Financial Derivatives Toolbox

For Use with MATLAB®

■ Computation

■ Visualization

■ Programming

User's Guide

Version 3

The MathWorks

Financial Derivatives Toolbox User's Guide

Printing History:	June 2000	First printing	New for Version 1 (Release 12)
	September 2001	Second printing	Updated for Version 2 (Release 12.1)
	June 2004	Third printing	Updated for Version 3 (Release 14)

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Getting Started

What is the Financial Derivatives Toolbox?

The Financial Derivatives Toolbox provides components for analyzing individual derivative instruments and portfolios containing several types of interest-rate-based and equity-based financial instruments.

Interest-Rate-Based Derivatives

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

- Bonds
- Bond options (put and call)
- Fixed rate notes
- Floating rate notes
- Caps
- Floors
- Swaps

Additionally, the toolbox provides functions for the creation of *arbitrary cash flow instruments*.

The toolbox provides pricing and sensitivity routines for these instruments. (See “Computing Prices and Sensitivities Using the Interest-Rate Term Structure” on page 2-21 or “Computing Prices and Sensitivities Using Interest-Rate Models” on page 2-43 for information.)

Equity Derivatives

The toolbox also provides functions for the creation and management of various equity derivatives, including

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

The toolbox also provides pricing and sensitivity routines for these instruments. (See “Computing Prices and Sensitivities for Equity Derivatives” on page 3-15.)

Portfolio Creation

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)
```

In a similar manner, `instadd` can create portfolios of other types of investment instruments. The use of `instadd` to create portfolios is described in

- "Interest-Rate-Based Derivatives" on page 1-4
- "Equity Derivatives" on page 1-5
- "Adding Instruments to an Existing Portfolio" on page 1-6

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)
```

Equity Derivatives

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

- Asian instrument

```
InstSet = instasian('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 ...Face
3     Bond 0.04       08-Feb-2000 15-Jan-2003 2      0        100
```

Portfolio Management

The portfolio management capabilities provided by the Financial Derivatives toolbox include

- Constructors for the most common financial instruments. (See "Instrument Constructors" on page 1-8.)
- The ability to create new instruments or to add new fields to existing instruments. (See "Creating New Instruments or Properties" on page 1-9.)
- The ability to search or subset a portfolio. See "Searching or Subsetting a Portfolio" on page 1-11.)

Instrument Constructors

The toolbox provides constructors for the most common financial instruments.

Note 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`

Instrument	Constructor
Lookback option	`instlookback`
Stock option	`instoptstock`
Swap	`instswap`

Each instrument has parameters (fields) that describe the instrument. The toolbox functions enable you to

- 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`, etc. Additionally, each instrument has a field that identifies the investment type (bond, cap, floor, etc.).

In reality the set of parameters for each instrument is not fixed. Users have the ability to add additional parameters. These additional fields will be 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 New Instruments or Properties

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

To create a new kind of instrument with `instaddfield`, you need to specify three arguments: `'Type'`, `'FieldName'`, and `'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 parameter is `'ClassList'`. `'ClassList'` specifies the data types of the contents of each unique field for the new instrument.

Here are the syntaxes to create a new kind of instrument using `instaddfield`.

```
InstSet = instaddfield('FieldName', FieldList, 'Data', DataList,
'Type', TypeString)
```

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

To add new instruments to an existing set, use

```
InstSetNew = instaddfield(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 the Financial Derivatives Toolbox does not directly support this instrument, you must create it using the function `instaddfield`. The parameters used for the creation of the instruments are

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

Enter the data into MATLAB.

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

Finally, create the portfolio with a single instrument.

```
Port = instaddfield('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 15-Jul-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 `instaddfield`. 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 Pricipal
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

The Financial Derivatives Toolbox 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 are categorized by type, and 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 exactly 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 .........           Name      Quantity
1     Bond 0.04       01-Jan-2000  01-Jan-2003  1      NaN.........             4% bond   100

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 three 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 Based Financial Derivatives

Introduction

The Financial Derivatives Toolbox extends the capabilities of the Financial Toolbox in the areas of fixed-income derivatives and of securities contingent upon interest rates. The toolbox provides components for analyzing individual financial derivative instruments and portfolios. Specifically, it provides the necessary functions for calculating prices and sensitivities, for hedging, and for visualizing results.

The chapter discusses the computation of prices and sensitivities using the interest-rate term structure (sets of zero coupon bonds) in the sections

- "Understanding the Interest-Rate Term Structure" on page 2-7
- "Computing Prices and Sensitivities Using the Interest-Rate Term Structure" on page 2-21

Similarly, the chapter discusses the computation of prices and sensitivities using interest-rate models in the sections

- "Understanding the Interest-Rate Term Structure" on page 2-7
- "Computing Prices and Sensitivities Using the Interest-Rate Term Structure" on page 2-21
- "Understanding Interest-Rate Models" on page 2-26
- "Computing Prices and Sensitivities Using Interest-Rate Models" on page 2-43
- "Graphical Representation of Trees" on page 2-54

Financial Instruments

The toolbox provides a set of functions that perform computations upon portfolios containing up to seven types of interest-rate based financial instruments.

Bond. A long-term debt security with preset interest rate and maturity, by which the principal and interest must be paid.

Bond Option. Puts and calls on portfolios of bonds. The toolbox supports three types of put and call options on bonds:

- American option: An option that can be exercised any time until its expiration date.
- European option: An option that can be exercised only on its expiration date.
- Bermuda option: A Bermuda option is somewhat like a hybrid of American and European options. It can be exercised on predetermined dates only, usually once a month.

Fixed Rate Note. 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. In this version of the Financial Derivatives Toolbox, the principal is always paid at maturity.

Floating Rate Note. 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.

Cap. A contract which includes a guarantee that sets the maximum interest rate to be paid by the holder, based upon an otherwise floating interest rate.

Floor. A contract which includes a guarantee setting the minimum interest rate to be received by the holder, based upon an otherwise floating interest rate.

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

Additionally, the toolbox provides functions for the creation and pricing of *arbitrary cash flow instruments* based upon zero coupon bonds or upon the BDT or HJM models.

Interest-Rate Modeling

The Financial Derivatives Toolbox computes prices and sensitivities of interest-rate contingent claims based upon three methods of modeling changes in interest rates over time:

- The interest-rate term structure (sets of zero coupon bonds)
- The Heath-Jarrow-Morton (HJM) model of the interest-rate term structure. This 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 upon a statistical process.

- The Black-Derman-Toy (BDT) model for pricing interest-rate derivatives. In the BDT model all security prices and rates depend upon the short rate (annualized one-period interest rate). The model uses long rates and their volatilities to construct a tree of possible future short rates. It then determines the value of interest-rate sensitive securities from this tree.

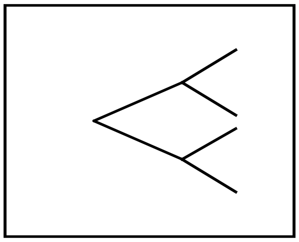
For detailed information, see

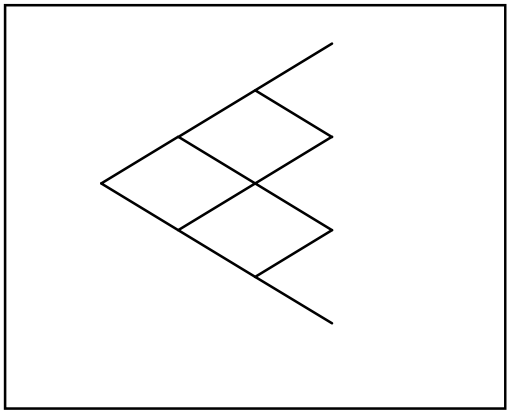
- "Computing Prices and Sensitivities Using the Interest-Rate Term Structure" on page 2-21 for a discussion of price and sensitivity based upon portfolios of zero coupon bonds.
- "Computing Prices and Sensitivities Using Interest-Rate Models" on page 2-43 for a discussion of price and sensitivity based upon the HJM and BDT interest-rate models.

Trees

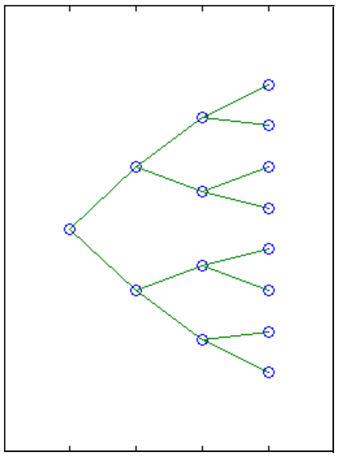
The Heath-Jarrow-Morton model works with a type of interest rate tree called a *bushy tree*. A bushy tree is a tree in which the number of branches increases exponentially relative to observation times; branches never recombine.

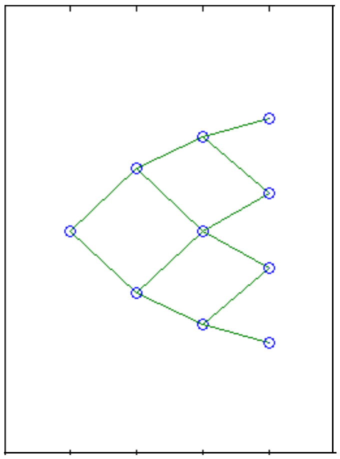
The Black-Derman-Toy model, on the other hand, works with a *recombining tree*. A recombining tree is the opposite of a bushy tree. A recombining tree has branches that recombine over time. From any given node, the node reached by taking the path up-down is the same node reached by taking the path down-up. A bushy and a recombining tree are illustrated below.


Bushy Tree


Recombining Tree

This toolbox provides the data file `deriv.mat` that contains two interest-rate based trees, `HJMTree`, a bushy tree, and `BDTTree`, a recombining tree. 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)

Hedging

The Financial Derivatives Toolbox also includes hedging functionality, allowing the rebalancing of portfolios to reach target costs or target sensitivities, which may be set to zero for a neutral-sensitivity portfolio. Optionally, the rebalancing process can be self-financing or directed by a set of user-supplied constraints. For information, see

- "Hedging" on page 4-2 for a discussion of the hedging process.
- "hedgeopt" on page 5-109 for a description of the function that allocates an optimal hedge.
- "hedgeslf" on page 5-112 for a description of the function that allocates a self-financing hedge.

Understanding the Interest-Rate Term Structure

The *interest-rate term structure* is the representation of the evolution of interest rates through time. In MATLAB, the interest-rate environment is encapsulated in a structure called `RateSpec` (*rate specification*). This structure holds all information needed to identify completely the evolution of interest rates. Several functions included in the Financial Derivatives Toolbox are dedicated to the creation and management 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 rates and interest rates. The third function, `ratetimes`, calculates the effect of term changes on the interest rates.

The topics pertaining to the interest-rate term structure covered in this section include

- "Interest Rates vs. Discount Factors" on page 2-7
- "Interest-Rate Term Conversions" on page 2-12
- "Functions that Model the Interest-Rate Term Structure" on page 2-16

Interest Rates vs. Discount Factors

Discount factors are coefficients commonly used to find the present 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 above rates table 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 zeros. Also, since the value of `Compounding` is 2, the rates are compounded semiannually, which sets the units of periodic discount to six months. The vector `EndDates` is composed of dates separated by intervals of six months from the valuation date. This explains why the `EndTimes` vector is a progression of integers from one to five.

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 zero, 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 times-based calling syntax is

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

Using this syntax, we 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 earlier.

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 similar to the one above. 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 function `rate2times` can provide the additional output arguments `StartTimes` and `EndTimes`, which represent the time factor equivalents to the `StartDates` and `EndDates` vectors. The `ratetimes` fuction 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 six-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
```

Functions that Model the Interest-Rate Term Structure

The Financial Derivatives Toolbox 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

- "Creation or Modification (intenvset)" on page 2-16 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 2-18 for a discussion of how to extract specific properties from a `RateSpec`.

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

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

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.

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

Obtaining Specific Properties (intenvget)

The complementary function to intenvset is intenvget. This function obtains specific properties from the interest-rate term structure. The syntax of this function 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`.

Note Although you can directly access these fields within the structure instead of using `intenvget`, we strongly advise against this. 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 upon 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 six months is represented with a value of

0.5, and a period of one 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 zero. On the other hand, the values in the `EndDates` vector are dates separated by six-month periods. Since the redefined value of compounding is 1, `EndTimes` becomes a sequence of numbers separated by increments of 0.5.

Computing Prices and Sensitivities Using the Interest-Rate Term Structure

The Financial Derivatives Toolbox contains a family of functions that finds the price and sensitivities of several financial instruments based on interest-rate curves. For information, see

- "Computing Instrument Prices" on page 2-22 for a discussion on using the `intenvprice` function to price a portfolio of instruments based on a set of zero curves.
- "Computing Instrument Sensitivities" on page 2-24 for a discussion on computing delta and gamma sensitivities with the `intenvsens` function.

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

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-rates 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.

The Financial Derivatives Toolbox additionally 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 additionally support computations involving options and interest-rate floors and caps. See "Computing Prices and Sensitivities Using Interest-Rate Models" on page 2-43 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

`bondbyzero`:	Price bond by a set of zero curves
`fixedbyzero`:	Price fixed rate note by a set of zero curves
`floatbyzero`:	Price floating rate note by a set of zero curves
`swapbyzero`:	Price swap by a set of zero curves

Each of these functions can be used individually to price an instrument. Consult the reference pages for specific information on the use of 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`. To learn more about `instadd` and the interest rate term structure, see Chapter 1, "Getting Started."

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 the Financial Derivatives Toolbox.

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, sensitivities can be computed 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 as well as 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
```

Understanding Interest-Rate Models

The Financial Derivatives Toolbox supports both the Heath-Jarrow-Morton (HJM) and Black-Derman-Toy (BDT) 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 upon 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.

Building an Interest-Rate Tree

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 the Financial Derivatives Toolbox.

The MATLAB functions that create rate trees are `hjmtree` and `bdttree`. `hjmtree` 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 2-28.)
- The interest-rate term structure `RateSpec`. (See "Specifying the Interest-Rate Term Structure (RateSpec)" on page 2-30.)

- The tree time layout `TimeSpec`. (See "Specifying the Time Structure (TimeSpec)" on page 2-32.)

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 2-54 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. `VolSpec` is created 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

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

  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. This structure is created with the function `intenvset`. (See "Functions that Model the Interest-Rate Term Structure" on page 2-16.)

- TimeSpec is the tree time layout specification. This variable is created 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 three) volatility models while BDT supports only a single volatility factor, the hjmvolspec and bdtvolspec functions require somewhat different inputs and generate slightly different outputs. For examples see "Creating a HJM Volatility Model" on page 2-28. For BDT examples see "Creating a BDT Volatility Model" on page 2-29.

Creating a 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 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 σ. 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 three 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 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. The section “Functions that Model the Interest-Rate Term Structure” on page 2-16 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 example

```
Compounding = 1;
Rates = [0.02; 0.02; 0.02; 0.02];
StartDates = ['01-Jan-2000';
              '01-Jan-2001';
              '01-Jan-2002';
              '01-Jan-2003'];
EndDates =   ['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` functions. 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 example

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

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

Note that the maturities specified when building `TimeSpec` do not have to 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 found in `TimeSpec`.

Creating a BDT Time Specification. Consider the example

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

BDTTimeSpec =

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

Examples of Tree Creation

Use the `VolSpec`, `RateSpec`, and `TimeSpec` you have previously created as inputs to the functions used to create HJM and a 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(BDTVolSpec, 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, the Financial Derivatives Toolbox uses trees to represent forward rates, prices, etc. At the highest level, these trees have structures wrapped around them. The structures encapsulate information needed 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

BDTInstSet            1x1           22708  struct array
BDTTree               1x1            5522  struct array
CRRInstSet            1x1           12434  struct array
CRRTree               1x1            5058  struct array
EQPInstSet            1x1           12434  struct array
EQPTree               1x1            5058  struct array
HJMInstSet            1x1           22700  struct array
HJMTree               1x1            6318  struct array
ZeroInstSet           1x1           14442  struct array
ZeroRateSpec          1x1            1580  struct array
```

HJM Tree Structure

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

```
HJMTree

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]}
```

`FwdTree` contains the actual forward rate tree. It is represented in MATLAB 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 of these 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 The Financial Derivatives Toolbox uses *inverse discount* notation for forward rates in the tree. An inverse discount represents a factor by which the present 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, `tObs = 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 the Financial Derivatives Toolbox, 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 2 3]
        TFwd: {[4x1 double]  [3x1 double]  [2x1 double]  [3]}
      CFlowT: {[4x1 double]  [3x1 double]  [2x1 double]  [4]}
     FwdTree: {1x4 cell}
```

FwdTree contains the actual rate tree. It is represented in MATLAB 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 of these are VolSpec, TimeSpec, and RateSpec, which contain the volatility, rate structure, and time 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.

```
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(BDTTree.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.

Computing Prices and Sensitivities Using Interest-Rate Models

This section explains how to use the Financial Derivatives Toolbox to compute prices and sensitivities of several financial instruments. For information, see

- "Computing Instrument Prices" on page 2-43 for a discussion of using the pricing functions to compute prices for a portfolio of instruments.
- "Computing Instrument Sensitivities" on page 2-51 for a discussion of using the sensitivity functions to compute delta, gamma, and vega portfolio sensitivities.

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
- Arbitrary cash flows
- Fixed-rate notes
- Floating-rate notes
- Caps
- Floors
- Swaps

For example, the syntax for calling `hjmprice` is

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

Similarly, the calling syntax for `bdtprice` is

```
[Price, PriceTree] = bdtprice(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 "Derivatives Pricing Options" on page A-1 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 an Interest-Rate Tree” on page 2-26 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. “Getting Started” on page 1-1 explains how to create this variable.

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 A-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, and swapbyhjm. A similarly named set of functions exists for BDT models. For a list of these, see “Price and Sensitivity from Black-Derman-Toy Trees” on page 5-3.

You can also use these functions directly to calculate the price of sets of instruments of the same type. See the documentation for these individual functions for further information.

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

BDTInstSet          1x1           22708  struct array
```

```
  BDTTree           1x1           5522  struct array
  CRRInstSet        1x1          12434  struct array
  CRRTree           1x1           5058  struct array
  EQPInstSet        1x1          12434  struct array
  EQPTree           1x1           5058  struct array
  HJMInstSet        1x1          22700  struct array
  HJMTree           1x1           6318  struct array
  ZeroInstSet       1x1          14442  struct array
  ZeroRateSpec      1x1           1580  struct array
```

`HJMTree` and `HJMInstSet` are the input arguments needed 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 ......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
```

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

BDTInstSet            1x1          22708  struct array
BDTTree               1x1           5522  struct array
CRRInstSet            1x1          12434  struct array
CRRTree               1x1           5058  struct array
EQPInstSet            1x1          12434  struct array
EQPTree               1x1           5058  struct array
HJMInstSet            1x1          22700  struct array
HJMTree               1x1           6318  struct array
ZeroInstSet           1x1          14442  struct array
```

```
  ZeroRateSpec       1x1           1580  struct array
```

BDTTree and BDTInstSet are the input arguments needed 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 .........            Name      Quantity
1     Bond 0.1        01-Jan-2000  01-Jan-2003  1      NaN.........               10% bond  100
2     Bond 0.1        01-Jan-2000  01-Jan-2004  2      NaN.........               10% bond  50

Index Type    UnderInd OptSpec Strike ExerciseDates  AmericanOpt Name        Quantity
3     OptBond 1        call    9501   Jan-2002       NaN         Option 95   -50

Index Type  CouponRate Settle      Maturity       FixedReset Basis Principal Name      Quantity
4     Fixed 0.10       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
    100.6054
      1.4863
      0.0245
      7.3032
```

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, e.g.,

```
[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 actually 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(BDTTree, BDTInstSet)

PriceTree.PTree{1}

ans =
    95.5030
    93.9079
     1.7657
    95.5030
   100.6054
     1.4863
     0.0245
     7.3032
```

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

BDT Sensitivities Example

For BDT sensitivities, use the calling syntax

```
[Delta, Gamma, Vega, Price] = bdtsens(BDTTree, 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
```

```
        0.04         2.08        1.40       100.61
       78.38       748.98       13.54         1.49
       -4.36       382.06        2.50         0.02
     -254.11       864.19       -1.40         7.30
```

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
        0.00         0.02        0.01       100.61
       52.73       503.92        9.11         1.49
     -177.89     15577.42      101.87         0.02
      -34.79       118.33       -0.19         7.30
```

Graphical Representation of 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. To get started with this process, first load the data file `deriv.mat` included in this toolbox.

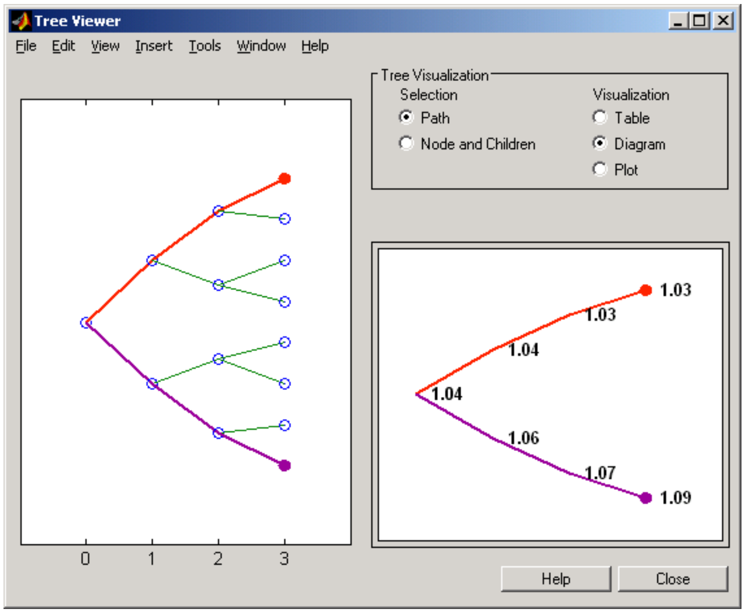
```
load deriv.mat
```

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).

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 `treeviewer` representation of all the rates along both the up and down branches of `HJMTree`.

```
treeviewer(HJMTree)
```

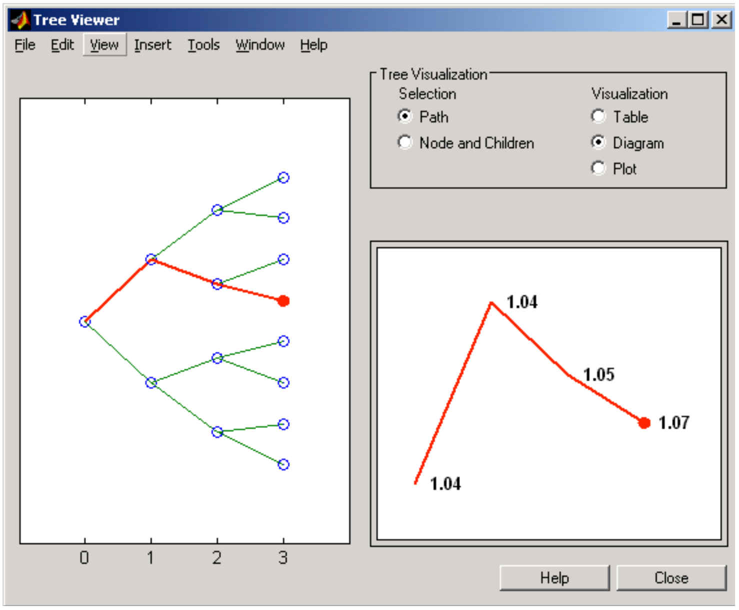


Tree Visualization: Selection [✓ Path] Node and Children; Visualization Table [✓ Diagram] Plot

A previous example 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
```

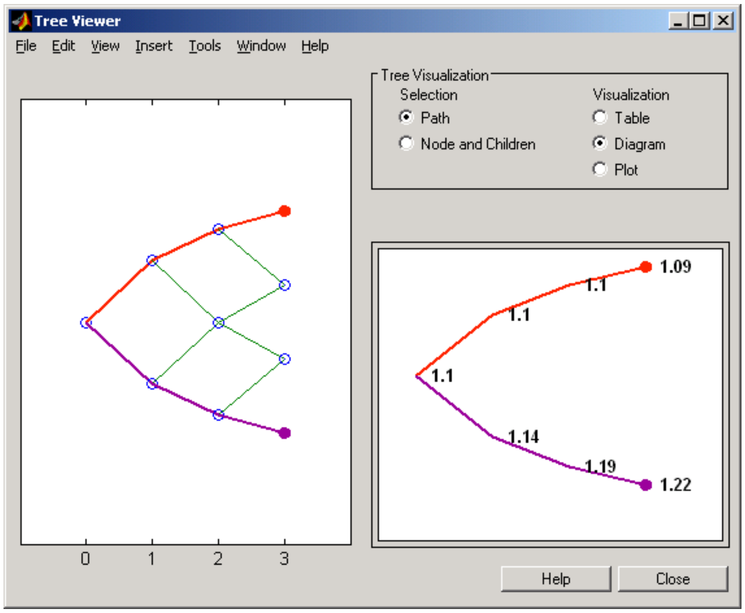
With the treeviewer function you can display the identical information by clicking along the same sequence of nodes, as shown next.



Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot

Next is a `treeviewer` representation of interest rates along several branches of `BDTTree`.

