defined) prepayment vectors. The calculated PSA speed produces the same price, modified duration, or modified convexity, depending upon the output requested.

`ImpSpdOnPrc` calculates the equivalent PSA benchmark prepayment speed for the pass-through to carry the same price.

`ImpSpdOnDur` calculates the equivalent PSA benchmark prepayment speed for the pass-through to carry the same modified duration.

`ImpSpdOnCnv` calculates the equivalent PSA benchmark prepayment speed for the pass-through to carry the same modified convexity.

All outputs are NMBS-by-1 vectors.

## Examples

### Compute PSA Prepayment Speeds

This example shows how to compute the equivalent PSA benchmark prepayment speeds for a mortgage pool with the following characteristics and prepayment matrix.

```
Price          = 101;
Settle         = datenum('1-Jan-2000');
Maturity       = datenum('1-Jan-2030');
IssueDate      = datenum('1-Jan-2000');
GrossRate      = 0.08125;
PrepayMatrix   = 0.005*ones(360,1);
CouponRate     = 0.075;
Delay          = 14;

[ImpSpdOnPrc, ImpSpdOnDur, ImpSpdOnCnv] = ...
mbsprice2speed(Price,Settle, Maturity, IssueDate, ...
GrossRate, PrepayMatrix, CouponRate, Delay)
```

```
ImpSpdOnPrc =
    118.5980
```

```
ImpSpdOnDur =
```



118.3946

ImpSpd0nCnv =

109.5115

## References

[1] *PSA Uniform Practices*, SF-49

## See Also

mbsprice | mbsyield2speed

## mbswal

Weighted average life of mortgage pool

## Compatibility

PSA

## Syntax

WAL = mbswal(Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, PrepaySpeed, PrepayMatrix)

## Arguments

Settle	Settlement date. A serial date number or date string. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. A serial date number or date string.
IssueDate	Issue date. A serial date number or date string.
GrossRate	Gross coupon rate (including fees), in decimal.
CouponRate	(Optional) Net coupon rate, in decimal. Default = <b>GrossRate</b> .
Delay	(Optional) Delay (in days) between payment from homeowner and receipt by bondholder. Default = 0 (no delay between payment and receipt).
PrepaySpeed	(Optional) Relation of the conditional payment rate (CPR) to the benchmark model. Default = end of month's CPR. Set <b>PrepaySpeed</b> to [ ] if you input a customized prepayment matrix.
PrepayMatrix	(Optional) Customized prepayment matrix. A matrix of size <code>max(TermRemaining)</code> -by-NMBS. Missing values are padded with NaNs. Each column corresponds to a mortgage-backed security, and each row corresponds to each month after settlement.

All inputs (except **PrepayMatrix**) are number of mortgage-backed securities (NMBS) by 1 vectors.

## Description

WAL = mbswal(Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, PrepaySpeed, PrepayMatrix) computes the weighted average life, in number of years, of a mortgage pool, as measured from the settlement date.

## Examples

### Determine the Weighted Average Life of a Mortgage Pool

This example shows how to determine the weighted average life of a mortgage pool, given a pass-through security with the following characteristics.

```
Settle = datenum('15-Apr-2002');  
Maturity = datenum('1 Jan 2030');  
IssueDate = datenum('1-Jan-2000');  
GrossRate = 0.08125;  
CouponRate = 0.075;  
Delay = 14;  
Speed = 100;
```

```
WAL = mbswal(Settle, Maturity, IssueDate, GrossRate, ...  
CouponRate, Delay, Speed)
```

```
WAL =
```

```
10.5477
```

## References

[1] *PSA Uniform Practices*, SF-49

## See Also

mbspassthrough

## mbsyield

Mortgage-backed security yield given price

### Syntax

```
[MYield, BEMBSYield] = mbsyield(Price, Settle, Maturity, IssueDate,
GrossRate, CouponRate, Delay, PrepaySpeed, PrepayMatrix)
```

### Arguments

Price	Clean price for every \$100 face value.
Settle	Settlement date. A serial date number or date string. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. A serial date number or date string.
IssueDate	Issue date. A serial date number or date string.
GrossRate	Gross coupon rate (including fees), in decimal.
CouponRate	(Optional) Net coupon rate, in decimal. Default = <b>GrossRate</b> .
Delay	(Optional) Delay (in days) between payment from homeowner and receipt by bondholder. Default = 0 (no delay between payment and receipt).
PrepaySpeed	(Optional) Relation of the conditional payment rate (CPR) to the benchmark model. Default = 0 (no prepayment). Set <b>PrepaySpeed</b> to [ ] if you input a customized prepayment matrix.
PrepayMatrix	(Optional) Customized prepayment matrix. A matrix of size $\max(\text{TermRemaining})$ -by-NMBS. Missing values are padded with NaNs. Each column corresponds to a mortgage-backed security, and each row corresponds to each month after settlement.

All inputs (except **PrepayMatrix**) are number of mortgage-backed securities (NMBS) by 1 vectors.

## Description

[MYield, BEMBSYield] = mbsyield(Price, Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, PrepaySpeed, PrepayMatrix) computes a mortgage-backed security yield to maturity and the bond equivalent yield, given time information, price at settlement, and optionally, a prepayment model.

MYield is the yield to maturity of the mortgage-backed security (the mortgage yield). This yield is compounded monthly (12 times a year).

BEMBSYield is the corresponding bond equivalent yield of the mortgage-backed security. This yield is compounded semiannually (two times a year).

## Examples

### Determine a Mortgage-Backed Security Yield Given the Price

This example shows how to determine the mortgage-backed security yield, given a mortgage-backed security with the following characteristics.

```
Price = 102;  
Settle = '15-Apr-2002';  
Maturity = '1 Jan 2030';  
IssueDate = '1-Jan-2000';  
GrossRate = 0.08125;  
CouponRate = 0.075;  
Delay = 14;  
Speed = 100;
```

```
[MYield, BEMBSYield] = mbsyield(Price, Settle, Maturity, ...  
IssueDate, GrossRate, CouponRate, Delay, Speed)
```

```
MYield =
```

```
0.0715
```

```
BEMBSYield =
```

```
0.0725
```

### Determine Multiple Mortgage-Backed Securities Yields Given the Price

This example shows how to determine multiple mortgage-backed securities yields, given a portfolio of mortgage-backed securities with the following characteristics.

```
Price = 102;
Settle = datenum(['13-Feb-2000'; '17-Apr-2002'; '17-May-2002'; ...
'13-Jan-2000']);
Maturity = datenum('1-Jan-2030');
IssueDate = datenum('1-Jan-2000');
GrossRate = 0.08125;
CouponRate = [0.075; 0.07875; 0.0775; 0.08125];
Delay = 14;
Speed = 100;
```

```
[MYield, BEMBSYield] = mbsyield(Price, Settle, Maturity, ...
IssueDate, GrossRate, CouponRate, Delay, Speed)
```

```
MYield =
```

```
    0.0717
    0.0751
    0.0739
    0.0779
```

```
BEMBSYield =
```

```
    0.0728
    0.0763
    0.0750
    0.0791
```

## References

[1] *PSA Uniform Practices*, SF-49

## See Also

mbsprice

# mbsyield2oas

Option-adjusted spread given yield

## Syntax

OAS = mbsyield2oas(ZeroCurve, Yield, Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, Interpolation PrepaySpeed, PrepayMatrix)

## Arguments

ZeroCurve	A matrix of three columns: <ul style="list-style-type: none"> <li>• Column 1: Serial date numbers.</li> <li>• Column 2: Spot rates with maturities corresponding to the dates in Column 1, in decimal (for example, 0.075).</li> <li>• Column 3: Compounding of the rates in Column 2. Values are 1 (annual), 2 (semiannual), 3 (three times per year), 4 (quarterly), 6 (bimonthly), 12 (monthly), and -1 (continuous).</li> </ul>
Yield	Mortgage yield, compounded monthly (in decimal).
Settle	Settlement date (scalar only). A serial date number or date string. Date when option-adjusted spread is calculated. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. Scalar or vector in serial date number or date string format.
IssueDate	Issue date. A serial date number or date string.
GrossRate	Gross coupon rate (including fees), in decimal.
CouponRate	(Optional) Net coupon rate, in decimal. Default = <b>GrossRate</b> .
Delay	(Optional) Delay (in days) between payment from homeowner and receipt by bondholder. Default = 0 (no delay between payment and receipt).
Interpolation	Interpolation method. Computes the corresponding spot rates for the bond's cash flow. Available methods are (0) nearest, (1)

	linear, and (2) cubic spline. Default = 1. See <code>interp1</code> for more information.
<code>PrepaySpeed</code>	(Optional) Relation of the conditional payment rate (CPR) to the benchmark model. Default = end of month's CPR. Set <code>PrepaySpeed</code> to <code>[]</code> if you input a customized prepayment matrix.
<code>PrepayMatrix</code>	(Optional) Customized prepayment matrix. A matrix of size <code>max(TermRemaining)</code> -by-NMBS. Missing values are padded with NaNs. Each column corresponds to a mortgage-backed security, and each row corresponds to each month after settlement.

All inputs (except `PrepayMatrix`) are number of mortgage-backed securities (NMBS) by 1 vectors.

## Description

`OAS = mbsyield2oas(ZeroCurve, Yield, Settle, Maturity, IssueDate, GrossRate, CouponRate, Delay, Interpolation, PrepaySpeed, PrepayMatrix)` computes the option-adjusted spread in basis points.

## Examples

### Calculate the Option-Adjusted Spread of a 30-Year Fixed-Rate Mortgage Pool

Calculate the option-adjusted spread of a 30-year, fixed-rate mortgage pool with about 28-year weighted average maturity left, given assumptions of 0, 50, and 100 PSA prepayments. First, create the bonds matrix:

```
Bonds = [datenum('11/21/2002') 0      100 0 2 1;
          datenum('02/20/2003') 0      100 0 2 1;
          datenum('07/31/2004') 0.03   100 2 3 1;
          datenum('08/15/2007') 0.035  100 2 3 1;
          datenum('08/15/2012') 0.04875 100 2 3 1;
          datenum('02/15/2031') 0.05375 100 2 3 1];
```

Choose a settlement date.

```
Settle = datenum('20-Aug-2002');
```

Assume the following clean prices for the bonds:



```
Prices = [ 98.97467;
          98.58044;
          100.10534;
          98.18054;
          101.38136;
          99.25411];
```

Use the following formula to compute spot compounding for the bonds:

```
SpotCompounding = 2*ones(size(Prices));
```

Compute the zero curve.

```
[ZeroRatesP, CurveDatesP] = zbtprice(Bonds, Prices, Settle);
ZeroCurve = [CurveDatesP, ZeroRatesP, SpotCompounding]
```

```
ZeroCurve =
```

```
1.0e+05 *
    7.3154    0.0000    0.0000
    7.3163    0.0000    0.0000
    7.3216    0.0000    0.0000
    7.3327    0.0000    0.0000
    7.3510    0.0000    0.0000
    7.4185    0.0000    0.0000
```

Assign the following parameters:

```
Price          = 95;
Maturity       = datenum('02-Jan-2030');
IssueDate     = datenum('02-Jan-2000');
GrossRate     = 0.08125;
CouponRate    = 0.075;
Delay         = 14;
Interpolation = 1;
PrepaySpeed   = [0 50 100];
```

Compute the yield, and from the yield, compute the option-adjusted spread.

```
[mbsyld, beyld] = mbsyield(Price, Settle, ...
Maturity, IssueDate, GrossRate, CouponRate, Delay, PrepaySpeed);
```

```
OAS = mbsyield2oas(ZeroCurve, mbsyld, Settle, ...  
Maturity, IssueDate, GrossRate, CouponRate, Delay, ...  
Interpolation, PrepaySpeed)
```

```
OAS =
```

```
26.0508  
28.6355  
31.2232
```

### See Also

[mbssoas2price](#) | [mbssoas2yield](#) | [mbsprice2oas](#)

# mbsyield2speed

Implied PSA prepayment speeds given yield

## Syntax

```
[ImpSpdOnYld, ImpSpdOnDur, ImpSpdOnCnv] = mbsyield2speed(Yield,
Settle, Maturity, IssueDate, GrossRate, PrepayMatrix, CouponRate,
Delay)
```

## Arguments

Yield	Mortgage yield, compounded monthly, in decimal.
Settle	Settlement date. A serial date number or date string. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. A serial date number or date string.
IssueDate	Issue date. A serial date number or date string.
GrossRate	Gross coupon rate (including fees), in decimal.
PrepayMatrix	Customized prepayment matrix. A matrix of size <code>max(TermRemaining)</code> -by-NMBS. Missing values are padded with NaNs. Each column corresponds to a mortgage-backed security, and each row corresponds to each month after settlement.
CouponRate	(Optional) Net coupon rate, in decimal. Default = <b>GrossRate</b> .
Delay	(Optional) Delay (in days) between payment from homeowner and receipt by bondholder. Default = 0 (no delay between payment and receipt).

