Financial Derivatives Toolbox

For Use with MATLAB®

- Computation
- Visualization
- Programming

User's Guide

Version 4

The MathWorks

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Financial Derivatives Toolbox User's Guide

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Contents

1 Getting Started

2 Interest-Rate Based Financial Derivatives

3 Equity Derivatives

4 Hedging Portfolios

5 Functions — By Category

6 Functions — Alphabetical List

A Derivatives Pricing Options

B Bibliography

C Examples

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 2-24 or “Computing Prices and Sensitivities Using Interest-Rate Models” on page 2-50 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 = instadd('Asian', OptSpec, Strike, Settle,
ExerciseDates, AmericanOpt, AvgType, AvgPrice, AvgDate)
```

- Barrier instrument

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

- Compound instrument

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

- Lookback instrument

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

- Stock option instrument

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

Adding Instruments to an Existing Portfolio

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

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

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

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

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

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

```
instdisp(Port_1)
```

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

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

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

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

```
instdisp(Port_1)

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

Index Type CouponRate Settle      Maturity    Period Basis ...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 let you

- 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 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 on 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.

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

- "Understanding the Interest-Rate Term Structure" on page 2-9
- "Computing Prices and Sensitivities Using the Interest-Rate Term Structure" on page 2-24

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

- "Understanding the Interest-Rate Term Structure" on page 2-9
- "Computing Prices and Sensitivities Using the Interest-Rate Term Structure" on page 2-24
- "Understanding Interest-Rate Models" on page 2-29
- "Computing Prices and Sensitivities Using Interest-Rate Models" on page 2-50
- "Graphical Representation of Trees" on page 2-62

Financial Instruments

The toolbox provides a set of functions that perform computations on 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 that includes a guarantee that sets the maximum interest rate to be paid by the holder, based on an otherwise floating interest rate.

Floor. A contract that includes a guarantee setting the minimum interest rate to be received by the holder, based on 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 on zero coupon bonds or on any of the various interest rate models that the toolbox supports. (See "Interest-Rate Modeling" on page 2-3.)

Interest-Rate Modeling

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

- The interest-rate term structure

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

- Heath-Jarrow-Morton (HJM) model

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

- Black-Derman-Toy (BDT) model

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

- Hull-White (HW) model

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

- Black-Karasinski (BK) model

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

For detailed information about interest-rate models, see

- "Computing Prices and Sensitivities Using the Interest-Rate Term Structure" on page 2-24 for a discussion of price and sensitivity based on portfolios of zero coupon bonds.
- "Computing Prices and Sensitivities Using Interest-Rate Models" on page 2-50 for a discussion of price and sensitivity based on the HJM and BDT interest-rate models.

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

The HW and BK tree structures are very similar to the BDT tree structure. To avoid needless repetition throughout this chapter, we provide documentation only where significant deviations from the BDT structure exist. Specifically, "HW and BK Tree Structures" on page 2-46 explains the few noteworthy differences among the various formats.

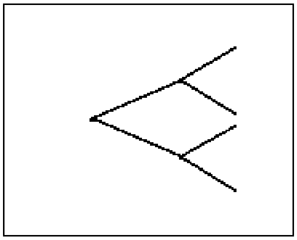
If you need more detailed information about functions that use the HW and BK tree structures, see the Chapter 5, "Functions — By Category" which provides extensive reference information for all functions that compose this toolbox.

Rate and Price Trees

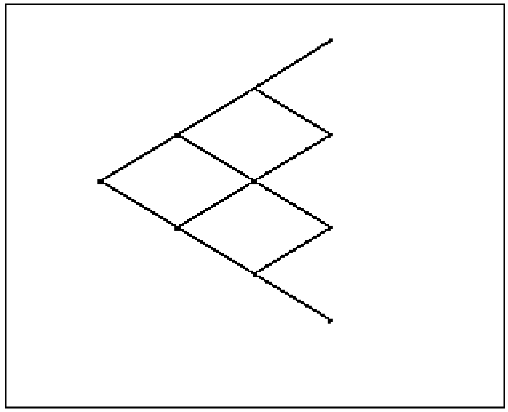
The interest-rate or price trees supported in this toolbox can be either *binomial* (two branches per node) or *trinomial* (three branches per node). Typically, binomial trees assume that underlying interest rates or prices can only either increase or decrease at each node. Trinomial trees allow for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

Types of Trees

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



Bushy Tree



Recombining Binomial Tree

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

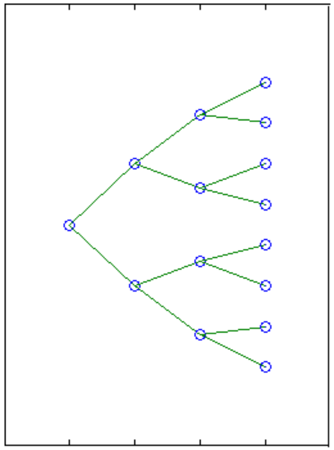
The other two interest rate models supported in this toolbox, Hull-White and Black-Karasinski, work with recombining trinomial trees.

Viewing Rate or Price Movement with This Toolbox

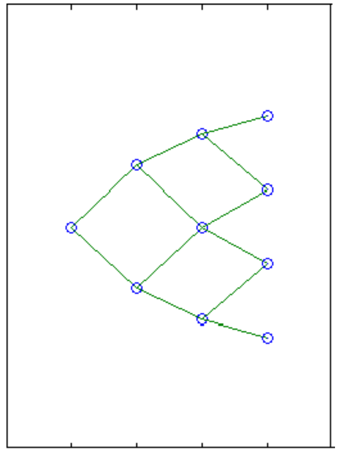
This toolbox provides the data file `deriv.mat` that contains four interest-rate based trees:

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

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

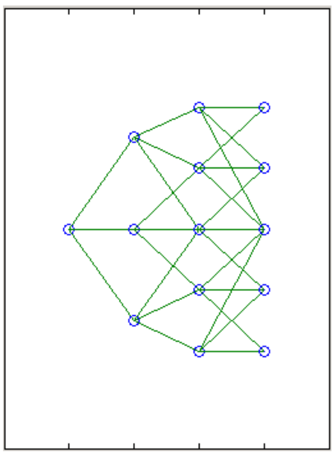


HJMTree (bushy)



BDTTree (recombining)

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



HWTree and BKTree (recombining)

Hedging

The Financial Derivatives Toolbox also includes hedging functionality, allowing the rebalancing of portfolios to reach target costs or target sensitivities, which you can 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` for a description of the function that allocates an optimal hedge.
- `hedgeslf` 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 factors 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 2-9
- "Interest-Rate Term Conversions" on page 2-14
- "Functions That Model the Interest-Rate Term Structure" on page 2-18

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 time based calling syntax is

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

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

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

Rates =

    0.0500
    0.0560
    0.0600
    0.0650
    0.0750
```

Interest-Rate Term Conversions

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

Spot Curve to Forward Curve Conversion

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

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

where:

- `Compounding` represents the frequency at which the zero rates are compounded when annualized.
- `RefRates` is a vector of initial interest rates representing the interest rates applicable to the initial time intervals.
- `RefEndDates` is a vector of dates representing the end of the interest rate terms (period) applicable to `RefRates`.
- `RefStartDates` is a vector of dates representing the beginning of the interest rate terms applicable to `RefRates`.
- `EndDates` represent the maturity dates for which the interest rates are interpolated.
- `StartDates` represent the starting dates for which the interest rates are interpolated.
- `ValuationDate` is the date of observation, from which the `StartTimes` and `EndTimes` are calculated. This date represents time = 0.

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

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

As an example, consider the rate table specified 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

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

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

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

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

RefEndTimes =

     1
     2
     3
     4
     5

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

```
RefStartTimes =

     0
```

These are the expected values, given semiannual discounts (as denoted by a value of 2 in the variable `Compounding`), end dates separated by 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 2-19 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 2-21 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 on 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 on it. As an exercise, change the value of `Compounding` from 2 (semiannual) to 1 (annual).

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

Since `StartTimes` and `EndTimes` are measured in units of periodic discount, a change in `Compounding` from 2 to 1 redefines the basic unit from semiannual to annual. This means that a period of 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 find the price and sensitivities of several financial instruments based on interest-rate curves. For information, see

- "Computing Instrument Prices" on page 2-25 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 2-27 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 2-50 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

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

`intenvprice` takes as input an interest-rate term structure created with `intenvprice`, 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, you can compute sensitivities either as dollar price changes or as percentage price changes. The toolbox reports all sensitivities as dollar sensitivities.

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

The intenvsens function computes instrument sensitivities 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 the Black-Derman-Toy (BDT), Black-Karasinski (BK), Heath-Jarrow-Morton (HJM), and Hull-White (HW) interest-rate models.

- To learn how to create forward-rate trees from their component elements, see "Building a Tree of Forward Rates" on page 2-30. This section provides detailed information about creating the volatility, rate, and time specifications that serve as inputs to the tree creation functions. You will find the details under these headings:
  - "Specifying the Volatility Model (VolSpec)" on page 2-32.
  - "Specifying the Interest-Rate Term Structure (RateSpec)" on page 2-35.
  - "Specifying the Time Structure (TimeSpec)" on page 2-36.
- To view some examples of trees, see "Examples of Tree Creation" on page 2-38.
- To examine the details of an interest-rate structure, see "Examining Trees" on page 2-39.

The Heath-Jarrow-Morton model is one of the most widely used models for pricing interest-rate derivatives. The model considers a given initial term structure of interest rates and a specification of the volatility of forward rates to build a tree representing the evolution of the interest rates, based on a statistical process. For further explanation, see the book *Modelling Fixed Income Securities and Interest Rate Options* by Robert A. Jarrow.

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

The Hull-White model incorporates the initial term structure of interest rates and the volatility term structure to build a trinomial recombining tree of short rates. The resulting tree is used to value interest rate dependent securities.

The implementation of the Hull-White model in the Financial Derivatives Toolbox is limited to one factor.

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

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

Building a Tree of Forward Rates

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

Note To avoid needless repetition, this document uses the HJM and BDT models to illustrate the creation and use of interest-rate trees. The HW and BK models are similar to the BDT model. Where specific differences exist, they are documented in "HW and BK Tree Structures" on page 2-46.

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

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

These functions take three structures as input arguments:

- The volatility model `VolSpec`. (See "Specifying the Volatility Model (VolSpec)" on page 2-32.)
- The interest-rate term structure `RateSpec`. (See "Specifying the Interest-Rate Term Structure (RateSpec)" on page 2-35.)
- The tree time layout `TimeSpec`. (See "Specifying the Time Structure (TimeSpec)" on page 2-36.)

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 2-62 for information about `treeviewer`.

Calling Sequence

The calling syntax for `hjmtree` is

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

Similarly, the calling syntax for `bdttree` is

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

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

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

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

  - Constant
  - Stationary
  - Exponential
  - Vasicek
  - Proportional

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

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

- `RateSpec` is the interest-rate specification of the initial rate curve. You create this structure with the function `intenvset`. (See "Functions That Model the Interest-Rate Term Structure" on page 2-18.)
- `TimeSpec` is the tree time layout specification. You create this variable with the functions `hjmtimespec` or `bdttimespec`. It represents the mapping between level times and level dates for rate quoting. This structure indirectly determines the number of levels in the tree.

Specifying the Volatility Model (VolSpec)

Because HJM supports multifactor (up to three) volatility models while BDT (also, BK and HW) supports only a single volatility factor, the `hjmvolspec` and `bdtvolspec` functions require somewhat different inputs and generate slightly different outputs. For examples, see "Creating an HJM Volatility Model" on page 2-32. For BDT examples see "Creating a BDT Volatility Model" on page 2-34.

Creating an HJM Volatility Model

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

HJM Volatility Specification Example. Consider an example that uses a single factor, specifically, a constant-sigma factor. The constant factor specification requires only one parameter, the value of 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. "Functions That Model the Interest-Rate Term Structure" on page 2-18 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` function. These functions require three input arguments:

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

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

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

where:

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

Creating a Time Specification

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

HJM Time Specification Example. Consider the 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 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          15956  struct array
  BDTTree          1x1           5138  struct array
  BKInstSet        1x1          15946  struct array
  BKTree           1x1           5904  struct array
  CRRInstSet       1x1          12434  struct array
  CRRTree          1x1           5058  struct array
  EQPInstSet       1x1          12434  struct array
  EQPTree          1x1           5058  struct array
  HJMInstSet       1x1          15948  struct array
  HJMTree          1x1           5838  struct array
  HWInstSet        1x1          15946  struct array
  HWTree           1x1           5904  struct array
  ZeroInstSet      1x1          10282  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. MATLAB represents it as a cell array with each cell array element containing a tree level.

The other fields contain other information relevant to interpreting the values in `FwdTree`. The most important 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. MATLAB represents it as a cell array with each cell array element containing a tree level.

The other fields contain other information relevant to interpreting the values in FwdTree. The most important 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.

HW and BK Tree Structures

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