```
treeviewer(BDTTree)
```



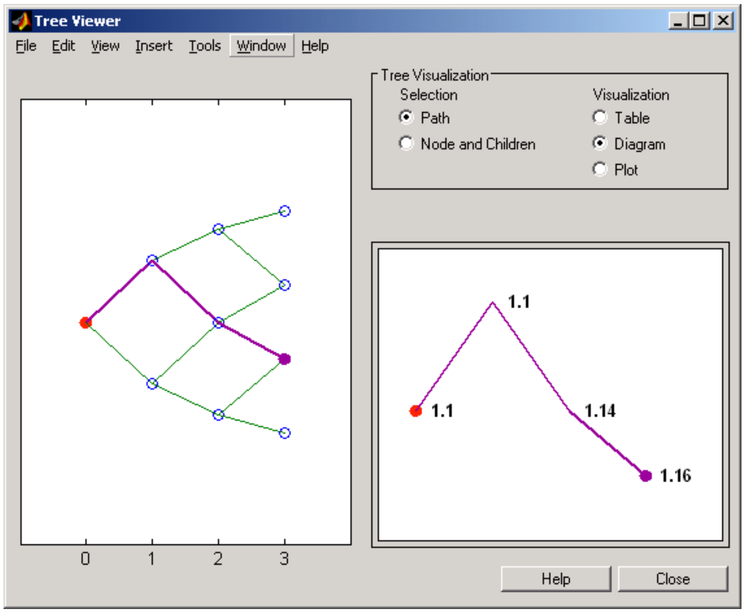
Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot

Note When using `treeviewer` with BDT trees, you must click on each node in succession from the beginning to the end. Because BDT trees can recombine, `treeviewer` is unable to complete the path automatically.

A previous example 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.



Tree Visualization

Selection: [✓ Path] Node and Children

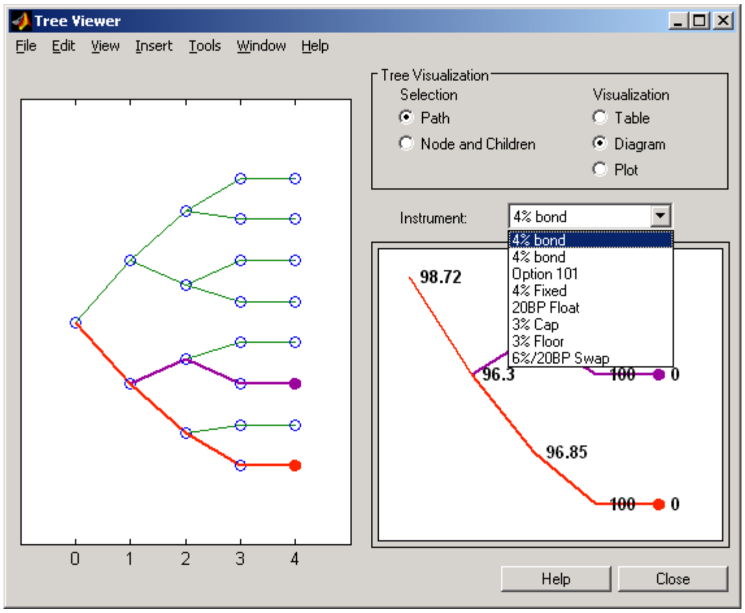
Visualization: Table [✓ Diagram] Plot

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.



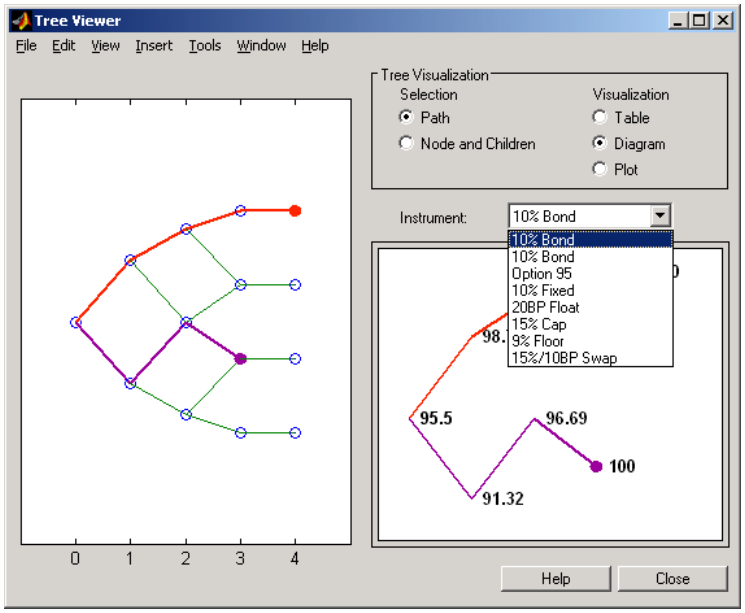
Tree Visualization
Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot

Instrument: 4% bond

- 4% bond
- 4% bond
- Option 101
- 4% Fixed
- 20BP Float
- 3% Cap
- 3% Floor
- 6%/20BP Swap

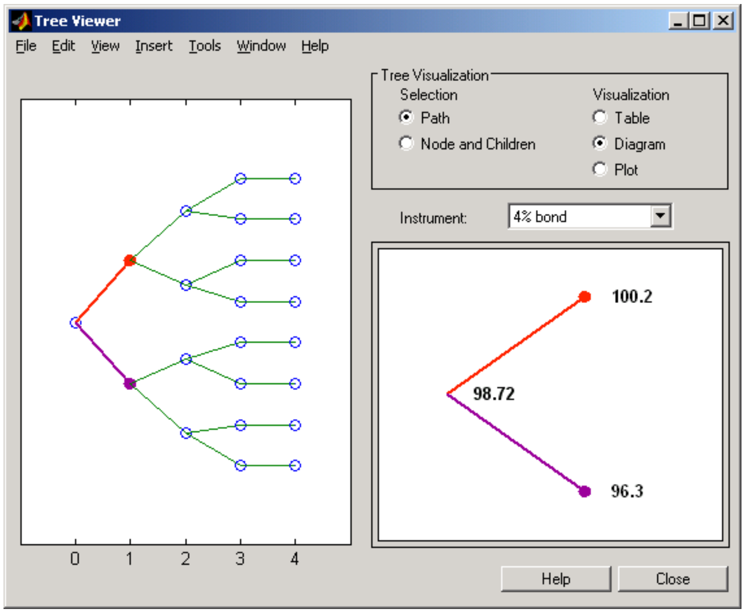
You can use an analogous process to view instrument prices based upon the BDT interest rate tree included in `deriv.mat`.

```
load deriv.mat
[BDTPrice, BDTPriceTree] = bdtprice(BDTTree, 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.



Tree Visualization

Selection: [✓ Path] Node and Children

Visualization: Table [✓ Diagram] Plot

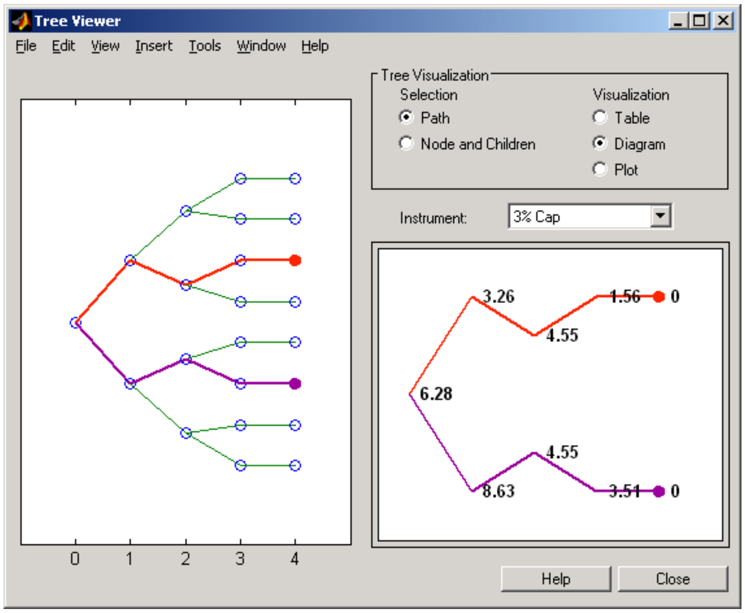
Instrument: 4% bond

100.2

98.72

96.3

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.



Tree Visualization — Selection: [✓ Path] Node and Children; Visualization: Table [✓ Diagram] Plot

Instrument: 3% Cap

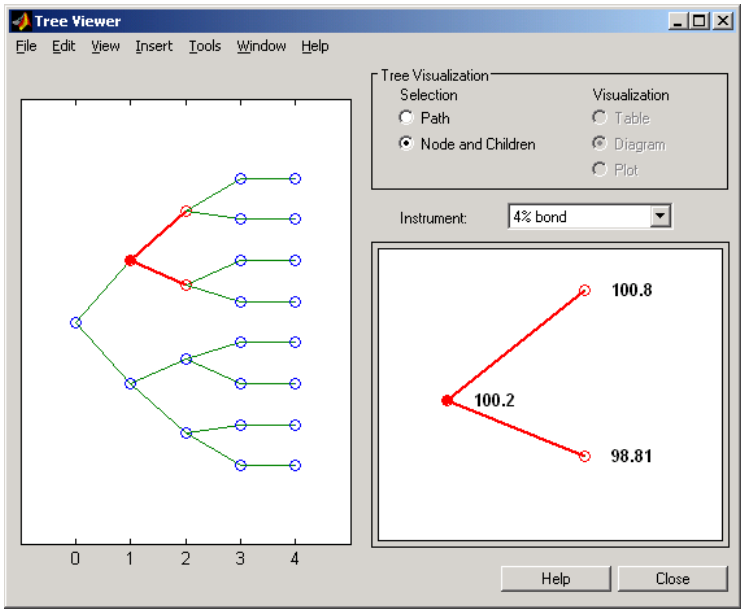
Additional Observation Times

The second node represents the first rate observation time, `tObs = 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.



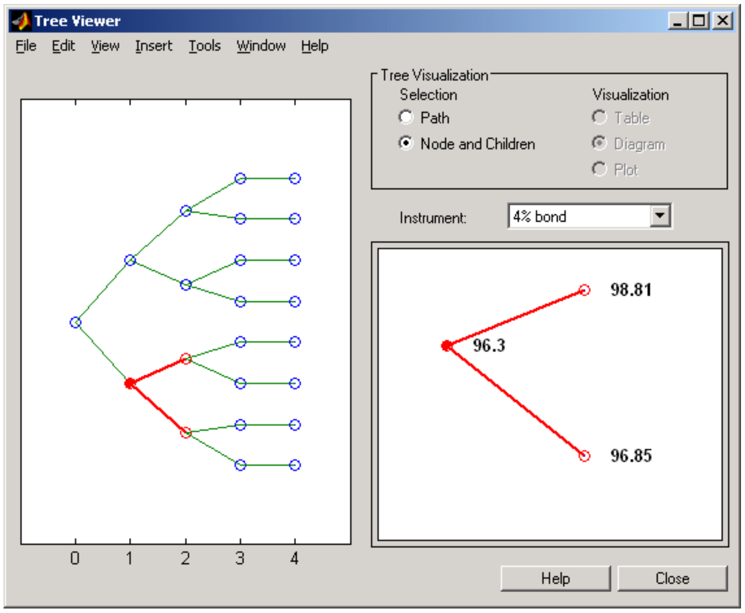
Tree Visualization Selection: Node and Children; Visualization: Diagram

Instrument: 4% bond

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.



Tree Visualization

Selection: Path [✓ Node and Children]

Visualization: Table [✓ Diagram] Plot

Instrument: 4% bond

Equity Derivatives

Understanding Equity Binary Trees

The Financial Derivatives Toolbox supports two types of recombining tree models to represent the evolution of stock prices: the Cox-Ross-Rubinstein (CRR) model and the Equal Probabilities (EQP) model. For a discussion of recombining trees, see "Trees" on page 2-4.

The CRR and EQP models are examples of discrete time models. A discrete time model divides time into discrete bits, and prices can be computed at these specific times only.

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 a large number of 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, e.g., 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.

This section

- Describes how to build equity binary trees ("Building Equity Binary Trees" on page 3-2)
- Provides examples of equity tree creation ("Examples of Equity Tree Creation" on page 3-6)
- Uses the provided file `deriv.mat` to show how to examine trees ("Examining Trees" on page 3-7)
- Explains the difference between the CRR and EQP tree structures ("Differences Between CRR and EQP Tree Structures" on page 3-10)

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 `crrtree` and `eqptree` create CRR trees and EQP trees respectively. The functions create an output tree structure along with information about the parameters used for creating the tree.

Both the functions `crrtree` and `eqptree` 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

The calling syntax for `crrtree` is

```
CRRTree = crrtree (StockSpec, RateSpec, TimeSpec)
```

Similarly, the calling syntax for `eqptree` is

```
EQPTree = eqptree (StockSpec, RateSpec, TimeSpec)
```

Both functions require the structures `StockSpec`, `RateSpec`, and `TimeSpec` as input arguments:

- `StockSpec` is a structure that specifies parameters of the stock whose price evolution will be 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 `crrtimespec` and `eqptimespec`. 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

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 upon 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 upon 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 upon the nature of `DividendType`. For `DividendType 'cash'` or `'constant'`, `ExDividendDates` is vector of dividend dates. For `DividendType 'continuous'`, `ExDividendDates` is ignored.

Stock Structure Example

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

The structure `RateSpec` defines the interest rate environment used when building the stock price binary tree. The section "Functions that Model the Interest-Rate Term Structure" on page 2-16 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

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)
```

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, e.g., `NumPeriods = 10` implies ten time steps and 11 tree levels (0, 1, 2, ..., 9, 10).

TimeSpec Example

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 needed to meet the time distribution of the tree.

Examples of Equity Tree Creation

You can now use the `StockSpec` and `TimeSpec` structures described previously to build an equal probability tree (`EQPTree`) and a CRR tree (`CRRTree`). First, you need to 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]
```

Examining Trees

The Financial Derivatives Toolbox uses 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 needed to interpret the information contained in the tree.

To examine a tree, load the data in the MAT-file `deriv.mat` into the MATLAB workspace.

```
load deriv
```

Display the list of variables loaded from the MAT-file with the `whos` command.

```
Name                  Size                       Bytes  Class

  BDTInstSet          1x1                        15956  struct array
  BDTTree             1x1                         5138  struct array
  CRRInstSet          1x1                        12450  struct array
  CRRTree             1x1                         5058  struct array
  EQPInstSet          1x1                        12450  struct array
  EQPTree             1x1                         5058  struct array
  HJMInstSet          1x1                        15948  struct array
  HJMTree             1x1                         5838  struct array
  ZeroInstSet         1x1                        10282  struct array
  ZeroRateSpec        1x1                         1580  struct array
```

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

```
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 four 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 one day. This means that all values in `tObs` that correspond to a given day between 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 one 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 top-most element of the third level of the tree, and `CRRTree.STree{3}(end)` represents the bottom element of the same level of the tree.

Isolating a Specific Node

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

```
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.

Differences Between CRR and EQP Tree Structures

In essence, the structures representing CRR trees and EQP trees are similar. If you create an EQP tree and a CRR 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.

Understanding Equity Exotic Options

The Financial Derivatives Toolbox supports five types of equity exotic options:

- Asian
- Barrier
- Compound
- Lookback
- Stock options (Bermuda put and call schedule).

Support for all of these equity exotic option types additionally includes American and European puts and calls. Here is a brief description of the various option types.

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 options types, each with its own characteristic payoff formula:

- Fixed call:$(0, S_{av} - X)$
- Fixed put: $max(0, X - S_{av})$
- Floating call: $max(0, S - S_{av})$
- Floating put: $max(0, S_{av} - S)$

where

S_{av} is the average 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 asian options),

S_{av} can be defined using either a geometric or an arithmetic average.

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.

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 is allowed to pay the first strike price and receive 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.

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.

The Financial Derivatives Toolbox 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).

Bermuda Put and Call Schedule

A Bermuda option is somewhat like a hybrid of American and European options. It can be exercised on predetermined dates only, usually once a month. In the Financial Derivatives Toolbox, the relevant information for a Bermuda option is indicated in two input matrices:

`Strike`: contains the strike price values for the option.

`ExcerciseDates`: contains the schedule when the option can be exercised.

Computing Prices and Sensitivities for Equity Derivatives

This section explains how to use the Financial Derivatives Toolbox to compute prices and sensitivities of vanilla options and several types of equity exotic options, based on binary trees. For information see

- "Computing Instrument Prices" on page 3-15 for a discussion of using the pricing functions to compute prices for a portfolio of equity options.
- "Computing Instrument Sensitivities" on page 3-22 for a discussion of using the sensitivity functions to compute delta, gamma, and vega sensitivities for a portfolio of equity options.

Computing Instrument Prices

The portfolio pricing functions `crrprice` and `eqpprice` calculate the price of any set of supported instruments based on a binary equity price tree. These functions are capable of pricing these instrument types:

- Vanilla stock options
  - America 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)
```

Similarly, the syntax for `eqpprice` is

```
[Price, PriceTree] = eqpprice(EQPTree, InstSet, Options)
```

Both 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. See "Building Equity Binary Trees" on page 3-2 to learn how to create these structures.

InstSet is a structure that represents the set of instruments to be priced independently using the model. Chapter 1 "Getting Started" explains how to create this variable.

Optional Argument

You can enter a third optional argument, Options, used when pricing barrier options. See Appendix A, "Derivatives Pricing Options", for more specific information.

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 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

BDTInstSet            1x1                        15956  struct array
BDTTree               1x1                         5138  struct array
CRRInstSet            1x1                        12450  struct array
CRRTree               1x1                         5058  struct array
EQPInstSet            1x1                        12450  struct array
EQPTree               1x1                         5058  struct array
HJMInstSet            1x1                        15948  struct array
```

```
  HJMTree            1x1                       5838  struct array
  ZeroInstSet        1x1                      10282  struct array
  ZeroRateSpec       1x1                       1580  struct array
```

`CRRTree` and `CRRInstSet` are the input arguments you need to call the function `crrprice`.

Use the command `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 ....COptSpec CStrike CSettle       CExerciseDates CAmericanOpt Name      Quantity
4     Compound call     ....put      5       01-Jan-2003    01-Jan-2005    1            Compound1 3

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

  BDTInstSet             1x1                     15956  struct array
  BDTTree                1x1                      5138  struct array
  CRRInstSet             1x1                     12450  struct array
  CRRTree                1x1                      5058  struct array
  EQPInstSet             1x1                     12450  struct array
  EQPTree                1x1                      5058  struct array
  HJMInstSet             1x1                     15948  struct array
  HJMTree                1x1                      5838  struct array
  ZeroInstSet            1x1                     10282  struct array
  ZeroRateSpec           1x1                      1580  struct array
```

`EQPTree` and `EQPInstSet` are the input arguments you need 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 ....COptSpec CStrike CSettle        CExerciseDates CAmericanOpt Name      Quantity
4     Compound call     ....put      5       01-Jan-2003    01-Jan-2005    1            Compound1 3

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
```

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`).

Price Tree Output

If you call a pricing function with two output arguments, e.g.,

```
[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 =

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 `eqptree` also returns a price tree that you can examine in exactly the same way.

Prices for Lookback and Asian Options

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
```

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` and `eqpsens` 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).

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 A, "Derivatives Pricing Options" 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` and `eqpprice`. For the other options (stock option, barrier, and compound), delta and gamma are computed from the CRR and EQP 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
```

Graphical Representation of CRR and EQP 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 and EQP trees are equivalent to those of Black-Derman-Toy (BDT) trees, given that they are all binary recombining trees. See “Graphical Representation of Trees” on page 2-54 for an overview on the use of `treeviewer` with CRR trees, EQP trees, and their corresponding option price trees. Follow the instructions for BDT trees.

Hedging Portfolios

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 very expensive. Therefore, traders and portfolio managers must carefully assess the cost needed to achieve a particular portfolio sensitivity (e.g., maintaining delta, gamma, and vega neutrality). Thus, the hedging problem involves the fundamental tradeoff between portfolio insurance and the cost of such insurance coverage.

The major topics covered in this chapter include

- "Hedging Functions" on page 4-3
- "Specifying Constraints with ConSet" on page 4-15
- "Hedging with Constrained Portfolios" on page 4-20

Hedging Functions

The Financial Derivatives Toolbox 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 (i.e., 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` or `eqpsens` 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 2-24. Likewise, for examples showing the computation of sensitivities for equity exotic options, see "Computing Instrument Sensitivities" on page 3-22.

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

and extract the current portfolio holdings.

```
Holdings = instget(HJMInstSet, '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
```

Our 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 upon the previous example, 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 above example 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 zeros and call `hedgeopt` again.

```
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 needed 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 above examples 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 simply 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 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')
```

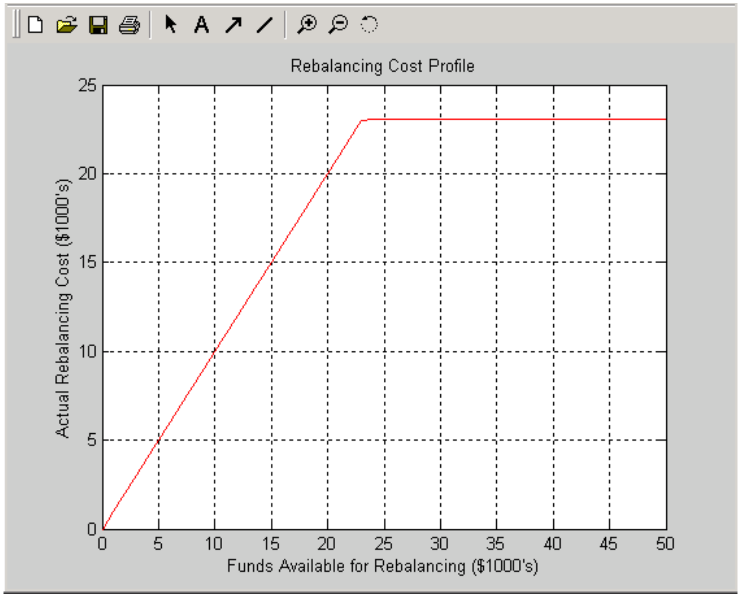


Figure 4-1: Rebalancing Cost Profile

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)
```

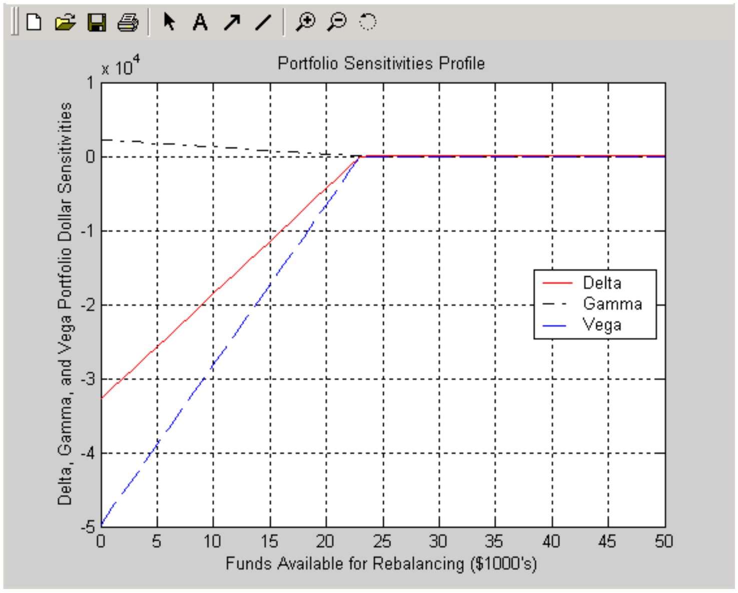


Figure 4-2: Funds Available for Rebalancing

Self-Financing Hedges with hedgeslf

Figure 4-1 and Figure 4-2 indicate that there is no benefit to be gained 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 our 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)
```

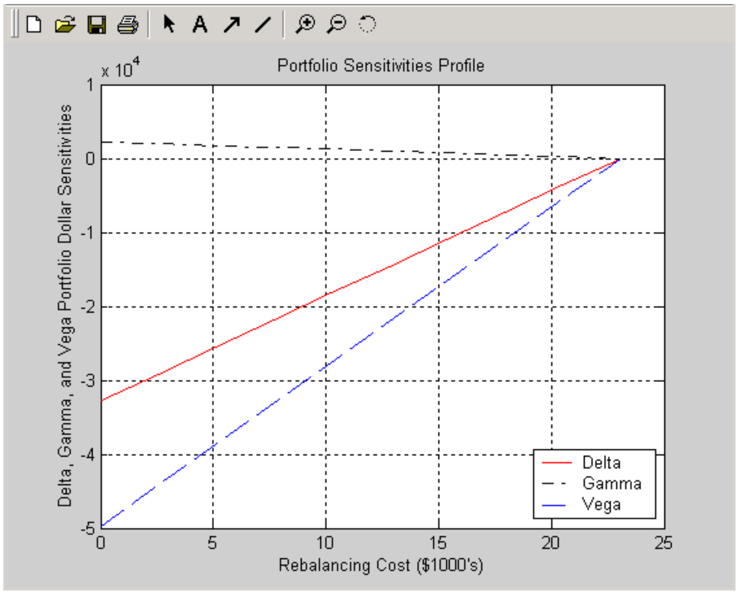


Figure 4-3: Rebalancing Cost

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 upon 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 4-20 for additional information.

Specifying Constraints with ConSet

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 quite brief. For additional information regarding portfolio constraint specifications, refer to the section "Analyzing Portfolios" found in the Financial Toolbox documentation.

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 zero). 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 below 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 needed 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 the 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
```

hedgeslf 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, invoke 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 Figure 4-3, Rebalancing Cost, on page 4-14.