All inputs (except **PrepayMatrix**) are number of mortgage-backed securities (NMBS) by 1 vectors.

## Description

[ImpSpdOnYld, ImpSpdOnDur, ImpSpdOnCnv] = mbsyield2speed(Yield, Settle, Maturity, IssueDate, GrossRate, PrepayMatrix, CouponRate, Delay) computes PSA prepayment speeds implied by pool yields and projected (user-defined) prepayment vectors. The calculated PSA speed produces the same yield, modified duration, or modified convexity, depending upon the output requested.

ImpSpdOnPrc calculates the equivalent PSA benchmark prepayment speed for the pass-through to carry the same price.

ImpSpdOnDur calculates the equivalent PSA benchmark prepayment speed for the pass-through to carry the same modified duration.

ImpSpdOnCnv calculates the equivalent PSA benchmark prepayment speed for the pass-through to carry the same modified convexity.

All outputs are NMBS-by-1 vectors.

## Examples

Calculate the equivalent PSA benchmark prepayment speeds for a security with these characteristics and prepayment matrix.

```
Yield = 0.065;
Settle = datenum('1-Jan-2000');
Maturity = datenum('1-Jan-2030');
IssueDate = datenum('1-Jan-2000');
GrossRate = 0.08125;
PrepayMatrix = 0.005*ones(360,1);
CouponRate = 0.075;
Delay = 14;

[ImpSpdOnYld, ImpSpdOnDur, ImpSpdOnCnv] = ...
mbsyield2speed(Yield, Settle, Maturity, IssueDate, GrossRate, ...
PrepayMatrix, CouponRate, Delay)
```

```
ImpSpdOnYld =
```

```
117.7644
```

```
ImpSpdOnDur =
```

```
116.7436
```

ImpSpdOnCnv =

108.3309

## References

[1] *PSA Uniform Practices*, SF-49

## See Also

mbsyield | mbsprice2speed

## psaspeed2default

Benchmark default

### Syntax

```
[ADRPSA, MDRPSA] = psaspeed2default(DefaultSpeed)
```

### Arguments

DefaultSpeed	Annual speed relative to the benchmark. PSA benchmark = 100.
--------------	--

### Description

[ADRPSA, MDRPSA] = psaspeed2default(DefaultSpeed) computes the benchmark default on the performing balance of mortgage-backed securities per PSA benchmark speed.

ADRPSA is the PSA default rate, in decimal (360-by-1).

MDRPSA is the PSA monthly default rate, in decimal (360-by-1).

### Examples

#### Compute the Benchmark Default Rates on the Performing Balance of Mortgage-Backed Securities Per PSA Benchmark Speed

This example shows how to compute the benchmark default rates on the performing balance of mortgage-backed securities per PSA benchmark speed, given a mortgage-backed security with annual speed set at the PSA default benchmark.

```
DefaultSpeed = 100;
```







0.0036  
0.0035  
0.0034  
0.0033  
0.0032  
0.0032  
0.0031  
0.0030  
0.0029  
0.0028  
0.0027  
0.0026  
0.0025  
0.0024  
0.0023  
0.0022  
0.0021  
0.0020  
0.0019  
0.0018  
0.0017  
0.0016  
0.0015  
0.0014  
0.0013  
0.0013  
0.0012  
0.0011  
0.0010  
0.0009  
0.0008  
0.0007  
0.0006  
0.0005  
0.0004  
0.0003  
0.0003  
0.0003  
0.0003  
0.0003  
0.0003  
0.0003  
0.0003  
0.0003











0  
0  
0  
0  
0  
0  
0  
0  
0  
0  
0  
0

MDRPSA =

1.0e-03 \*

0.0167  
0.0333  
0.0500  
0.0667  
0.0834  
0.1001  
0.1167  
0.1334  
0.1501  
0.1668  
0.1835  
0.2002  
0.2169  
0.2336  
0.2503  
0.2671  
0.2838  
0.3005  
0.3172  
0.3339  
0.3507  
0.3674  
0.3841  
0.4009  
0.4176  
0.4344





0.4139  
0.4059  
0.3980  
0.3900  
0.3821  
0.3741  
0.3662  
0.3582  
0.3503  
0.3423  
0.3344  
0.3264  
0.3185  
0.3105  
0.3026  
0.2946  
0.2867  
0.2788  
0.2708  
0.2629  
0.2549  
0.2470  
0.2391  
0.2311  
0.2232  
0.2153  
0.2073  
0.1994  
0.1915  
0.1835  
0.1756  
0.1677  
0.1597  
0.1518  
0.1439  
0.1359  
0.1280  
0.1201  
0.1122  
0.1042  
0.0963  
0.0884  
0.0805  
0.0725











0.0250  
0.0250  
0.0250  
0.0250  
0.0250  
0.0250  
0.0250  
0.0250  
0.0250  
0.0250  
0.0250  
0.0250  
0.0250  
0  
0  
0  
0  
0  
0  
0  
0  
0  
0  
0  
0  
0  
0

**See Also**

psaspeed2rate

## psaspeed2rate

Single monthly mortality rate given PSA speed

### Syntax

```
[CPRPSA, SMMPSA]= psaspeed2rate(PSASpeed)
```

### Arguments

PSASpeed	Any value > 0 representing the annual speed relative to the benchmark. PSA benchmark = 100.
----------	---

### Description

[CPRPSA, SMMPSA]= psaspeed2rate(PSASpeed) calculates vectors of PSA prepayments, each containing 360 prepayment elements, to represent the 360 months in a 30-year mortgage pool.

CPRPSA is the PSA conditional prepayment rate, in decimal [360-by-1].

SMMPSA is the PSA single monthly mortality rate, in decimal [360-by-1].

### Examples

#### Compute the Prepayment and Mortality Rates

This example shows how to compute the prepayment and mortality rates, given a mortgage-backed security with annual speed set at the PSA default benchmark.

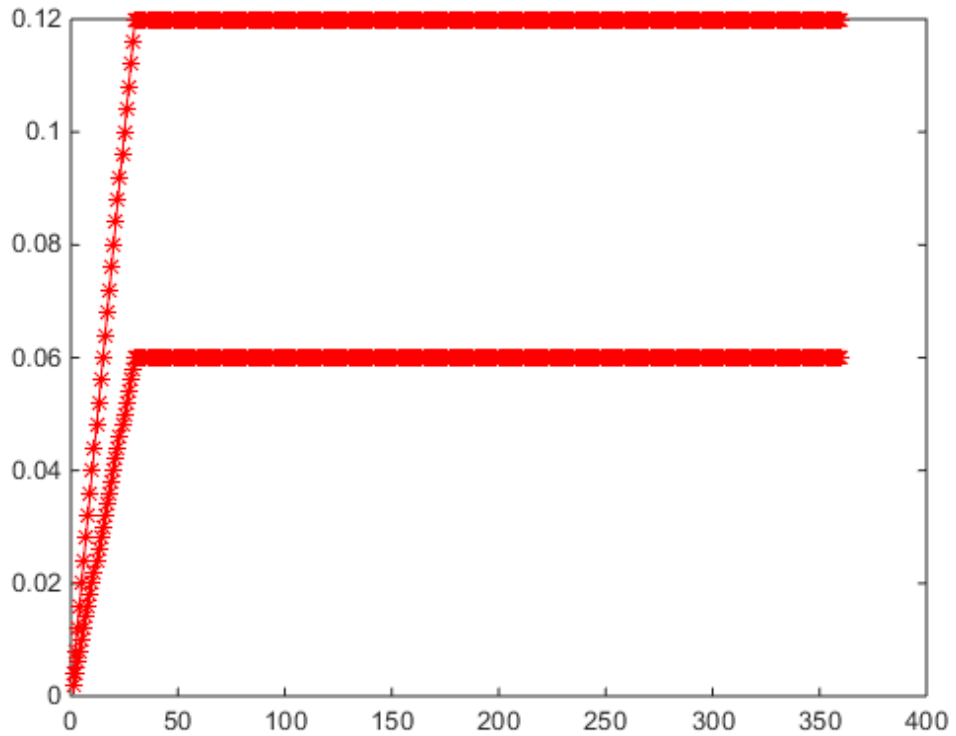
```
PSASpeed = [100 200];
```

```
[CPRPSA, SMMPSA]= psaspeed2rate(PSASpeed);
```

```
% view the plot of the output
```



psaspeed2rate (PSASpeed)



### See Also

psaspeed2default

## stepcpncfamounts

Cash flow amounts and times for bonds and stepped coupons

### Syntax

[CFlows, CDates, CTimes] = stepcpncfamounts(Settle, Maturity, ConvDates, CouponRates, Period, Basis, EndMonthRule, Face)

### Arguments

Settle	Settlement date. A scalar or vector of serial date numbers. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. A scalar or vector of serial date numbers.
ConvDates	Matrix of serial date numbers representing conversion dates after <b>Settle</b> . Size = number of instruments by maximum number of conversions. Fill unspecified entries with NaN.
CouponRates	Matrix indicating the coupon rates for each bond in decimal form. Size = number of instruments by maximum number of conversions + 1. First column of this matrix contains rates applicable between <b>Settle</b> and the first conversion date (date in the first column of <b>ConvDates</b> ). Fill unspecified entries with NaN. See Note below.
Period	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2, 3, 4, 6, and 12. Default = 2.
Basis	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> </ul>

	<ul style="list-style-type: none"> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
EndMonthRule	(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
Face	(Optional) Face value of each bond in the portfolio. Default = 100.

All arguments must be scalars or number of bonds (**NUMBONDS**)-by-1 vectors, except for **ConvDates** and **CouponRates**.

**Note** **ConvDates** has the same number of rows as **CouponRates** to reflect the same number of bonds. However, **ConvDates** has one less column than **CouponRates**. This situation is illustrated by

```
Settle-----ConvDate1-----ConvDate2-----Maturity
          Rate1           Rate2           Rate3
```

## Description

[**CFlows**, **CDates**, **CTimes**] = **stepcpncfamounts**(**Settle**, **Maturity**, **ConvDates**, **CouponRates**, **Period**, **Basis**, **EndMonthRule**, **Face**) returns matrices of cash flow amounts, cash flow dates, and time factors for a portfolio of **NUMBONDS** stepped-coupon bonds.

**CFLOWS** is a matrix of cash flow amounts. The first entry in each row vector is a negative number indicating the accrued interest due at settlement. If no accrued interest is due, the first column is 0.

**CDates** is a matrix of cash flow dates in serial date number form. At least two columns are always present, one for settlement and one for maturity.

**CTimes** is a matrix of time factors for the SIA semiannual price/yield conversion.

$\text{DiscountFactor} = (1 + \text{Yield}/2)^{-\text{TFactor}}$

Time factors are in units of semiannual coupon periods. In computing time factors, use SIA actual/actual conventions for all time factor calculations.

---

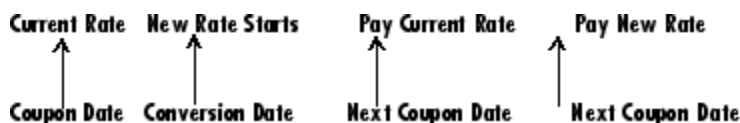
**Note** For bonds with fixed coupons, use **cfamounts**. If you use a fixed-coupon bond with **stepcpncfamounts**, MATLAB software generates an error.