```
load deriv.mat:

HWTree

FinObj: 'HWFwdTree'
VolSpec: [1x1 struct]
TimeSpec: [1x1 struct]
RateSpec: [1x1 struct]
tObs: [0 1 2 3]
dObs: [731947 732313 732678 733043]
CFlowT: {[4x1 double]  [3x1 double]  [2x1 double]  [4]}
```

```
Probs: {[3x1 double]  [3x3 double]  [3x5 double]}
Connect: {[2]  [2 3 4]  [2 2 3 4 4]}
FwdTree: {1x4 cell}
```

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

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

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

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

```
HWTree.Probs{1}

0.16666666666667
0.66666666666667
0.16666666666667

HWTree.Probs{2}

0.12361333418768   0.16666666666667   0.21877591615172
0.65761074966060   0.66666666666667   0.65761074966060
0.21877591615172   0.16666666666667   0.12361333418768
```

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

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

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

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

1.0000    1.0000    1.0000
```

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

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

```
HWTree.Connect

ans =

     [2]    [1x3 double]    [1x5 double]
```

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

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

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

```
HWTree.Connect{1}

ans =

      2
```

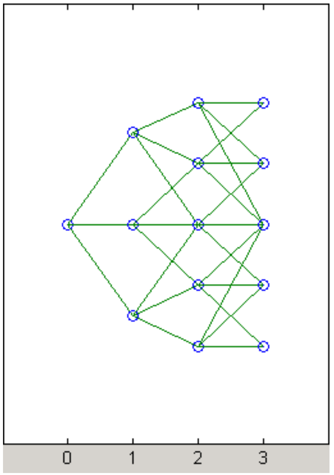
This indicates that the middle branch of the root node connects to the second (from the top) node of the next level, as expected. If you subtract 1 from this value, you obtain 1, which tells you that the up branch goes to the top node. If you add 1, you obtain 3, which points to the last node of the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

Now consider level 3 in this example:

```
HWTree.Connect{3}

2     2     3     4     4
```

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

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



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

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. See

- "Computing Instrument Prices" on page 2-50 for a discussion of using the pricing functions to compute prices for a portfolio of instruments.
- "Computing Instrument Sensitivities" on page 2-59 for a discussion of using the sensitivity functions to compute delta, gamma, and vega portfolio sensitivities.

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

Computing Instrument Prices

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

- Bonds
- Bond options
- 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 Appendix A, "Derivatives Pricing Options" for information about the Options argument.)

HJMTree is the Heath-Jarrow-Morton tree sampling of a forward-rate process, created using hjmtree. BDTTree is the Black-Derman-Toy tree sampling of an interest-rate process, created using bdttree. See "Building a Tree of Forward Rates" on page 2-30 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. Chapter 1, "Getting Started" 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 Chapter 6, "Functions — Alphabetical List" 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            15956  struct array
  BDTTree             1x1             5138  struct array
  BKInstSet           1x1            15946  struct array
  BKTree              1x1             5904  struct array
  CRRInstSet          1x1            12434  struct array
  CRRTree             1x1             5058  struct array
  EQPInstSet          1x1            12434  struct array
  EQPTree             1x1             5058  struct array
  HJMInstSet          1x1            15948  struct array
  HJMTree             1x1             5838  struct array
  HWInstSet           1x1            15946  struct array
  HWTree              1x1             5904  struct array
  ZeroInstSet         1x1            10282  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           15956  struct array
  BDTTree             1x1            5138  struct array
  BKInstSet           1x1           15946  struct array
  BKTree              1x1            5904  struct array
  CRRInstSet          1x1           12434  struct array
  CRRTree             1x1            5058  struct array
  EQPInstSet          1x1           12434  struct array
  EQPTree             1x1            5058  struct array
  HJMInstSet          1x1           15948  struct array
  HJMTree             1x1            5838  struct array
```

```
HWInstSet        1x1          15946  struct array
HWTree           1x1           5904  struct array
ZeroInstSet      1x1          10282  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
  100.4865
    1.4863
    0.0245
    7.4222
```

Price Vector Output

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

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

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

InstNames =

4% bond
4% bond
Option 101
4% Fixed
```

```
20BP Float
3% Cap
3% Floor
6%/20BP Swap
```

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

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

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

InstNames =

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

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

Price Tree Structure Output

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

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

you generate a price tree along with the price information.

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

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

In this example the price tree looks like

```
PriceTree =

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

Both PBush and AIBush are 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
  100.4865
    1.4863
    0.0245
    7.4222
```

Computing Instrument Sensitivities

The toolbox reports sensitivities 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

The calling syntax for the function is

```
[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
       0.84         2.45          0      100.49
      78.38       748.98      13.54        1.49
      -4.36       382.06       2.50        0.02
    -253.23       863.81          0        7.42
```

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

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

All =

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

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
```

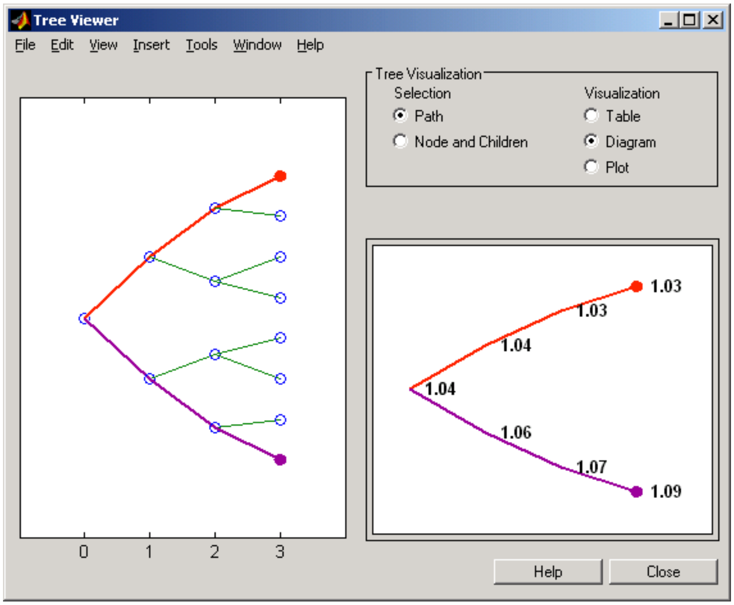
Note `treeviewer` price tree diagrams follow the convention that increasing prices appear on the upper branch of a tree and, consequently, decreasing prices appear on the lower branch. Conversely, for interest rate displays, *decreasing* interest rates appear on the upper branch (prices are rising) and *increasing* interest rates on the lower branch (prices are falling).

For information on the use of `treeviewer` to observe interest rate movement, see “Observing Interest Rates” on page 2-62. For information on using `treeviewer` to observe the movement of prices, see “Observing Instrument Prices” on page 2-66.

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`.

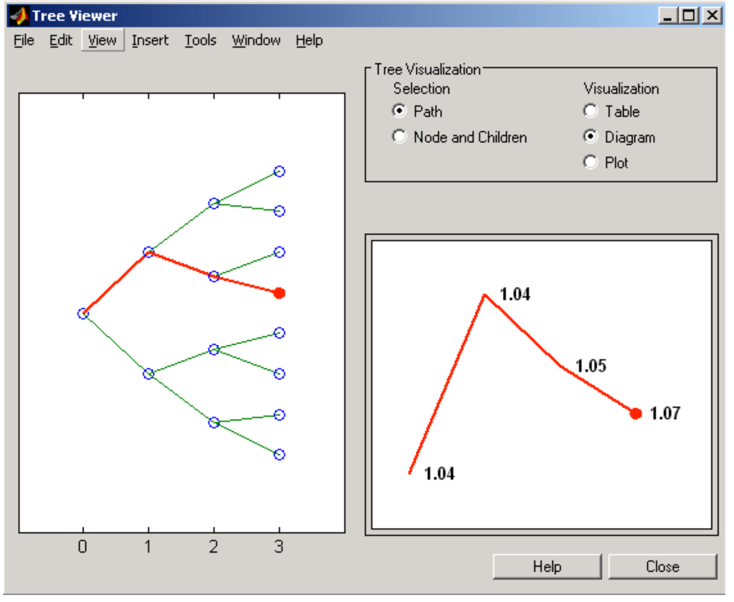
```
treeviewer(HJMTree)
```



The example in "Isolating a Specific Node" on page 3-10 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.

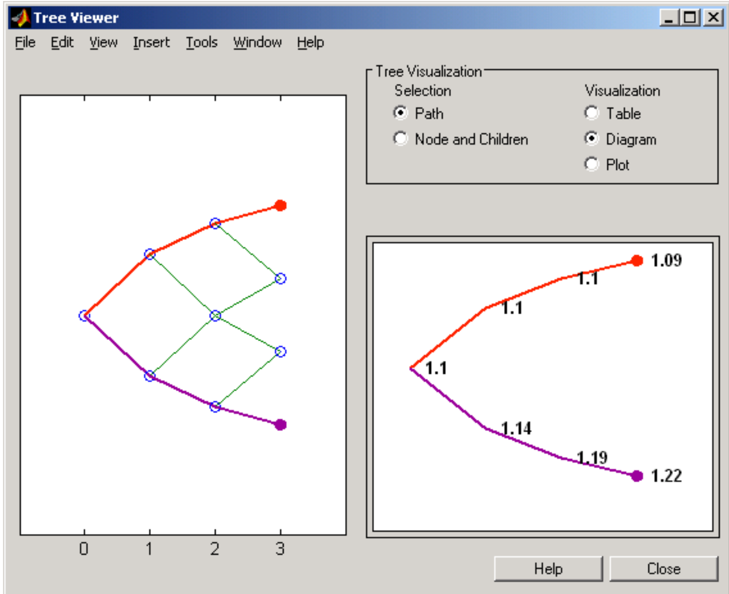
```
FRates = bushpath(HJMTree.FwdTree, [1 2 2])

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.