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

Both hedging functions cast the optimization as a constrained linear least squares problem. (See the function `lsqlin` in the Optimization Toolbox for details.) In particular, `lsqlin` attempts to minimize the constrained linear least squares problem

$$\min_{x} \frac{1}{2}\|Cx-d\|_2^2 \qquad \text{such that} \qquad \begin{array}{l} A \cdot x \le b \\ Aeq \cdot x = beq \\ lb \le x \le ub \end{array}$$

where C, A, and Aeq are matrices, and d, b, beq, lb, and ub are vectors. For the Financial Derivatives Toolbox, x is a vector of asset holdings (contracts).

This section provides some examples of setting constraints and discusses how to recognize situations when the least squares problem is improperly constrained:

- "Example: Fully Hedged Portfolio" on page 4-20
- "Example: Minimize Portfolio Sensitivities" on page 4-22
- "Example: Under-Determined System" on page 4-24
- "Example: Portfolio Constraints with hedgeslf" on page 4-25

Depending upon the constraints 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 fully-hedged portfolio example 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 requirements 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, e.g., `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` (e.g., `[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 we 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 Figure 4-1, Figure 4-2, and Figure 4-3.

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 the 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 hedgeopt 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 `hedgeslf` enforces the upper bound on the fourth instrument, and the portfolio continues to be fully hedged and self-financing.

Function Reference

Functions - Categorical List

This chapter provides detailed descriptions of the functions in the Financial Derivatives Toolbox. The categories of functions described are

- “Portfolio Hedge Allocation”
- “Price and Sensitivity from the Interest-Rate Term Structure”
- “Price and Sensitivity from Heath-Jarrow-Morton Trees”
- “Price and Sensitivity from Black-Derman-Toy Trees”
- “Price and Sensitivity from Cox-Ross-Rubinstein Trees”
- “Price and Sensitivity from Equal Probabilities Binomial Trees”
- “Heath-Jarrow-Morton Utilities”
- “Black-Derman-Toy Utilities”
- “Cox-Ross-Rubinstein Utilities”
- “Equal Probabilities Tree Utilities”
- “Heath-Jarrow-Morton Bushy Tree Manipulation”
- “Recombining Tree Manipulation”
- “Derivatives Pricing Options”
- “Instrument Portfolio Handling”
- “Financial Object Structures”
- “Interest Term Structure”
- “Date Function”
- “Graphical Display Function”

Portfolio Hedge Allocation

`hedgeslf`	Self-financing hedge
`hedgeopt`	Allocate optimal hedge for target costs or sensitivities

Price and Sensitivity from the Interest-Rate Term Structure

`bondbyzero`	Price bond by a set of zero curves
`cfbyzero`	Price cash flows by a set of zero curves
`fixedbyzero`	Price fixed-rate note by a set of zero curves
`floatbyzero`	Price floating-rate note by a set of zero curves
`intenvprice`	Price instruments by a set of zero curves
`intenvsens`	Instrument prices and sensitivities by a set of zero curves
`swapbyzero`	Price swap instrument by a set of zero curves

Price and Sensitivity from Heath-Jarrow-Morton Trees

`hjmprice`	Instrument prices from an HJM interest-rate tree
`hjmsens`	Instrument prices and sensitivities from an HJM interest-rate tree
`hjmtimespec`	Specify time structure for HJM interest-rate tree
`hjmtree`	Construct HJM interest-rate tree
`hjmvolspec`	HJM volatility process specification

Price and Sensitivity from Black-Derman-Toy Trees

`bdtprice`	Instrument prices from a BDT interest-rate tree
`bdtsens`	Instrument prices and sensitivities from a BDT interest-rate tree
`bdttimespec`	Specify time structure for BDT interest-rate tree

`bdttree`	Construct BDT interest-rate tree
`bdtvolspec`	BDT volatility process specification

Price and Sensitivity from Cox-Ross-Rubinstein Trees

`crrprice`	Instrument prices from a CRR tree
`crrsens`	Instrument prices and sensitivities by a CRR tree
`crrtimespec`	Specify time structure for CRR tree
`crrtree`	Construct CRR stock tree

Price and Sensitivity from Equal Probabilities Binomial Trees

`eqpprice`	Instrument prices from an EQP binomial tree
`eqpsens`	Instrument prices and sensitivities from an EQP binomial tree
`eqptimespec`	Specify time structure for EQP tree
`eqptree`	Construct EQP stock tree

Heath-Jarrow-Morton Utilities

`bondbyhjm`	Price bond by an HJM interest-rate tree
`capbyhjm`	Price cap instrument by an HJM interest-rate tree
`cfbyhjm`	Price arbitrary set of cash flows by an HJM interest-rate tree
`fixedbyhjm`	Price fixed-rate note by an HJM interest-rate tree
`floatbyhjm`	Price floating-rate note by an HJM interest-rate tree
`floorbyhjm`	Price floor instrument by an HJM interest-rate tree
`mmktbyhjm`	Create money market tree from an HJM tree

`optbndbyhjm`	Price bond option by an HJM interest-rate tree
`swapbyhjm`	Price swap instrument by an HJM interest-rate tree

Black-Derman-Toy Utilities

`bondbybdt`	Price bond by a BDT interest-rate tree
`capbybdt`	Price cap by a BDT interest-rate tree
`cfbybdt`	Price arbitrary set of cash flows by a BDT interest-rate tree
`fixedbybdt`	Price fixed-rate note by a BDT interest-rate tree
`floatbybdt`	Price floating-rate note by a BDT interest-rate tree
`floorbybdt`	Price floor instrument by a BDT interest-rate tree
`mmktbybdt`	Create money market tree from a BDT tree
`optbndbybdt`	Price bond option by a BDT interest-rate tree
`swapbybdt`	Price swap instrument by a BDT interest-rate tree

Cox-Ross-Rubinstein Utilities

`asianbycrr`	Price Asian option by a CRR tree
`barrierbycrr`	Price barrier option by a CRR tree
`compoundbycrr`	Price compound option by a CRR tree
`lookbackbycrr`	Price lookback option by a CRR tree
`optstockbycrr`	Price stock option by a CRR tree

Equal Probabilities Tree Utilities

`asianbyeqp`	Price Asian option by an EQP tree
`barrierbyeqp`	Price barrier option by an EQP tree
`compoundbyeqp`	Price compound option by an EQP tree

`lookbackbyeqp`	Price lookback option by an EQP tree
`optstockbyeqp`	Price stock option by an EQP tree

Heath-Jarrow-Morton Bushy Tree Manipulation

`bushpath`	Extract entries from node of bushy tree
`bushshape`	Retrieve shape of bushy tree
`mkbush`	Create bushy tree

Recombining Tree Manipulation

`mktree`	Create recombining tree
`treepath`	Extract entries from node of recombining tree
`treeshape`	Retrieve shape of recombining tree

Derivatives Pricing Options

`derivget`	Get derivatives pricing options
`derivset`	Set or modify derivatives pricing options

Instrument Portfolio Handling

`instadd`	Add types to instrument collection
`instaddfield`	Add new instruments to an instrument collection
`instasian`	Construct Asian option instrument
`instbarrier`	Construct barrier option instrument
`instbond`	Construct bond instrument
`instcap`	Construct cap instrument
`instcf`	Constructor for arbitrary cash flow instrument
`instcompound`	Construct compound option instrument

`instdelete`	Complement of subset of instruments by matching conditions
`instdisp`	Display instruments
`instfields`	List field names
`instfind`	Search instruments for matching conditions
`instfixed`	Construct fixed-rate instrument
`instfloat`	Construct floating-rate instrument
`instfloor`	Construct floor instrument
`instget`	Retrieve data from instrument variable
`instgetcell`	Retrieve data and context from instrument variable
`instlength`	Count instruments
`instlookback`	Construct lookback instrument
`instoptbnd`	Construct bond option
`instoptstock`	Construct stock option
`instselect`	Create instrument subset by matching conditions
`instsetfield`	Add or reset data for existing instruments
`instswap`	Construct swap instrument
`insttypes`	List types

Financial Object Structures

`classfin`	Create financial structure or return financial structure class name
`isafin`	True if financial structure type or financial object class
`stockspec`	Create stock structure

Interest Term Structure

`date2time`	Time and frequency from dates
`disc2rate`	Interest rates from cash flow discounting factors
`intenvget`	Get properties of interest-rate environment
`intenvset`	Set properties of interest-rate environment
`rate2disc`	Discounting factors from interest rates
`ratetimes`	Change time intervals defining interest-rate environment
`time2date`	Dates from time and frequency

Date Function

`datedisp`	Display date entries

Graphical Display Function

`treeviewer`	Display tree information

Functions — Alphabetical List

This section contains function reference pages listed alphabetically.

asianbycrr

Purpose Price Asian option by a CRR binomial tree

Syntax

```
Price = asianbycrr(CRRTree, OptSpec, Strike, Settle, ExerciseDates,
 AmericanOpt, AvgType, AvgPrice, AvgDate)
```

Arguments

`CRRTree`	Stock tree structure created by `crrtree`.
`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 Asian option is set to the valuation date of the stock tree. The Asian 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`	(Optional) If `AmericanOpt = 0`, `NaN`, or is unspecified, the option is a European option. If `AmericanOpt = 1`, 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 `Settle`. This argument is used when `AvgDate < Settle`. Default is the current stock price.

`AvgDate`	(Optional) Scalar representing the date on which the averaging period begins. Default = `Settle`.

Description

`Price = asianbycrr(CRRTree, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt, AvgType, AvgPrice, AvgDate)` calculates 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 equity tree.

Load the file `deriv.mat`, which provides `CRRTree`. The `CRRTree` structure contains the stock specification and time information needed to price the option.

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
OptSpec = 'put';
Strike = NaN;
Settle = '01-Jan-2003';
ExerciseDates = '01-Jan-2004';
```

Use `asianbycrr` to compute the price of the option.

```
Price = asianbycrr(CRRTree, OptSpec, Strike, Settle, ...
ExerciseDates)

Price =

  1.2177
```

See Also `crrtree`, `instasian`

References Hull, J., and A. White, “Efficient Procedures for Valuing European and American Path-Dependent Options,” *Journal of Derivatives*, Volume 1, pp. 21-31.

Purpose

Price Asian option by an EQP binomial tree

Syntax

```
Price = asianbyeqp(CRRTree, OptSpec, Strike, Settle, ExerciseDates,
 AmericanOpt, AvgType, AvgPrice, AvgDate)
```

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 Asian option is set to the valuation date of the stock tree. The Asian 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`	(Optional) If `AmericanOpt = 0`, `NaN`, or is unspecified, the option is a European option. If `AmericanOpt = 1`, 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 `Settle`. This argument is used when `AvgDate < Settle`. Default is the current stock price.

`AvgDate`	(Optional) Scalar representing the date on which the averaging period begins. Default = `Settle`.

Description

`Price = asianbyeqp(EQPTree, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt, AvgType, AvgPrice, AvgDate)` calculates 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.

Load the file `deriv.mat`, which provides `EQPTree`. The `EQPTree` structure contains the stock specification and time information needed to price the option.

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
OptSpec = 'put';
Strike = NaN;
Settle = '01-Jan-2003';
ExerciseDates = '01-Jan-2004';
```

Use `asianbyeqp` to compute the price of the option.

```
Price = asianbyeqp(EQPTree, OptSpec, Strike, Settle, ...
ExerciseDates)

Price =

  1.2724
```

See Also

`eqptree`, `instasian`

References

Hull, J., and A. White, “Efficient Procedures for Valuing European and American Path-Dependent Options,” *Journal of Derivatives*, Volume 1, pp. 21-31.

Purpose

Price barrier option by a CRR binomial tree

Syntax

```
[Price, PriceTree] = barrierbycrr(CRRTree, OptSpec, Strike, Settle,
   ExerciseDates, AmericanOpt, BarrierSpec, Barrier, Rebate,
   Options)
```

Arguments

`CRRTree`	Stock tree structure created by `crrtree`.
`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] = 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 equity tree.

Load the file `deriv.mat`, which provides `CRRTree`. The `CRRTree` structure contains the stock specification and time information needed to price the option.

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
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
```

See Also `crrtree`, `instbarrier`

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.

Purpose

Price barrier option by an EQP 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.

Load the file `deriv.mat`, which provides `EQPTree`. The `EQPTree` structure contains the stock specification and time information needed to price the option.

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
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
```

See Also

`eqptree`, `instbarrier`

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.

Purpose

Instrument prices from a BDT interest-rate tree

Syntax

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

Arguments

`BDTTree`	Interest-rate tree structure created by `bdttree`.
`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

`[Price, PriceTree] = bdtprice(BDTTree, 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. 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'`, `'Fixed'`, `'Float'`, `'Cap'`, `'Floor'`, `'Swap'`. See `instadd` to construct defined types.

Related single-type pricing functions are:

- `bondbybdt`: Price a bond by a BDT tree.
- `capbybdt`: Price a cap by a BDT tree.
- `cfbybdt`: Price an arbitrary set of cash flows by a BDT tree.
- `fixedbybdt`: Price a fixed-rate note by a BDT tree.
- `floatbybdt`: Price a floating-rate note by a BDT tree.

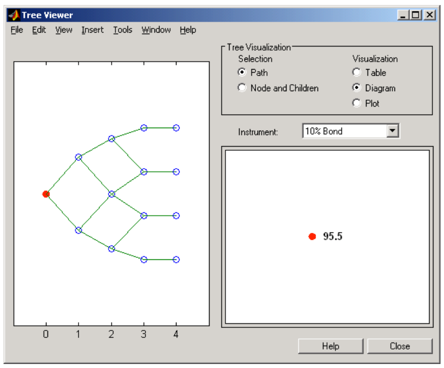
- `floorbybdt`: Price a floor by a BDT tree.
- `optbndbybdt`: Price a bond option by a BDT tree.
- `swapbybdt`: Price a swap by a BDT tree.

Examples

Load the BDT tree and instruments from the data file `deriv.mat`. Price the cap and bond instruments contained in the instrument set.

```
  load deriv.mat;
  BDTSubSet = instselect(BDTInstSet,'Type', {'Bond', 'Cap'});

  instdisp(BDTSubSet)

Index Type   CouponRate Settle      Maturity    Period  Name ...
1     Bond   0.1        01-Jan-2000 01-Jan-2003 1       10% bond
2     Bond   0.1        01-Jan-2000 01-Jan-2004 2       10% bond

Index Type Strike Settle      Maturity     CapReset...  Name ...
3     Cap  0.15   01-Jan-2000 01-Jan-2004  1            15% Cap

  [Price, PriceTree] = bdtprice(BDTTree, BDTSubSet);

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

  Price =

     95.5030
     93.9079
      1.4863
```

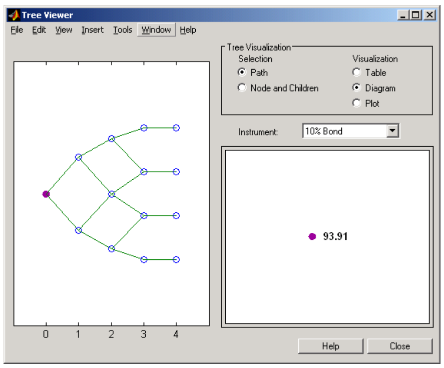
You can use `treeviewer` to see the prices of these three instruments along the price tree.



Tree Visualization
Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot
Instrument: 10% Bond

95.5

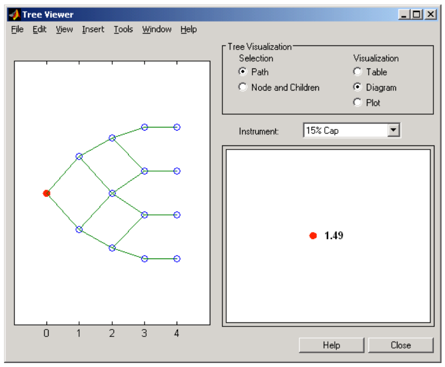
First 10% Bond



Tree Visualization
Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot
Instrument: 10% Bond

93.91

Second 10% Bond



Tree Visualization
Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot
Instrument: 15% Cap

1.49

15% Cap

See Also

`bdtsens`, `bdttree`, `instadd`, `intenvprice`, `intenvsens`

bdtsens

Purpose Instrument prices and sensitivities from a BDT interest-rate tree

Syntax

```
[Delta, Gamma, Vega, Price] = bdtsens(BDTTree, InstSet, Options)
```

Arguments

`BDTTree`	Interest-rate tree structure created by `bdttree`.
`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] = 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'`, `'Fixed'`, `'Float'`, `'Cap'`, `'Floor'`, `'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

Load the tree and instruments from a data file. Compute delta and gamma for the cap and bond instruments contained in the instrument set.

```
   load deriv.mat;
   BDTSubSet = instselect(BDTInstSet,'Type', {'Bond', 'Cap'});

   instdisp(BDTSubSet)

Index Type CouponRate Settle        Maturity     Period  Name ...
1     Bond 0.1        01-Jan-2000   01-Jan-2003  1       10% Bond
2     Bond 0.1        01-Jan-2000   01-Jan-2004  2       10% Bond

Index Type Strike Settle      Maturity     CapReset...  Name ...
3     Cap  0.15   01-Jan-2000 01-Jan-2004  1            15% Cap


   [Delta, Gamma] = bdtsens(BDTTree, BDTSubSet)

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

   Delta =

    -232.6681
    -281.0517
      78.3776
```

```
Gamma =

  1.0e+003 *

    0.8037
    1.1819
    0.7490
```

See Also bdtprice, bdttree, bdtvolspec, instadd

Purpose

Specify time structure for BDT 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`	(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:
	
	`Compounding` = `1`, `2`, `3`, `4`, `6`, `12`
	
	`Disc = (1 + Z/F)^(-T)`, where `F` is the compounding frequency, `Z` is the zero rate, and `T` is the time in periodic units, e.g. `T = F` is one year.
	
	`Compounding` = `365`
	
	`Disc = (1 + Z/F)^(-T)`, where `F` is the number of days in the basis year and `T` is a number of days elapsed computed by basis.
	
	`Compounding` = `-1`
	
	`Disc = exp(-T*Z)`, where `T` is time in years.

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 four period tree with annual nodes. 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'];
Volatility = [.2; .19; .18; .17; .16];

TimeSpec = bdttimespec(ValuationDate, Maturity, Compounding)

TimeSpec =

           FinObj: 'BDTTimeSpec'
    ValuationDate: 730486
         Maturity: [5x1 double]
      Compounding: 1
            Basis: 0
     EndMonthRule: 1
```

See Also

`bdttree`, `bdtvolspec`

Purpose

Build BDT interest rate tree

Syntax

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

Arguments

`VolSpec`	Volatility process specification. See `bdtvolspec` 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 BDT tree and the `Compounding` rule for date to time mapping and price-yield formulas. See `bdttimespec` 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.

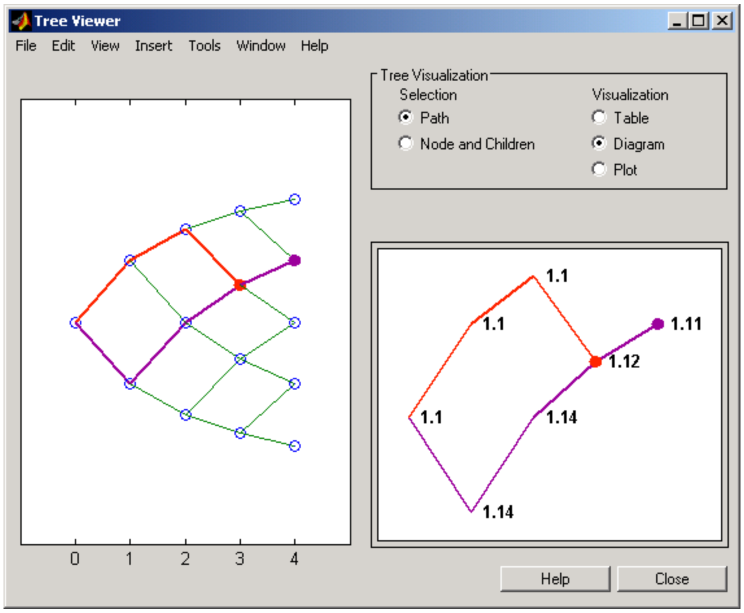
Examples

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);
```

Use `treeviewer` to observe the tree you have created.

```
treeviewer(BDTTree)
```



Tree Visualization
Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot

See Also `bdtprice`, `bdttimespec`, `bdtvolspec`, `intenvset`

Purpose Specify a BDT 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.
`InterpMethod`	(Optional) Interpolation method. Default is `'linear'`. See `interp1` for more information.

Description `Volspec = bdtvolspec(ValuationDate, VolDates, VolCurve, InterpMethod)` creates a structure specifying the volatility for `bdttree`.

Examples Using the data provided, create a BDT volatility specification (`VolSpec`).

```
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`

bondbybdt

Purpose Price bond by a BDT interest-rate tree

Syntax

```
[Price, PriceTree] = bondbybdt(BDTTree, CouponRate, Settle,
  Maturity, Period, Basis, EndMonthRule, IssueDate,
  FirstCouponDate, LastCouponDate, StartDate, Face, Options)
```

Arguments

`BDTTree`	Interest-rate tree structure created by `bdttree`.
`CouponRate`	Decimal annual rate.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`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 bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`EndMonthRule`	(Optional) End-of-month rule. A 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'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.
`IssueDate`	(Optional) Date when a bond was issued.
`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

`LastCouponDate`	(Optional) Last coupon date of a bond prior to the maturity date. 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.
`StartDate`	Ignored.
`Face`	(Optional) Face value. Default is `100`.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

The `Settle` date for every bond is set to the `ValuationDate` of the BDT tree. The bond argument `Settle` is ignored.

Description

`[Price, PriceTree] = bondbybdt(BDTTree, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face, Options)` computes the price of a bond by 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 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.

Examples

Price a 10% bond using a BDT interest-rate tree.

Load the file `deriv.mat`, which provides `BDTTree`. `BDTTree` contains the time and interest-rate information needed to price the bond.

```
load deriv
```

Set the required values. Other arguments will 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
```

See Also

bdttree, bdtprice, instbond

Purpose

Price bond by an HJM interest-rate tree

Syntax

```
[Price, PriceTree] = bondbyhjm(HJMTree, CouponRate, Settle,
   Maturity, Period, Basis, EndMonthRule, IssueDate,
   FirstCouponDate, LastCouponDate, StartDate, Face, Options)
```

Arguments

`HJMTree`	Forward rate tree structure created by `hjmtree`.
`CouponRate`	Decimal annual rate.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`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 bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`EndMonthRule`	(Optional) End-of-month rule. A 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'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.
`IssueDate`	(Optional) Date when a bond was issued.
`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

`LastCouponDate`	(Optional) Last coupon date of a bond prior to the maturity date. 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.
`StartDate`	Ignored.
`Face`	(Optional) Face value. Default = `100`.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

The `Settle` date for every bond is set to the `ValuationDate` of the HJM tree. The bond argument `Settle` is ignored.

Description

`[Price, PriceTree] = bondbyhjm(HJMTree, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face, Options)` computes the price of a bond by an HJM forward 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 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.

Examples

Price a 4% bond 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 bond.

```
load deriv
```

Set the required values. Other arguments will 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
```

See Also

`hjmtree`, `hjmprice`, `instbond`

bondbyzero

Purpose Price bond by a set of zero curves

Syntax

```
Price = bondbyzero(RateSpec, CouponRate, Settle, Maturity, Period,
   Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate,
   StartDate, Face)
```

Arguments

`RateSpec`	A structure containing the properties of an interest-rate structure. See `intenvset` for information on creating `RateSpec`.
`CouponRate`	Decimal annual rate.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`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 bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`EndMonthRule`	(Optional) End-of-month rule. A 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'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.
`IssueDate`	(Optional) Date when a bond was issued.
`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

`LastCouponDate`	(Optional) Last coupon date of a bond prior to the maturity date. 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.
`StartDate`	Ignored.
`Face`	(Optional) Face value. Default = `100`.

All inputs are either scalars or number of instruments (`NINST`)-by-1 vectors unless otherwise specified. Dates can be serial date numbers or date strings. Optional arguments can be passed as empty matrix `[]`.

Description

`Price = 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.

Examples

Price a 4% bond using a set of zero curves.

Load the file `deriv.mat`, which provides `ZeroRateSpec`, the interest-rate term structure needed to price the bond.

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
CouponRate = 0.04;
Settle = '01-Jan-2000';
Maturity = '01-Jan-2004';
```

Use `bondbyzero` to compute the price of the bond.

```
Price = bondbyzero(ZeroRateSpec, CouponRate, Settle, Maturity)

Price =
  97.5334
```

See Also

`cfbyzero`, `fixedbyzero`, `floatbyzero`, `swapbyzero`

bushpath

Purpose

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 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 bushy tree.