---

## Examples

This example generates stepped cash flows for three different bonds, all paying interest semiannually. Their life span is about 18 to 19 years each:

- Bond A has two conversions, but the first one occurs on the settlement date and immediately expires.
- Bond B has three conversions, with conversion dates exactly on the coupon dates.
- Bond C has three conversions, with some conversion dates not on the coupon dates. It has the longest maturity. This case illustrates that only cash flows for full periods after conversion dates are affected, as illustrated below.



The following table illustrates the interest rate characteristics of this bond portfolio.

Bond A Dates	Bond A Rates	Bond B Dates	Bond B Rates	Bond C Dates	Bond C Rates
Settle (02-Aug-92)	7.5%	Settle (02-Aug-92)	7.5%	Settle (02-Aug-92)	2.5%

Bond A Dates	Bond A Rates	Bond B Dates	Bond B Rates	Bond C Dates	Bond C Rates
First Conversion (02-Aug-92)	8.875%	First Conversion (15-Jun-97))	8.875%	First Conversion (14-Jun-97))	5.0%
Second Conversion (15-Jun-03)	9.25%	Second Conversion (15-Jun-01)	9.25%	Second Conversion (14-Jun-01)	7.5%
Maturity (15-Jun-10)	NaN	Third Conversion (15-Jun-05)	10.0%	Third Conversion (14-Jun-05)	10.0%
		Maturity (15-Jun-10)	NaN	Maturity (15-Jun-11)	NaN

```

Settle = datenum('02-Aug-1992');

ConvDates = [datenum('02-Aug-1992'), datenum('15-Jun-2003'),...
             nan;
             datenum('15-Jun-1997'), datenum('15-Jun-2001'),...
             datenum('15-Jun-2005');
             datenum('14-Jun-1997'), datenum('14-Jun-2001'),...
             datenum('14-Jun-2005')];

Maturity = [datenum('15-Jun-2010');
            datenum('15-Jun-2010');
            datenum('15-Jun-2011')];

CouponRates = [0.075 0.08875 0.0925 nan;
               0.075 0.08875 0.0925 0.1;
               0.025 0.05 0.0750 0.1];

Basis = 1;
Period = 2;
EndMonthRule = 1;
Face = 100;

```

Call `stepcpncfamounts` to compute cash flows and timings.

```

[CFloWS, CDates, CTimes] = stepcpncfamounts(Settle, Maturity, ...
ConvDates, CouponRates);

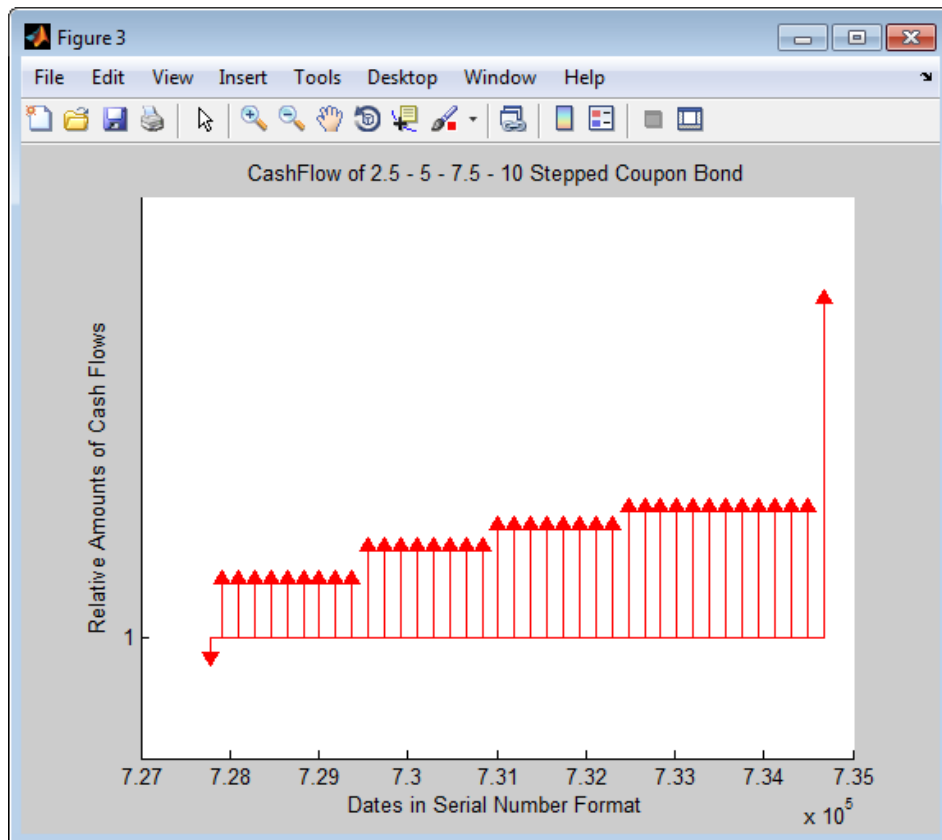
```

Visualize the third bond cash flows (2.5 - 5 - 7.5 - 10) using the `cfplot` function.

```

cfplot(CDates(3,:), CFloWS(3,:));
xlabel('Dates in Serial Number Format')
ylabel('Relative Amounts of Cash Flows')
title('CashFlow of 2.5 - 5 - 7.5 - 10 Stepped Coupon Bond')

```



## See Also

`cfplot` | `stepcpnprice` | `stepcpnyield`

## Related Examples

- “Cash Flows from Stepped-Coupon Bonds”
- “Price and Yield of Stepped-Coupon Bonds”

# stepcpnprice

Price bond with stepped coupons

## Syntax

[Price, AccruedInterest] = stepcpnprice(Yield, Settle, Maturity, ConvDates, CouponRates, Period, Basis, EndMonthRule, Face)

## Arguments

Yield	Scalar or vector containing yield to maturity of instruments.
Settle	Settlement date. A scalar or vector of serial date numbers. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. A scalar or vector of serial date numbers.
ConvDates	Matrix of serial date numbers representing conversion dates after <b>Settle</b> . Size = number of instruments by maximum number of conversions. Fill unspecified entries with <b>NaN</b> .
CouponRates	Matrix indicating the coupon rates for each bond in decimal form. Size = number of instruments by maximum number of conversions + 1. First column of this matrix contains rates applicable between <b>Settle</b> and the first conversion date (date in the first column of <b>ConvDates</b> ). Fill unspecified entries with <b>NaN</b> . See Note below.
Period	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2, 3, 4, 6, and 12. Default = 2.
Basis	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> </ul>

	<ul style="list-style-type: none"> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
EndMonthRule	(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
Face	(Optional) Face value of each bond in the portfolio. Default = 100.

All arguments must be scalars or number of bonds (NUMBONDS)-by-1 vectors, except for **ConvDates** and **CouponRates**.

---

**Note** **ConvDates** has the same number of rows as **CouponRate** to reflect the same number of bonds. However, **ConvDates** has one less column than **CouponRate**. This situation is illustrated by

Settle-----	ConvDate1-----	ConvDate2-----	Maturity
Rate1	Rate2	Rate3	

## Description

[Price, AccruedInterest] = stepcpnprice(Yield, Settle, Maturity, ConvDates, CouponRates, Period, Basis, EndMonthRule, Face) computes the



price of bonds with stepped coupons given the yield to maturity. The function supports any number of conversion dates.

Price is a NUMBONDS-by-1 vector of clean prices.

AccruedInterest is a NUMBONDS-by-1 vector of accrued interest payable at settlement dates.

---

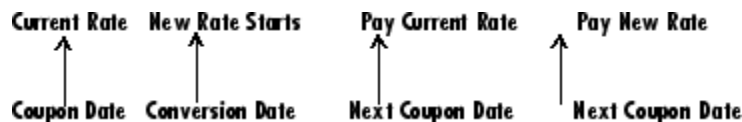
**Note** For bonds with fixed coupons, use `bndprice`. If you use a fixed-coupon bond with `stepcpnprice`, you will receive the error: `incorrect number of inputs`.

---

## Examples

Compute the price and accrued interest due on a portfolio of stepped-coupon bonds having a yield of 7.221%, given three conversion scenarios:

- Bond A has two conversions, the first one falling on the settle date and immediately expiring.
- Bond B has three conversions, with conversion dates exactly on the coupon dates.
- Bond C has three conversions, with one or more conversion dates not on coupon dates. This case illustrates that only cash flows for full periods after conversion dates are affected, as illustrated below.



The following table illustrates the interest rate characteristics of this bond portfolio.

Bond A Dates	Bond A Rates	Bond B Dates	Bond B Rates	Bond C Dates	Bond C Rates
Settle (02-Aug-92)	7.5%	Settle (02-Aug-92)	7.5%	Settle (02-Aug-92)	7.5%
First Conversion (02-Aug-92)	8.875%	First Conversion (15-Jun-97)	8.875%	First Conversion (14-Jun-97)	8.875%

Bond A Dates	Bond A Rates	Bond B Dates	Bond B Rates	Bond C Dates	Bond C Rates
Second Conversion (15-Jun-03)	9.25%	Second Conversion (15-Jun-01)	9.25%	Second Conversion (14-Jun-01)	9.25%
Maturity (15-Jun-10)	NaN	Third Conversion (15-Jun-05)	10.0%	Third Conversion (14-Jun-05)	10.0%
		Maturity (15-Jun-10)	NaN	Maturity (15-Jun-10)	NaN

```

Yield = 0.07221;
Settle = datenum('02-Aug-1992');
ConvDates = [datenum('02-Aug-1992'), datenum('15-Jun-2003'),...
             nan;
             datenum('15-Jun-1997'), datenum('15-Jun-2001'),...
             datenum('15-Jun-2005');
             datenum('14-Jun-1997'), datenum('14-Jun-2001'),...
             datenum('14-Jun-2005')];
Maturity = datenum('15-Jun-2010');

CouponRates = [0.075 0.08875 0.0925 nan;
               0.075 0.08875 0.0925 0.1;
               0.075 0.08875 0.0925 0.1];

Basis = 1;
Period = 2;
EndMonthRule = 1;
Face = 100;

[Price, AccruedInterest] = ...
stepcpnprice(Yield, Settle, Maturity, ConvDates, CouponRates, ...
             Period, Basis, EndMonthRule, Face)

Price =

    117.3824
    113.4339
    113.4339

AccruedInterest =

    1.1587
    0.9792
    0.9792

```

## References

This function adheres to *SIA Fixed Income Securities Formulas for Price, Yield, and Accrued Interest*, Volume 1, 3rd edition, pp. 120 - 123, on zero-coupon instruments pricing.

## See Also

bndprice | cdprice | stepcpncfamounts | stepcpnprice | stepcpnyield |  
tbillprice

## Related Examples

- “Cash Flows from Stepped-Coupon Bonds”
- “Price and Yield of Stepped-Coupon Bonds”

## stepcpnyield

Yield to maturity of bond with stepped coupons

### Syntax

Yield = stepcpnyield(Price, Settle, Maturity, ConvDates, CouponRate, Period, Basis, EndMonthRule, Face)

### Arguments

Price	Vector containing price of the bonds.
Settle	Settlement date. A vector of serial date numbers. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. A vector of serial date numbers.
ConvDates	Matrix of serial date numbers representing conversion dates after <b>Settle</b> . Size = number of instruments by maximum number of conversions. Fill unspecified entries with NaN.
CouponRates	Matrix indicating the coupon rates for each bond in decimal form. Size = number of instruments by maximum number of conversions + 1. First column of this matrix contains rates applicable between <b>Settle</b> and the first conversion date (date in the first column of <b>ConvDates</b> ). Fill unspecified entries with NaN. See Note below.
Period	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2, 3, 4, 6, and 12. Default = 2.
Basis	(Optional) Day-count basis of the instrument. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> </ul>

	<ul style="list-style-type: none"> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
EndMonthRule	(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
Face	(Optional) Face value of each bond in the portfolio. Default = 100.