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

```
treeviewer(BDTTree)
```

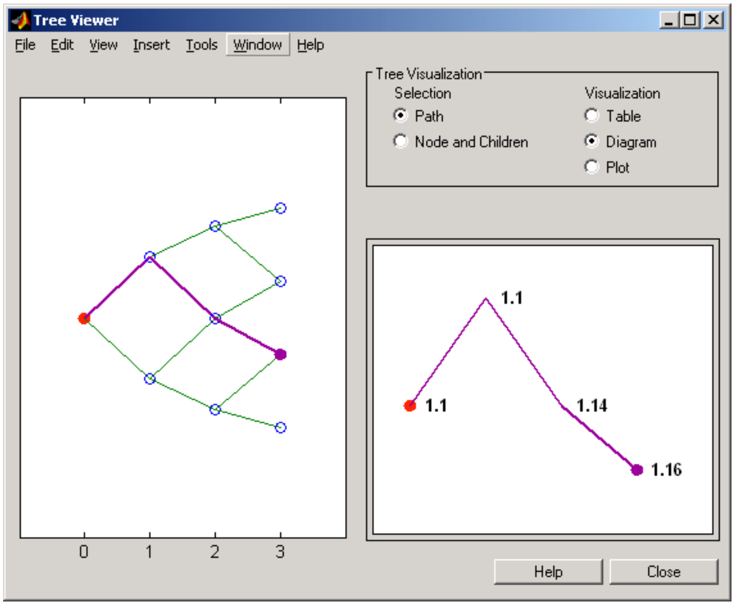


Note When using `treeviewer` with recombining trees, such as BDT, BK, and HW, you must click each node in succession from the beginning to the end. Because these trees can recombine, `treeviewer` is unable to complete the path automatically.

The example in "Isolating a Specific Node" on page 3-10 used `treepath` to find the path of interest rates taking the first branch up and then two branches down the rate tree.

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

FRates =

    1.1000
    1.0979
    1.1377
    1.1606
```

You can display the identical information by clicking along the same sequence of nodes, as shown next.

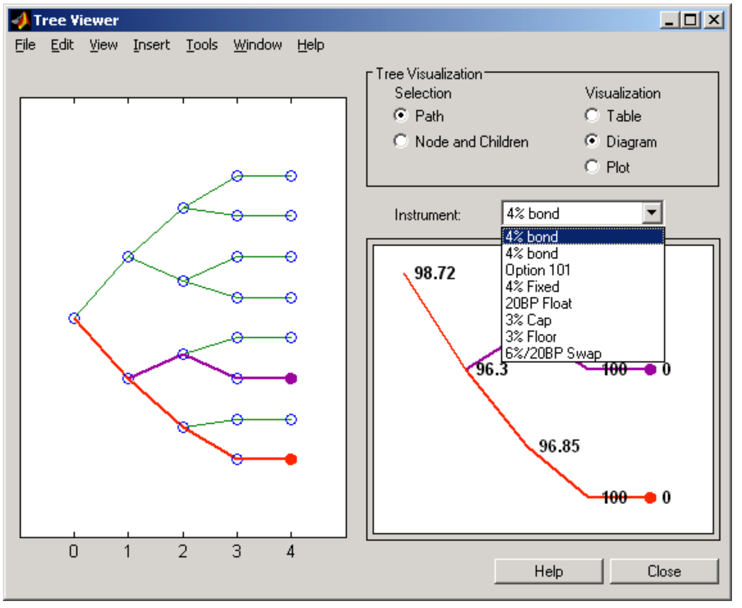


Observing Instrument Prices

To use `treeviewer` to display a tree of instrument prices, provide the name of an instrument set along with the name of a price tree in your call to `treeviewer`, for example:

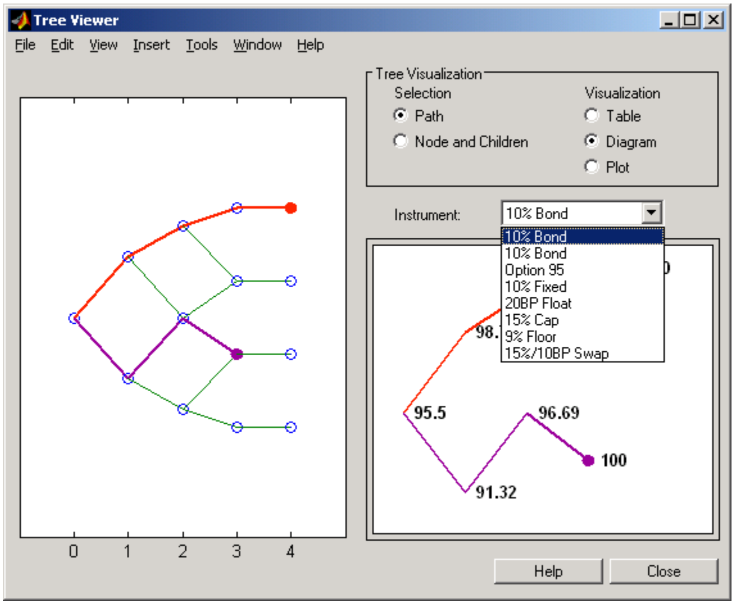
```
load deriv.mat
[Price, PriceTree] = hjmprice(HJMTree, HJMInstSet);
treeviewer(PriceTree, HJMInstSet)
```

With `treeviewer` you select *each instrument individually* in the instrument portfolio for display.



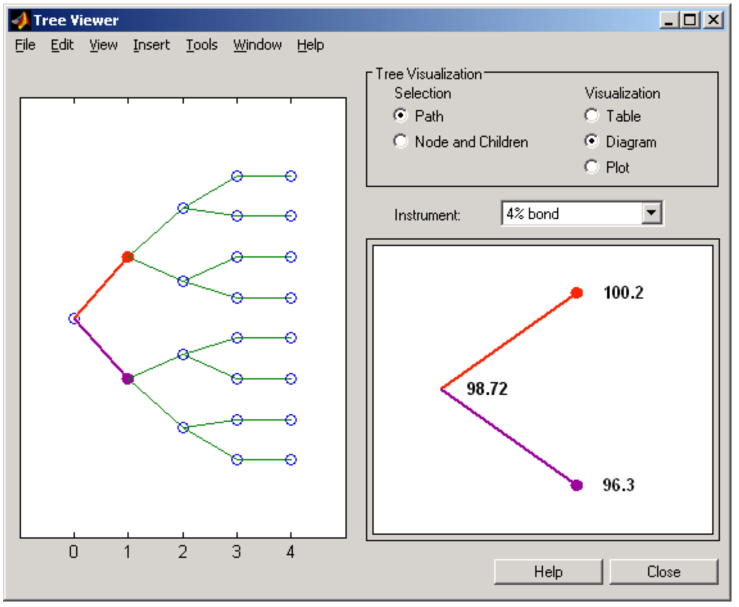
You can use an analogous process to view instrument prices based on the BDT interest rate tree included in `deriv.mat`.

```
load deriv.mat
[BDTPrice, BDTPriceTree] = bdtprice(BDTTree, BDTInstSet);
treeviewer(BDTPriceTree, BDTInstSet)
```

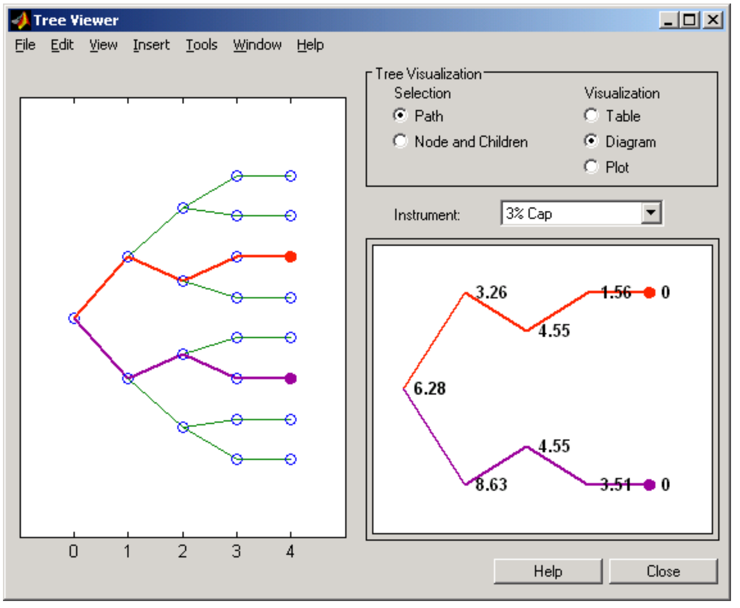


Valuation Date Prices

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.



As a further example, look at the sixth instrument in the price vector, the 3% cap. At the valuation date its value obtained directly from the structure is 6.2831. Use `treeviewer` on this instrument to confirm this price.



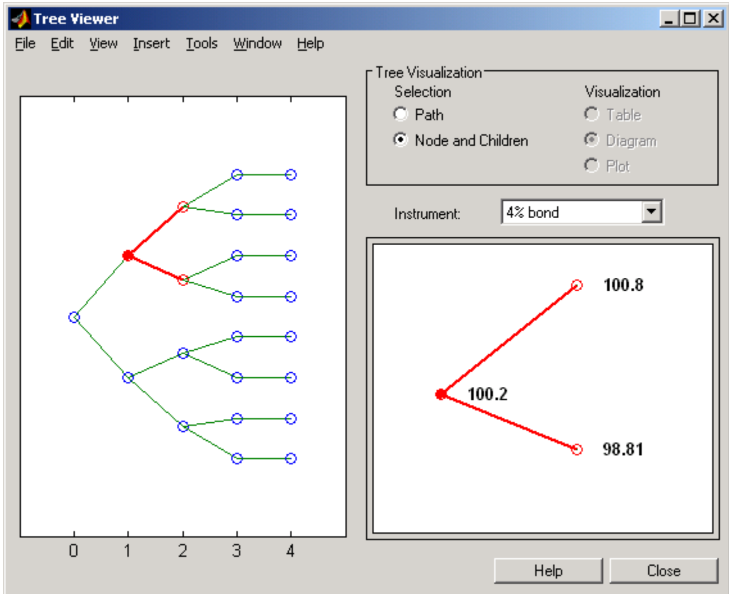
Additional Observation Times

The second node represents the first rate observation time, `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
```