Examples

Create an HJM tree by loading the example file.

```
load deriv.mat;
```

Then

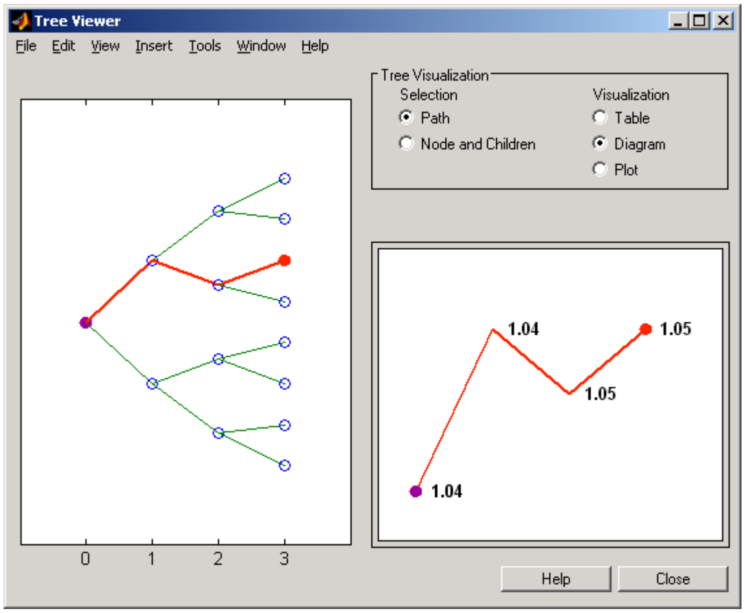
```
FwdRates = bushpath(HJMTree.FwdTree, [1 2 1])
```

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)
```



Selection: [✓ Path] Node and Children

Visualization: Table [✓ Diagram] Plot

See Also

bushshape, mkbush

bushshape

Purpose 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.

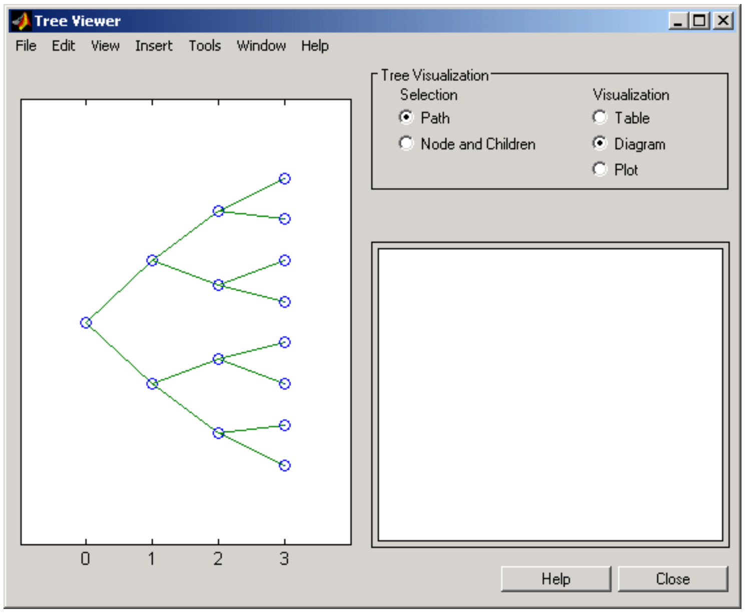
`NumStates` is a `1`-by-`NUMLEVELS` vector containing the number of state vectors in each level.

`Trim` is `1` if `NumPos` decreases by one when moving from one time level to the next. Otherwise, it is `0`.

Examples Create an HJM tree by loading the example file.

```
load deriv.mat;
```

With `treeviewer` you can see the general shape of the HJM interest-rate tree.



Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot

With this tree

```
[NumLevels, NumChild, NumPos, NumStates, Trim] =...
bushshape(HJMTree.FwdTree)
```

returns

```
NumLevels   =
     4

NumChild    =
     2      2      2      0

NumPos      =
     4      3      2      1

NumStates   =
     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`

Purpose

Price cap instrument by a BDT interest-rate tree

Syntax

```
[Price,PriceTree]=capbybdt(BDTTree, Strike,Settle,Maturity,
   Reset, Basis, Principal, Options)
```

Arguments

`BDTTree`	Interest-rate tree structure created by `bdttree`.
`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) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) The notional principal amount. Default = `100`.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

Description

`[Price,PriceTree]=capbybdt(BDTTree,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.

Examples

Example 1. Price a 3% cap instrument using a BDT interest-rate tree.

Load the file `deriv.mat`, which provides `BDTTree`. `BDTTree` contains the time and interest-rate information needed to price the cap instrument.

```
load deriv
```

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(BDTTree, Strike, Settle, Maturity)

Price =

  28.5191
```

Example 2. Here is a second example, showing the pricing of a 10% cap instrument using a newly created BDT 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];
```

Next 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);
```

Now create the BDT tree from the specifications.

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

Set the cap arguments.

```
CapStrike = 0.10;
Settlement = ValuationDate;
Maturity = '01-01-2002';
CapReset = 1;
```

Remaining arguments will use defaults.

Finally, use `capbybdt` to find the price of the cap instrument.

```
Price= capbybdt(BDTTree, CapStrike, Settlement, Maturity,...
CapReset)

Price =

    1.6923
```

See Also `bdttree`, `cfbybdt`, `floorbybdt`, `swapbybdt`

capbyhjm

Purpose

Price cap instrument by an HJM interest-rate tree

Syntax

```
[Price,PriceTree]=capbyhjm(HJMTree, Strike,Settle,Maturity,
   Reset, Basis, Principal, Options)
```

Arguments

`HJMTree`	Forward rate tree structure created by `hjmtree`.
`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) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) The notional principal amount. Default = `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.

Examples

Price a 3% cap instrument using an HJM forward rate tree.

Load the file `deriv.mat`, which provides `HJMTree`. `HJMTree` contains the time and forward rate information needed to price the cap instrument.

```
load deriv
```

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
```

See Also

`cfbyhjm`, `floorbyhjm`, `hjmtree`, `swapbyhjm`

cfbybdt

Purpose

Price cash flows from a BDT interest-rate tree

Syntax

```
[Price, PriceTree] = cfbybdt(BDTTree, CFlowAmounts, CFlowDates,
   Settle, Basis, Options)
```

Arguments

`BDTTree`	Forward rate tree structure created by `bdttree`.
`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 `NaN`s.
`CFlowDates`	`NINST`-by-`MOSTCFS` matrix of cash flow dates. Each entry contains the date of the corresponding cash flow in `CFlowAmounts`.
`Settle`	Settlement date. A vector of serial date numbers or date strings. The `Settle` date for every cash flow is set to the `ValuationDate` of the HJM tree. The cash flow argument, `Settle`, is ignored.
`Basis`	(Optional) Day-count basis of the bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

Description

`[Price, PriceTree] = cfbybdt(BDTTree, CFlowAmounts, CFlowDates, 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

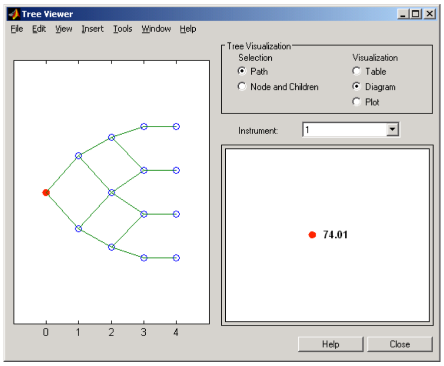
Price a portfolio containing two cash flow instruments paying interest annually over the four year period from January 1, 2000 to January 1, 2004.

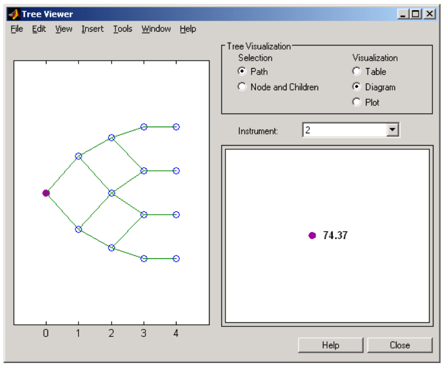
Load the file `deriv.mat`, which provides `BDTTree`. The `BDTTree` structure contains the time and interest-rate information needed to price the instruments.

```
load deriv
CFlowAmounts =[5 NaN 5.5 105;5 0 6 105];
CFlowDates = [730852, NaN, 731582,731947;
              730852, 731217, 731582, 731947];

Price = 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)
```





See Also

`bdttree`, `bdtprice`, `cfamounts`, `instcf`

cfbyhjm

Purpose

Price cash flows from an HJM interest-rate tree

Syntax

```
[Price, PriceTree] = cfbyhjm(HJMTree, CFlowAmounts, CFlowDates,
   Settle, Basis, Options)
```

Arguments

`HJMTree`	Forward rate tree structure created by `hjmtree`.
`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 `NaN`s.
`CFlowDates`	`NINST`-by-`MOSTCFS` matrix of cash flow dates. Each entry contains the date of the corresponding cash flow in `CFlowAmounts`.
`Settle`	Settlement date. A vector of serial date numbers or date strings. The `Settle` date for every cash flow is set to the `ValuationDate` of the HJM tree. The cash flow argument, `Settle`, is ignored.
`Basis`	(Optional) Day-count basis of the bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

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

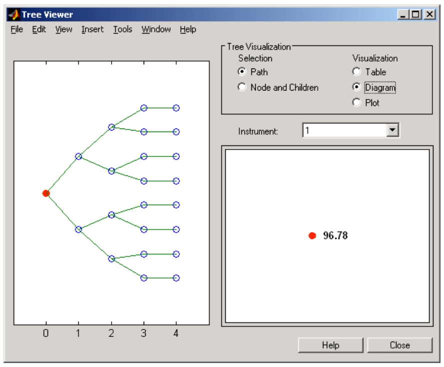
Price a portfolio containing two cash flow instruments paying interest annually over the four year period from January 1, 2000 to January 1, 2004.

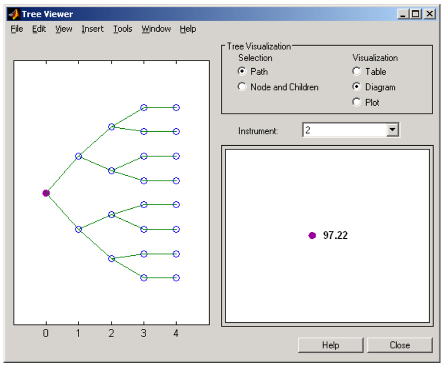
Load the file `deriv.mat`, which provides `HJMTree`. `HJMTree` contains the time and forward rate information needed to price the instruments.

```
load deriv
CFlowAmounts =[5 NaN 5.5 105;5 0 6 105];
CFlowDates = [730852, NaN, 731582,731947;
              730852, 731217, 731582, 731947];

[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)
```





See Also

`cfamounts`, `hjmprice`, `hjmtree`, `instcf`

Purpose

Price cash flows by a set of zero curves

Syntax

```
Price = cfbyzero(RateSpec, CFlowAmounts, CFlowDates, Settle, Basis)
```

Arguments

`RateSpec`	A structure containing the properties of an interest-rate structure. See `intenvset` for information on creating `RateSpec`.
`CFlowAmounts`	Number of instruments (`NINST`) by maximum number of cash flows (`MOSTCFS`) matrix with entries listing cash flow amounts corresponding to each date in `CFlowDates`. 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 `NaN`s.
`CFlowDates`	`NINST`-by-`MOSTCFS` matrix of cash flow dates. Each entry contains the serial date of the corresponding cash flow in `CFlowAmounts`.
`Settle`	Settlement date on which the cash flows are priced.
`Basis`	(Optional) Day-count basis of the bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.

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

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
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`

Purpose Create financial structure or return financial structure class name

Syntax

```
Obj = classfin(ClassName)
Obj = classfin(Struct, ClassName)
ClassName = classfin(Obj)
```

Arguments

`ClassName`	String containing name of 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 Example 1. Create an `HJMTimeSpec` financial structure 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 =

           FinObj: 'HJMTimeSpec'
    ValuationDate: 730464
         Maturity: 731560
      Compounding: 2
            Basis: 0
     EndMonthRule: 1
```

Example 2. 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'
```

Example 3. Obtain a financial structure's class name.

```
load deriv.mat
ClassName = classfin(HJMTree)

ClassName =

HJMFwdTree
```

See Also `isafin`

compoundbycrr

Purpose Price compound option by a CRR binomial tree

Syntax

```
[Price, PriceTree] = compoundbycrr(CRRTree, UOptSpec, UStrike,
  USettle, UExerciseDates, UAmericanOpt, COptSpec, CStrike,
  CSettle, CExerciseDates, CAmericanOpt)
```

Arguments

`CRRTree`	Stock tree structure created by `crrtree`.
`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.
`CSettle`	`1`-by-`1` vector containing the settlement or trade date.

`CExerciseDates`	For a European option (`CAmericanOpt = 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 (`CAmericanOpt = 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.

`CAmericanOpt`	(Optional) If `CAmericanOpt = 0`, `NaN`, or is unspecified, the option is a European option. If `CAmericanOpt = 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 equity tree.

Load the file `deriv.mat`, which provides `CRRTree`. `CRRTree` contains the stock specification and time information needed to price the option.

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
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
```

See Also `crrtree`, `instcompound`

References Rubinstein, Mark, “Double Trouble,” *Risk 5*, 1991, p. 73

Purpose

Price compound option by an EQP 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.
`CSettle`	`1`-by-`1` vector containing the settlement or trade date.

`CExerciseDates`	For a European option (`CAmericanOpt = 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 (`CAmericanOpt = 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.
`CAmericanOpt`	If `CAmericanOpt = 0`, `NaN`, or is unspecified, the option is a European option. If `CAmericanOpt = 1`, 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.

Load the file `deriv.mat`, which provides `EQPTree`. `EQPTree` contains the stock specification and time information needed to price the option.

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
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
```

See Also `eqptree`, `instcompound`

References Rubinstein, Mark, "Double Trouble," *Risk 5*, 1991, p. 73

Purpose Instrument prices from a CRR tree

Syntax `[Price, PriceTree] = crrprice(CRRTree, InstSet, Options)`

Arguments

`CRRTree`	Interest-rate tree structure created by `crrtree`.
`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

`[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 by a CRR tree.
- `barrierbycrr`: Price a barrier option by a CRR tree.
- `compoundbycrr`: Price a compound option by a CRR tree.
- `lookbackbycrr`: Price a lookback option by a CRR tree.
- `optstockbycrr`: Price an American, Bermuda, or European option by 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.

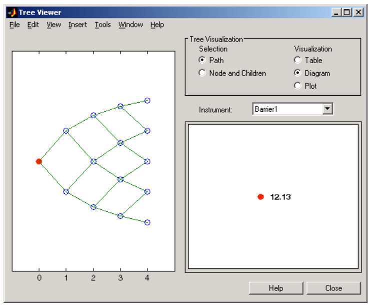
```
load deriv.mat;
CRRSubSet = instselect(CRRInstSet,'Type', ...
{'Barrier', 'Lookback'});

instdisp(CRRSubSet)
```

```
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 `treeviewer` to see the prices of these three instruments along the price tree.

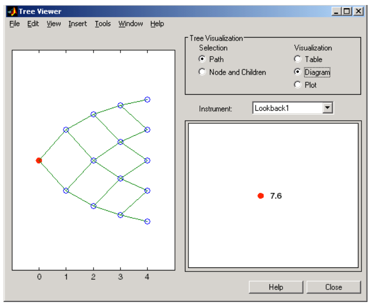
```
treeviewer(PriceTree, CRRSubSet)
```



Tree Visualization
Selection: (•) Path ( ) Node and Children
Visualization: ( ) Table (•) Diagram ( ) Plot
Instrument: Barrier1

12.13

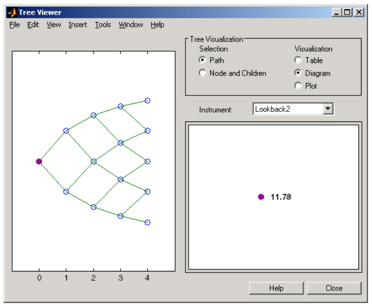
Barrier1



Tree Visualization
Selection: (•) Path ( ) Node and Children
Visualization: ( ) Table (•) Diagram ( ) Plot
Instrument: Lookback1

7.6

Lookback1



Tree Visualization
Selection: (•) Path ( ) Node and Children
Visualization: ( ) Table (•) Diagram ( ) Plot
Instrument: Lookback2

11.78

Lookback2

See Also

`crrsens`, `crrtree`, `instadd`

Purpose

Instrument prices and sensitivities from a CRR tree

Syntax

```
[Delta, Gamma, Vega, Price] = crrsens(CRRTree, InstSet, Options)
```

Arguments

`CRRTree`	Interest-rate tree structure created by `crrtree`.
`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] = crrsens(BDTTree, 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

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 ...
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

   [Delta, Gamma] = crrsens(CRRTree, CRRSubSet)

   Delta =

    0.6885
    0.6049
    0.8187

   Gamma =

    0.0310
   -0.0000
    0.0000
```

See Also

`crrprice`, `crrtree`

crrtimespec

Purpose Specify time structure for a CRR 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 Specify a four period CRR tree with time steps of one 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
```

See Also `crrtree`, `stockspec`

crrtree

Purpose

Construct a CRR stock tree

Syntax

```
CRRTree =  crrtree(StockSpec, RateSpec, TimeSpec)
```

Arguments

`StockSpec`	Stock specification. See `stockspec` for information on creating a stock specification.
`RateSpec`	Interest-rate specification for the initial risk free rate curve. See `intenvset` for information on declaring an interest-rate variable.
`TimeSpec`	Tree time layout specification. Defines the observation dates of the CRR binomial tree. See `crrtimespec` 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

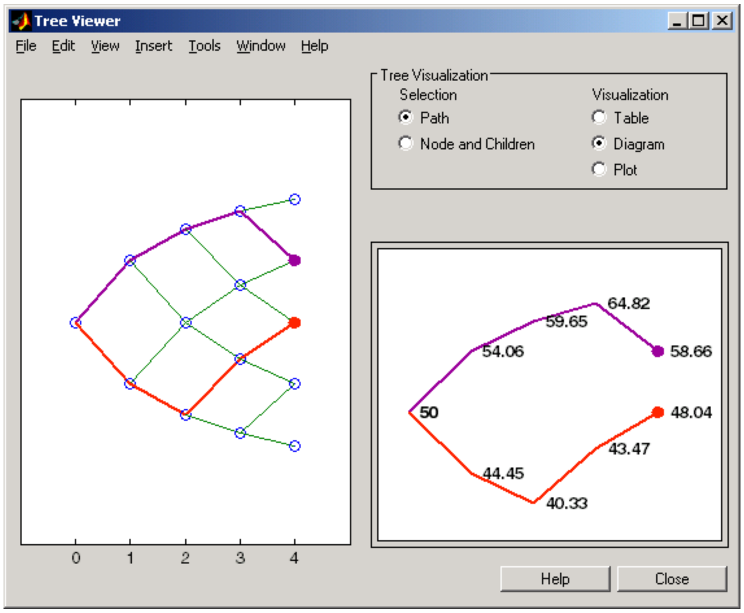
Using the data provided, create a stock specification (`StockSpec`), rate specification (`RateSpec`), and tree time layout specification (`TimeSpec`). Then use these specifications to create a CRR tree with `crrtree`.

```
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
```

```
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 `treeviewer` to observe the tree you have created.



Tree Visualization: Selection [✓ Path] Node and Children; Visualization Table [✓ Diagram] Plot

See Also

`crrtimespec`, `intenvset`, `stockspec`

Purpose

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`	A vector of dates corresponding to the compounding value.
`Compounding`	Scalar value representing the rate at which the input zero rates were compounded when annualized. This argument determines the formula for the discount factors:

`Compounding` = 1, 2, 3, 4, 6, 12

`Disc = (1 + Z/F)^(-T)`, where `F` is the compounding frequency, `Z` is the zero rate, and `T` is the time in periodic units, e.g. `T = F` is one year.

`Compounding` = 365

`Disc = (1 + Z/F)^(-T)`, where `F` is the number of days in the basis year and `T` is a number of days elapsed computed by basis.

`Compounding` = -1

`Disc = exp(-T*Z)`, where `T` is time in years.

`Basis`	(Optional) Day-count basis of the bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`EndMonthRule`	(Optional) End-of-month rule. A 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'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.

`date2time` is the inverse of `time2date`.

See Also

`cftimes` in the Financial Toolbox documentation

`disc2rate`, `rate2disc`, `time2date`

Purpose

Display date entries

Syntax

```
datedisp(NumMat, DateForm)
CharMat = datedisp(NumMat, DateForm)
```

Arguments

`NumMat`	Numeric matrix to display
`DateForm`	(Optional) Date format. See `datestr` 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.

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
```

See Also

`datenum`, `datestr` in the Financial Toolbox documentation

Remarks

This function is identical to the `datedisp` function in the Financial Toolbox.

derivget

Purpose

Get derivatives pricing options

Syntax

```
Value = derivget(Options, 'Parameter')
```

Arguments

`Options`	Existing options specification structure, probably created from previous call to `derivset`.
`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

Purpose

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 previous call to `derivset`.
`Parameter`*`n`*	The parameter must be `'Diagnostics'`, `'Warnings'`, `'ConstRate'`, or `'BarrierMethod'`. Parameters can be entered in any order.
`Value`*`n`*	For HJM and BDT pricing, the parameter values for the following three options can be `'on'` or `'off'`: • `'Diagnostics' 'on'` generates diagnostic information. The default is `'Diagnostics' 'off'`. • `'Warnings' 'on'` (default) displays a warning message when executing a pricing function. • `'ConstRate' 'on'` (default) assumes a constant rate between tree nodes. 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.
`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   ]
```

See Also barrierbycrr, barrierbyeqp, derivget

Purpose

Interest rates from cash flow discounting factors

Syntax

Usage 1: Interval points are input as times in periodic units.

```
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)
```

Arguments

`Compounding`	Scalar value representing the rate at which the input zero rates were compounded when annualized. This argument determines the formula for the discount factors:
	
	`Compounding` = `1, 2, 3, 4, 6, 12`
	
	`Disc = (1 + Z/F)^(-T)`, where `F` is the compounding frequency, `Z` is the zero rate, and `T` is the time in periodic units, e.g. `T = F` is one year.
	
	`Compounding` = `365`
	
	`Disc = (1 + Z/F)^(-T)`, where `F` is the number of days in the basis year and `T` is a number of days elapsed computed by basis.
	
	`Compounding` = `-1`
	
	`Disc = exp(-T*Z)`, where `T` is time in years.

`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.

`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.
`StartDates`	(Optional) `NPOINTS`-by-`1` vector or scalar of serial dates starting the interval to discount over. 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 = disc2rate(Compounding, Disc, EndTimes, StartTimes)` and `[Rates, EndTimes, StartTimes] = disc2rate(Compounding, Disc, EndDates, StartDates, ValuationDate)` convert cash flow discounting factors to interest rates. `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.

`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.

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 = Tsemi/2 * F`, where `F` is the compounding frequency.

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.

See Also

`rate2disc`, `ratetimes`

Purpose

Instrument prices from an EQP binomial tree

Syntax

`[Price, PriceTree] = crrprice(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

`[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 by an EQP tree.
- `barrierbyeqp`: Price a barrier option by an EQP tree.
- `compoundbyeqp`: Price a compound option by an EQP tree.
- `lookbackbyeqp`: Price a lookback option by an EQP tree.
- `optstockbyeqp`: Price an American, Bermuda, or European option by 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.