All arguments must be number of bonds (NUMBONDS)-by-1 vectors, except for **ConvDates** and **CouponRate**.

**Note** **ConvDates** has the same number of rows as **CouponRate** to reflect the same number of bonds. However, **ConvDates** has one less column than **CouponRate**. This situation is illustrated by

Settle-----	ConvDate1-----	ConvDate2-----	Maturity
Rate1	Rate2	Rate3	

## Description

Yield = stepcpnyield(Price, Settle, Maturity, ConvDates, CouponRate, Period, Basis, EndMonthRule, Face) computes the yield to maturity of bonds

with stepped coupons given the price. The function supports any number of conversion dates.

Yield is a NUMBONDS-by-1 vector of yields to maturity in decimal form.

---

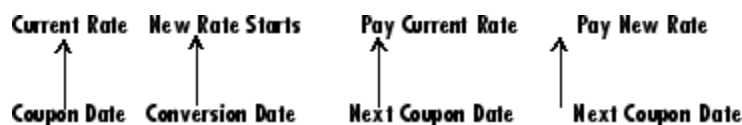
**Note** For bonds with fixed coupons, use `bndyield`. You will receive the error `incorrect number of inputs` if you use a fixed-coupon bond with `stepcpnyield`.

---

## Examples

Find the yield to maturity of three stepped-coupon bonds of known price, given three conversion scenarios:

- Bond A has two conversions, the first one falling on the settle date and immediately expiring.
- Bond B has three conversions, with conversion dates exactly on the coupon dates.
- Bond C has three conversions, with one or more conversion dates not on coupon dates. This case illustrates that only cash flows for full periods after conversion dates are affected, as illustrated below.



The following table illustrates the interest rate characteristics of this bond portfolio.

Bond A Dates	Bond A Rates	Bond B Dates	Bond B Rates	Bond C Dates	Bond C Rates
Settle (02-Aug-92)	7.5%	Settle (02-Aug-92)	7.5%	Settle (02-Aug-92)	7.5%
First Conversion (02-Aug-92)	8.875%	First Conversion (15-Jun-97)	8.875%	First Conversion (14-Jun-97)	8.875%
Second Conversion (15-Jun-03)	9.25%	Second Conversion (15-Jun-01)	9.25%	Second Conversion (14-Jun-01)	9.25%

Bond A Dates	Bond A Rates	Bond B Dates	Bond B Rates	Bond C Dates	Bond C Rates
Maturity (15-Jun-10)	NaN	Third Conversion (15-Jun-05)	10.0%	Third Conversion (14-Jun-05)	10.0%
		Maturity (15-Jun-10)	NaN	Maturity (15-Jun-10)	NaN

```

format long
Price = [117.3824; 113.4339; 113.4339];
Settle = datenum('02-Aug-1992');

ConvDates = [datenum('02-Aug-1992'), datenum('15-Jun-2003'), nan;
datenum('15-Jun-1997'), datenum('15-Jun-2001'), datenum('15-Jun-2005');
datenum('14-Jun-1997'), datenum('14-Jun-2001'), datenum('14-Jun-2005')];

Maturity = datenum('15-Jun-2010');

CouponRates = [0.075 0.08875 0.0925 nan;
0.075 0.08875 0.0925 0.1;
0.075 0.08875 0.0925 0.1];

Basis = 1;
Period = 2;
EndMonthRule = 1;
Face = 100;

Yield = stepcpnyield(Price, Settle, Maturity, ConvDates, ...
CouponRates, Period, Basis, EndMonthRule, Face)

Yield =

0.07221440204915
0.07221426780036
0.07221426780036

```

## References

This function adheres to *SIA Fixed Income Securities Formulas for Price, Yield, and Accrued Interest*, Volume 1, 3rd edition, pp. 120 - 123, on zero-coupon instruments pricing.

## See Also

bndprice | cdprice | stepcpncfamounts | stepcpnprice | stepcpnprice |  
tbillprice | zeroprice

### **Related Examples**

- “Cash Flows from Stepped-Coupon Bonds”
- “Price and Yield of Stepped-Coupon Bonds”



# tfutbyprice

Future prices of Treasury bonds given spot price

## Syntax

```
[QtdFutPrice, AccrInt] = tfutbyprice(SpotCurve, Price, SettleFut, MatFut,
ConvFactor, CouponRate, Maturity, Interpolation)
```

## Arguments

SpotCurve	Treasury spot curve; a number of futures (NFUT) by 3 matrix in the form of [SpotDates SpotRates Compounding].  Allowed compounding values are -1, 1, 2 (default), 3, 4, and 12, where -1 is continuous compounding.
Price	Scalar or vector containing prices of Treasury bonds or notes per \$100 notional. Use <code>bndprice</code> for theoretical value of bond.
SettleFut	Scalar or vector of identical elements containing settlement date of futures contract.
MatFut	Scalar or vector containing maturity dates (or anticipated delivery dates) of futures contract.
ConvFactor	Conversion factor. See <code>convfactor</code> .
CouponRate	Scalar or vector containing underlying bond annual coupon in decimal.
Maturity	Scalar or vector containing underlying bond maturity.
Interpolation	(Optional) Interpolation method. Available methods are (0) nearest, (1) linear, and (2) cubic. Default = 1. See <code>interp1</code> for more information.

Inputs (except `SpotCurve`) must either be a scalar or a vector of size equal to the number of Treasury futures (NFUT) by 1 or 1-by-NFUT.

## Description

[QtdFutPrice, AccrInt] = tfutbyprice(SpotCurve, Price, SettleFut, MatFut, ConvFactor, CouponRate, Maturity, Interpolation) computes future prices of Treasury notes and bonds given the spot price. The output arguments are:

- QtdFutPrice — Quoted futures price, per \$100 notional.
- AccrInt — Accrued interest due at delivery date, per \$100 notional.

In addition, you can use the Financial Instruments Toolbox method `getZeroRates` for an `IRDataCurve` object with a `Dates` property to create a vector of dates and data acceptable for `tfutbyprice`. For more information, see “Converting an `IRDataCurve` or `IRFunctionCurve` Object” on page 9-44.

## Examples

### Determine the Future Prices of Treasury Bonds Given the Spot Price

This example shows how to determine the future price of two Treasury bonds based upon a spot rate curve constructed from data for November 14, 2002.

```
% construct spot curve from Nov 14, data
Bonds = [datenum('02/13/2003'),      0;
         datenum('05/15/2003'),      0;
         datenum('10/31/2004'),    0.02125;
         datenum('11/15/2007'),     0.03;
         datenum('11/15/2012'),     0.04;
         datenum('02/15/2031'),    0.05375];

Yields = [1.20; 1.25; 1.86; 2.99; 4.02; 4.93]/100;

Settle = datenum('11/15/2002');

[ZeroRates, CurveDates] = ...
zbyield(Bonds, Yields, Settle);

SpotCurve = [CurveDates, ZeroRates];

% calculate a particular bond's future quoted price
RefDate    = [datenum('1-Dec-2002'); datenum('1-Mar-2003')];
```

```
MatFut      = [datenum('15-Dec-2002'); datenum('15-Mar-2003')];
Maturity    = [datenum('15-Aug-2009'); datenum('15-Aug-2010')];
CouponRate  = [0.06; 0.0575];
ConvFactor  = convfactor(RefDate, Maturity, CouponRate);
Price       = [114.416; 113.171];
Interpolation = 1;

[QtdFutPrice, AccrInt] = tfutbyprice(SpotCurve, Price, Settle, ...
    MatFut, ConvFactor, CouponRate, Maturity, Interpolation)
```

```
QtdFutPrice =
```

```
    114.0409
    113.4029
```

```
AccrInt =
```

```
    1.9891
    0.4448
```

- “Computing Treasury Bill Price and Yield”

## More About

- “Treasury Bills Defined”

## See Also

convfactor | tfutbyyield

## tfutbyyield

Future prices of Treasury bonds given current yield

### Syntax

```
[QtdFutPrice, AccrInt] = tfutbyyield(SpotCurve, Yield, SettleFut, MatFut,
ConvFactor, CouponRate, Maturity, Interpolation)
```

### Arguments

SpotCurve	Treasury spot curve. A number of futures (NFUT)-by-3 matrix in the form of [SpotDates SpotRates Compounding].  Allowed compounding values are -1, 1, 2 (default), 3, 4, and 12, where -1 is continuous compounding.
Yield	Scalar or vector containing yield to maturity of bonds. Use <b>bdyield</b> for theoretical value of bond yield.
SettleFut	Scalar or vector of identical elements containing settlement date of futures contract.
MatFut	Scalar or vector containing maturity dates (or anticipated delivery dates) of futures contract.
ConvFactor	Conversion factor. See <b>convfactor</b> .
CouponRate	Scalar or vector containing underlying bond annual coupon in decimal.
Maturity	Scalar or vector containing underlying bond maturity.
Interpolation	(Optional) Interpolation method. Available methods are (0) nearest, (1) linear, and (2) cubic. Default = 1. See <b>interp1</b> for more information.

Inputs (except **SpotCurve**) must either be a scalar or a vector of size equal to the number of Treasury futures (NFUT) by 1 or 1-by-NFUT.

## Description

[QtdFutPrice, AccrInt] = tfutbyield(SpotCurve, Yield, SettleFut, MatFut, ConvFactor, CouponRate, Maturity, Interpolation) computes future prices of Treasury notes and bonds given current yields of Treasury bonds/notes. The output arguments are:

- QtdFutPrice — Quoted futures price, per \$100 notional.
- AccrInt — Accrued Interest due at delivery date, per \$100 notional.

In addition, you can use the Financial Instruments Toolbox method `getZeroRates` for an `IRDataCurve` object with a `Dates` property to create a vector of dates and data acceptable for `tfutbyield`. For more information, see “Converting an `IRDataCurve` or `IRFunctionCurve` Object” on page 9-44.

## Examples

### Determine Future Prices of Treasury Bonds Given the Current Yield

This example shows how to determine the future price of two Treasury bonds based upon a spot rate curve constructed from data for November 14, 2002.

```
% construct spot curve from Nov 14, data
Bonds = [datenum('02/13/2003'),      0;
         datenum('05/15/2003'),      0;
         datenum('10/31/2004'),    0.02125;
         datenum('11/15/2007'),     0.03;
         datenum('11/15/2012'),     0.04;
         datenum('02/15/2031'),    0.05375];

Yields = [1.20; 1.25; 1.86; 2.99; 4.02; 4.93]/100;

Settle = datenum('11/15/2002');

[ZeroRates, CurveDates] = ...
zbyield(Bonds, Yields, Settle);

SpotCurve = [CurveDates, ZeroRates];

% calculate a particular bond's future quoted price
RefDate = [datenum('1-Dec-2002'); datenum('1-Mar-2003')];
```

```
MatFut      = [datenum('15-Dec-2002'); datenum('15-Mar-2003')];
Maturity    = [datenum('15-Aug-2009'); datenum('15-Aug-2010')];
CouponRate  = [0.06; 0.0575];
ConvFactor  = convfactor(RefDate, Maturity, CouponRate);
Yield       = [0.03576; 0.03773];
Interpolation = 1;

[QtdFutPrice, AccrInt] = tfutbyyield(SpotCurve, Yield, Settle, ...
MatFut, ConvFactor, CouponRate, Maturity, Interpolation)
```

```
QtdFutPrice =
```

```
    114.0416
    113.4034
```

```
AccrInt =
```

```
    1.9891
    0.4448
```

- “Computing Treasury Bill Price and Yield”

## More About

- “Treasury Bills Defined”

## See Also

[convfactor](#) | [tfutbyprice](#)

# tfutimprepo

Implied repo rates for Treasury bond future given price

## Syntax

```
ImpliedRepo = tfutimprepo(ReinvestData, Price, QtdFutPrice, Settle,
MatFut, ConvFactor, CouponRate, Maturity)
```

## Arguments

ReinvestData	Number of futures (NFUT) by 2 matrix of rates and bases for the reinvestment of intervening coupons in the form of [ReinvestRate ReinvestBasis].  ReinvestRate is the simple reinvestment rate, in decimal. Specify ReinvestBasis as 0 = not reinvested, 2 = actual/360, or 3 = actual/365.
Price	Current bond price per \$100 notional.
QtdFutPrice	Quoted bond futures price per \$100 notional.
Settle	Settlement/valuation date of futures contract.
MatFut	Maturity date (or anticipated delivery dates) of futures contract.
ConvFactor	Conversion factor. See <code>convfactor</code> .
CouponRate	Underlying bond annual coupon, in decimal.
Maturity	Underlying bond maturity date.