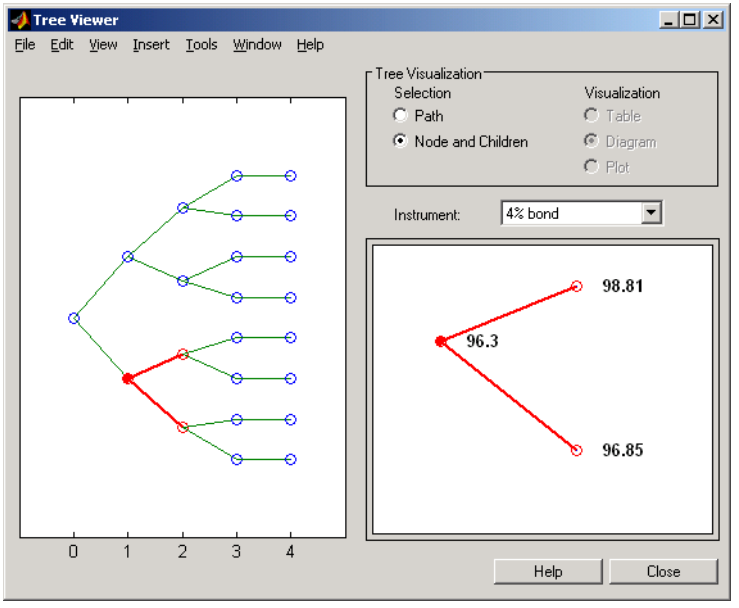
As before, you can use `treeviewer`, this time to examine the price for the 4% bond on the up branch. `treeviewer` displays a price of 100.2 for the first node of the up branch, as expected.



Now examine the corresponding down branch.

```
PriceTree.PBush{2}(:,:,2)

ans =

   96.3041
   94.1986
         0
   96.3041
  100.3671
    8.6342
         0
   -0.3923
```

Use `treeviewer` once again, now to observe the price of the 4% bond on the down branch. The displayed price of 96.3 conforms to the price obtained from direct access of the `PriceTree` structure. You may continue this process as far along the price tree as you want.



Equity Derivatives

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 "Rate and Price Trees" on page 2-5.

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 3-3)
- Provides examples of equity tree creation ("Examples of Equity Tree Creation" on page 3-7)
- Uses the provided file `deriv.mat` to show how to examine trees ("Examining Trees" on page 3-8)
- 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 on the existence and type of dividend payments.

The syntax for calling `stockspec` is:

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

where:

- `Sigma` is the decimal annual volatility of the underlying security.
- `AssetPrice` is the price of the stock at the valuation date.
- `DividendType` is a string specifying the type of dividend paid by the stock. Allowed values are `cash`, `constant`, or `continuous`.
- `DividendAmounts` has a value that depends on the specification of `DividendType`. For `DividendType` `cash`, `DividendAmounts` is a vector of cash dividends. For `DividendType` `constant`, it is a vector of constant annualized dividend yields. For `DividendType` `continuous`, it is a scalar representing a continuously annualized dividend yield.
- `ExDividendDates` also has a value that depends on the nature of `DividendType`. For `DividendType` `cash` or `constant`, `ExDividendDates` is vector of dividend dates. For `DividendType` `continuous`, `ExDividendDates` is ignored.

Stock Structure Example

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.“Functions That Model the Interest-Rate Term Structure” on page 2-18 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 topmost element of the third level of the tree, and CRRTree.STree{3}(end) represents the bottom element of the same level of the tree.

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: $max(0, S_{av} - X)$
- 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 3-23 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 the following instrument types:

- Vanilla stock options
  - American and European puts and calls
- Exotic options
  - Asian
  - Barrier
  - Compound
  - Lookback
  - Stock options (Bermuda put and call schedules)

The syntax for calling the function `crrprice` is

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

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 3-3 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 instdispinstdisp 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 2-62 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.

4

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.

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 4-3.

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 2-27. Likewise, for examples showing the computation of sensitivities for equity exotic options, see "Computing Instrument Sensitivities" on page 3-23.

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 on the example in "Maintaining Existing Allocations" on page 4-5, suppose you want to know the cost to achieve an overall portfolio dollar sensitivity of `[-23000 -3300 3000]`, while allowing trading only in instruments 2, 3, and 6 (holding the positions of instruments 1, 4, 5, 7, and 8 fixed.) To find the cost, first set the target portfolio dollar sensitivity.

```
TargetSens = [-23000 -3300 3000];
```

Then, specify the instruments to be fixed.

```
FixedInd = [1 4 5 7 8];
```

Finally, call `hedgeopt`

```
[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price,...
Holdings, FixedInd, [], [], TargetSens);
```

and again examine the results.

```
Sens =

     -23000.00      -3300.00       3000.00

Cost =

      19174.02

Quantity' =

        100.00
       -141.03
        137.26
         80.00
          8.00
        -57.96
         40.00
         10.00
```

Recompute `Value1`, the portfolio value after rebalancing.

```
Value1 = Quantity * Price

Value1 =

      4500.60
```

As expected, the cost, $19174.02, is the difference between `Value0` and `Value1`, $23674.62 — $4500.60. Only the positions in instruments 2, 3, and 6 have been changed.

Fully Hedged Portfolio

The example in "Partially Hedged Portfolio" on page 4-6 illustrates a partial hedge, but perhaps the most interesting case involves the cost associated with a fully hedged portfolio (simultaneous delta, gamma, and vega neutrality). In this case, set the target sensitivity to a row vector of 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 examples in "Fully Hedged Portfolio" on page 4-7 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.

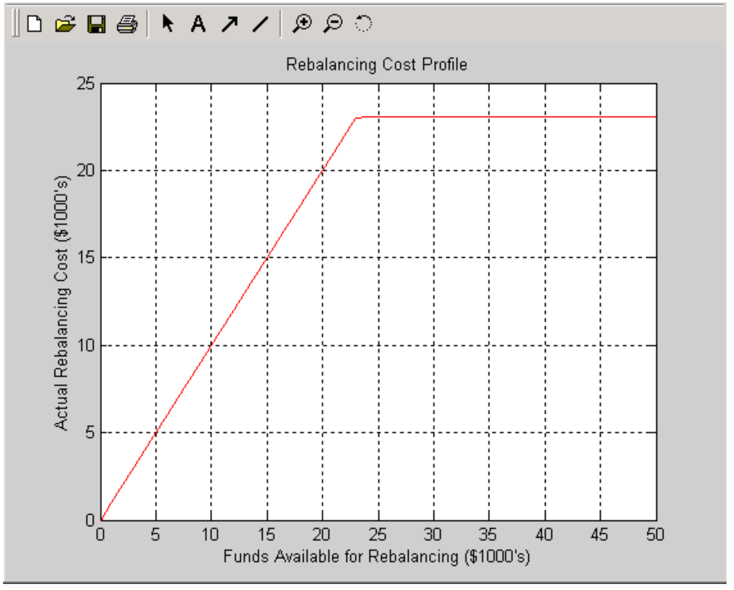
```
MaxCost = [0:1000:50000];
```

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)

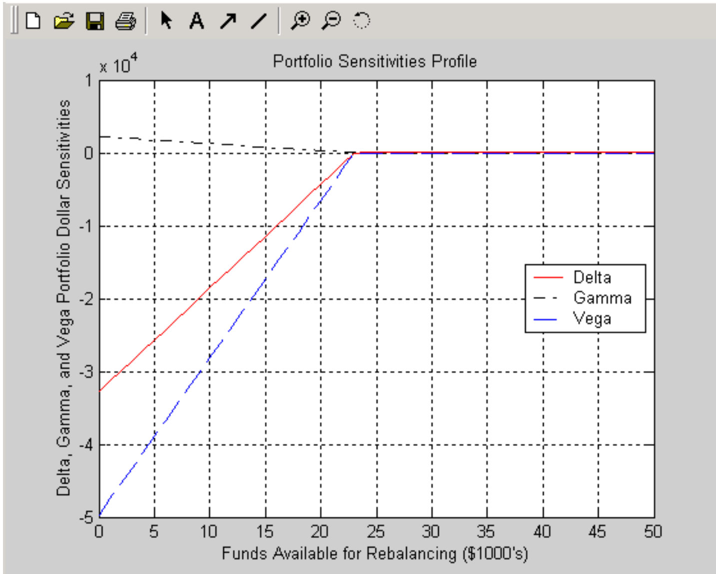
```
plot(MaxCost/1000, Cost/1000, 'red'), grid
xlabel('Funds Available for Rebalancing ($1000''s)')
ylabel('Actual Rebalancing Cost ($1000''s)')
title ('Rebalancing Cost Profile')
```



Rebalancing Cost Profile

and the portfolio dollar sensitivities versus the funds available.

```
figure
plot(MaxCost/1000, Sens(:,1), '-red')
hold('on')
plot(MaxCost/1000, Sens(:,2), '-.black')
plot(MaxCost/1000, Sens(:,3), '--blue')
grid
xlabel('Funds Available for Rebalancing ($1000''s)')
ylabel('Delta, Gamma, and Vega Portfolio Dollar Sensitivities')
title ('Portfolio Sensitivities Profile')
legend('Delta', 'Gamma', 'Vega', 0)
```



Funds Available for Rebalancing

Self-Financing Hedges with hedgeslf

The figures Rebalancing Cost Profile on page 4-10 and Funds Available for Rebalancing on page 4-11 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.