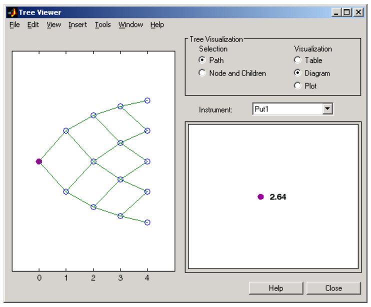
```
load deriv.mat;
EQPSubSet = instselect(EQPInstSet, 'FieldName', 'OptSpec', ...
'Data', 'put')

instdisp(EQPSubSet)
```

```
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]
```

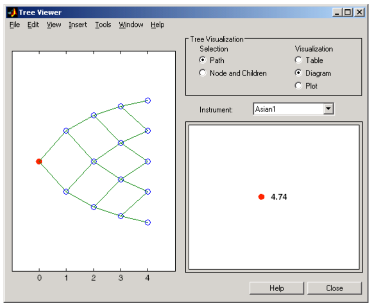
You can use `treeviewer` to see the prices of these three instruments along the price tree.

```
treeviewer(PriceTree, EQPSubSet)
```



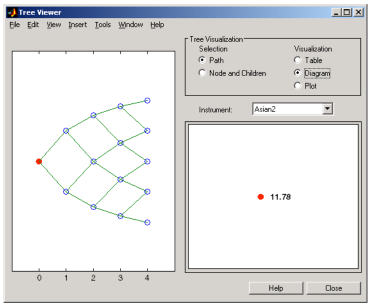
Tree Visualization
Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot
Instrument: Put1
2.64

Put1



Tree Visualization
Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot
Instrument: Asian1
4.74

Asian11



Tree Visualization
Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot
Instrument: Asian2
11.78

Asian2

See Also

eqpsens, eqptimespec, eqptree

Purpose

Instrument prices and sensitivities from an EQP 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'`, `'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

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)
```

```
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...
```

```
[Delta, Gamma] = eqpsens(EQPTree, EQPSubSet)

Delta =

 -0.2336
 -0.5443
 -0.4516

Gamma =

 0.0218
 0.0000
 0.0000
```

See Also

`eqpprice`, `eqptree`

eqptimespec

Purpose Specify time structure for EQP 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 Specify a four period tree with time steps of one 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
```

See Also `eqptree`, `stockspec`

Purpose

Construct EQP stock tree

Syntax

```
EQPTree =  eqptree(StockSpec, RateSpec, TimeSpec)
```

Arguments

`StockSpec`	Stock specification. See `stockspec` for information on creating a stock specification.
`RateSpec`	Interest-rate specification for the initial risk free rate curve. See `intenvset` for information on declaring an interest-rate variable.
`TimeSpec`	Tree time layout specification. Defines the observation dates of the equal probabilities binomial tree. See `eqptimespec` 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

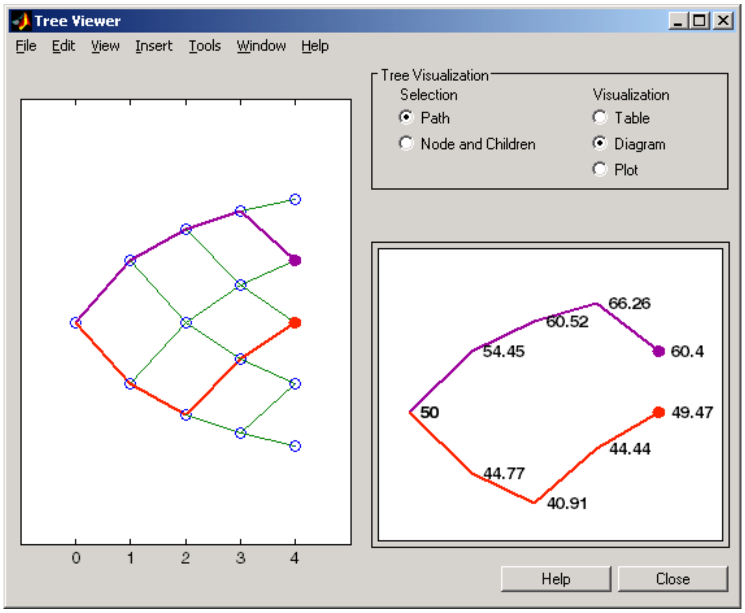
Using the data provided, create a stock specification (`StockSpec`), rate specification (`RateSpec`), and tree time layout specification (`TimeSpec`). Then use these specifications to create a CRR tree with `crrtree`.

```
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 = eqptimespec(ValuationDate, Maturity, 4)

TimeSpec =

          FinObj: 'BinTimeSpec'
   ValuationDate: 731582
        Maturity: 731946
      NumPeriods: 4
           Basis: 0
    EndMonthRule: 1
```

```
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 `treeviewer` to observe the tree you have created.



Tree Visualization
Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot

See Also

`eqptimespec`, `intenvset`, `stockspec`

fixedbybdt

Purpose Price fixed-rate note from a BDT interest-rate tree

Syntax

```
[Price, PriceTree] = fixedbybdt(BDTTree, CouponRate, Settle,
   Maturity, Reset, Basis, Principal, Options)
```

Arguments

`BDTTree`	Interest-rate tree structure created by `bdttree`.
`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.
`Reset`	(Optional) `NINST`-by-`1` vector representing the frequency of payments per year. Default = `1`.
`Basis`	(Optional) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) The notional principal amount. Default = `100`.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

Description

`[Price, PriceTree] = fixedbybdt(HJMTree, CouponRate, Settle, Maturity, Reset, Basis, Principal, Options)` computes the price of a fixed-rate note from a BDT interest-rate tree.

`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.

Load the file `deriv.mat`, which provides `BDTTree`. `BDTTree` contains the time and interest-rate information needed to price the note.

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
CouponRate = 0.10;
Settle = '01-Jan-2000';
Maturity = '01-Jan-2004';
Reset = 1;
```

Use `fixedbybdt` to compute the price of the note.

```
Price = fixedbybdt(BDTTree, CouponRate, Settle, Maturity, Reset)

Price =

  92.9974
```

See Also

`bdttree`, `bondbybdt`, `capbybdt`, `cfbybdt`, `floatbybdt`, `floorbybdt`, `swapbybdt`

fixedbyhjm

Purpose

Price fixed-rate note from an HJM interest-rate tree

Syntax

```
[Price, PriceTree] = fixedbyhjm(HJMTree, CouponRate, Settle,
   Maturity, Reset, Basis, Principal, Options)
```

Arguments

`HJMTree`	Forward rate tree structure created by `hjmtree`.
`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.
`Reset`	(Optional) `NINST`-by-`1` vector representing the frequency of payments per year. Default = `1`.
`Basis`	(Optional) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) The notional principal amount. Default = `100`.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

Description

`[Price, PriceTree] = fixedbyhjm(HJMTree, CouponRate, Settle, Maturity, Reset, Basis, Principal, Options)` computes the price of a fixed-rate note from a HJM forward rate tree.

`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.

Load the file `deriv.mat`, which provides `HJMTree`. `HJMTree` contains the time and forward rate information needed to price the note.

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
CouponRate = 0.04;
Settle = '01-Jan-2000';
Maturity = '01-Jan-2003';
```

Use `fixedbyhjm` to compute the price of the note.

```
Price = fixedbyhjm(HJMTree, CouponRate, Settle, Maturity)

Price =

  98.7159
```

See Also

`bondbyhjm`, `capbyhjm`, `cfbyhjm`, `floatbyhjm`, `floorbyhjm`, `hjmtree`, `swapbyhjm`

fixedbyzero

Purpose

Price fixed-rate note by a set of zero curves

Syntax

```
Price = fixedbyzero(RateSpec, CouponRate, Settle, Maturity, Reset,
   Basis, Principal)
```

Arguments

`RateSpec`	A 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 earlier than or equal to `Maturity`.
`Maturity`	Maturity date.
`Reset`	(Optional) Frequency of payments per year. Default = `1`.
`Basis`	(Optional) Day count basis. Default = `0` (actual/actual).
`Principal`	(Optional) The notional principal amount. Default = `100`.

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 `[]`.

Description

`Price = fixedbyzero(RateSpec, CouponRate, Settle, Maturity, Reset, Basis, Principal)` computes the price of a fixed-rate note by a set of zero curves.

`Price` is 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.

Examples

Price a 4% fixed-rate note using a set of zero curves.

Load the file `deriv.mat`, which provides `ZeroRateSpec`, the interest-rate term structure needed to price the note.

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
CouponRate = 0.04;
Settle = '01-Jan-2000';
Maturity = '01-Jan-2003';
```

Use `fixedbyzero` to compute the price of the note.

```
Price = fixedbyzero(ZeroRateSpec, CouponRate, Settle, Maturity)

Price =

  98.7159
```

See Also `bondbyzero`, `cfbyzero`, `floatbyzero`, `swapbyzero`

floatbybdt

Purpose Price floating-rate note from a BDT interest-rate tree

Syntax

```
[Price, PriceTree] = floatbybdt(BDTTree, Spread, Settle, Maturity,
   Reset, Basis, Principal, Options)
```

Arguments

`BDTTree`	Interest-rate tree structure created by `bdttree`.
`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.
`Maturity`	`NINST`-by-`1` vector of dates representing the maturity dates of the floating-rate note.
`Reset`	(Optional) `NINST`-by-`1` vector representing the frequency of payments per year. Default = `1`.
`Basis`	(Optional) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) `NINST`-by-`1` vector of the notional principal amount. Default = `100`.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

Description

`[Price, PriceTree] = floatbyhjm(HJMTree, Spread, Settle, Maturity, Reset, Basis, Principal, Options)` computes the price of a floating-rate note from a BDT tree.

`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 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
```

Set the required values. Other arguments will 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 =

  100.6054
```

See Also

bdttree, bondbybdt, capbybdt, cfbybdt, fixedbybdt, floorbybdt, swapbybdt

floatbyhjm

Purpose

Price floating-rate note from an HJM interest-rate tree

Syntax

```
[Price, PriceTree] = floatbyhjm(HJMTree, Spread, Settle, Maturity,
   Reset, Basis, Principal, Options)
```

Arguments

`HJMTree`	Forward rate tree structure created by `hjmtree`.
`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.
`Maturity`	`NINST`-by-`1` vector of dates representing the maturity dates of the floating-rate note.
`Reset`	(Optional) `NINST`-by-`1` vector representing the frequency of payments per year. Default = `1`.
`Basis`	(Optional) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) `NINST`-by-`1` vector of the notional principal amount. Default = `100`.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

Description

`[Price, PriceTree] = floatbyhjm(HJMTree, Spread, Settle, Maturity, Reset, Basis, Principal, Options)` computes the price of a floating-rate note from an HJM tree.

`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 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 forward rate information needed to price the note.

```
load deriv
```

Set the required values. Other arguments will 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
```

See Also

`bondbyhjm`, `capbyhjm`, `cfbyhjm`, `fixedbyhjm`, `floorbyhjm`, `hjmtree`, `swapbyhjm`

floatbyzero

Purpose

Price floating-rate note prices by a set of zero curves

See Also

```
Price = floatbyzero(RateSpec, Spread, Settle, Maturity, Reset,
   Basis, Principal)
```

Arguments

`RateSpec`	A 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 earlier than or equal to `Maturity`.
`Maturity`	Maturity date.
`Reset`	(Optional) Frequency of payments per year. Default = `1`.
`Basis`	(Optional) Day count basis. Default = `0` (actual/actual).
`Principal`	(Optional) The notional principal amount. Default = `100`.

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 `[]`.

Description

`Price = floatbyzero(RateSpec, Spread, Settle, Maturity, Reset, Basis, Principal)` computes the price of a floating-rate note by a set of zero curves.

`Price` is a number of instruments (`NINST`) by number of curves (`NUMCURVES`) matrix of floating-rate note prices. Each column arises from one of the zero curves.

Examples

Price a 20 basis point floating-rate note using a set of zero curves.

Load the file `deriv.mat`, which provides `ZeroRateSpec`, the interest-rate term structure needed to price the note.

```
load deriv
```

Set the required values. Other arguments will 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
```

See Also

`bondbyzero`, `cfbyzero`, `fixedbyzero`, `swapbyzero`

floorbybdt

Purpose

Price floor instrument by a BDT interest-rate tree

Syntax

```
[Price, PriceTree] = floorbybdt(BDTTree, Strike, Settle, Maturity,
   Reset, Basis, Principal, Options)
```

Arguments

`BDTTree`	Interest-rate tree structure created by `bdttree`.
`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 `Settle` date for every floor is set to the `ValuationDate` of the BDT tree. The floor argument `Settle` 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) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) The notional principal amount. Default = `100`.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

Description

`[Price, PriceTree] = floorbybdt(BDTTree, 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.

Examples

Example 1. Price a 10% floor instrument using a BDT interest-rate tree.

Load the file `deriv.mat`, which provides `BDTTree`. `BDTTree` contains the time and interest-rate information needed to price the floor instrument.

```
load deriv
```

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(BDTTree, Strike, Settle, Maturity)

Price =

   0.1770
```

Example 2. Here is a second example, showing the pricing of a 10% floor instrument using a newly created BDT 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];
```

Next 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);
```

Now create the BDT tree from the specifications.

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

Set the floor arguments.

```
FloorStrike = 0.10;
Settlement = ValuationDate;
Maturity = '01-01-2002';
FloorReset = 1;
```

Remaining arguments will use defaults.

Finally, use `floorbybdt` to find the price of the floor instrument.

```
Price= floorbybdt(BDTTree, FloorStrike, Settlement, Maturity,...
FloorReset)

Price =

    0.0431
```

See Also

`bdttree`, `capbybdt`, `cfbybdt`, `swapbybdt`

Purpose

Price floor instrument by an HJM interest-rate tree

Syntax

```
[Price, PriceTree] = floorbyhjm(HJMTree, Strike, Settle, Maturity,
   Reset, Basis, Principal, Options)
```

Arguments

`HJMTree`	Forward rate tree structure created by `hjmtree`.
`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 `Settle` date for every floor is set to the `ValuationDate` of the HJM tree. The floor argument `Settle` 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) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) The notional principal amount. Default = `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.

Examples

Price a 3% floor instrument using an HJM forward rate tree.

Load the file `deriv.mat`, which provides `HJMTree`. `HJMTree` contains the time and forward rate information needed to price the floor instrument.

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
Strike = 0.03;
Settle = '01-Jan-2000';
Maturity = '01-Jan-2004';
```

Use `floorbyhjm` to compute the price of the floor instrument.

```
Price = floorbyhjm(HJMTree, Strike, Settle, Maturity)

Price =

  0.0486
```

See Also

`capbyhjm`, `cfbyhjm`, `hjmtree`, `swapbyhjm`

Purpose

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 `FixedInd = [1 3]`. Default = `[]`, no instruments held fixed.
`NumCosts`	(Optional) Number of points generated along the cost frontier when a vector of target costs (`TargetCost`) is not specified. The default is 10 equally spaced points between the point of minimum cost and the point of minimum exposure. When specifying `TargetCost`, enter `NumCosts` as an empty matrix `[]`.
`TargetCost`	(Optional) Vector of target cost values along the cost frontier. If `TargetCost` is empty, or not entered, `hedgeopt` evaluates `NumCosts` equally spaced target costs between the minimum cost and minimum exposure. When specified, the elements of `TargetCost` 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 <= b`, where `A = ConSet(:,1:end-1)` and `b = ConSet(:,end)`.

Notes 1. 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.

2. `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.

3. Not all problems are solvable (e.g., 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 `NaN`'s 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 allows investors to 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 in the Financial Toolbox documentation

lsqlin in the Optimization Toolbox documentation

Purpose 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 `FixedInd = 1`; 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 `FixedInd = []`.
`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, `PortHolds`, satisfies all the inequalities `A*PortHolds <= 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 1. The constraints PortHolds(FixedInd) = CurrentHolds(FixedInd) are appended to any constraints passed in ConSet. Pass FixedInd = [] to specify all constraints through ConSet.

2. The default constraints generated by portcons are inappropriate, since they require the sum of all holdings to be positive and equal to one.

3. hedgeself 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];
W0 = [1; 1];
[PortSens, PortValue, PortHolds]= hedgeslf(Sens, Price, W0)

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 instruments(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` in the Optimization Toolbox documentation

`portcons` in the Financial Toolbox documentation

hjmprice

Purpose Instrument prices by an HJM interest-rate tree

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

Arguments

`HJMTree`	Heath-Jarrow-Morton tree sampling a forward rate process. See `hjmtree` for information on creating `HJMTree`.
`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 `derivset`.

Description

`Price = hjmprice(HJMTree, InstSet, Options)` computes arbitrage free prices for instruments using an interest-rate tree created with `hjmtree`. `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'`, `'Fixed'`, `'Float'`, `'Cap'`, `'Floor'`, `'Swap'`. See `instadd` to construct defined types.

Related single-type pricing functions are

- `bondbyhjm`: Price a bond by an HJM tree.
- `capbyhjm`: Price a cap by an HJM tree.
- `cfbyhjm`: Price an arbitrary set of cash flows by an HJM tree.
- `fixedbyhjm`: Price a fixed-rate note by an HJM tree.

- `floatbyhjm`: Price a floating-rate note by an HJM tree.
- `floorbyhjm`: Price a floor by an HJM tree.
- `optbndbyhjm`: Price a bond option by an HJM tree.
- `swapbyhjm`: Price a swap by an HJM tree.

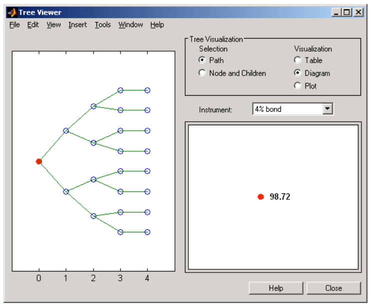
Examples

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)

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

Index Type Strike Settle      Maturity     CapReset...  Name ...
3     Cap  0.03   01-Jan-2000 01-Jan-2004  1            3% Cap

   [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: {1x5 cell}
       AIBush: {1x5 cell}
         tObs: [0 1 2 3 4]
```

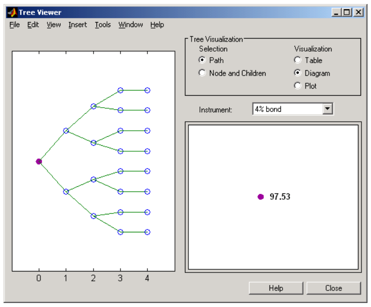
You can use `treeviewer` to see the prices of these three instruments along the price tree.

```
treeviewer(PriceTree, HJMSubSet)
```



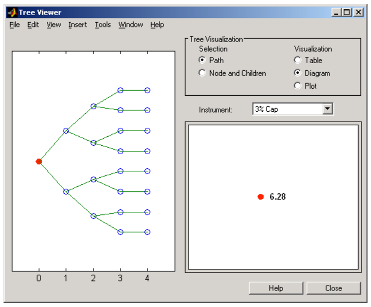
Selection: (●) Path ( ) Node and Children
Visualization: ( ) Table (●) Diagram ( ) Plot
Instrument: 4% bond
● 98.72

4% Bond (Maturity 2003)



Selection: (●) Path ( ) Node and Children
Visualization: ( ) Table (●) Diagram ( ) Plot
Instrument: 4% bond
● 97.53

4% Bond (Maturity 2004)



Selection: (●) Path ( ) Node and Children
Visualization: ( ) Table (●) Diagram ( ) Plot
Instrument: 3% Cap
● 6.28

3% Cap

See Also

`hjmsens`, `hjmtree`, `hjmvolspec`, `instadd`, `intenvprice`, `intenvsens`

Purpose

Instrument prices and sensitivities from an HJM interest-rate tree

Syntax

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

Arguments

`HJMTree`	Heath-Jarrow-Morton tree sampling a forward rate process. Ssee `hjmtree` for information on creating `HJMTree`.
`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 `derivset`.

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'`, `'Fixed'`, `'Float'`, `'Cap'`, `'Floor'`, `'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

Load the tree and instruments from a 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  Name ...
1     Bond   0.04       01-Jan-2000 01-Jan-2003  1       4% bond
2     Bond   0.04       01-Jan-2000 01-Jan-2004  2       4% bond

Index Type Strike Settle      Maturity     CapReset...  Name ...
3     Cap  0.03   01-Jan-2000 01-Jan-2004  1            3% Cap

   [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+003 *

    1.0299
    1.6227
    6.8526
```

See Also `hjmprice`, `hjmtree`, `hjmvolspec`, `instadd`

hjmtimespec

Purpose

Specify time structure for HJM 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`	(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:

`Compounding` = `1`, `2`, `3`, `4`, `6`, `12`

`Disc = (1 + Z/F)^(-T)`, where `F` is the compounding frequency, `Z` is the zero rate, and `T` is the time in periodic units, e.g. `T = F` is one year.

`Compounding` = `365`

`Disc = (1 + Z/F)^(-T)`, where `F` is the number of days in the basis year and `T` is a number of days elapsed computed by basis.

`Compounding` = `-1`

`Disc = exp(-T*Z)`, where `T` is time in years.

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

Specify an eight-period tree with semiannual nodes (every six months). 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

Purpose

Build an HJM forward 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 `hjmvolspec` 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 HJM tree and the `Compounding` rule for date to time mapping and price-yield formulas. See `hjmtimespec` 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

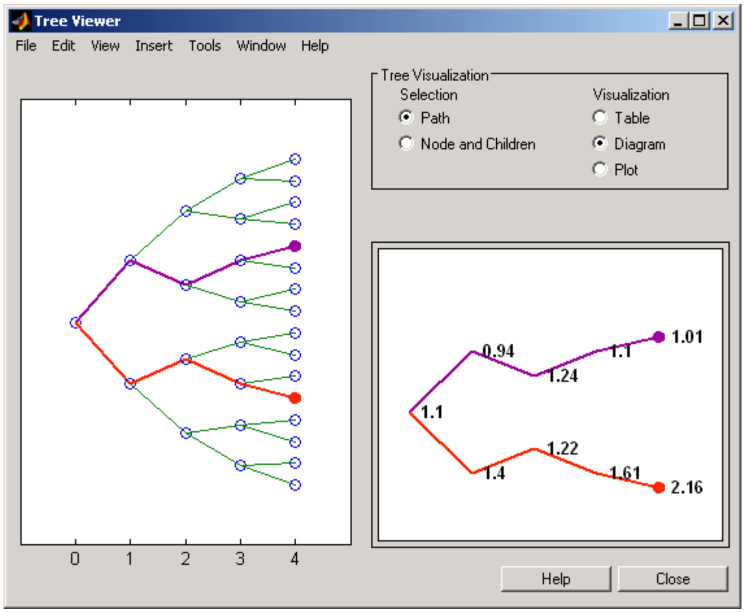
Using the data provided, create a HJM volatility specification (`VolSpec`), rate specification (`RateSpec`), and tree time layout specification (`TimeSpec`). Then use these specifications to create a HJM tree with `hjmtree`.

```
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];
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);
```

Use `treeviewer` to observe the tree you have created.

```
treeviewer(HJMTree)
```



Tree Visualization
Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot

See Also

`hjmprice`, `hjmtimespec`, `hjmvolspec`, `intenvset`

hjmvolspec

Purpose

Specify an HJM forward 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 table below defines the various arguments to `hjmvolspec`.

Argument	Description
`Sigma_0`	Scalar base volatility over a unit time.
`Lambda`	Scalar decay factor.
`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.

Argument	Description
`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 a HJM forward rate volatility process. Each factor is specified with one of the functional forms:

Volatility Specification	Formula
Constant	$\sigma(t, T)$ `= Sigma_0`
Stationary	$\sigma(t, T)$ `= Vol(T-t) = Vol(Term)`
Exponential	$\sigma(t, T)$ `= Sigma_0*exp(-Lambda*(T-t))`
Vasicek, Hull-White	$\sigma(t, T)$ `= Sigma_0*exp(-Decay(T-t))`
Proportional	$\sigma(t, T)$ `= Prop(T-t)*max(SpotRate(t), 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

Example 1. 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]
```

Example 2. 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`

Purpose

Add types to instrument collection

Syntax

Arbitrary cash flow instrument. (See also `instcf`.)

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

Asian instrument. (See also `instasian`.)

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

Barrier instrument. (See also `instbarrier`.)

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

Bond instrument. (See also `instbond`.)

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

Bond option. (See also `instoptbnd`.)

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

Cap instrument. (See also `instcap`.)

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

Compound instrument. (See also `instcompound`.)

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

Fixed-rate note instrument. (See also `instfixed`.)

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

Floating-rate note instrument. (See also `instfloat`.)

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

Floor instrument. (See also `instfloor`.)

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

Lookback instrument. (See also `instlookback`.)

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

Stock option instrument. (See also `instoptstock`.)

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

Swap instrument. (See also `instswap`.)

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

To add instruments to an existing collection:

```
InstSet = instadd(InstSetOld, TypeString, Data1, Data2, ...)
```

Arguments

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.

`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.

Description

`instadd` stores instruments of types `'Asian'`, `'Barrier'`, `'Bond'`, `'Cap'`, `'CashFlow'`, `'Compound'`, `'Fixed'`, `'Float'`, `'Floor'`, `'Lookback'`, `'OptBond'`, `'OptStock'`, or `'Swap'`. This toolbox provides pricing and sensitivity routines for these instruments.

`InstSet` is an instrument set variable containing the new input data.

Examples

Create a portfolio with two cap instruments and a 4% bond.

```
Strike = [0.06; 0.07];
CouponRate = 0.04;
Settle = '06-Feb-2000';
Maturity = '15-Jan-2003';

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 NaN      NaN   NaN
2     Cap  0.07   06-Feb-2000 15-Jan-2003 NaN      NaN   NaN

Index Type CouponRate Settle         Maturity ...
3     Bond 0.04       06-Feb-2000    15-Jan-2003...
```

See Also

instasian, instbarrier, instbond, instcap, instcf, instcompound, instfixed, instfloat, instfloor, instlookback, instoptbnd, instoptstock, instswap

Purpose

Add new instruments to an 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

`FieldList`	String or number of fields (`NFIELDS`)-by-`1` cell array of strings listing the name of each data field. `FieldList` cannot be named with the reserved names `Type` or `Index`.
`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.
`ClassList`	(Optional) String or `NFIELDS`-by-`1` cell array of strings listing the data class of each field. The class determines how `DataList` is parsed. Valid strings are `'dble'`, `'date'`, and `'char'`. The `'FieldClass', ClassList` pair is always optional. `ClassList` is inferred from existing fieldnames or from the data if not entered.
`TypeString`	String specifying the type of instrument added. Instruments of different types can have different fieldname collections.
`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

Use instaddfield 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, 'Data', DataList, 'Type', TypeString) and

InstSet = instaddfield('FieldName', FieldList, 'FieldClass', ClassList, 'Data', DataList, 'Type', TypeString) create 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`

instasian

Purpose

Construct Asian option instrument

Syntax

```
InstSet = instasian(InstSet, OptSpec, Strike, Settle, ExerciseDates,
   AmericanOpt, AvgType, AvgPrice, AvgDate)
[FieldList, ClassList, TypeString] = instasian
```

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.
`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.
`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`	(Optional) If `AmericanOpt = 0`, `NaN`, or is unspecified, the option is a European option. If `AmericanOpt = 1`, 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 Settle. This argument is used when AvgDate < Settle. Default is the current stock price.
AvgDate	(Optional) Scalar representing the date on which the averaging period begins. Default = Settle.

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'.

See Also

instadd, instdisp, instget

instbarrier

Purpose Construct barrier option instrument

Syntax

```
InstSet = instbarrier(InstSet, OptSpec, Strike, Settle,
   ExerciseDates, AmericanOpt, BarrierSpec, Barrier, Rebate)
[FieldList, ClassList, TypeString] = instbarrier
```

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.
`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.

`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) 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'`.

See Also

`instadd`, `instdisp`, `instget`

instbond

Purpose

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 `instget` for more information on the `InstSet` variable.
`CouponRate`	Decimal number indicating the annual percentage rate used to determine the coupons payable on a bond.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`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 bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`EndMonthRule`	(Optional) End-of-month rule. A 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'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.
`IssueDate`	(Optional) Date when a bond was issued.

`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.
`LastCouponDate`	(Optional) Last coupon date of a bond prior to the maturity date. 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.
`StartDate`	Ignored.
`Face`	(Optional) Face or par value. 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'`.

See Also

`hjmprice`, `instaddfield`, `instdisp`, `instget`, `intenvprice`

instcap

Purpose 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 `instget` for more information on the `InstSet` 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) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) The notional principal amount. Default = `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'`.

See Also

`hjmprice`, `instaddfield`, `instbond`, `instdisp`, `instfloor`, `instswap`, `intenvprice`

instcf

Purpose

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 `instget` for more information on the `InstSet` 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 `NaN`s.
`CFlowDates`	`NINST`-by-`MOSTCFS` matrix of cash flow dates. Each entry contains the date of the corresponding cash flow in `CFlowAmounts`.
`Settle`	Settlement date on which the cash flows are priced.
`Basis`	(Optional) Day-count basis of the bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.

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 meta-data for an instrument of type `CashFlow`.

`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` specifies the type of instrument added, e.g.,
`TypeString = 'CashFlow'`.

See Also

`instadd`, `instdisp`, `instget`, `intenvprice`

instcompound

Purpose

Construct compound option instrument

Syntax

```
InstSet = instcompound(InstSet, UOptSpec, UStrike, USettle,
  UExerciseDates, UAmericanOpt, COptSpec, CStrike, CSettle,
  CExerciseDates, CAmericanOpt)
[FieldList, ClassList, TypeString] = instcompound
```

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.
`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.

`CSettle`	`1`-by-`1` vector containing the settlement or trade date.

`CExerciseDates`	For a European option (`CAmericanOpt = 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 (`CAmericanOpt = 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.

`CAmericanOpt`	If `CAmericanOpt = 0`, `NaN`, or is unspecified, the option is a European option. If `CAmericanOpt = 1`, 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'`.

See Also

`instadd`, `instdisp`, `instget`

instdelete

Purpose

Complement of a subset of instruments found 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 `NaN`s 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.

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

Purpose Display instruments

Syntax `CharTable = instdisp(InstSet)`

Arguments

`InstSet`	Variable containing a collection of instruments. See `instaddfield` 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.

`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
```

See Also

`datestr` in the Financial Toolbox documentation

`num2str` in the MATLAB Reference

`instaddfield`, `instget`

instfields

Purpose

List fields

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)` retrieve 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 =

    'dble'
    'dble'
    'char'
    'dble'
```

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`

Purpose

Search instruments for matching conditions

Syntax

```
IndexMatch = instfind(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 `NaN`s 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.