Inputs (except `ReinvestData`) must either be a scalar or a vector of size equal to the number of Treasury futures (NFUT) by 1 or 1-by-NFUT.

## Description

`ImpliedRepo = tfutimprepo(ReinvestData, Price, QtdFutPrice, Settle, MatFut, ConvFactor, CouponRate, Maturity)` computes the implied repo rate

that prevents arbitrage of Treasury bond futures, given the clean price at the settlement and delivery dates.

`ImpliedRepo` is the implied annual repo rate, in decimal, with an actual/360 basis.

## Examples

### Compute the Implied Repo Rates for Treasury Bond Futures Given the Price

This example shows how to compute the implied repo rate given the following set of data.

```
ReinvestData = [0.018 3];
Price = [114.4160; 113.1710];
QtdFutPrice = [114.1201; 113.7090];
Settle = datenum('11/15/2002');
MatFut = [datenum('15-Dec-2002'); datenum('15-Mar-2003')];
ConvFactor = [1; 0.9854];
CouponRate = [0.06; 0.0575];
Maturity = [datenum('15-Aug-2009'); datenum('15-Aug-2010')];

ImpliedRepo = tfutimprepo(ReinvestData, Price, QtdFutPrice, ...
    Settle, MatFut, ConvFactor, CouponRate, Maturity)
```

```
ImpliedRepo =
```

```
    0.0200
    0.0200
```

- “Computing Treasury Bill Price and Yield”

## More About

- “Treasury Bills Defined”

## See Also

`tfutpricebyrepo` | `tfutyieldbyrepo`



# tfutpricebyrepo

Calculates Treasury bond futures price given the implied repo rates

## Syntax

```
[QtdFutPrice AccrInt] = tfutpricebyrepo(RepoData, ReinvestData,
Price, Settle, MatFut, ConvFactor, CouponRate, Maturity)
```

## Arguments

RepoData	Number of futures (NFUT) by 2 matrix of simple term repo/ funding rates in decimal and their bases in the form of [RepoRate RepoBasis].  Specify RepoBasis as 2 = actual/360 or 3 = actual/365.
ReinvestData	Number of futures (NFUT) by 2 matrix of rates and bases for the reinvestment of intervening coupons in the form of [ReinvestRate ReinvestBasis].  ReinvestRate is the simple reinvestment rate, in decimal. Specify ReinvestBasis as 0 = not reinvested, 2 = actual/360, or 3 = actual/365.
Price	Quoted clean prices of Treasury bonds per \$100 notional at Settle.
Settle	Settlement/valuation date of futures contract.
MatFut	Maturity date (or anticipated delivery dates) of futures contract.
ConvFactor	Conversion factor. See convfactor.
CouponRate	Underlying bond annual coupon, in decimal.
Maturity	Underlying bond maturity date.

Inputs (except RepoData and ReinvestData) must either be a scalar or a vector of size equal to the number of Treasury futures (NFUT) by 1 or 1-by-NFUT.

## Description

[QtdFutPrice AccrInt] = tfutpricebyrepo(RepoData, ReinvestData, Price, Settle, MatFut, ConvFactor, CouponRate, Maturity) computes the theoretical futures bond price given the settlement price, the repo/funding rates, and the reinvestment rate.

QtdFutPrice is the quoted futures price, per \$100 notional.

AccrInt is the accrued interest due at the delivery date, per \$100 notional.

## Examples

### Compute Treasury Bond Futures Price Given the Implied Repo Rates

This example shows how to compute the quoted futures price and accrued interest due on the target delivery date, given the following data.

```
RepoData      = [0.020  2];
ReinvestData  = [0.018  3];
Price         = [114.416; 113.171];
Settle        = datenum('11/15/2002');
MatFut        = [datenum('15-Dec-2002'); datenum('15-Mar-2003')];
ConvFactor    = [1 ; 0.9854];
CouponRate    = [0.06;0.0575];
Maturity      = [datenum('15-Aug-2009'); datenum('15-Aug-2010')];
```

```
[QtdFutPrice AccrInt] = tfutpricebyrepo(RepoData, ...
ReinvestData, Price, Settle, MatFut, ConvFactor, CouponRate, ...
Maturity)
```

```
QtdFutPrice =
```

```
    114.1201
    113.7090
```

```
AccrInt =
```

```
    1.9891
    0.4448
```

- “Computing Treasury Bill Price and Yield”

## **More About**

- “Treasury Bills Defined”

## **See Also**

tfutimprepo | tfutyieldbyrepo

## tfutyieldbyrepo

Calculates Treasury bond futures yield given the implied repo rates

### Syntax

```
FwdYield = tfutyieldbyrepo(RepoData, ReinvestData, Yield, Settle,
MatFut, ConvFactor, CouponRate, Maturity)
```

### Arguments

RepoData	Number of futures (NFUT) by 2 matrix of simple term repo/ funding rates in decimal and their bases in the form of [RepoRate RepoBasis].  Specify RepoBasis as 2 = actual/360 or 3 = actual/365.
ReinvestData	Number of futures (NFUT) by 2 matrix of rates and bases for the reinvestment of intervening coupons in the form of [ReinvestRate ReinvestBasis].  ReinvestRate is the simple reinvestment rate, in decimal. Specify ReinvestBasis as 0 = not reinvested, 2 = actual/360, or 3 = actual/365.
Yield	Yield to maturity of Treasury bonds per \$100 notional at Settle.
Settle	Settlement/valuation date of futures contract.
MatFut	Maturity date (or anticipated delivery dates) of futures contract.
ConvFactor	Conversion factor. See convfactor.
CouponRate	Underlying bond annual coupon, in decimal.
Maturity	Underlying bond maturity date.

Inputs (except RepoData and ReinvestData) must either be a scalar or a vector of size equal to the number of Treasury futures (NFUT) by 1 or 1-by-NFUT.

## Description

FwdYield = tfutyieldbyrepo(RepoData, ReinvestData, Yield, Settle, MatFut, ConvFactor, CouponRate, Maturity) computes the theoretical futures bond yield given the settlement yield, the repo/funding rate, and the reinvestment rate.

FwdYield is the forward yield to maturity, in decimal, compounded semiannually.

## Examples

### Compute the Treasury Bond Futures Yield Given the Implied Repo Rates

This example shows how to compute the quoted futures bond yield, given the following data.

```
RepoData      = [0.020  2];
ReinvestData  = [0.018  3];
Yield         = [0.0215; 0.0257];
Settle        = datenum('11/15/2002');
MatFut        = [datenum('15-Dec-2002'); datenum('15-Mar-2003')];
ConvFactor    = [1; 0.9854];
CouponRate    = [0.06; 0.0575];
Maturity      = [datenum('15-Aug-2009'); datenum('15-Aug-2010')];
```

```
FwdYield = tfutyieldbyrepo(RepoData, ReinvestData, Yield, ...
    Settle, MatFut, ConvFactor, CouponRate, Maturity)
```

```
FwdYield =
```

```
    0.0221
    0.0282
```

- “Computing Treasury Bill Price and Yield”

## More About

- “Treasury Bills Defined”

**See Also**

tfutimprepo | tfutpricebyrepo

# toRateSpec

Convert IRDataCurve object to RateSpec

## Class

@IRDataCurve

## Syntax

F = toratespec(CurveObj, InpDates)

## Arguments

CurveObj	Interest-rate curve object that is constructed using IRDataCurve.
InpDates	Vector of input dates using MATLAB date format. The input dates must be after the settle date.

## Description

F = toratespec(CurveObj, InpDates) returns a RateSpec object that is identical to the RateSpec structure created by the Financial Instruments Toolbox function intenvset.

## Examples

### Convert an IRDataCurve Object to a RateSpec

This example shows how to convert an IRDataCurve object to a RateSpec. First, an IRDataCurve object is created using the function IRDataCurve constructor with Dates and Data, then this object is converted to a RateSpec structure using the toRateSpec method.

```
Data = [2.09 2.47 2.71 3.12 3.43 3.85 4.57 4.58]/100;
Dates = daysadd(today,[360 2*360 3*360 5*360 7*360 10*360 20*360 30*360],1);
irdc = IRDataCurve('Forward',today,Dates,Data);
toRateSpec(irdc, today+30:30:today+365)
```

```
ans =
```

```
      FinObj: 'RateSpec'
  Compounding: 2
        Disc: [12x1 double]
        Rates: [12x1 double]
     EndTimes: [12x1 double]
   StartTimes: [12x1 double]
     EndDates: [12x1 double]
   StartDates: 735862
ValuationDate: 735862
         Basis: 0
  EndMonthRule: 1
```

## More About

- “@IRDataCurve”



# toRateSpec

Convert IRFunctionCurve object to RateSpec

## Class

@IRFunctionCurve

## Syntax

F = toRateSpec(CurveObj, InpDates)

## Arguments

CurveObj	Interest-rate curve object that is constructed using IRFunctionCurve.
InpDates	Vector of input dates using MATLAB date format. The input dates must be after the settle date.

## Description

F = toRateSpec(CurveObj, InpDates) returns a RateSpec object that is identical to the RateSpec structure created by the Financial Instruments Toolbox function `intenvset`.

## Examples

### Convert an IRFunctionCurve Object to a RateSpec

This example shows how to convert an IRFunctionCurve object to a RateSpec. First, an IRFunctionCurve object is created using the function IRFunctionCurve constructor, then a RateSpec structure is created using the toRateSpec method.

```
irfc = IRFunctionCurve('Forward',today,@(t) polyval([-0.0001 0.003 0.02],t));  
toRateSpec(irfc, today+30:30:today+365)
```

```
ans =
```

```
    FinObj: 'RateSpec'  
  Compounding: 2  
    Disc: [12x1 double]  
    Rates: [12x1 double]  
  EndTimes: [12x1 double]  
  StartTimes: [12x1 double]  
    EndDates: [12x1 double]  
  StartDates: 735862  
ValuationDate: 735862  
    Basis: 0  
  EndMonthRule: 1
```

## More About

- “@IRFunctionCurve”

# zeroprice

Price zero-coupon instruments given yield

## Syntax

Price = zeroprice(Yield, Settle, Maturity, Period, Basis, EndMonthRule)

## Arguments

Yield	Scalar or vector containing yield to maturity of instruments.
Settle	Settlement date. A vector of serial date numbers or date strings. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. A vector of serial date numbers or date strings.
Period	(Optional) Scalar or vector specifying number of quasi-coupons per year. Default = 2.
Basis	(Optional) Day-count basis of the bond. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> </ul>

	<ul style="list-style-type: none"> <li>• 13 = BUS/252</li> </ul> For more information, see <b>basis</b> .
EndMonthRule	(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

## Description

`Price = zeroprice(Yield, Settle, Maturity, Period, Basis, EndMonthRule)` calculates the prices for a portfolio of general short and long term zero-coupon instruments given the yield of reference bonds. In other words, if the zero-coupon computed with this yield is used to discount the reference bond, the value of that reference bond will be equal its price.

**Price** is a column vector containing a price for each zero-coupon instrument per \$100 notional.

When there is less than one quasi-coupon, the function uses a simple yield based upon  $(\text{Period}) \times (\text{Number of Days in quasi coupon period})$  day-year. The default period is 2 and the default number of days is 180, which makes the user-supplied yield a simple yield on a 360-day year.

For longer term computations (more than one quasi-coupon), use the bond equivalent yield based upon present value (or compounding).

## Algorithms

To compute the price when there is 1 or 0 quasi-coupon periods to redemption, `zeroprice` uses the formula

$$Price = \frac{RV}{1 + \left( \frac{DSR}{E} \times \frac{Y}{M} \right)}$$

*Quasi-coupon periods* are the coupon periods that would exist if the bond were paying interest at a rate other than zero.