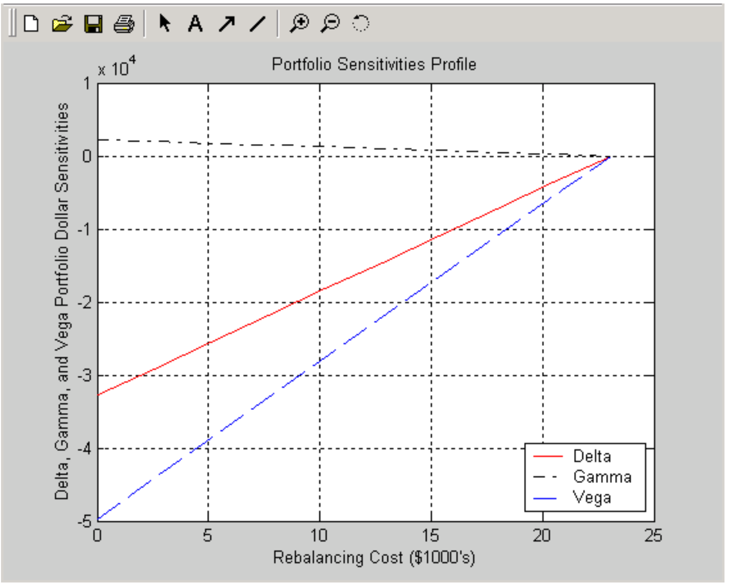
There is, in fact, a third calling syntax available for `hedgeopt` directly related to the results shown above for `hedgeslf`. Suppose, instead of directly specifying the funds available for rebalancing (the most money you are willing to spend), you want to simply specify the number of points along the 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)
```



Rebalancing Cost

In this calling form, `hedgeopt` calls `hedgeslf` internally to determine the maximum cost needed to minimize the portfolio sensitivities ($23,055.90), and evenly samples the cost frontier between $0 and $23,055.90.

Note that both `hedgeopt` and `hedgeslf` cast the optimization problem as a constrained linear least squares problem. Depending on the instruments and constraints, neither function is guaranteed to converge to a solution. In some cases, the problem space may be unbounded, and additional instrument equality constraints, or user-specified constraints, may be necessary for convergence. See "Hedging with Constrained Portfolios" on page 4-20 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 "Analyzing Portfolios" 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 0). Recall that when hedgeopt computes the cost of rebalancing a portfolio, the input target sensitivities you specify are treated as equality constraints during the optimization process. The situation is reproduced next for convenience.

```
TargetSens = [0 0 0];
[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price,...
Holdings, FixedInd, [], [], TargetSens);
```

The outputs provide a fully hedged portfolio

```
Sens =
         -0.00          -0.00          -0.00
```

at an expense of over $23,000.

```
Cost =
      23055.90
```

The positions 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 the figure 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

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

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 4-23
- "Example: Under-Determined System" on page 4-24
- "Example: Portfolio Constraints with hedgeslf" on page 4-25

Depending on 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 example in "Fully Hedged Portfolio" on page 4-7 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 $Z \le 1$. Furthermore, assume we somehow add another constraint that effectively restricts $Z \le 0$. The constraint $Z \le 1$ now has no effect on the optimization.

Example: Minimize Portfolio Sensitivities

To illustrate using `hedgeopt` to minimize portfolio sensitivities for a given maximum target cost, specify a target cost of $20,000 and determine the new portfolio sensitivities, holdings, and cost of the rebalanced portfolio.

```
MaxCost = 20000;
[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price,...
Holdings, [1 4 5 7 8], [], MaxCost);

Sens =

      -4345.36        295.81      -6586.64

Cost =

       20000.00

Quantity' =

        100.00
       -151.86
       -253.47
         80.00
          8.00
        -18.18
         40.00
         10.00
```

This example corresponds to the $20,000 point along the cost axis in the figures Rebalancing Cost Profile on page 4-10, Funds Available for Rebalancing on page 4-11, and Rebalancing Cost on page 4-14.

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.

Functions — By Category

Portfolio Hedge Allocation

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

Price and Sensitivity from Interest-Rate Term Structure

`bondbyzero`	Price bond from set of zero curves
`cfbyzero`	Price cash flows from set of zero curves
`fixedbyzero`	Price fixed-rate note from set of zero curves
`floatbyzero`	Price floating-rate note from set of zero curves

`intenvprice`	Price instruments from set of zero curves
`intenvsens`	Instrument price and sensitivities from set of zero curves
`swapbyzero`	Price swap instrument from set of zero curves

Price and Sensitivity from Heath-Jarrow-Morton Trees

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

Price and Sensitivity from Black-Derman-Toy Trees

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

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

Price and Sensitivity from Black-Karasinski Trees

`bkprice`	Instrument prices from Black-Karasinski interest-rate tree
`bksens`	Instrument prices and sensitivities from Black-Karasinski interest-rate tree
`bktimespec`	Specify time structure for Black-Karasinski tree
`bktree`	Construct Black-Karasinski interest-rate tree
`bkvolspec`	Specify Black-Karasinski interest-rate volatility process

Price and Sensitivity from Cox-Ross-Rubinstein Trees

`crrprice`	Instrument prices from CRR tree
`crrsens`	Instrument prices and sensitivities from 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 EQP binomial tree
`eqpsens`	Instrument prices and sensitivities from EQP binomial tree
`eqptimespec`	Specify time structure for EQP binomial tree
`eqptree`	Construct EQP stock tree

Price and Sensitivity from Hull-White Trees

`hwprice`	Instrument prices from Hull-White interest-rate tree
`hwsens`	Instrument prices and sensitivities from HW interest-rate tree
`hwtimespec`	Specify time structure for Hull-White tree
`hwtree`	Construct Hull-White interest-rate tree
`hwvolspec`	Specify Hull-White interest-rate volatility process

Heath-Jarrow-Morton Utilities

bondbyhjm	Price bond from HJM interest-rate tree
capbyhjm	Price cap instrument from HJM interest-rate tree
cfbyhjm	Price cash flows from HJM interest-rate tree
fixedbyhjm	Price fixed-rate note from HJM interest-rate tree
floatbyhjm	Price floating-rate note from HJM interest-rate tree
floorbyhjm	Price floor instrument from HJM interest-rate tree
mmktbyhjm	Create money-market tree from HJM interest-rate tree
optbndbyhjm	Price bond option from HJM interest-rate tree
swapbyhjm	Price swap instrument from HJM interest-rate tree

Black-Derman-Toy Utilities

bondbybdt	Price bond from BDT interest-rate tree
capbybdt	Price cap instrument from BDT interest-rate tree
cfbybdt	Price cash flows from BDT interest-rate tree
fixedbybdt	Price fixed-rate note from BDT interest-rate tree

`floatbybdt`	Price floating-rate note from BDT interest-rate tree
`floorbybdt`	Price floor instrument from BDT interest-rate tree
`mmktbybdt`	Create money-market tree from BDT interest-rate tree
`optbndbybdt`	Price bond option from BDT interest-rate tree
`swapbybdt`	Price swap instrument from BDT interest-rate tree

Black-Karasinski Utilities

`bondbybk`	Price bond from Black-Karasinski interest-rate tree
`capbybk`	Price cap instrument from Black-Karasinski interest-rate tree
`cfbybk`	Price cash flows from Black-Karasinski interest-rate tree
`fixedbybk`	Price fixed-rate note from Black-Karasinski interest-rate tree
`floatbybk`	Price floating-rate note from Black-Karasinski interest-rate tree
`floorbybk`	Price floor instrument from Black-Karasinski interest-rate tree

optbndbybk	Price bond option from Black-Karasinski interest-rate tree
swapbybk	Price swap instrument from Black-Karasinski interest-rate tree

Cox-Ross-Rubinstein Utilities

asianbycrr	Price Asian option from CRR binomial tree
barrierbycrr	Price barrier option from CRR binomial tree
compoundbycrr	Price compound option from CRR binomial tree
lookbackbycrr	Price lookback option from CRR tree
optstockbycrr	Price stock option from CRR tree

Equal Probabilities Tree Utilities

asianbyeqp	Price Asian option from EQP binomial tree
barrierbyeqp	Price barrier option from EQP binomial tree
compoundbyeqp	Price compound option from EQP binomial tree
lookbackbyeqp	Price lookback option from EQP binomial tree
optstockbyeqp	Price stock option from EQP binomial tree

Hull-White Utilities

`bondbyhw`	Price bond from Hull-White interest-rate tree
`capbyhw`	Price cap instrument from Hull-White interest-rate tree
`cfbyhw`	Price cash flows from Hull-White interest-rate tree
`fixedbyhw`	Price fixed-rate note from Hull-White interest-rate tree
`floatbyhw`	Price floating-rate note from Hull-White interest-rate tree
`floorbyhw`	Price floor instrument from Hull-White interest-rate tree
`optbndbyhw`	Price bond option from Hull-White interest-rate tree
`swapbyhw`	Price swap instrument from Hull-White interest-rate tree

Tree Manipulation

`bushpath`	Extract entries from node of bushy tree
`bushshape`	Retrieve shape of bushy tree
`cvtree`	Convert inverse-discount tree to interest-rate tree
`mkbush`	Create bushy tree
`mktree`	Create recombining binomial tree
`mktrintree`	Create recombining trinomial tree

`treepath`	Entries from node of recombining binomial tree
`treeshape`	Shape of recombining binomial tree
`trintreepath`	Entries from node of recombining trinomial tree
`trintreeshape`	Shape of recombining trinomial 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 instrument collection
`instasian`	Construct Asian option
`instbarrier`	Construct barrier option
`instbond`	Construct bond instrument
`instcap`	Construct cap instrument
`instcf`	Construct cash flow instrument
`instcompound`	Construct compound option
`instdelete`	Complement of instrument set 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`	Data from instrument variable
`instgetcell`	Data and context from instrument variable
`instlength`	Count instruments
`instlookback`	Construct lookback option
`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`	Properties of interest-rate structure
`intenvset`	Set properties of interest-rate structure
`rate2disc`	Discount factors from interest rates
`ratetimes`	Change time intervals defining interest-rate environment
`time2date`	Dates from time and frequency

Date

`datedisp`	Display date entries

Graphical Display

`treeviewer`	Tree information

6

Functions — Alphabetical List

asianbycrr

Purpose

Price Asian option from 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 the value of fixed- and floating-strike Asian options. To compute the value of a floating-strike Asian option, specify Strike as NaN. Fixed-strike Asian options are also known as average price options. Floating-strike Asian options are also known as average strike options.

Price is a NINST-by-1 vector of expected prices at time 0.

Asian options are priced using Hull-White (1993). Consequently, for these options only the root node contains a unique price.

Examples

Price a floating-strike Asian option using a CRR binomial tree.

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 from EQP binomial tree

Syntax

```
Price = asianbyeqp(EQPTree, 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.

Description

Price = asianbyeqp(EQPTree, OptSpec, Strike, Settle, ExerciseDates, AmericanOpt, AvgType, AvgPrice, AvgDate) calculates the value of fixed- and floating-strike Asian options. To compute the value of a floating-strike Asian option, specify Strike as NaN. Fixed-strike Asian options are also known as average price options. Floating-strike Asian options are also known as average strike options.

Price is a NINST-by-1 vector of expected prices at time 0.

Examples

Price a floating-strike Asian option using an EQP equity tree.