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

Purpose

Construct fixed-rate instrument

Syntax

```
InstSet = instfixed(InstSet, CouponRate, Settle, Maturity, Reset,
   Basis, Principal)
[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 `instget` for more information on the `InstSet` 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) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) The notional principal amount. 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 = instfixed(InstSet, Strike, Settle, Maturity, Reset, Basis, Principal)` 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'`.

See Also

`hjmprice`, `instaddfield`, `instbond`, `instcap`, `instdisp`, `instswap`, `intenvprice`

instfloat

Purpose Construct floating-rate instrument

Syntax

```
InstSet = instfloat(InstSet, Spread, Settle, Maturity, Reset, Basis,
   Principal)
[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 `instget` for more information on the `InstSet` 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) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) The notional principal amount. 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 = instfloat(InstSet, Spread, Settle, Maturity, Reset, Basis, Principal)` creates a new instrument set containing floating-rate instruments or adds 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'.

See Also

hjmprice, instaddfield, instbond, instcap, instdisp, instswap, intenvprice

instfloor

Purpose

Construct floor instrument

Syntax

```
InstSet = instfloor(InstSet, Strike, Settle, Maturity, Reset, Basis,
   Principal)
[FieldList, ClassList, TypeString] = instfloor
```

Arguments

`InstSet`	Instrument variable. This argument is specified only when adding floor instruments to an existing instrument set. See `instget` for more information on the `InstSet` variable.
`Strike`	Rate at which the floor is exercised, as a decimal number.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Reset`	(Optional) `NINST`-by-`1` vector representing the frequency of payments per year. Default = `1`.
`Basis`	(Optional) Day-count basis of the bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`Principal`	(Optional) The notional principal amount. Default = `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'`.

See Also

`hjmprice`, `instaddfield`, `instbond`, `instcap`, `instdisp`, `instswap`, `intenvprice`

instget

Purpose

Retrieve data from instrument variable

Syntax

```
[Data_1, Data_2,...,Data_n] = instget(InstSet, 'FieldName',
   FieldList,  '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`	(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. `FieldList` 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.
`IndexSet`	(Optional) Number of instruments (`NINST`)-by-`1` vector of positions of instruments to work on. If `TypeList` is also entered, instruments referenced must be one of `TypeList` types and contained in `IndexSet`. 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.

Parameter 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)` retrieve 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 which 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`

Purpose

Retrieve data and context from instrument variable

Syntax

```
[DataList, FieldList, ClassList, IndexSet, TypeSet] =
   instgetcell(InstSet, 'FieldName', FieldList,  '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`	(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. FieldList should not be either `Type` or `Index`; these field names are reserved. The default is all fields available for the returned set of instruments.
`IndexSet`	(Optional) Number of instruments (`NINST`)-by-`1` vector of positions of instruments to work on. If `TypeList` is also entered, instruments referenced must be one of `TypeList` types and contained in `IndexSet`. 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.

Parameter 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 = 

    'dble'
    'dble'
    'char'
    'dble'
```

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

Purpose 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`

Purpose

Construct lookback option

Syntax

```
InstSet = instlookback(InstSet, OptSpec, Strike, Settle,
   ExerciseDates, AmericanOpt)
[FieldList, ClassList, TypeString] = instlookback
```

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.
`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.

`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`	(Optional) If `AmericanOpt = 0`, `NaN`, or is unspecified, the option is a European option. If `AmericanOpt = 1`, 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'`.

See Also

`instadd`, `instdisp`, `instget`

Purpose Construct bond option

Syntax

```
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'`.

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 `NaN`s. For an American option: `NINST`-by-`1` vector of strike price values for each option.

`ExerciseDates`	`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. 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` and the single listed exercise date.

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'`.

See Also

`hjmprice`, `instadd`, `instdisp`, `instget`

Purpose

Construct stock option

Syntax

```
InstSet = instoptstock(InstSet, StockIndex, OptSpec, Strike, Settle,
   ExerciseDates, AmericanOpt)
[FieldList, ClassList, TypeString] = instoptstock
```

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.
`StockIndex`	Number of instruments (`NINST`)-by-`1` vector of indices pointing to underlying instruments of type `'Stock'` which are also stored in `InstSet`.
`OptSpec`	`NINST`-by-`1` list of string values `'Call'` or `'Put'`.

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 `NaN`s. American option: `NINST`-by-`1` vector of strike price values for each option.
`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 schedule for one option. For a European option, there is only one exercise date, 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` and the single listed exercise date.

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, StockIndex, 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] = 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'`.

See Also

`instadd`, `instdisp`, `instget`

Purpose

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 `NaN`s 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.

Parameter value pairs can be entered in any order. The `InstSet` variable must be the first argument. `'FieldName'` and `'Data'` parameters must appear together or not at all. `'Index'` and `'Type'` parameters 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`

Purpose

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`	(Required) 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. `InstSet` 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. `FieldList` cannot be named with the reserved names `Type` or `Index`.
`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 `TypeList` is also entered, instruments referenced must be one of `TypeList` types and contained in `IndexSet`.
`TypeList`	String or number of types (`NTYPES`)-by-`1` cell array of strings restricting instruments worked on to match one of `TypeList` 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

Purpose

Construct swap instrument

Syntax

```
InstSet = instswap(InstSet, LegRate, Settle, Maturity, LegReset,
   Basis, Principal, LegType)
[FieldList, ClassList, TypeString] = instswap
```

Arguments

`InstSet`	Instrument variable. This argument is specified only when adding a swap to an existing instrument set. See `instget` for more information on the `InstSet` 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 or equal to `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) `NINST`-by-1 vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) `NINST`-by-1 vector of the notional principal amounts. Default = `100`.
`LegType`	(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.

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, LegReset, Basis, Principal, LegType)` creates a new instrument set containing swap instruments or adds swap instruments to an existing instrument set.

`[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'`.

See Also

`hjmprice`, `instaddfield`, `instbond`, `instcap`, `instdisp`, `instfloor`, `intenvprice`

Purpose

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

Purpose Obtain properties of an interest term structure

Syntax

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

Arguments

`RateSpec`	A structure containing the properties of an interest-rate structure. See `intenvset` for information on creating `RateSpec`.
`ParameterName`	String indicating the parameter name to be accessed. The value of the named parameter is extracted from the structure `RateSpec`. 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

Purpose Price instruments by a set of zero curves

Syntax `Price = intenvprice(RateSpec, InstSet)`

Arguments

`RateSpec`	A structure containing the properties of an interest-rate structure. See `intenvset` for information on creating `RateSpec`.
`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.

`bondbyzero`	Price bonds by a set of zero curves.
`cfbyzero`	Price arbitrary cash flow instrument by a set of zero curves.
`fixedbyzero`	Fixed-rate note prices by zero curves.
`floatbyzero`	Floating-rate note prices by zero curves.
`swapbyzero`	Swap prices by a set of zero curves.

Examples

Load the zero curves and instruments from a data file.

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

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

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
```

```
Price = intenvprice(ZeroRateSpec, ZeroInstSet)

Price =

  98.7159
  97.5334
  98.7159
 100.5529
   3.6923
```

See Also

`hjmprice`, `hjmsens`, `instadd`, `intenvsens`, `intenvset`

Purpose

Instrument price and sensitivities by a set of zero curves

Syntax

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

Arguments

`RateSpec`	A structure containing the properties of an interest-rate structure. See `intenvset` for information on creating `RateSpec`.
`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 using a zero coupon bond rate term 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 forward yield 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 forward yield 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 ...                   Name    Quantity
1     Bond 0.04       01-Jan-2000    01-Jan-2003    1                            4% bond 100
2     Bond 0.04       01-Jan-2000    01-Jan-2004    2                            4% bond  50

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

Purpose Set properties of interest-rate environment

Syntax

```
[RateSpec, RateSpecOld] = intenvset(RateSpec, 'Parameter1', Value1,
   'Parameter2', Value2, ...)
[RateSpec, RateSpecOld] = intenvset
intenvset
```

Arguments

`RateSpec`	(Optional) An existing interest-rate specification structure to be changed, probably created from a previous call to `intenvset`.

Parameters may be chosen from the table below and specified in any order.

`Compounding`	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:
	
	`Compounding` = `1`, `2`, `3`, `4`, `6`, `12`
	
	`Disc = (1 + Z/F)^(-T)`, where `F` is the compounding frequency, `Z` is the zero rate, and `T` is the time in periodic units, e.g. `T = F` is one year.
	
	`Compounding` = `365`
	
	`Disc = (1 + Z/F)^(-T)`, where `F` is the number of days in the basis year and `T` is a number of days elapsed computed by basis.
	
	`Compounding` = `-1`
	
	`Disc = exp(-T*Z)`, where `T` is time in years.

`Disc`	Number of points (`NPOINTS`) by number of curves (`NCURVES`) matrix of unit bond prices over investment intervals from `StartDates`, when the cash flow is valued, to `EndDates`, when the cash flow is received.

`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 `StartDates`, when the cash flow is valued, to `EndDates`, when the cash flow is received.
`EndDates`	`NPOINTS`-by-`1` vector or scalar of serial maturity dates ending the interval to discount over.
`StartDates`	`NPOINTS`-by-`1` vector or scalar of serial dates starting the interval to discount over. Default = `ValuationDate`.
`ValuationDate`	(Optional) Scalar value in serial date number form representing the observation date of the investment horizons entered in `StartDates` and `EndDates`. Default = `min(StartDates)`.
`Basis`	(Optional) Day-count basis of the bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`EndMonthRule`	(Optional) End-of-month rule. A 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'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.

It is sufficient to type only the leading characters that uniquely identify the parameter. Case is ignored for parameter names.

When creating a new `RateSpec`, the set of parameters 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 parameter names and possible values.

Description

`[RateSpec, RateSpecOld] = intenvset(RateSpec, 'Parameter1', Value1, 'Parameter2', Value2, ...)` creates an interest term structure (`RateSpec`) in which the input argument list is specified as parameter name /parameter value pairs. The parameter name portion of the pair must be recognized as a valid field of the output structure `RateSpec`; the parameter 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 parameters to the specified values and recalculating the parameters 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 parameter names and possible values.

`RateSpecOld` is a structure containing the properties of an interest-rate structure prior to the changes introduced by the call to `intenvset`.

Examples

Use `intenvset` to create a `RateSpec`.

```
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 parameter 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 parameter 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 ]
         EndMonthRule: [ 0 | {1} ]
```

See Also

intenvget

isafin

Purpose True if financial structure type or financial object class

Syntax

```
IsFinObj = isafin(Obj, ClassName)
```

Arguments

`Obj`	Name of a financial structure.
`ClassName`	String containing name of financial structure class.

Description `IsFinObj = isafin(Obj, ClassName)` is True (1) if the input argument is a financial structure type or financial object class.

Examples

```
load deriv.mat
IsFinObj = isafin(HJMTree, 'HJMFwdTree')

IsFinObj =

     1
```

See Also `classfin`

Purpose Price lookback option by a CRR tree

Syntax

```
[Price, PriceTree] = lookbackbycrr(CRRTree, OptSpec, Strike, Settle,
   ExerciseDates, AmericanOpt)
```

Arguments

`CRRTree`	Stock tree structure created by `crrtree`.
`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 strike as `NaN`.
`Settle`	`NINST`-by-`1` vector of `Settle` dates. The settle date for every lookback is set to the valuation date of the stock tree. The lookback 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`	(Optional) If `AmericanOpt = 0`, `NaN`, or is unspecified, the option is a European option. If `AmericanOpt = 1`, the option is an American option.

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 `[]`.

lookbackbycrr

Description

[Price, PriceTree] = lookbackbycrr(CRRTree, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt) calculates the value of fixed- and floating-strike lookback options.

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 a lookback option using a CRR equity tree.

Load the file deriv.mat, which provides CRRTree. CRRTree contains the stock specification and time information needed to price the option.

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
OptSpec = 'Call';
Strike = 115;
Settle = '01-Jan-2003';
ExerciseDates = '01-Jan-2006';

Price = lookbackbycrr(CRRTree, OptSpec, Strike, Settle, ...
ExerciseDates)

Price =

    7.6015
```

See Also

crrtree, instlookback

References

Hull, J., and A. White, “Efficient Procedures for Valuing European and American Path-Dependent Options,” *Journal of Derivatives*, Fall 1993, pp. 21-31.

Purpose

Price lookback option by an EQP binary tree

Syntax

```
[Price, PriceTree] = lookbackbyeqp(EQPTree, OptSpec, Strike, Settle,
   ExerciseDates, AmericanOpt)
```

Arguments

`EQPTree`	Stock tree structure created by `eqptree`.
`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 strike as `NaN`.
`Settle`	`NINST`-by-`1` vector of `Settle` dates. The settle date for every lookback is set to the valuation date of the stock tree. The lookback 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`	(Optional) If `AmericanOpt = 0`, `NaN`, or is unspecified, the option is a European option. If `AmericanOpt = 1`, the option is an American option.

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 `[]`.

lookbackbyeqp

Description

[Price, PriceTree] = lookbackbyeqp(EQPTree, OptSpec, Strike, ExerciseDates, AmericanOpt) calculates the value of fixed- and floating-strike lookback options.

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 a lookback option using an EQP equity tree.

Load the file deriv.mat, which provides EQPTree. EQPTree contains the stock specification and time information needed to price the option.

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
OptSpec = 'Call';
Strike = 115;
Settle = '01-Jan-2003';
ExcerciseDates = '01-Jan-2006';

Price = lookbackbyeqp(EQPTree, OptSpec, Strike, Settle, ...
ExerciseDates)

Price =

  8.7941
```

See Also

eqptree, instlookback

References

Hull, J., and A. White, “Efficient Procedures for Valuing European and American Path-Dependent Options,” *Journal of Derivatives*, Fall 1993, pp. 21-31.

Purpose

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`	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`	Initial value at each node of the tree. Default = `NaN`.

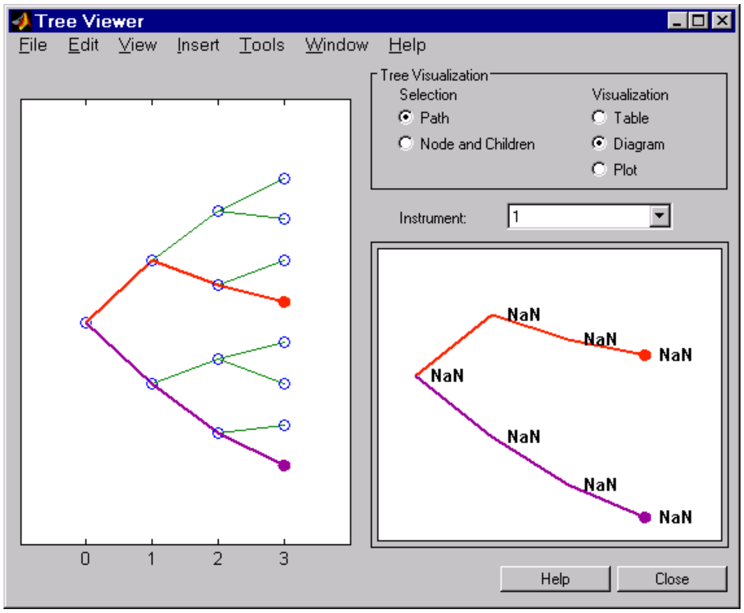
Description

`[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)
```



Tree Visualization
Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot
Instrument: 1

See Also

bushpath, bushshape

mktree

Purpose

Create recombining 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`	Initial value at each node of the tree. Default = `NaN`.
`IsPriceTree`	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`

mmktbybdt

Purpose

Create money market tree from a BDT tree

Syntax

```
MMktTree = mmktbybdt(BDTTree)
```

Arguments

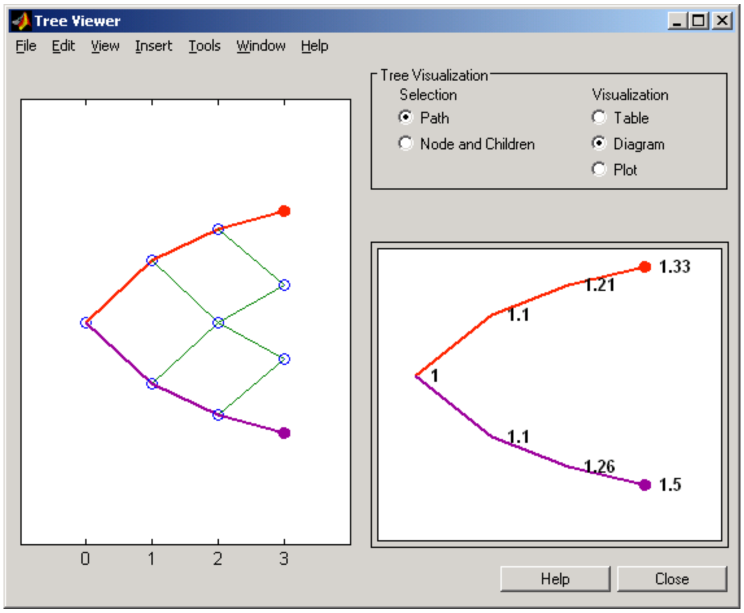
`BDTTree`	Interest-rate tree structure created by `bdttree`.

Description

`MMktTree = mmktbybdt(BDTTree)` creates a money market tree from an interest-rate tree structure created by `bdttree`.

Examples

```
load deriv.mat;
MMktTree = mmktbybdt(BDTTree);
treeviewer(MMktTree)
```



See Also

`bdttree`

Purpose

Create money market tree from an HJM tree

Syntax

```
MMktTree = mmktbyhjm(HJMTree)
```

Arguments

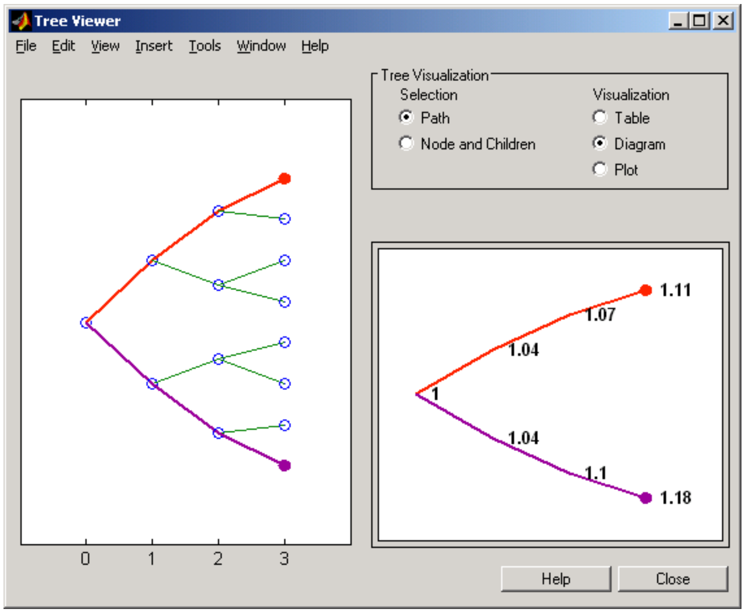
`HJMTree`	Forward rate tree structure created by `hjmtree`.

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)
```



Tree Visualization
Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot

See Also

`hjmtree`

optbndbybdt

Purpose

Price bond option by a BDT 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

`BDTTree`	Forward rate tree structure created by `bdttree`.
`OptSpec`	Number of instruments (`NINST`)-by-1 cell array of string values `'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 `NaN`s. For an American option: `NINST`-by-1 vector of strike price values for each option.
`ExerciseDates`	`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. 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` and the single listed exercise date.

`AmericanOpt`	`NINST`-by-`1` vector of flags: `0` (European/Bermuda) or `1` (American).
`CouponRate`	Decimal annual rate.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`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 bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`EndMonthRule`	(Optional) End-of-month rule. A 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'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.
`IssueDate`	(Optional) Date when a bond was issued.
`FirstCouponDate`	Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.
`LastCouponDate`	Last coupon date of a bond prior to the maturity date. 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.

StartDate	Ignored.
Face	Face value. Default is 100.
Options	(Optional) Derivatives pricing options structure created with derivset.

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. BDTTree contains the time and forward rate information needed to price the bond.

```
load deriv;
```

Use optbondbybdt 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
```

See Also

`bdtprice`, `bdttree`, `instoptbnd`

optbndbyhjm

Purpose

Price bond option by an HJM 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 `hjmtree`.
`OptSpec`	Number of instruments (`NINST`)-by-1 cell array of string values `'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 `NaN`s. For an American option: `NINST`-by-1 vector of strike price values for each option.
`ExerciseDates`	`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. 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` and the single listed exercise date.

`AmericanOpt`	`NINST`-by-`1` vector of flags: `0` (European/Bermuda) or `1` (American).
`CouponRate`	Decimal annual rate.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`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 bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`EndMonthRule`	(Optional) End-of-month rule. A 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'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.
`IssueDate`	(Optional) Date when a bond was issued.
`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.
`LastCouponDate`	(Optional) Last coupon date of a bond prior to the maturity date. 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.

StartDate	Ignored.
Face	(Optional) Face value. Default = 100.
Options	(Optional) Derivatives pricing options structure created with derivset.

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

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. HJMTree contains the time and forward rate information needed to price the bond.

```
load deriv;
```

Use 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
```

See Also

hjmprice, hjmtree, instoptbnd

Purpose

Price stock option by a CRR tree

Syntax

```
[Price, PriceTree] = optstockbycrr(CRRTree, OptSpec, Strike, Settle,
   ExerciseDates, AmericanOpt)
```

Arguments

`CRRTree`	Stock tree structure created by `crrtree`.
`OptSpec`	Number of instruments (`NINST`)-by-`1` cell array of strings `'call'` or `'put'`.

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 `NaN`s. American option: `NINST`-by-`1` vector of strike price values for each option.
`Settle`	`NINST`-by-`1` vector of settlement or trade dates.

ExerciseDates	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. 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 and the single listed exercise date.

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 a stock option using a CRR equity tree.

Load the file deriv.mat, which provides CRRTree. CRRTree contains the stock specification and time information needed to price the option.

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
OptSpec = 'Call';
Strike = 105;
Settle = '01-Jan-2003';
ExerciseDates = '01-Jan-2005';
```

```
Price = optstockbycrr(CRRTree, OptSpec, Strike, Settle, ...
ExerciseDates)

Price =

  8.2863
```

See Also `crrtree`, `instoptstock`

optstockbyeqp

Purpose

Price stock option by an EQP tree

Syntax

```
[Price, PriceTree] = optstockbyeqp(EQPTree, OptSpec, Strike, Settle,
   ExerciseDates, AmericanOpt)
```

Arguments

`EQPTree`	Stock tree structure created by `eqptree`.
`OptSpec`	Number of instruments (`NINST`)-by-`1` cell array of strings `'call'` or `'put'`.

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 `NaN`s. American option: `NINST`-by-`1` vector of strike price values for each option.
`Settle`	`NINST`-by-`1` vector of settlement or trade dates.

ExerciseDates	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. 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 and the single listed exercise date.

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 a stock option using an EQP equity tree.