When there is more than one quasi-coupon period to the redemption date, **zeroprice** uses the formula

$$Price = \frac{RV}{\left(1 + \frac{Y}{M}\right)^{Nq - 1 + \frac{DSC}{E}}}$$

The elements of the equations are defined as follows.

Variable	Definition
<i>DSC</i>	Number of days from settlement date to next quasi-coupon date as if the security paid periodic interest.
<i>DSR</i>	Number of days from settlement date to the redemption date (call date, put date, and so on).
<i>E</i>	Number of days in quasi-coupon period.
<i>M</i>	Number of quasi-coupon periods per year (standard for the particular security involved).
<i>Nq</i>	Number of quasi-coupon periods between settlement date and redemption date. If this number contains a fractional part, raise it to the next whole number.
<i>Price</i>	Dollar price per \$100 par value.
<i>RV</i>	Redemption value.
<i>Y</i>	Annual yield (decimal) when held to redemption.

## Examples

### Compute the Price of a Short-Term Zero-Coupon Instrument

This example shows how to compute the price of a short-term zero-coupon instrument.

```
Settle = '24-Jun-1993';  
Maturity = '1-Nov-1993';  
Period = 2;  
Basis = 0;  
Yield = 0.04;  
  
Price = zeroprice(Yield, Settle, Maturity, Period, Basis)
```

```
Price =  
  
    98.6066
```

### Compute the Prices of a Portfolio of Two Zero-Coupon Instruments

This example shows how to compute the prices of a portfolio of two zero-coupon instruments, one short-term, and the other long-term.

```
Settle = '24-Jun-1993';  
Maturity = ['01-Nov-1993'; '15-Jan-2024'];  
Basis = [0; 1];  
Yield = [0.04; 0.1];  
  
Price = zeroprice(Yield, Settle, Maturity, [], Basis)
```

```
Price =  
  
    98.6066  
     5.0697
```

- “Computing Treasury Bill Price and Yield”
- “Pricing Treasury Notes”
- “Pricing Corporate Bonds”

## More About

- “Measuring Zero-Coupon Bond Function Quality”

## References

- [1] Mayle, Jan. *Standard Securities Calculation Methods*. New York: Securities Industry Association, Inc. Vol. 1, 3rd ed., 1993, ISBN 1-882936-01-9. Vol. 2, 1994, ISBN 1-882936-02-7.

## See Also

bndprice | cdprice | tbillprice | zeroyield

## zeroyield

Yield of zero-coupon instruments given price

### Syntax

Yield = zeroyield(Price, Settle, Maturity, Period, Basis, EndMonthRule)

### Arguments

Price	Scalar or vector containing prices of instruments.
Settle	Settlement date. A vector of serial date numbers or date strings. <b>Settle</b> must be earlier than <b>Maturity</b> .
Maturity	Maturity date. A vector of serial date numbers or date strings.
Period	(Optional) Scalar or vector specifying number of quasi-coupons per year. Default = 2.
Basis	(Optional) Day-count basis of the bond. A vector of integers. <ul style="list-style-type: none"> <li>• 0 = actual/actual (default)</li> <li>• 1 = 30/360 (SIA)</li> <li>• 2 = actual/360</li> <li>• 3 = actual/365</li> <li>• 4 = 30/360 (BMA)</li> <li>• 5 = 30/360 (ISDA)</li> <li>• 6 = 30/360 (European)</li> <li>• 7 = actual/365 (Japanese)</li> <li>• 8 = actual/actual (ICMA)</li> <li>• 9 = actual/360 (ICMA)</li> <li>• 10 = actual/365 (ICMA)</li> <li>• 11 = 30/360E (ICMA)</li> <li>• 12 = actual/actual (ISDA)</li> </ul>



	<ul style="list-style-type: none"> <li>• 13 = BUS/252</li> </ul> <p>For more information, see <b>basis</b>.</p>
EndMonthRule	(Optional) End-of-month rule. A vector. This rule applies only when <b>Maturity</b> is an end-of-month date for a month having 30 or fewer days. <b>0</b> = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. <b>1</b> = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

## Description

`Yield = zeroyield(Price, Settle, Maturity, Period, Basis, EndMonthRule)` calculates the bond-equivalent yield for a portfolio of general short and long term zero-coupon instruments given the price of the instruments. In other words, if the zero-coupon computed with this yield is used to discount the reference bond, the value of that reference bond will be equal its price.

**Yield** is a column vector containing a bond-equivalent yield for each zero-coupon instrument.

When the maturity date is fewer than 182 days away and the basis is **actual/365**, the function uses a simple-interest algorithm. If maturity is more than 182 days away, the function uses present value calculations.

When the basis is **actual/360**, the simple interest algorithm gives the money-market yield for short (1 to 6 months to maturity) Treasury bills.

The present value algorithm always gives the bond equivalent yield of the zero-coupon instrument. The algorithm is equivalent to calling `bndyield` with the zero-coupon information within one basis point.

## Algorithms

To compute the yield when there is zero or one quasi-coupon periods to redemption, `zeroyield` uses the formula

$$Yield = \left( \frac{RV - P}{P} \right) \times \left( \frac{M \times E}{DSR} \right)$$

*Quasi-coupon periods* are the coupon periods which would exist if the bond was paying interest at a rate other than zero. The first term calculates the yield on invested dollars. The second term converts this yield to a per annum basis.

When there is more than one quasi-coupon period to the redemption date, `zeroyield` uses the formula

$$Yield = \left( \left( \frac{RV}{P} \right)^{\frac{1}{Nq-1+\frac{DSC}{E}}} - 1 \right) \times M$$

The elements of the equations are defined as follows.

Variable	Definition
<i>DSC</i>	Number of days from the settlement date to next quasi-coupon date as if the security paid periodic interest.
<i>DSR</i>	Number of days from the settlement date to redemption date (call date, put date, and so on).
<i>E</i>	Number of days in quasi-coupon period.
<i>M</i>	Number of quasi-coupon periods per year (standard for the particular security involved).
<i>Nq</i>	Number of quasi-coupon periods between the settlement date and redemption date. If this number contains a fractional part, raise it to the next whole number.
<i>P</i>	Dollar price per \$100 par value.
<i>RV</i>	Redemption value.
<i>Yield</i>	Annual yield (decimal) when held to redemption.

## Examples

### Compute the Yield of a Short-Term Zero-Coupon Instrument

This example shows how to compute the yield of a short-term zero-coupon instrument.

```
Settle = '24-Jun-1993';  
Maturity = '1-Nov-1993';  
Basis = 0;  
Price = 95;
```

```
Yield = zeroyield(Price, Settle, Maturity, [], Basis)
```

```
Yield =  
  
    0.1490
```

### **Compute the Yield of a Short-Term Zero-Coupon Instrument Using a Day-Count Basis of 30/360 (SIA)**

This example shows how to compute the yield of a short-term zero-coupon instrument using a day-count basis of 30/360 (SIA).

```
Settle = '24-Jun-1993';  
Maturity = '1-Nov-1993';  
Basis = 1;  
Price = 95;
```

```
Yield = zeroyield(Price, Settle, Maturity, [], Basis)
```

```
Yield =  
  
    0.1492
```

### **Compute the Yield of a Long-Term Zero-Coupon Instrument**

This example shows how to compute the yield of a long-term zero-coupon instrument.

```
Settle = '24-Jun-1993';  
Maturity = '15-Jan-2024';  
Basis = 0;  
Price = 9;
```

```
Yield = zeroyield(Price, Settle, Maturity, [], Basis)
```

```
Yield =
```

0.0804

- “Computing Treasury Bill Price and Yield”
- “Pricing Treasury Notes”
- “Pricing Corporate Bonds”

## More About

- “Measuring Zero-Coupon Bond Function Quality”

## References

[1] Mayle, Jan. *Standard Securities Calculation Methods*. New York: Securities Industry Association, Inc. Vol. 1, 3rd ed., 1993, ISBN 1-882936-01-9. Vol. 2, 1994, ISBN 1-882936-02-7.

## See Also

`bndyield` | `cdyield` | `tbillyield` | `zeroprice`

# Derivatives Pricing Options

---

## Pricing Options Structure

In this section...
“Introduction” on page B-2
“Default Structure” on page B-2
“Customizing the Structure” on page B-4

### Introduction

The MATLAB `Options` structure provides additional input to most pricing functions. The `Options` structure

- Tells pricing functions how to use the interest-rate tree to calculate instrument prices.
- Determines what additional information the Command Window displays along with instrument prices.
- Tells pricing functions which method to use in pricing barrier options.

The pricing options structure is primarily used in the pricing of interest-rate-based financial derivatives. However, the `BarrierMethod` field in the structure allows you to use it in pricing equity barrier options as well.

You provide pricing options in an optional `Options` argument passed to a pricing function. (See, for example, `bondbyhjm`, `bdtprice`, `barrierbycrr`, `barrierbyeqp`, or `barrierbyitt`.)

### Default Structure

If you do not specify the `Options` argument in the call to a pricing function, the function uses a default structure. To observe the default structure, use `derivset` without any arguments.

```
Options = derivset
```

```
Options =
```

```
  Diagnostics: 'off'  
  Warnings:   'on'  
  ConstRate:  'on'
```

```
BarrierMethod: 'unenhanced'
```

The `Options` structure has four fields: `Diagnostics`, `Warnings`, `ConstRate`, and `BarrierMethod`.

### **Diagnostics Field**

`Diagnostics` indicates whether additional information is displayed if the tree is modified. The default value for this option is 'off'. If `Diagnostics` is set to 'on' and `ConstRate` is set to 'off', the pricing functions display information such as the number of nodes in the last level of the tree generated for pricing purposes.

### **Warnings Field**

`Warnings` indicates whether to display warning messages when the input tree is not adequate for accurately pricing the instruments. The default value for this option is 'on'. If both `ConstRate` and `Warnings` are 'on', a warning is displayed if any of the instruments in the input portfolio has a cash flow date between tree dates. If `ConstRate` is 'off', and `Warnings` is 'on', a warning is displayed if the tree is modified to match the cash flow dates on the instruments in the portfolio.

### **ConstRate Field**

`ConstRate` indicates whether the interest rates should be assumed constant between tree dates. By default this option is 'on', which is not an arbitrage-free assumption. Consequently the pricing functions return an approximate price for instruments featuring cash flows between tree dates. Instruments featuring cash flows only on tree nodes are not affected by this option and return exact (arbitrage-free) prices. When `ConstRate` is 'off', the pricing function finds the cash flow dates for all instruments in the portfolio. If these cash flows do not align exactly with the tree dates, a new tree is generated and used for pricing. This new tree features the same volatility and initial rate specifications of the input tree but contains tree nodes for each date in which at least one instrument in the portfolio has a cash flow. Keep in mind that the number of nodes in a tree grows exponentially with the number of tree dates. Consequently, setting `ConstRate` 'off' dramatically increases the memory and processor demands on the computer.

### **BarrierMethod Field**

When using binomial trees to price barrier options, you may require a large number of tree steps to achieve an accurate result when tree nodes do not align with the barrier

level. With the `BarrierMethod` field, the toolbox provides an enhancement method that improves the accuracy of the results without having to use large trees.

The `BarrierMethod` field can be set to `'unenhanced'` (default) or `'interp'`. If you specify `'unenhanced'`, no correction calculation is used. Otherwise, if you specify `'interp'`, the toolbox provides an enhanced valuation by interpolating between nodes on barrier boundaries.

You specify the barrier method in the last input argument, `Options`, of the functions `barrierbycrr`, `barrierbyeqp`, `barrierbyitt`, `crrprice`, `eqpprice`, `ittprice`, `crrsens`, `eqpsens`, or `ittsens`. `Options` is a structure that you create with the function `derivset`. Using `derivset`, you specify whether to use the enhanced or the unenhanced method.

For more information about this algorithm, see Derman, E., I. Kani, D. Ergener and I. Bardhan, "Enhanced Numerical Methods for Options with Barriers," *Financial Analysts Journal*, (Nov. - Dec. 1995), pp. 65-74.