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.

barrierbycrr

Purpose

Price barrier option from 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 binomial 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 from 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.

bdtprice

Purpose

Instrument prices from 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 from a BDT tree.
- `capbybdt`: Price a cap from a BDT tree.
- `cfbybdt`: Price an arbitrary set of cash flows from a BDT tree.
- `fixedbybdt`: Price a fixed-rate note from a BDT tree.
- `floatbybdt`: Price a floating-rate note from a BDT tree.
- `floorbybdt`: Price a floor from a BDT tree.
- `optbndbybdt`: Price a bond option from a BDT tree.
- `swapbybdt`: Price a swap from a BDT tree.

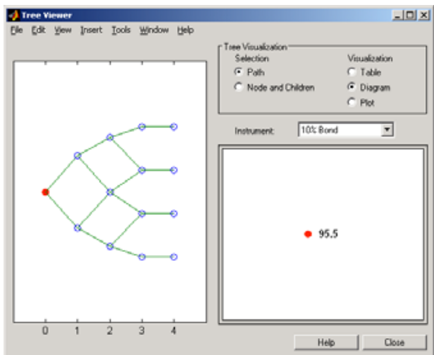
Examples

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

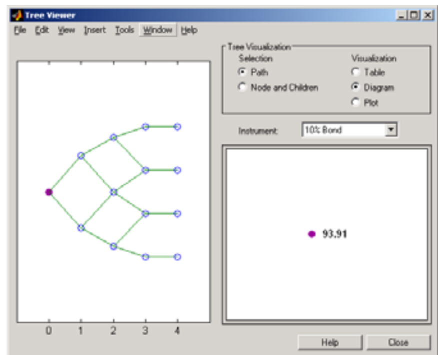
```
load deriv;
BDTSubSet = instselect(BDTInstSet,'Type', {'Bond', 'Cap'});

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
```

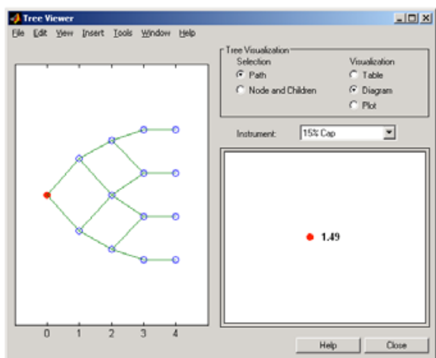
You can use `treeviewer` to see the prices of these three instruments along the price tree.



First 10% Bond (Maturity 2003)



Second 10% Bond (Maturity 2004)



15% Cap

See Also

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

Purpose

Instrument prices and sensitivities from 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;
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% Bo
nd
2     Bond 0.1        01-Jan-2000   01-Jan-2004  2       10% Bo
nd

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'];

TimeSpec = bdttimespec(ValuationDate, Maturity, Compounding)

TimeSpec =

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

See Also

bdttree, bdtvolspec

bdttree

Purpose

Construct 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

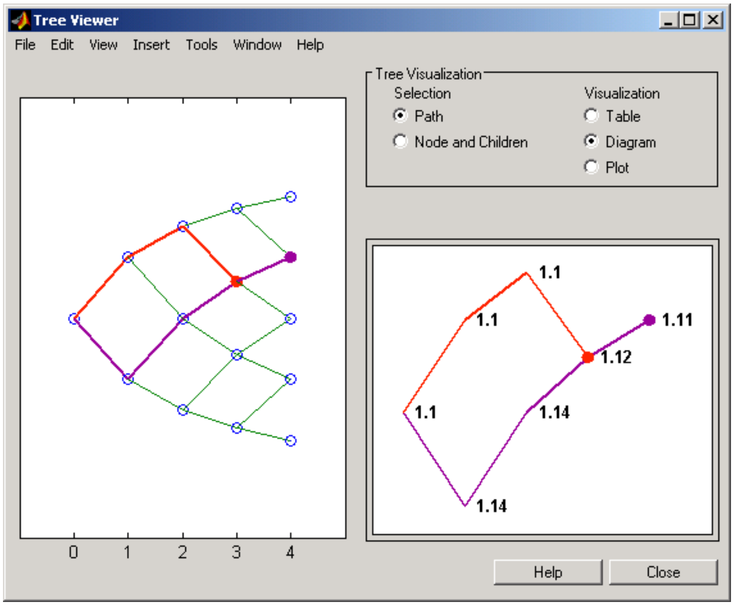
Using the data provided, create a BDT volatility specification (`VolSpec`), rate specification (`RateSpec`), and tree time layout specification (`TimeSpec`). Then use these specifications to create a BDT tree with `bdttree`.

```
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)
```



See Also

`bdtprice`, `bdttimespec`, `bdtvolspec`, `intenvset`

bdtvolspec

Purpose

Specify 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

bkprice

Purpose

Instrument prices from Black-Karasinski interest-rate tree

Syntax

```
[Price, PriceTree] = bkprice(BKTree, InstSet, Options)
```

Arguments

`BKTree`	Interest-rate tree structure created by `bktree`.
`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] = bkprice(BKTree, InstSet, Options)` computes arbitrage free prices for instruments using an interest-rate tree created with `bktree`. All instruments contained in a financial instrument variable, `InstSet`, are priced.

`Price` is a number of instruments `(NINST)`-by-1 vector of prices for each instrument. The prices are computed by backward dynamic programming on the interest-rate tree. If an instrument cannot be priced, `NaN` is returned.

`PriceTree` is a MATLAB structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node.

`PriceTree.PTree` contains the clean prices.

`PriceTree.AITree` contains the accrued interest.

`PriceTree.tObs` contains the observation times.

`bkprice` handles instrument types: `'Bond'`, `'CashFlow'`, `'OptBond'`, `'Fixed'`, `'Float'`, `'Cap'`, `'Floor'`, `'Swap'`. See `instadd` to construct defined types.

Related single-type pricing functions are

- `bondbybk`: Price a bond from a Black-Karasinski tree.
- `capbybk`: Price a cap from a Black-Karasinski tree.
- `cfbybk`: Price an arbitrary set of cash flows from a Black-Karasinski tree.
- `fixedbybk`: Price a fixed-rate note from a Black-Karasinski tree.
- `floatbybk`: Price a floating-rate note from a Black-Karasinski tree.
- `floorbybk`: Price a floor from a Black-Karasinski tree.
- `optbndbybk`: Price a bond option from a Black-Karasinski tree.
- `swapbybk`: Price a swap from a Black-Karasinski tree.

Examples

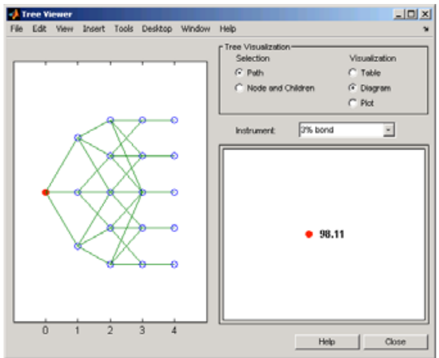
Load the BK tree and instruments from the data file `deriv.mat`. Price the cap and bond instruments contained in the instrument set.

```
load deriv;
BKSubSet = instselect(BKInstSet,'Type', {'Bond', 'Cap'});

instdisp(BKSubSet)

Index Type   CouponRate Settle      Maturity    Period  Name ...
1     Bond   0.03       01-Jan-2004 01-Jan-2007 1       3% bond
2     Bond   0.03       01-Jan-2004 01-Jan-2008 2       3% bond

Index Type Strike Settle      Maturity     CapReset...  Name ...
3     Cap  0.04   01-Jan-2004 01-Jan-2008  1            4% Cap

[Price, PriceTree] = bkprice(BKTree, BKSubSet);

Price =

   98.1096
   95.6734
```

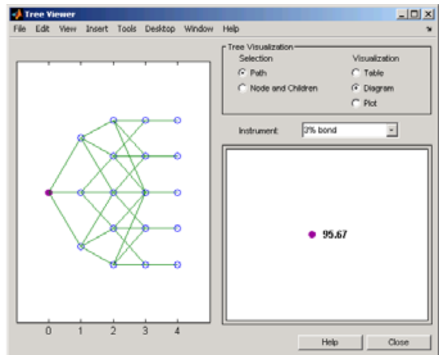
```
2.2706
```

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

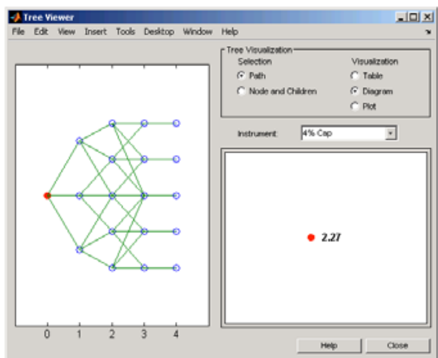
```
treeviewer(PriceTree, BKSubSet)
```



First 3% Bond (Maturity 2007)



Second 3% Bond (Maturity 2008)



4% Cap

See Also

bksens, bktree, instadd, intenvprice, intenvsens

Purpose

Instrument prices and sensitivities from Black-Karasinski interest-rate tree

Syntax

```
[Delta, Gamma, Vega, Price] = bksens(BKTree, InstSet,
   Options)
```

Arguments

`BKTree`	Interest-rate tree structure created by `bktree`.
`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] = bksens(BKTree, InstSet, Options)` computes instrument sensitivities and prices for instruments using an interest-rate tree created with the `bktree` function. `NINST` instruments from a financial instrument variable, `InstSet`, are priced. `bksens` handles instrument types: `'Bond'`, `'CashFlow'`, `'OptBond'`, `'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 `bktree`. See `bktree` for information on the observed yield curve.

`Gamma` is an `NINST`-by-1 vector of gammas, representing the rate of change of instrument deltas with respect to the changes in the interest rate. `Gamma` is computed by finite differences in calls to `bktree`.

`Vega` is an `NINST`-by-1 vector of vegas, representing the rate of change of instrument prices with respect to the changes in the volatility $\sigma(t, T)$.

Vega is computed by finite differences in calls to bktree. See bkvolspec for information on the volatility process.

Note All sensitivities are returned as dollar sensitivities. To find the per-dollar sensitivities, divide by the respective instrument price.

Price is an NINST-by-1 vector of prices of each instrument. The prices are computed by backward dynamic programming on the interest-rate tree. If an instrument cannot be priced, NaN is returned.

Delta and Gamma are calculated based on yield shifts of 100 basis points. Vega is calculated based on a 1% shift in the volatility process.