Load the file `deriv.mat`, which provides `EQPTree`. `EQPTree` contains the stock specification and time information needed to price the option.

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
OptSpec = 'Call';
Strike = 105;
Settle = '01-Jan-2003';
ExerciseDates = '01-Jan-2005';

Price = optstockbyeqp(EQPTree, OptSpec, Strike, Settle, ...
ExerciseDates)

Price =

  8.4791
```

See Also

`eqptree`, `instoptstock`

Purpose

Discounting factors from interest rates

Syntax

Usage 1: Interval points are input as times in periodic units.

```
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)
```

Arguments

`Compounding`	Scalar value representing the rate at which the input zero rates were compounded when annualized. This argument determines the formula for the discount factors: `Compounding` = 1, 2, 3, 4, 6, 12 `Disc = (1 + Z/F)^(-T)`, where `F` is the compounding frequency, `Z` is the zero rate, and `T` is the time in periodic units, e.g. `T = F` is one year. `Compounding` = 365 `Disc = (1 + Z/F)^(-T)`, where `F` is the number of days in the basis year and `T` is a number of days elapsed computed by basis. `Compounding` = -1 `Disc = exp(-T*Z)`, where `T` is time in years.
`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`	`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`.
`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. 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

`Disc = rate2disc(Compounding, Rates, EndTimes, StartTimes)` and `[Disc, EndTimes, StartTimes] = rate2disc(Compounding, Rates, EndDates, StartDates, ValuationDate)` convert interest rates to cash flow discounting factors. `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.

`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`.

`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.

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 = Tsemi/2*F`, where `F` is the compounding frequency.

The investment intervals can be specified 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.

Examples

Example 1. Compute discounts from a zero curve at 6 months, 12 months, and 24 months. The time to the cash flows is 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. 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. Compute discounts from the one-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`

Purpose 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`	Scalar value representing the rate at which the input zero rates were compounded when annualized. This argument determines the formula for the discount factors: `Compounding` = 1, 2, 3, 4, 6, 12 `Disc = (1 + Z/F)^(-T)`, where `F` is the compounding frequency, `Z` is the zero rate, and `T` is the time in periodic units, e.g. `T = F` is one year. `Compounding` = 365 `Disc = (1 + Z/F)^(-T)`, where `F` is the number of days in the basis year and `T` is a number of days elapsed computed by basis. `Compounding` = -1 `Disc = exp(-T*Z)`, where `T` is time in years.
`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. 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 piecewise 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 = Tsemi/2 * F, where F is the compounding frequency.

The investment intervals can be specified 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 six, 12, and 24 months. Create a collection of one year forward rates beginning at zero, six, 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

Purpose

Create stock structure

Syntax

```
StockSpec = stockspec(Sigma, AssetPrice, DividendType,
   DividendAmounts, ExDividendDates)
```

Arguments

`Sigma`	Decimal annual price volatility of underlying security.
`AssetPrice`	Scalar representing stock price at time 0.
`DividendType`	(Optional) Dividend type. Must be **`'cash'`** for actual dollar dividends, **`'constant'`** for constant dividend yield, or **`'continuous'`** for continuous dividend yield. Note: Dividends are assumed to be paid in cash. Noncash dividends (stock) are not allowed.
`DividendAmounts`	(Optional) Number of dividends (`NDIV`)-by-`1` vector of cash dividends or constant annualized dividend yields, or a scalar representing a continuous annualized dividend yield.
`ExDividendDates`	(Optional) `NDIV`-by-`1` vector of ex-dividend dates for cash and constant dividend types. Ignored for continuous dividend type.

Description

`StockSpec = stockspec(Sigma, AssetPrice, DividendType, DividendAmounts, ExDividendDates)` creates a MATLAB structure containing the properties of a stock.

Examples

```
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]
```

See Also `crrprice`, `crrtree`, `intenvset`

Purpose

Price swap instrument by a BDT interest-rate tree

Syntax

```
[Price, PriceTree, CFTree, SwapRate] = swapbybdt(BDTTree, LegRate,
   Settle, Maturity, LegReset, Basis, Principal, LegType, Options)
```

Arguments

`BDTTree`	Interest-rate tree structure created by `bdttree`.
`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 or equal to `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) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) `NINST`-by-`1` vector of the notional principal amounts. Default = `100`.
`LegType`	(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.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

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 zero. To do this enter `CouponRate` as `NaN`.

Description

`[Price, PriceTree, CFTree, SwapRate] = swapbybdt(BDTTree, LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType)` computes the price of a swap instrument from a BDT interest-rate tree.

`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.

`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`. `SwapRate` is padded with `NaN` for those instruments in which `CouponRate` is not set to `NaN`.

Examples

Example 1. 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 parameters 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 parameters 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;
```

Use `swapbybdt` to compute the price of the swap.

```
Price  = swapbybdt(BDTTree, LegRate, Settle, Maturity,...
LegReset, Basis, Principal, LegType)

Price =

  7.3032
```

Example 2. 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.

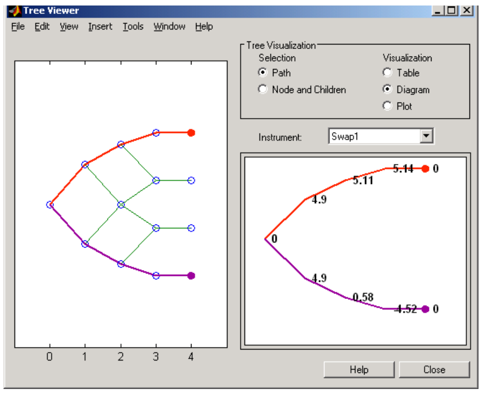
```
LegRate = [NaN 20];

[Price, PriceTree, CFTree, SwapRate] = swapbybdt(BDTTree,...
LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType)

Price =

 -2.8422e-014

PriceTree =

    FinObj: 'BDTPriceTree'
      tObs: [0 1 2 3 4]
     PTree: {1x5 cell}

CFTree =

    FinObj: 'BDTCFTree'
      tObs: [0 1 2 3 4]
    CFTree: {1x5 cell}

SwapRate =

    0.1210
```

Example 3. Calculate the cash flows from a pair of swaps and display the result.

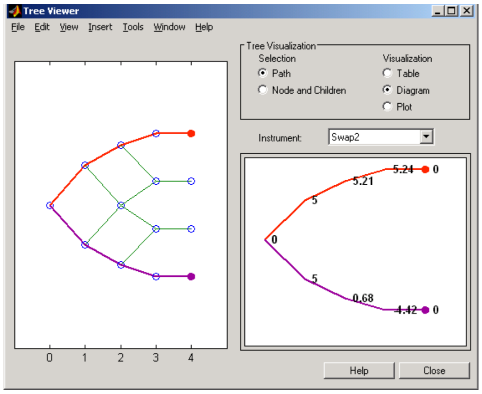
```
Settle = '01-Jan-2000';
Maturity = '01-Jan-2003';
Basis = 0;
Principal = 100;
LegRate= [0.15 10; 0.15 0]; % [CouponRate Spread]
LegType = [1 0; 1 0];
LegReset = [1 1; 1 1];

load deriv

[Price, PriceTree, CFTree, SwapRate] = swapbybdt(BDTTree,...
LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType);
```

Continuing on, provide names for the swaps. Then use `treeviewer` to observe the cash flow data graphically.

```
Names ={'Swap1', 'Swap2'};
treeviewer(CFTree, Names)
```


Tree Visualization — Selection: [✓ Path] Node and Children; Visualization: Table [✓ Diagram] Plot

Instrument: Swap1


Tree Visualization — Selection: [✓ Path] Node and Children; Visualization: Table [✓ Diagram] Plot

Instrument: Swap2

You can use `treeviewer` to display cash flow data at all observation times and along all branches of the tree.

See Also

`bdttree`, `capbybdt`, `cfbybdt`, `floorbybdt`

Purpose

Price swap instrument by an HJM interest-rate tree

Syntax

```
[Price, PriceTree, CFTree, SwapRate] = swapbyhjm(HJMTree, LegRate,
   Settle, Maturity, LegReset, Basis, Principal, LegType, Options)
```

Arguments

`HJMTree`	Forward rate tree structure created by `hjmtree`.
`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 or equal to `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) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) `NINST`-by-`1` vector of the notional principal amounts. Default = `100`.
`LegType`	(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.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

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.

Description

[Price, PriceTree, CFTree, SwapRate] = swapbyhjm(HJMTree, LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType) computes the price of a swap instrument from an HJM interest-rate tree.

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.

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. SwapRate is padded with NaN for those instruments in which CouponRate is not set to NaN.

Examples

Example 1. 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 parameters 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 parameters 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`. `HJMTree` contains the time and forward rate information needed to price the instrument.

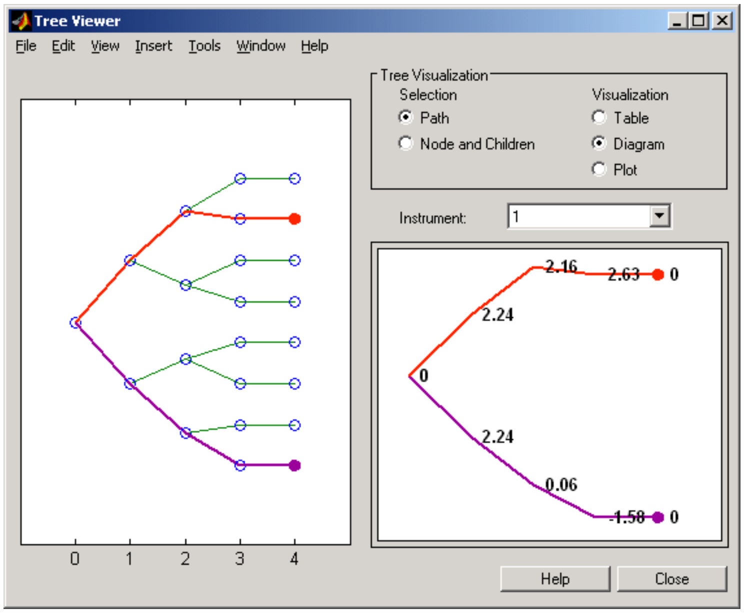
```
load deriv;
```

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]}
```

Using the function `treeviewer`, you can 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).

```
treeviewer(CFTree)
```



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).

In this example you have sold a swap (receive fixed and pay floating). 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.

Example 2. 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] = swapbyhjm(HJMTree,...
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
```

See Also

`capbyhjm`, `cfbyhjm`, `floorbyhjm`, `hjmtree`

Purpose

Price swap instrument by a set of zero curves

Syntax

```
[Price, SwapRate] = swapbyzero(RateSpec, LegRate, Settle, Maturity,
   LegReset, Basis,  Principal, LegType)
```

Arguments

`RateSpec`	A structure containing the properties of an interest-rate structure. See `intenvset` for information on creating `RateSpec`.
`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 or equal to `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) `NINST`-by-1 vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) `NINST`-by-1 vector of the notional principal amounts. Default = `100`.
`LegType`	(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.

Description

`[Price, SwapRate] = swapbyzero(RateSpec, LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType)` prices a swap instrument by a set of zero coupon bond rates.

`Price` is a `NINST` by number of curves (`NUMCURVES`) matrix of swap prices. Each column arises from one of the zero curves.

`SwapRate` is an `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`. `SwapRate` is padded with `NaN` for those instruments in which `CouponRate` is not set to `NaN`.

Examples

Example 1. 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 parameters 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 parameters 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
```

Use swapbyzero to compute the price of the swap.

```
Price = swapbyzero(ZeroRateSpec, LegRate, Settle, Maturity,...
LegReset, Basis, Principal, LegType)

Price =
   3.6923
```

Example 2. 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, SwapRate] = swapbyzero(ZeroRateSpec, LegRate, Settle,...
Maturity, LegReset, Basis, Principal, LegType)

Price =
   0

SwapRate =
   0.0466
```

See Also

bondbyzero, cfbyzero, fixedbyzero, floatbyzero

Purpose

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`	A vector of times corresponding to the compounding value. Times must be equal to or greater than zero.

`Compounding`	(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:
	
	`Compounding` = `1`, `2`, `3`, `4`, `6`, `12`
	
	`Disc = (1 + Z/F)^(-T)`, where `F` is the compounding frequency, `Z` is the zero rate, and `T` is the time in periodic units, e.g. `T = F` is one year.
	
	`Compounding` = `365`
	
	`Disc = (1 + Z/F)^(-T)`, where `F` is the number of days in the basis year and `T` is a number of days elapsed computed by basis.
	
	`Compounding` = `-1`
	
	`Disc = exp(-T*Z)`, where `T` is time in years.

`Basis`	(Optional) Day-count basis of the bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`EndMonthRule`	(Optional) End-of-month rule. A 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'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

`Dates = time2date(Settle, Times, Compounding, Basis, EndMonthRule)` computes dates corresponding to the times occurring beyond the settlement date.

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 = 1;
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` in the Financial Toolbox documentation

`date2time`, `disc2rate`, `rate2disc`

treepath

Purpose

Extract entries from node of recombining tree

Syntax

```
Values = treepath(Tree, BranchList)
```

Arguments

`Tree`	Recombining 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 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

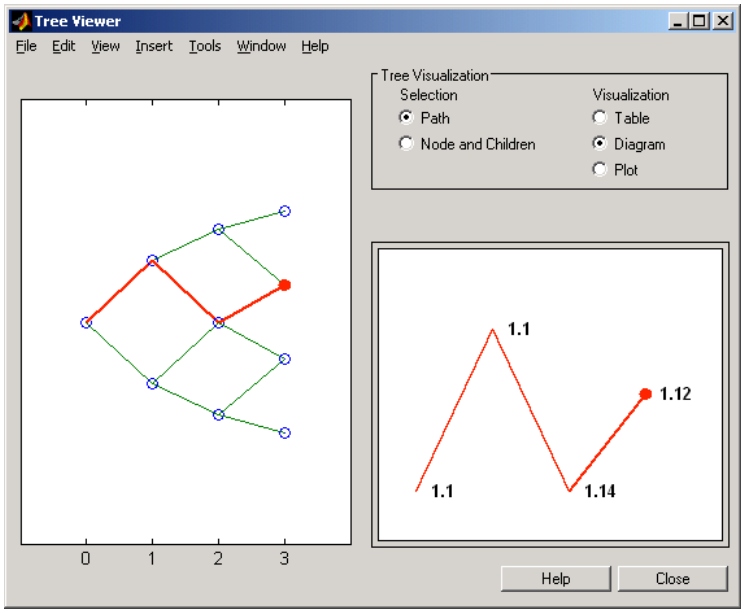
```
FwdRates = treepath(BDTTree.FwdTree, [1 2 1])
```

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)
```



Tree Visualization

Selection: [✓ Path] Node and Children

Visualization: Table [✓ Diagram] Plot

See Also

`mktree`, `treeshape`

treeshape

Purpose Retrieve shape of a recombining tree

Syntax `[NumLevels, NumPos, IsPriceTree] = treeshape(Tree)`

Arguments

`Tree`	Recombining tree.

Description `[NumLevels, NumPos, IsPriceTree] = treeshape(Tree)` returns information on a recombining 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.

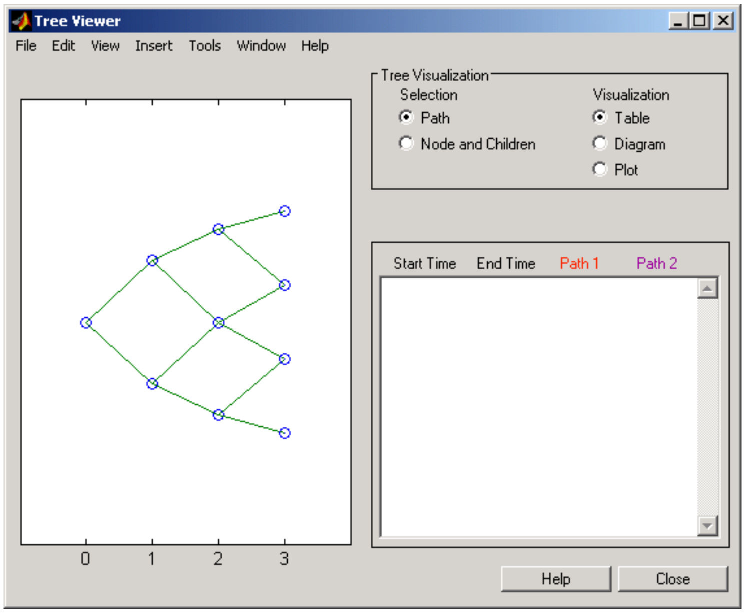
`IsPriceTree` is a Boolean determining if a final horizontal branch is present in the tree.

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(BDTTree)
```



With this tree

```
[NumLevels, NumPos, IsPriceTree] = treeshape(BDTTree.FwdTree)
```

returns

```
NumLevels  =
     4

NumPos     =
     1      1      1      1

IsPriceTree =
     0
```

See Also

`mktree`, `treepath`

treeviewer

Purpose Display tree information

Syntax

```
treeviewer(Tree)
treeviewer(PriceTree, InstSet)
treeviewer(CFTree, InstSet)
```

Arguments

`Tree`	`Tree` can be any of the following types of trees: • Black-Derman-Toy (`BDTTree`) • Heath-Jarrow-Morton (`HJMTree`) interest-rate tree • Money market tree (`MMktTree`). • Cox-Ross-Rubinstein stock price tree (`CRRTree`) • Equal probabilities stock price tree (`EQPTree`) See `bdttree` for information on creating `BDTTree`. See `hjmtree` for information on creating `HJMTree`. The functions `mmktbybdt` and `mmktbyhjm` create money market trees. Create a `CRRTree` with the function `crrtree` and an `EQPTree` with `eqptree`.
`PriceTree`	`PriceTree` is a Black-Derman-Toy (`BDTPriceTree`) or Heath-Jarrow-Morton (`HJMPriceTree`) tree of instrument prices.
`CFTree`	`CFTree` is a BDT (`BDTCFTree`) or HJM (`HJMCFTree`) tree of swap cash flows. You create cash flow trees when executing the functions `swapbybdt` and `swapbyhjm`.
`InstSet`	(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 `instadd` or as a cell array containing the names of the instruments. To display the names of the instruments, the field `Name` should exist in `InstSet`. If `InstSet` is not passed, `treeviewer` 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 below 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 below 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 below 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 below 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 on 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 end points of the path, and `treeviewer` displays all data from beginning to end. With BDT trees you must click on *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 on the nodes in the proper order, you are reminded with the message

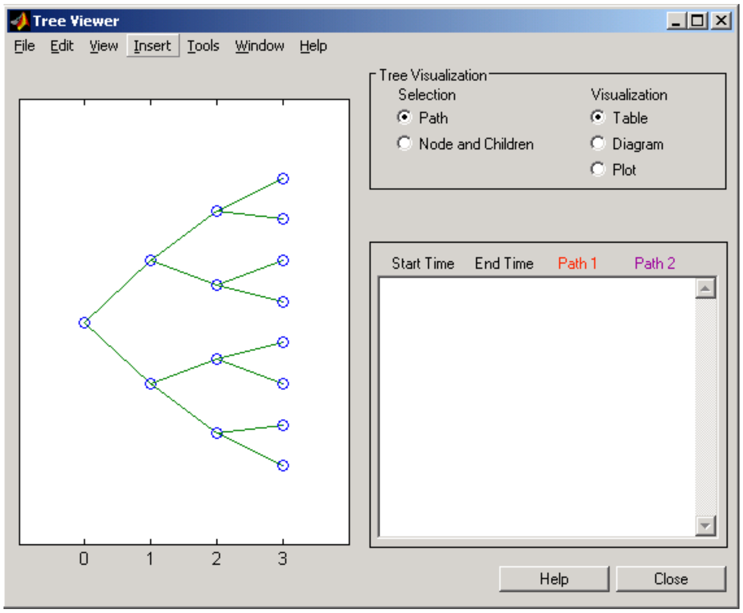
```
Parent of selected node must be selected.
```