## Customizing the Structure

Customize the `Options` structure by passing property name/property value pairs to the `derivset` function.

As an example, consider an `Options` structure with `ConstRate` `'off'` and `Diagnostics` `'on'`.

```
Options = derivset('ConstRate', 'off', 'Diagnostics', 'on')
```

```
Options =
```

```
    Diagnostics: 'on'  
    Warnings:   'on'  
    ConstRate:  'off'  
    BarrierMethod: 'unenhanced'
```

To obtain the value of a specific property from the `Options` structure, use `derivget`.

```
CR = derivget(Options, 'ConstRate')
```

```
CR =  
Off
```



---

**Note** Use `derivset` and `derivget` to construct the Options structure. These functions are guaranteed to remain unchanged, while the implementation of the structure itself may be modified in the future.

---

Now observe the effects of setting `ConstRate` 'off'. Obtain the tree dates from the HJM tree.

```
TreeDates = [HJMTree.TimeSpec.ValuationDate;...
HJMTree.TimeSpec.Maturity]
```

```
TreeDates =
```

```
    730486
    730852
    731217
    731582
    731947
```

```
datedisp(TreeDates)
```

```
01-Jan-2000
01-Jan-2001
01-Jan-2002
01-Jan-2003
01-Jan-2004
```

All instruments in `HJMInstSet` settle on January 1, 2000, and all have cash flows once a year, with the exception of the second bond, which features a period of 2. This bond has cash flows twice a year, with every other cash flow consequently falling between tree dates. You can extract this bond from the portfolio to compare how its price differs by setting `ConstRate` to 'on' and 'off'.

```
BondPort = instselect(HJMInstSet, 'Index', 2);
```

```
instdisp(BondPort)
```

```
Index Type CouponRate Settle      Maturity      Period Basis...
1      Bond 0.04           01-Jan-2000 01-Jan-2004  2      NaN...
```

First price the bond with `ConstRate` 'on' (default).

```
format long
[BondPrice, BondPriceTree] = hjmprice(HJMTree, BondPort)
```

```
Warning: Not all cash flows are aligned with the tree. Result will
be approximated.
```

```
BondPrice =
```

```
97.52801411736377
```

```
BondPriceTree =
```

```
FinObj: 'HJMPriceTree'
```

```
PBush: {1x5 cell}
```

```
AIBush: {[0] [1x1x2 double] ... [1x4x2 double] [1x8 double]}
```

```
tObs: [0 1 2 3 4]
```

Now recalculate the price of the bond setting `ConstRate` 'off'.

```
OptionsNoCR = derivset('ConstR', 'off')
```

```
OptionsNoCR =
```

```
Diagnostics: 'off'
```

```
Warnings: 'on'
```

```
ConstRate: 'off'
```

```
[BondPriceNoCR, BondPriceTreeNoCR] = hjmprice(HJMTree,...
```

```
BondPort, OptionsNoCR)
```

```
Warning: Not all cash flows are aligned with the tree. Rebuilding
tree.
```

```
BondPriceNoCR =
```

```
97.53342361674437
```

```
BondPriceTreeNoCR =
```

```
FinObj: 'HJMPriceTree'
```

```
PBush: {1x9 cell}
```

```
AIBush: {1x9 cell}
```

```
tObs: [0 0.5000 1 1.5000 2 2.5000 3 3.5000 4]
```

As indicated in the last warning, because the cash flows of the bond did not align with the tree dates, a new tree was generated for pricing the bond. This pricing method returns more accurate results since it guarantees that the process is arbitrage-free. It also takes longer to calculate and requires more memory. The `tObs` field of the price tree structure indicates the increased memory usage. `BondPriceTree.tObs` has only five elements, while `BondPriceTreeNoCR.tObs` has nine. While this may not seem like a large difference, it has a dramatic effect on the number of states in the last node.

```
size(BondPriceTree.PBush{end})
```

```
ans =
```

1 8

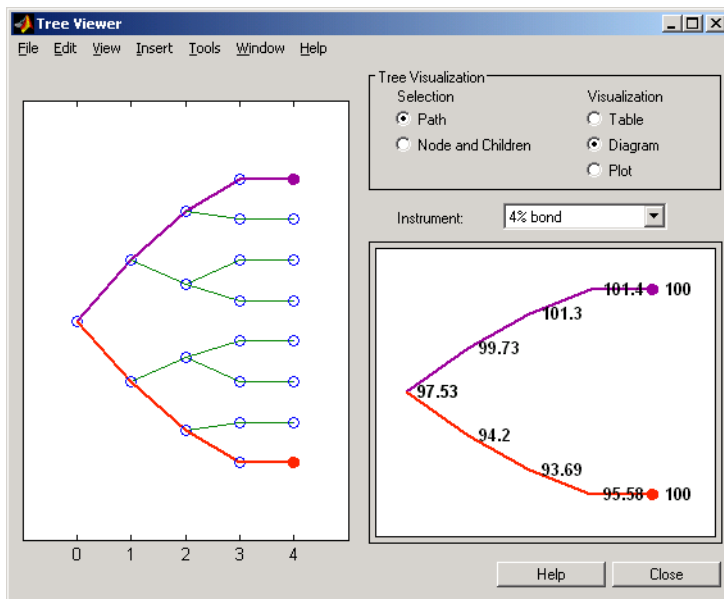
```
size(BondPriceTreeNoCR.PBush{end})
```

ans =

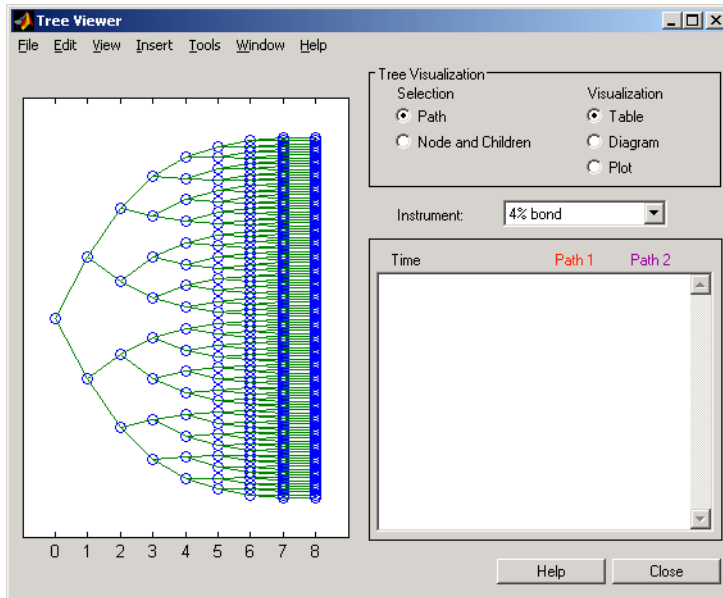
1 128

The differences become more obvious by examining the price trees with `treeviewer`.

```
treeviewer(BondPriceTree, BondPort)
```



```
treeviewer(BondPriceTreeNoCR, BondPort)
```



All = [Delta ./ Price, Gamma ./ Price, Vega ./ Price, Price]

All =

-2.76	10.43	0.00	98.72
-3.56	16.64	-0.00	97.53
-166.18	13235.59	700.96	0.05
-2.76	10.43	0.00	98.72
-0.01	0.03	0	100.55
46.95	1090.63	14.91	6.28
-969.85	173969.77	1926.72	0.05
-76.39	287.00	0.00	3.690

# Bibliography

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- “Black-Derman-Toy (BDT) Modeling” on page C-2
- “Heath-Jarrow-Morton (HJM) Modeling” on page C-3
- “Hull-White (HW) and Black-Karasinski (BK) Modeling” on page C-4
- “Cox-Ross-Rubinstein (CRR) Modeling” on page C-5
- “Implied Trinomial Tree (ITT) Modeling” on page C-6
- “Leisen-Reimer Tree (LR) Modeling” on page C-7
- “Equal Probabilities Tree (EQP) Modeling” on page C-8
- “Closed-Form Solutions Modeling” on page C-9
- “Financial Derivatives” on page C-10
- “Fitting Interest-Rate Curve Functions” on page C-11
- “Interest-Rate Modeling Using Monte Carlo Simulation” on page C-12
- “Bootstrapping a Swap Curve” on page C-13
- “Bond Futures” on page C-14
- “Credit Derivatives” on page C-15

## Black-Derman-Toy (BDT) Modeling

A description of the Black-Derman-Toy interest-rate model can be found in:

Black, Fischer, Emanuel Derman, and William Toy, "A One Factor Model of Interest Rates and its Application to Treasury Bond Options," *Financial Analysts Journal*, January - February 1990.

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Jarrow, Robert A., *Modelling Fixed Income Securities and Interest Rate Options*, McGraw-Hill, 1996, ISBN 0-07-912253-1.

## Hull-White (HW) and Black-Karasinski (BK) Modeling

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## Financial Derivatives

You can find information on the creation of financial derivatives and their role in the marketplace in numerous sources. Among those consulted in the development of Financial Instruments Toolbox software are:

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<b>American option</b>	An option that can be exercised any time until its expiration date. Contrast with <b>European option</b> .
<b>arbitrary cash flow instrument</b>	A set of generic cash flow amounts for which a price needs to be established.
<b>Asian option</b>	An option whose payoff depends upon the average price of the underlying asset over a certain period of time.
<b>asset-or-nothing option</b>	A digital option that pays the value of the underlying security if the option expires in the money.
<b>barrier option</b>	An option that is activated or deactivated only if the price of the underlying asset crosses a barrier. See also <b>knock-in</b> and <b>knock-out</b> . If the option fails to execute, the seller may pay to the purchaser a predetermined <b>rebate</b> .
<b>barrier option</b>	An option that is activated or deactivated only if the price of the underlying asset crosses a barrier. See also <b>knock-in</b> and <b>knock-out</b> . If the option fails to execute, the seller may pay to the purchaser a predetermined <b>rebate</b> .
<b>basis</b>	Day count basis determines how interest accrues over time for various instruments and the amount transferred on interest payment dates. The calculation of accrued interest for dates between payments also uses day count basis. Day count basis is a fraction of <b>Number of interest accrual days / Days in the relevant coupon period</b> . Supported day count conventions and basis values are:

Basis Value	Day Count Convention
0	actual/actual (default) — Number of days in both a period and a year is the actual number of days.
1	30/360 SIA — Year fraction is calculated based on a 360 day year with 30-day months, after applying the following rules: If the first date and the second date are the last day of February, the second date is changed to the 30th. If the

<b>Basis Value</b>	<b>Day Count Convention</b>
	first date falls on the 31st or is the last day of February, it is changed to the 30th. If after the preceding test, the first day is the 30th and the second day is the 31st, then the second day is changed to the 30th.
2	actual/360 — Number of days in a period is equal to the actual number of days, however the number of days in a year is 360.
3	actual/365 — Number of days in a period is equal to the actual number of days, however the number of days in a year is 365 (even in a leap year).
4	30/360 PSA — Number of days in every month is set to 30 (including February). If the start date of the period is either the 31st of a month or the last day of February, the start date is set to the 30th, while if the start date is the 30th of a month and the end date is the 31st, the end date is set to the 30th. The number of days in a year is 360.
5	30/360 ISDA — Number of days in every month is set to 30, except for February where it is the actual number of days. If the start date of the period is the 31st of a month, the start date is set to the 30th while if the start date is the 30th of a month and the end date is the 31st, the end date is set to the 30th. The number of days in a year is 360.
6	30E /360 — Number of days in every month is set to 30 except for February where it is equal to the actual number of days. If the start date or the end date of the period is the 31st of a month, that date is set to the 30th. The number of days in a year is 360.