Examples

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;
BKSubSet = instselect(BKInstSet,'Type', {'Bond', 'Cap'});

instdisp(BKSubSet)

Index Type CouponRate Settle        Maturity     Period  Name
...
1     Bond 0.03       01-Jan-2004   01-Jan-2007  1       3% Bon
d
2     Bond 0.03       01-Jan-2004   01-Jan-2008  1       3% Bon
d

Index Type Strike Settle      Maturity     CapReset...  Name ...
3     Cap  0.04   01-Jan-2004 01-Jan-2008  1            4% Cap

[Delta, Gamma] = bksens(BKTree, BKSubSet)

Delta =
```

```
 -285.7151
 -365.7048
  189.5319

Gamma =

  1.0e+003 *

    0.8456
    1.4345
    6.9999
```

See Also

bkprice, bktree, bkvolspec, instadd

bktimespec

Purpose Specify time structure for Black-Karasinski tree

Syntax

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

Arguments

`ValuationDate`	Scalar date marking the pricing date and first observation in the tree. Specify as a serial date number or date string.
`Maturity`	Number of levels (depth) of the tree. A number of levels (`NLEVELS`)-by-1 vector of dates marking the cash flow dates of the tree. Cash flows with these maturities fall on tree nodes. Maturity should be in increasing order.

`Compounding`	(Optional) Scalar value representing the rate at which the input zero rates were compounded when annualized. Default = `-1` (continuous compounding). This argument determines the formula for the discount factors:
	`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 = bktimespec(ValuationDate, Maturity, Compounding)` sets the number of levels and node times for an BK tree and determines the mapping between dates and time for rate quoting.

`TimeSpec` is a structure specifying the time layout for `bktree`. The state observation dates are `[Settle; Maturity(1:end-1)]`. Because a forward rate is stored at the last observation, the tree can value cash flows out to `Maturity`.

Examples

Specify a four-period tree with annual nodes. Use annual compounding to report rates.

```
ValuationDate = 'Jan-1-2004';
Maturity = ['12-31-2004'; '12-31-2005'; '12-31-2006';
'12-31-2007'];
Compounding = 1;
TimeSpec = bktimespec(ValuationDate, Maturity, Compounding)

TimeSpec =

           FinObj: 'BKTimeSpec'
    ValuationDate: 731947
         Maturity: [4x1 double]
      Compounding: 1
            Basis: 0
```

See Also

`bktree`, `bkvolspec`, `hwtree`

Purpose

Construct Black-Karasinski interest-rate tree

Syntax

`BKTree = bktree(VolSpec, RateSpec, TimeSpec)`

Arguments

`VolSpec`	Volatility process specification. See `bkvolspec` for information on the volatility process.
`RateSpec`	Interest-rate specification for the initial rate curve. See `intenvset` for information on declaring an interest-rate variable.
`TimeSpec`	Tree time layout specification. Defines the observation dates of the BK tree and the `Compounding` rule for date to time mapping and price-yield formulas. See `bktimespec` for information on the tree structure.

Description

`BKTree = bktree(VolSpec, RateSpec, TimeSpec)` creates a structure containing time and interest-rate information on a recombining tree.

Examples

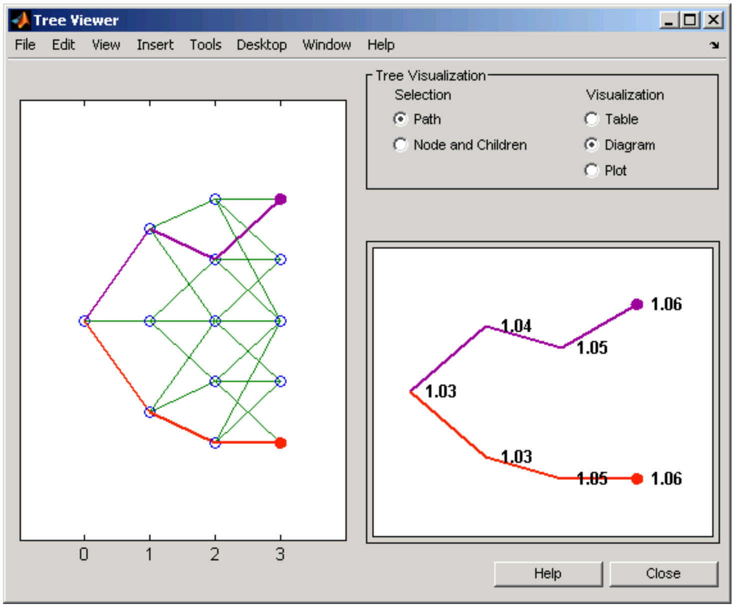
Using the data provided, create a BK volatility specification (`VolSpec`), rate specification (`RateSpec`), and tree time layout specification (`TimeSpec`). Then use these specifications to create a BK tree using `bktree`.

```
Compounding = -1;
ValuationDate = '01-01-2004';
StartDate = ValuationDate;
VolDates = ['12-31-2004'; '12-31-2005'; '12-31-2006';
'12-31-2007'];
VolCurve = 0.01;
AlphaDates = '01-01-2008';
AlphaCurve = 0.1;
Rates = [0.0275; 0.0312; 0.0363; 0.0415];
```

```
BKVolSpec = bkvolspec(ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);

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

BKTimeSpec = bktimespec(ValuationDate, VolDates, Compounding);

BKTree = bktree(BKVolSpec, RateSpec, BKTimeSpec)

BKTree =

      FinObj: 'BKFwdTree'
     VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
        tObs: [0 0.9973 1.9973 2.9973]
        dObs: [731947 732312 732677 733042]
      CFlowT: {[4x1 double]  [3x1 double]  [2x1 double]  [3.9973]}
       Probs: {[3x1 double]  [3x3 double]  [3x5 double]}
     Connect: {[2]  [2 3 4]  [2 2 3 4 4]}
     FwdTree: {1x4 cell}
```

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

```
treeviewer(BKTree)
```



See Also

`bkprice`, `bktimespec`, `bkvolspec`, `intenvset`

Purpose

Specify Black-Karasinski interest-rate volatility process

Syntax

```
Volspec = bkvolspec(ValuationDate, VolDates, VolCurve,
   AlphaDates,
AlphaCurve, InterpMethod)
```

Arguments

`ValuationDate`	Scalar value representing the observation date of the investment horizon.
`VolDates`	Number of points (`NPOINTS`)-by-1 vector of yield volatility end dates.
`VolCurve`	`NPOINTS`-by-1 vector of yield volatility values in decimal form.
`AlphaDates`	`NPOINTS`-by-1 vector of mean reversion end dates.
`AlphaCurve`	`NPOINTS`-by-1 vector of positive mean reversion values in decimal form.
`InterpMethod`	(Optional) Interpolation method. Default is `'linear'`. See `interp1` for more information.

Description

`Volspec = bkvolspec(ValuationDate, VolDates, VolCurve, AlphaDates,AlphaCurve, InterpMethod)` creates a structure specifying the volatility for `bktree`.

Examples

Using the data provided, create a Black-Karasinski volatility specification (`VolSpec`).

```
ValuationDate = '01-01-2004';
StartDate = ValuationDate;
VolDates = ['12-31-2004'; '12-31-2005'; '12-31-2006';
'12-31-2007'];
VolCurve = 0.01;
```

```
AlphaDates = '01-01-2008';
AlphaCurve = 0.1;
BKVolSpec = bkvolspec(ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve)

BKVolSpec =

            FinObj: 'BKVolSpec'
     ValuationDate: 731947
          VolDates: [4x1 double]
          VolCurve: [4x1 double]
        AlphaCurve: 0.1000
        AlphaDates: 733408
   VolInterpMethod: 'linear'
```

See Also

bktree, interp1

Purpose

Price bond from 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 instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).

`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 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 from 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 from Black-Karasinski interest-rate tree

Syntax

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

Arguments

`BKTree`	Forward rate tree structure created by `bktree`.
`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 instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).

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 BK tree. The bond argument Settle is ignored.

Description

```
[Price, PriceTree] = bondbybk(BKTree, CouponRate,
Settle, Maturity,Period, Basis, EndMonthRule, IssueDate,
```

`FirstCouponDate,LastCouponDate, StartDate, Face, Options)` computes the price of a bond from a Black-Karasinski interest-rate tree.

`Price` is a number of instruments (`NINST`)-by-`1` matrix of expected prices at time 0.

`PriceTree` is a structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node. Within `PriceTree`

- `PriceTree.PTree` contains the clean prices.
- `PriceTree.AITree` contains the accrued interest.
- `PriceTree.tObs` contains the observation times.

Examples

Price a 4% bond using a Black-Karasinski interest-rate tree.

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

```
load deriv;
```

Set the required values. Other arguments will use defaults.

```
CouponRate = 0.04;
Settle = '01-Jan-2004';
Maturity = '31-Dec-2008';
```

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

```
Price = bondbybk(BKTree, CouponRate, Settle, Maturity)
Warning: Not all cash flows are aligned with the tree. Result will
be approximated.

Price =

  98.0300
```

See Also `bkprice`, `bktree`, `hwprice`, `hwtree`, `instbond`

bondbyhjm

Purpose

Price bond from 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 instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).

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 from 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`

Purpose

Price bond from Hull-White interest-rate tree

Syntax

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

Arguments

`HWTree`	Forward-rate tree structure created by `hwtree`.
`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 instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).

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 HW tree. The bond argument Settle is ignored.

Description

```
[Price, PriceTree] = bondbyhw(HWTree, CouponRate,
Settle, Maturity,Period, Basis, EndMonthRule, IssueDate,
```

`FirstCouponDate,LastCouponDate, StartDate, Face, Options)` computes the price of a bond from a Hull-White interest-rate tree.

`Price` is a number of instruments (`NINST`)-by-`1` matrix of expected prices at time 0.

`PriceTree` is a structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node. Within `PriceTree`

- `PriceTree.PTree` contains the clean prices.
- `PriceTree.AITree` contains the accrued interest.
- `PriceTree.tObs` contains the observation times.

Examples

Price a 4% bond using a Hull-White interest-rate tree.

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

```
load deriv;
```

Set the required values. Other arguments will use defaults.

```
CouponRate = 0.04;
Settle = '01-Jan-2004';
Maturity = '31-Dec-2008';
```

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

```
Price = bondbyhw(HWTree, CouponRate, Settle, Maturity)
Warning: Not all cash flows are aligned with the tree. Result will
be approximated.