Examples

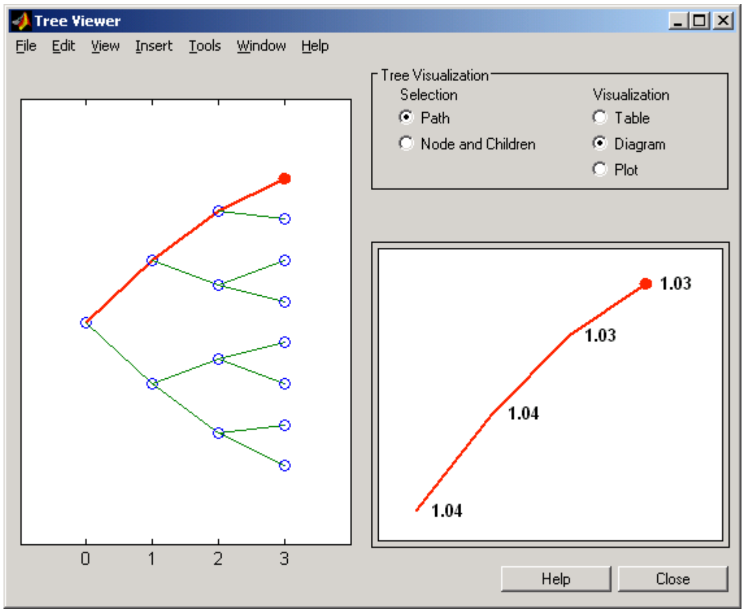
Example 1. Display an HJM interest-rate tree.

```
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.

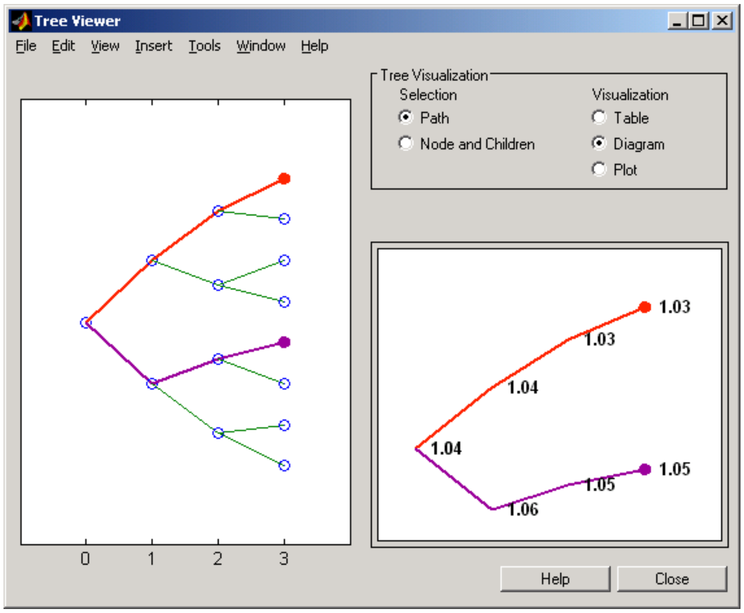


To visualize the actual interest-rate tree, go to the **Tree Visualization** pane and click on **Path** (the default) and **Diagram.** Now, select the first path by clicking on the last node (`t = 3`) of the upper branch.



Note that the entire upper path is highlighted in red.

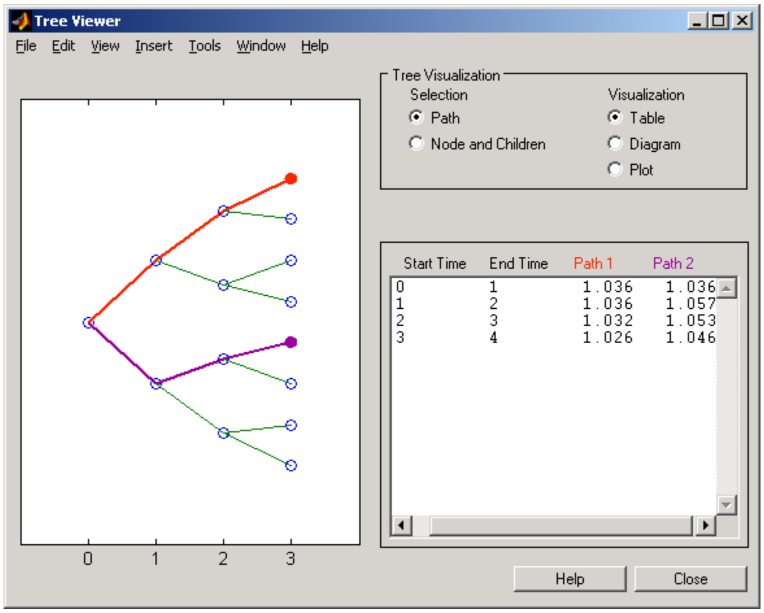
To complete the process, select a second path by clicking on the last node (`t = 3`) of another branch. The second path is highlighted in purple. The final display looks like this.



Tree Visualization: Selection [✓ Path] Node and Children; Visualization Table [✓ Diagram] Plot

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.



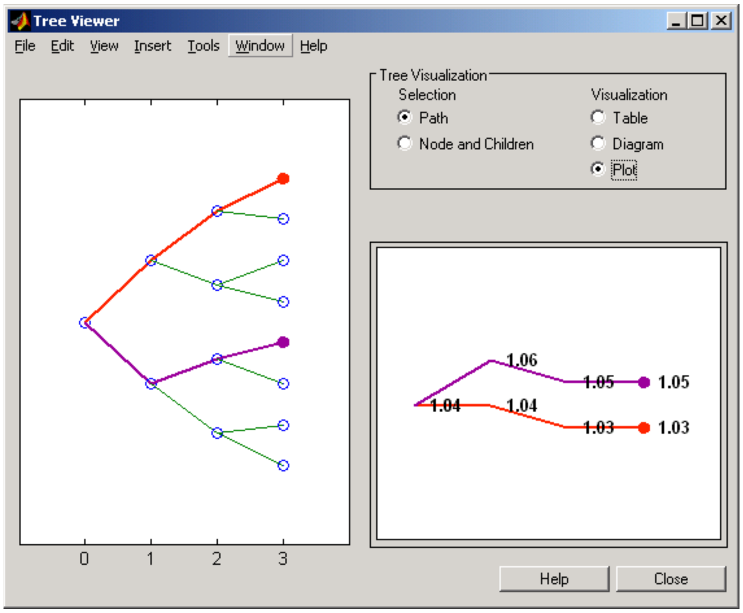
Tree Visualization

Selection: [✓ Path] Node and Children

Visualization: [✓ Table] Diagram Plot

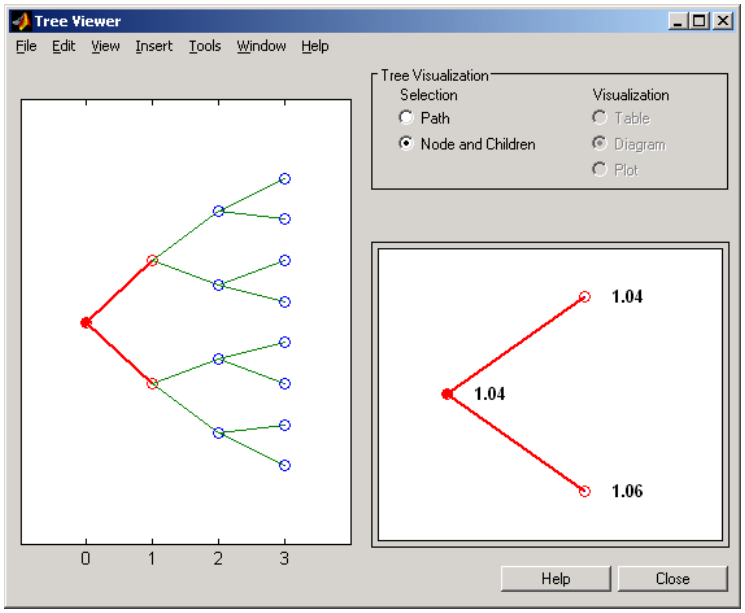
Start Time	End Time	Path 1	Path 2
0	1	1.036	1.036
1	2	1.036	1.057
2	3	1.032	1.053
3	4	1.026	1.046

To see a plot of interest rates along the chosen branches, choose **Path** and **Plot** in the **Tree Visualization** pane.



Note that with **Plot** selected rising interest rates are shown on the upper branch and declining interest rates on the lower.

Finally, if you choose **Node and Children** under **Tree Visualization**, you restrict the data displayed to just the selected parent node and its children.

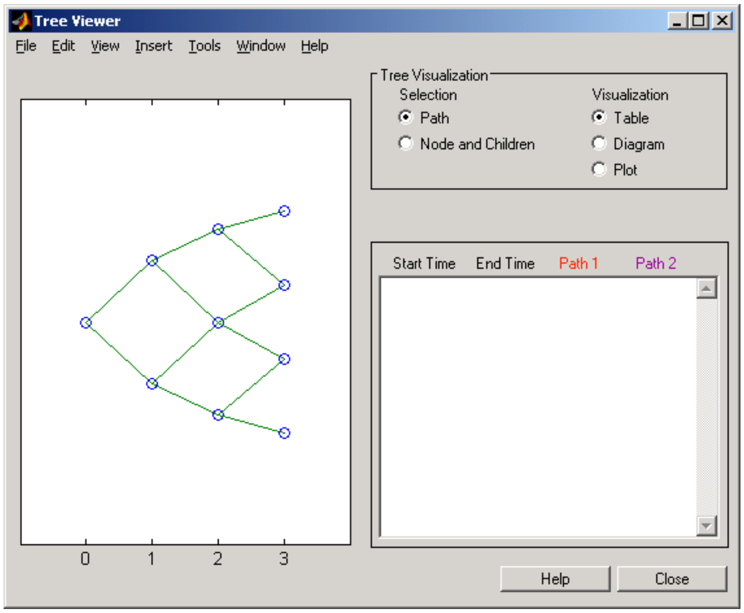


With **Node and Children** selected, the choices under **Visualization** are unavailable.

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.

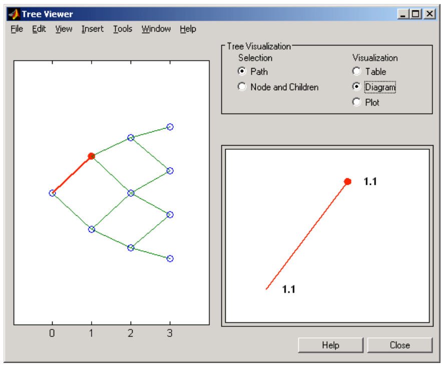

Tree Viewer
File Edit View Insert Tools Window Help
0 1 2 3
Start Time End Time Path 1 Path 2
Help Close

Tree Visualization

Selection: [✓ Path] Node and Children

Visualization: [✓ Table] Diagram Plot

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 first node of the up branch (`t = 1`). Continue by clicking on the down branch at the next node (`t = 2`). The two figures below show the treeviewer path diagrams for these selections.

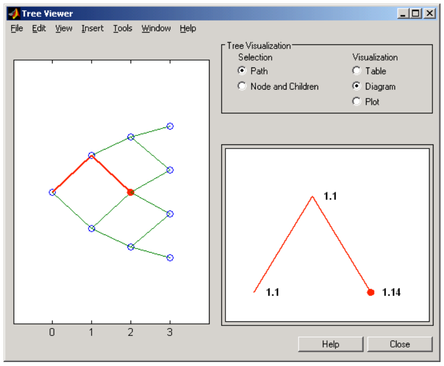


Tree Visualization

Selection: [✓ Path] Node and Children

Visualization: Table [✓ Diagram] Plot

t = 1



Tree Visualization

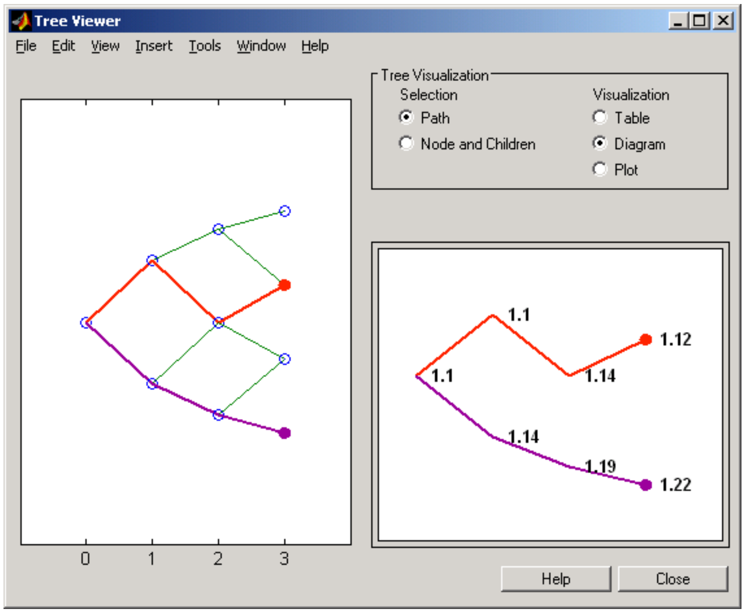
Selection: [✓ Path] Node and Children

Visualization: Table [✓ Diagram] Plot

t = 2

Continue clicking on all nodes in succession until you reach the end of the branch. Note that the entire path you have selected is highlighted in red.

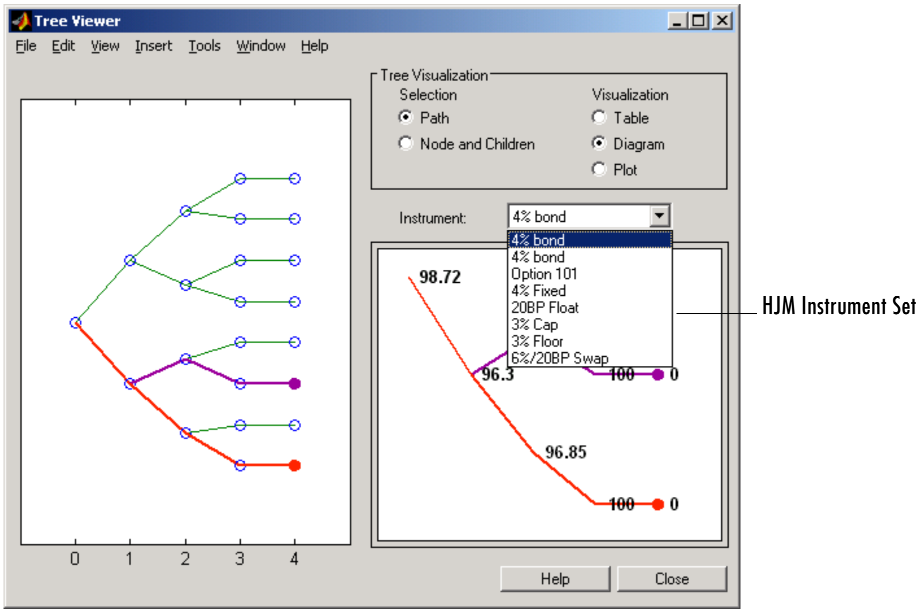
Select a second path by clicking on the first node of the lower branch (`t = 1`). Continue clicking on lower nodes as you did on the first branch. Note that the second branch is highlighted in purple. The final display looks like this.



Tree Visualization
Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot

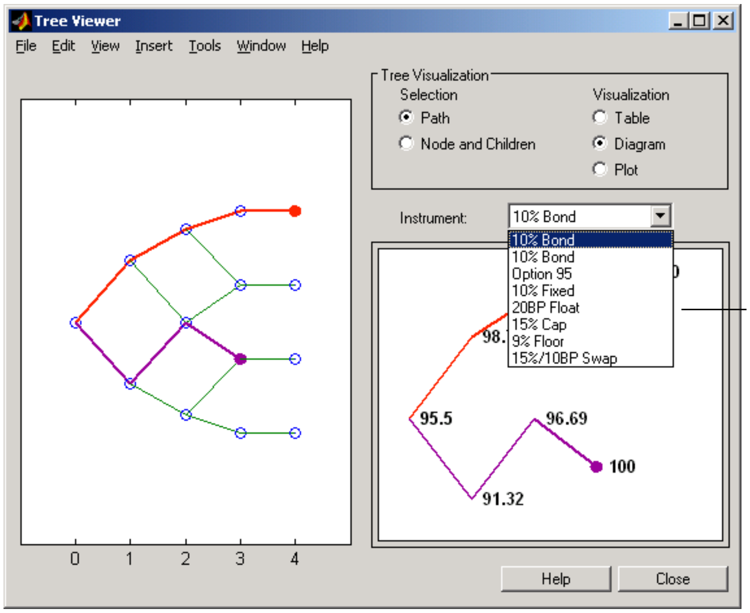
Example 3. Display an HJM price tree for named instruments.

```
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)
```

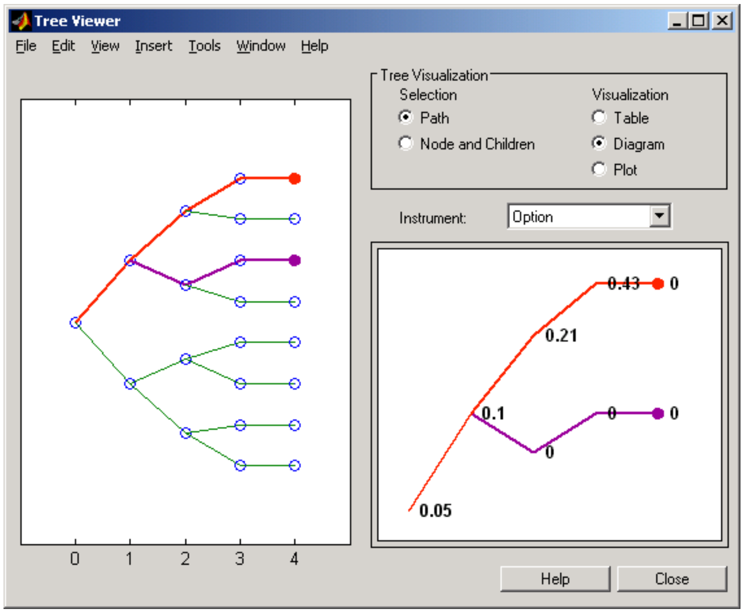


Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot

BDT Instrument Set

Example 5. Display an HJM price tree with renamed instruments.

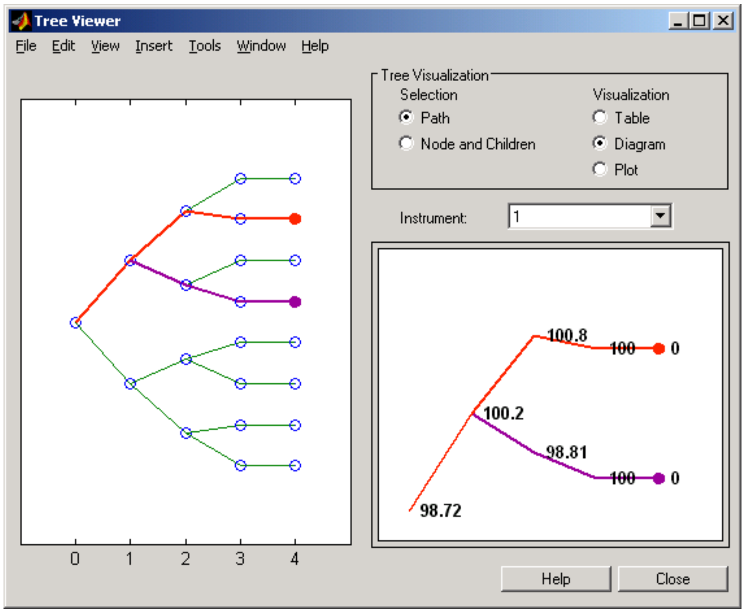
```
load deriv.mat
[Price, PriceTree] = hjmprice(HJMTree, HJMInstSet);
Names = {'Bond1', 'Bond2', 'Option', 'Fixed','Float', 'Cap',...
'Floor', 'Swap'};
treeviewer(PriceTree, Names)
```



Tree Visualization
Selection: (● Path) ○ Node and Children
Visualization: ○ Table (● Diagram) ○ Plot
Instrument: Option

Example 6. Display an HJM price tree using default instrument names (numbers).

```
load deriv.mat
[Price, PriceTree] = hjmprice(HJMTree, HJMInstSet);
treeviewer(PriceTree)
```



Tree Visualization
Selection: [✓ Path] Node and Children
Visualization: Table [✓ Diagram] Plot
Instrument: 1

See Also

`bdttree`, `hjmtree`, `instadd`, `mmktbybdt`, `mmktbyhjm`, `swapbybdt`, `swapbyhjm`

A

Derivatives Pricing Options

Pricing Options Structure

The MATLAB structure `Options` 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`, or `barrierbyeqp`.)

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`, `crrprice`, or `eqpprice`. `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 `Diagonistics` `'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 Jan 1st, 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'`.

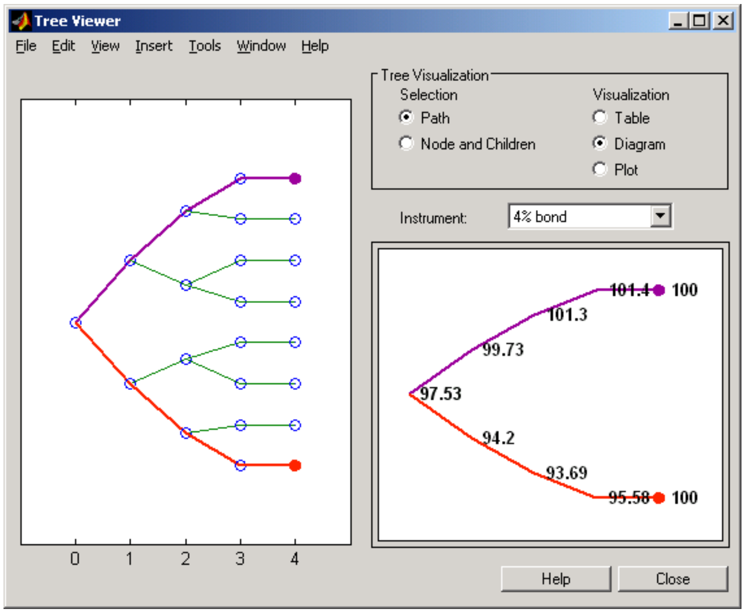
```
OptionsNoCR = derivset('ConstR', 'off')

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)
```

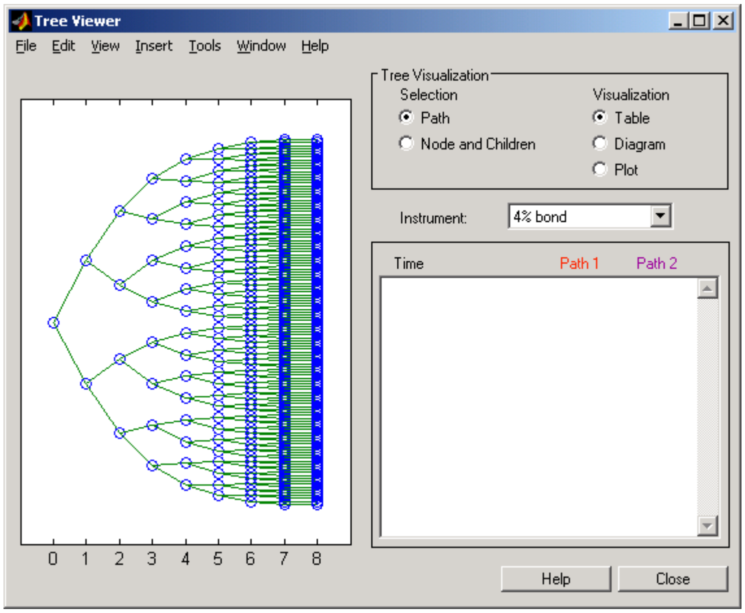


Selection: [✓ Path] Node and Children

Visualization: Table [✓ Diagram] Plot

Instrument: 4% bond

```
treeviewer(BondPriceTreeNoCR, BondPort)
```



Tree Visualization
Selection: [✓ Path] Node and Children
Visualization: [✓ Table] Diagram Plot
Instrument: 4% bond
Time Path 1 Path 2

```
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
```

Suggested Reading

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.

Heath-Jarrow-Morton (HJM) Modeling

An introduction to Heath-Jarrow-Morton modeling, used extensively in the Financial Derivatives Toolbox, can be found in

Jarrow, Robert A., *Modelling Fixed Income Securities and Interest Rate Options*, McGraw-Hill, 1996, ISBN 0-07-912253-1.

Cox-Ross-Rubinstein (CRR) Modeling

To learn about the CRR model see

Cox, J. C., S. A. Ross, and M. Rubinstein, “Option Pricing: A Simplified Approach,” *Journal of Financial Economics*, Number 7, 1979, pp.229-263.

Equal Probabilities Tree (EQP) Modeling

To learn about the EQP model see

Chriss, Neil A., *Black Scholes and Beyond: Option Pricing Models*, McGraw-Hill, 1996, ISBN 0-7863-1025-1.

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 the Financial Derivatives toolbox are

Chance, Don. M., *An Introduction to Derivatives*, The Dryden Press, 1998, ISBN 0-030-024483-8.

Fabozzi, Frank J., *Treasury Securities and Derivatives*, Frank J. Fabozzi Associates, 1998, ISBN 1-883249-23-6.

Hull, John C., *Options, Futures, and Other Derivatives*, Prentice-Hall, 1997, ISBN 0-13-186479-3.

Wilmott, Paul, *Derivatives: The Theory and Practice of Financial Engineering*, John Wiley and Sons, 1998, ISBN 0-471-983-89-6.

Glossary

American option	An option that can be exercised any time until its expiration date. Contrast with **European option**.
Asian option	An option whose payoff depends upon the average price of the underlying asset over a certain period of time.
arbitrary cash flow instrument	A set of generic cash flow amounts for which a price needs to be established.
Bermuda option	An option that can be exercised on predetermined dates only, usually every month. See also **American option** and **European option**.
barrier option	An option that is activated or deactivated only if the price of the underlying asset crosses a barrier. See also **knock-in** and **knock-out**. If the option fails to execute, the seller may pay to the purchaser a predetermined **rebate**.
beta	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.
binomial model	A method of pricing options or other equity derivatives in which the probability over time of each possible price follows a binomial distribution. The basic assumption is that prices can move to only two values (one higher and one lower) over any short time period.
Black-Derman-Toy (BDT) model	A model for pricing interest rate derivatives where all security prices and rates depend upon the short rate (annualized one-period interest rate).
bond	A long-term debt security with fixed interest payments and fixed maturity date.
bond option	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.
bushy tree	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 recombining tree.
call	**a.** An option to buy a certain quantity of a stock or commodity for a specified price within a specified time. See **put**. **b.** A demand to submit bonds to the issuer for redemption before the maturity date.
callable bond	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; i.e., the holder has sold a call option to the issuer. See **puttable bond**.
cap	Interest-rate option that guarantees that the rate on a floating-rate loan will not exceed a certain level.

compound option	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.
delta	The rate of change of the price of a derivative security relative to the price of the underlying asset; i.e., the first derivative of the curve that relates the price of the derivative to the price of the underlying security.
derivative	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.
deterministic model	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.
discount factor	Coefficient used to compute the present value of future cash flows.
dollar sensitivity	Sensitivity reported as a dollar price change instead of a percentage price change.
down-and-in	A type of **barrier option** that becomes active if the barrier is reached from above. See also **knock-in**.
down-and-out	A type of **barrier option** that becomes deactivated if the barrier is reached from above. See also **knock-out**.
European option	An option that can be exercised only on its expiration date. Contrast with **American option**.
ex-dividend date	Date when a declared dividend belongs to the seller rather than the buyer.
exercise price	The price set for buying an asset (call) or selling an asset (put). The strike price.
exotic option	Any nonstandard option. Opposite of **vanilla option**.
fixed lookback option	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.
fixed-rate note	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.
floating lookback option	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.

floating-rate note	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.
floor	Interest-rate option that guarantees that the rate on a floating-rate loan will not fall below a certain level.
forward curve	The curve of forward interest rates vs. maturity dates for bonds.
forward rate	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.
gamma	The rate of change of delta for a derivative security relative to the price of the underlying asset; i.e., the second derivative of the option price relative to the security price.
Heath-Jarrow-Morton (HJM) model	A model of the interest rate term structure that works with a type of interest rate tree called a **bushy tree**.
hedge	A securities transaction that reduces or offsets the risk on an existing investment position.
instrument set	A collection of financial assets. A portfolio.
inverse discount	A factor by which the present value of an asset is multiplied to find its future value. The reciprocal of the discount factor.
knock-in	A **barrier option** that is activated when the price of the underlying asset achieves a designated target. There are two types: **up-and-in** and **down-and-in**.
knock-out	A **barrier option** that is deactivated when the price of the underlying asset achieves a designated target. There are two types: **up-and-out** and **down-and-out**.
least squares method	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.
long rate	The yield on a zero-coupon Treasury bond.
lookback option	An option that reduces uncertainties associated with the timing of market entry. Lookback options can be either **fixed** and **floating**.

option	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.
per-dollar sensitivity	The dollar sensitivity divided by the corresponding instrument price.
portfolio	A collection of financial assets. Also called an instrument set.
price tree structure	A MATLAB structure that holds all pricing information.
price vector	A vector of instrument prices.
pricing options structure	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.
put	An option to sell a stipulated amount of stock or securities within a specified time and at a fixed exercise price. See **call**.
puttable bond	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; i.e., the holder has bought a put option. See **callable bond**.
rate specification	A MATLAB structure that holds all information needed to identify completely the evolution of interest rates.
rebate	A predetermined amount of money paid to the purchaser of a **barrier option** if the option fails to execute.
recombining tree	A tree of prices or interest rates whose branches recombine over time. Opposite of a **bushy tree**.
self-financing hedge	A trading strategy whereby the value of a portfolio after rebalancing is equal to its value at any previous time.
sensitivity	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 **dollar sensitivity**.
short rate	The annualized one-period interest rate.
spot curve, spot yield curve	See **zero curve**.

spot rate	The current interest rate appropriate for discounting a cash flow of some given maturity.
spread	For options, a combination of call or put options on the same stock with differing exercise prices or maturity dates.
stochastic model	Involving or containing a random variable or variables; involving chance or probability.
strike	Exercise a put or call option.
strike price	See **exercise price**.
swap	A contract between two parties to exchange cash flows in the future according to some formula.
time specification	A MATLAB structure that represents the mapping between times and dates for interest rate quoting.
under-determined system	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.
up-and-in	A type of **barrier option** that becomes active if the barrier is reached from below. See also **knock-in**.
up-and-out	A type of **barrier option** that becomes deactivated if the barrier is reached from below. See also **knock-out**.
vanilla option	A common option, such as a put or call. Opposite of **exotic option**.
vanilla swap	A **swap** agreement to exchange a fixed rate for a floating rate.
vega	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.
volatility specification	A MATLAB structure that specifies the forward rate volatility process.
zero curve, zero-coupon yield curve	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.

zero-coupon bond, or Zero	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.

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