Basis Value	Day Count Convention
7	actual/365 Japanese — Number of days in a period is equal to the actual number of days, except for leap days (29th February) which are ignored. The number of days in a year is 365 (even in a leap year).
8	actual/actual ICMA — Number of days in both a period and a year is the actual number of days and the compounding frequency is annual.
9	actual/360 ICMA — Number of days in a period is equal to the actual number of days, however the number of days in a year is 360 and the compounding frequency is annual.
10	actual/365 ICMA — Number of days in a period is equal to the actual number of days, however the number of days in a year is 365 (even in a leap year) and the compounding frequency is annual.
11	30/360 ICMA — Number of days in every month is set to 30, except for February where it is equal to the actual number of days. If the start date or the end date of the period is the 31st of a month, that date is set to the 30th. The number of days in a year is 360 and the compounding frequency is annual.
12	actual/365 ISDA — The day count fraction is calculated using the following formula: (Actual number of days in period that fall in a leap year / 366) + (Actual number of days in period that fall in a normal year / 365 ).
13	bus/252 — The number of days in a period is equal to the actual number of business days. The number of business days in a year is 252.

**basket option**

An option that provides a payoff dependent on the value of a portfolio of assets.

<b>beta</b>	The price volatility of a financial instrument relative to the price volatility of a market or index as a whole. Beta is most commonly used with respect to equities. A high-beta instrument is riskier than a low-beta instrument.
<b>binomial model</b>	A method in which the probability over time of each possible price or rate follows a binomial distribution. The basic assumption is that prices or rates can move to only two values (one higher and one lower) over any short time period. See also <b>trinomial model</b> .
<b>Black-Derman-Toy (BDT) model</b>	A model for pricing interest rate derivatives where all security prices and rates depend upon the short rate (annualized one-period interest rate).
<b>bond</b>	A long-term debt security with fixed interest payments and fixed maturity date.
<b>bond option</b>	The right to sell a bond back to the issuer (put) or to redeem a bond from its current owner (call) at a specific price and on a specific date.
<b>bushy tree</b>	A tree of prices or interest rates in which the number of branches increases exponentially relative to observation times; branches never recombine. Opposite of a <b>recombining tree</b> .
<b>call</b>	<ol style="list-style-type: none"><li>1. An option to buy a certain quantity of a stock or commodity for a specified price within a specified time. See also <b>put</b>.</li><li>2. A demand to submit bonds to the issuer for redemption before the maturity date.</li></ol>
<b>call swaption</b>	Allows the option buyer to enter into an interest rate swap in which the buyer of the option pays the fixed rate and receives the floating rate.
<b>callable bond</b>	A bond that allows the issuer to buy back the bond at a predetermined price at specified future dates. The bond contains an embedded call option; that is, the holder has sold a call option to the issuer. See also <b>puttable bond</b> .



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<b>cap</b>	Interest-rate option that guarantees that the rate on a floating-rate loan will not exceed a certain level.
<b>caplet</b>	An interim cap component in a multiperiod interest-rate cap agreement.
<b>cash-or-nothing option</b>	A digital option that pays some fixed amount of cash if the option expires in the money.
<b>compound option</b>	An option on an option, such as a call on a call, a put on a put, a call on a put, or a put on a call.
<b>delta</b>	The rate of change of the price of a derivative security relative to the price of the underlying asset; that is, the first derivative of the curve that relates the price of the derivative to the price of the underlying security.
<b>derivative</b>	A financial instrument that is based on some underlying asset. For example, an option is a derivative instrument based on the right to buy or sell an underlying instrument.
<b>deterministic model</b>	An interest rate model in which the values of the rates in the next time step are determined solely by the values of the rates in the current time step.
<b>digital option</b>	An option whose payout is fixed after the underlying stock exceeds the predetermined threshold or strike price.
<b>discount factor</b>	Coefficient used to compute the present value of future cash flows.
<b>dollar sensitivity</b>	Sensitivity reported as a dollar price change instead of a percentage price change.
<b>down-and-in</b>	A type of <b>barrier option</b> that becomes active if the barrier is reached from above. See also <b>knock-in</b> .
<b>down-and-out</b>	A type of <b>barrier option</b> that becomes deactivated if the barrier is reached from above. See also <b>knock-out</b> .
<b>European option</b>	An option that can be exercised only on its expiration date. Contrast with <b>American option</b> .

<b>ex-dividend date</b>	Date when a declared dividend belongs to the seller rather than the buyer.
<b>exercise price</b>	The price set for buying an asset (call) or selling an asset (put). The strike price.
<b>exotic option</b>	Any nonstandard option. Opposite of <b>vanilla option</b> .
<b>fixed lookback option</b>	Strike price is fixed at purchase. The underlying is priced at its highest or lowest level, depending whether it is a call or put, during the life of the option rather than expiring at market.
<b>fixed-rate note</b>	A long-term debt security with preset interest rate and maturity, by which the interest must be paid. The principal may or may not be paid at maturity.
<b>floating lookback option</b>	Strike price is fixed at maturity. For a call, the price is fixed at the lowest price during the life of the option; for a put it is fixed at the highest price.
<b>floating-rate note</b>	A security similar to a bond, but in which the note's interest rate is reset periodically, relative to a reference index rate, to reflect fluctuations in market interest rates.
<b>floor</b>	Interest-rate option that guarantees that the rate on a floating-rate loan will not fall below a certain level.
<b>floorlet</b>	One of the interim period floors in a multiple period floor agreement.
<b>forward curve</b>	The curve of forward interest rates vs. maturity dates for bonds.
<b>forward rate</b>	The future interest rate of a bond inferred from the term structure, especially from the yield curve of zero-coupon bonds, calculated from the growth factor of an investment in a zero held until maturity.
<b>gamma</b>	The rate of change of delta for a derivative security relative to the price of the underlying asset; that is, the second derivative of the option price relative to the security price.

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<b>gap option</b>	A digital option in which one strike decides if the option is in or out of money and another strike decides the size the size of the payoff.
<b>Heath-Jarrow-Morton (HJM) model</b>	A model of the interest rate term structure that works with a type of interest rate tree called a <b>bushy tree</b> .
<b>hedge</b>	A securities transaction that reduces or offsets the risk on an existing investment position.
<b>instrument set</b>	A collection of financial assets. A portfolio.
<b>inverse discount</b>	A factor by which the present value of an asset is multiplied to find its future value. The reciprocal of the discount factor.
<b>irregular coupon</b>	A bond interest payment for more or less than six-months' interest. The first coupon on many bonds is irregular because payment is other than six months from the dated date.
<b>knock-in</b>	A <b>barrier option</b> that is activated when the price of the underlying asset achieves a designated target. There are two types: <b>up-and-in</b> and <b>down-and-in</b> .
<b>knock-out</b>	A <b>barrier option</b> that is deactivated when the price of the underlying asset achieves a designated target. There are two types: <b>up-and-out</b> and <b>down-and-out</b> .
<b>Lambda</b>	The percentage change in an option price divided by the percentage change in an underlying price.
<b>least-squares method</b>	A mathematical method of determining the best fit of a curve to a series of observations by choosing the curve that minimizes the sum of the squares of all deviations from the curve.
<b>long rate</b>	The yield on a zero-coupon Treasury bond.
<b>lookback option</b>	An option that reduces uncertainties associated with the timing of market entry. Lookback options can be either <b>fixed lookback option</b> and <b>floating lookback option</b> .

<b>mean reversion</b>	The tendency of a variable to return to its mean value after reaching a point of excessive positive or negative valuation relative to the mean.
<b>option</b>	A right to buy or sell specific securities or commodities at a stated price (exercise or strike price) within a specified time. An option is a type of derivative.
<b>per-dollar sensitivity</b>	The dollar <b>sensitivity</b> divided by the corresponding instrument price.
<b>portfolio</b>	A collection of financial assets. Also called an instrument set.
<b>price tree structure</b>	A MATLAB structure that holds all pricing information.
<b>price vector</b>	A vector of instrument prices.
<b>pricing options structure</b>	A MATLAB structure that defines how the price tree is used to find the price of instruments in the portfolio, and how much additional information is displayed in the command window when the pricing function is called.
<b>put</b>	An option to sell a stipulated amount of stock or securities within a specified time and at a fixed exercise price. See also <b>call</b> .
<b>put swaption</b>	Allows the option buyer to enter into an interest rate swap in which the buyer of the option receives the fixed rate and pays the floating rate.
<b>puttable bond</b>	A bond that allows the holder to redeem the bond at a predetermined price at specified future dates. The bond contains an embedded put option; that is, the holder has bought a put option. See also <b>callable bond</b> .
<b>rainbow option</b>	A single option linked to two or more underlying assets. In order for the option to pay off, all the underlying assets must move in the intended direction.
<b>rate specification</b>	A MATLAB structure that holds all information needed to identify completely the evolution of interest rates.

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<b>rebate</b>	A predetermined amount of money paid to the purchaser of a <b>barrier option</b> if the option fails to execute.
<b>recombining tree</b>	A tree of prices or interest rates whose branches recombine over time. Opposite of a <b>bushy tree</b> .
<b>self-financing hedge</b>	A trading strategy whereby the value of a portfolio after rebalancing is equal to its value at any previous time.
<b>sensitivity</b>	The “what if” relationship between variables; the degree to which changes in one variable cause changes in another variable. A specific synonym is volatility. See also <b>dollar sensitivity</b> .
<b>short rate</b>	The annualized one-period interest rate.
<b>sinking fund bond</b>	A sinking fund bond is a coupon bond with a sinking fund provision. This provision obligates the issuer to amortize portions of the principal prior to maturity, affecting bond prices since the time of the principal repayment changes.
<b>spot curve, spot yield curve</b>	See <b>zero curve, zero-coupon yield curve</b> .
<b>spot rate</b>	The current interest rate appropriate for discounting a cash flow of some given maturity.
<b>spread</b>	For options, a combination of call or put options on the same stock with differing exercise prices or maturity dates.
<b>stepped coupon bond</b>	A step-up and step-down bond is a debt security with a predetermined coupon structure over time.
<b>stochastic model</b>	Involving or containing a random variable or variables; involving chance or probability.
<b>strike</b>	Exercise a put or call option.
<b>strike price</b>	See <b>exercise price</b> .
<b>supershare option</b>	A digital option that pays out a proportion of the assets underlying a portfolio if the asset lies between a lower and an upper bound at the expiry of the option.

<b>swap</b>	A contract between two parties to exchange cash flows in the future according to some formula.
<b>swaption</b>	An option on an interest rate swap. It grants the option buyer the right to enter into an interest rate swap at a future date.
<b>time specification</b>	A MATLAB structure that represents the mapping between times and dates for interest rate quoting.
<b>trinomial model</b>	A method in which the basic assumption is that prices or rates can move to one of three possible values over any short time period. At any time step the price or rate direction can be upward, neutral, or downward. See also <b>binomial model</b> .
<b>under-determined system</b>	A set of simultaneous equations in which the number of independent variables exceeds the number of equations in the set, leading to an infinite number of solutions.
<b>up-and-in</b>	A type of <b>barrier option</b> that becomes active if the barrier is reached from below. See also <b>knock-in</b> .
<b>up-and-out</b>	A type of <b>barrier option</b> that becomes deactivated if the barrier is reached from below. See also <b>knock-out</b> .
<b>vanilla option</b>	A common option, such as a put or call. Opposite of <b>exotic option</b> .
<b>vanilla swap</b>	A <b>swap</b> agreement to exchange a fixed rate for a floating rate.
<b>vega</b>	The rate of change in the price of a derivative security relative to the volatility of the underlying security. When vega is large, the security is sensitive to small changes in volatility.
<b>volatility specification</b>	A MATLAB structure that specifies the forward rate volatility process.
<b>yields</b>	The zero coupon rate.
<b>yield curve</b>	The zero curve.

<b>yield volatility</b>	The zero coupon volatilities.
<b>zero curve, zero-coupon yield curve</b>	A yield curve for zero-coupon bonds; zero rates versus maturity dates. Since the maturity and duration (Macaulay duration) are identical for zeros, the zero curve is a pure depiction of supply/demand conditions for loanable funds across a continuum of durations and maturities. Also known as spot curve or spot yield curve.
<b>zero-coupon bond, or zero</b>	A bond that, instead of carrying a coupon, is sold at a discount from its face value, pays no interest during its life, and pays the principal only at maturity.