Price =

  98.0483
```

See Also

bkprice, bktree, hwprice, hwtree, instbond

Purpose

Price bond from set of zero curves

Syntax

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

Arguments

RateSpec	Structure containing the properties of an interest-rate structure. See intenvset for information on creating RateSpec.
CouponRate	Decimal annual rate.
Settle	Settlement date. 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 instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).

`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`

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;
```

Then

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

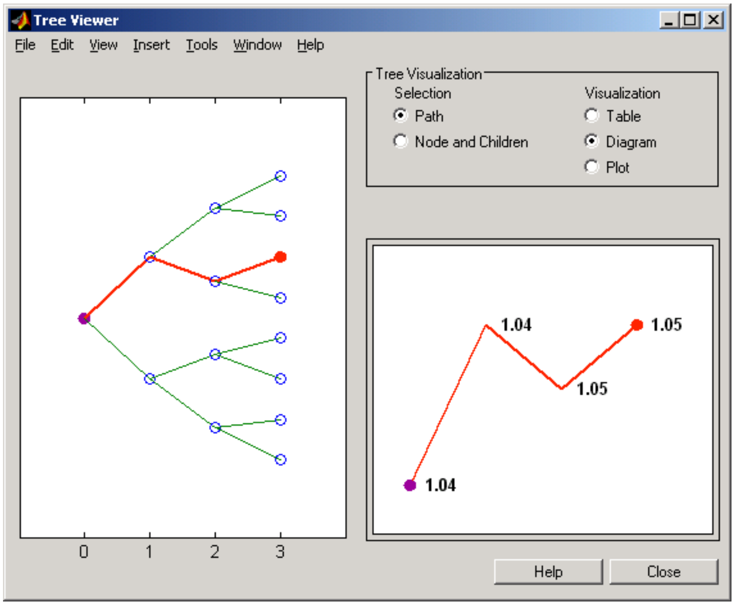
returns the rates at the tree nodes located by taking the up branch, then the down branch, and finally the up branch again.

```
FwdRates =

    1.0356
    1.0364
    1.0526
```

```
    1.0463
```

You can visualize this with the `treeviewer` function.

```
treeviewer(HJMTree)
```



See Also

`bushshape`, `mkbush`

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.

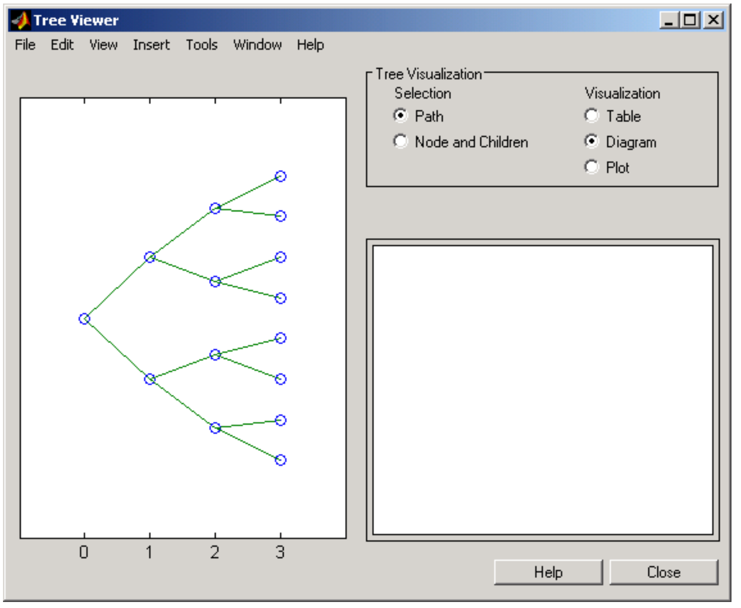
`Trim` is `1` if `NumPos` decreases by 1 when moving from one time level to the next. Otherwise, it is `0`.

Examples

Create an HJM tree by loading the example file.

```
load deriv;
```

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



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 from 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) Day-count basis of the instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`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. The BDTTree structure 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. This example shows 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. Remaining arguments will use defaults.

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

Use capbybdt to find the price of the cap instrument.

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

Price =

    1.6923
```

See Also

bdttree, cfbybdt, floorbybdt, swapbybdt

Purpose

Price cap instrument from Black-Karasinski interest-rate tree

Syntax

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

Arguments

`BKTree`	Interest-rate tree structure created by `bktree`.
`Strike`	Number of instruments (`NINST`)-by-`1` vector of rates at which the cap is exercised.
`Settle`	Settlement dates. `NINST`-by-`1` vector of dates representing the settlement dates of the cap.
`Maturity`	`NINST`-by-`1` vector of dates representing the maturity dates of the cap.
`Reset`	(Optional) `NINST`-by-`1` vector representing the frequency of payments per year. Default = `1`.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`Principal`	(Optional) The notional principal amount. Default = `100`.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

Description

`[Price, PriceTree] = capbybk(BKTree, Strike, Settle, Maturity,Reset, Basis, Principal, Options)` computes the price of a cap instrument from a Black-Karasinski interest-rate tree.

`Price` is the expected price of the cap at time 0.

`PriceTree` is the tree structure with values of the cap at each node.

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

Examples

Price a 3% cap instrument using a Black-Karasinski interest-rate tree.

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

```
load deriv;
```

Set the required values. Other arguments will use defaults.

```
Strike = 0.03;
Settle = '01-Jan-2005';
Maturity = '01-Jan-2009';
```

Use `capbybk` to compute the price of the cap instrument.

```
Price = capbybk(BKTree, Strike, Settle, Maturity)

Price =

    6.8337
```

See Also

`cfbybk`, `floorbybk`, `bktree`, `swapbybk`

Purpose

Price cap instrument from 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) Day-count basis of the instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`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. The HJMTree structure 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

Purpose

Price cap instrument from Hull-White interest-rate tree

Syntax

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

Arguments

`HWTree`	Interest-rate tree structure created by `hwtree`.
`Strike`	Number of instruments (`NINST`)-by-`1` vector of rates at which the cap is exercised.
`Settle`	Settlement dates. `NINST`-by-`1` vector of dates representing the settlement dates of the cap.
`Maturity`	`NINST`-by-`1` vector of dates representing the maturity dates of the cap.
`Reset`	(Optional) `NINST`-by-`1` vector representing the frequency of payments per year. Default = `1`.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`Principal`	(Optional) The notional principal amount. Default = `100`.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

Description

`[Price, PriceTree] = capbyhw(HWTree, Strike, Settle, Maturity,Reset, Basis, Principal, Options)` computes the price of a cap instrument from a Hull-White interest-rate tree.

`Price` is the expected price of the cap at time 0.

`PriceTree` is the tree structure with values of the cap at each node.

The Settle date for every cap is set to the ValuationDate of the HW tree. The cap argument Settle is ignored.

Examples

Price a 3% cap instrument using a Hull-White interest-rate tree.

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

```
load deriv;
```

Set the required values. Other arguments will use defaults.

```
Strike = 0.03;
Settle = '01-Jan-2005';
Maturity = '01-Jan-2009';
```

Use capbyhw to compute the price of the cap instrument.

```
Price = capbyhw(HWTree, Strike, Settle, Maturity)

Price =

    7.0707
```

See Also

cfbyhw, floorbyhw, hwtree, swapbyhw

Purpose

Price cash flows from 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 serial date number 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 BDT tree. The cash flow argument, `Settle`, is ignored.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`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;
```

The valuation date (settle date) specified in `BDTTree` is January 1, 2000 (date number `730486`).

```
BDTTree.RateSpec.ValuationDate

ans =

      730486
```

Provide values for the other required arguments.

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

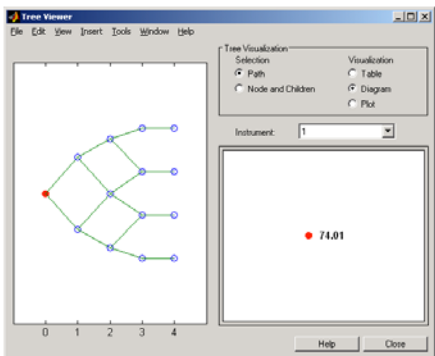
Use this information to compute the prices of the two cash flow instruments.

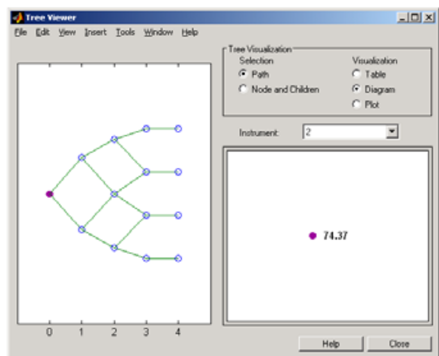
```
[Price, PriceTree] = cfbybdt(BDTTree, CFlowAmounts, ...
CFlowDates, BDTTree.RateSpec.ValuationDate)
```

```
Price =

   74.0112
   74.3671

PriceTree =

     FinObj: 'BDTPriceTree'
       tObs: [0 1.00 2.00 3.00 4.00]
      PTree: {1x5 cell}
```

You can visualize the prices of the two cash flow instruments with the `treeviewer` function.

```
treeviewer(PriceTree)
```





See Also

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

Purpose

Price cash flows from Black-Karasinski interest-rate tree

Syntax

```
[Price, PriceTree] = cfbybk(BKTree, CFlowAmounts, CFlowDates,
Settle, Basis, Options)
```

Arguments

BKTree	Forward-rate tree structure created by bktree.
CFlowAmounts	Number of instruments (NINST) by maximum number of cash flows (MOSTCFS) matrix of cash flow amounts. Each row is a list of cash flow values for one instrument. If an instrument has fewer than MOSTCFS cash flows, the end of the row is padded with NaNs.
CFlowDates	NINST-by-MOSTCFS matrix of cash flow dates. Each entry contains the serial date number of the corresponding cash flow in CFlowAmounts.
Settle	Settlement date. A vector of serial date numbers or date strings. The Settle date for every cash flow is set to the ValuationDate of the BK tree. The cash flow argument, Settle, is ignored.
Basis	(Optional) Day-count basis of the instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).
Options	(Optional) Derivatives pricing options structure created with derivset.

Description

[Price, PriceTree] = cfbybk(BKTree, CFlowAmounts, CFlowDates, Settle, Basis, Options) prices cash flows from a Black-Karasinski interest-rate tree.

`Price` is an `NINST`-by-1 vector of expected prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

Examples

Price a portfolio containing two cash flow instruments paying interest annually over the four-year period from January 1, 2005 to January 1, 2009.

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

```
load deriv;
```

The valuation date (settle date) specified in `BKTree` is January 1, 2004 (date number `731947`).

```
BKTree.RateSpec.ValuationDate

ans =

      731947
```

Provide values for the other required arguments.

```
CFlowAmounts =[5 NaN 5.5 105; 5 0 6 105];
CFlowDates = [732678, NaN, 733408,733774;
              732678, 733034, 733408, 734774];
```

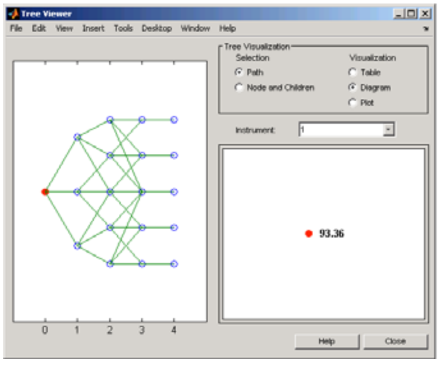
Use this information to compute the prices of the two cash flow instruments.

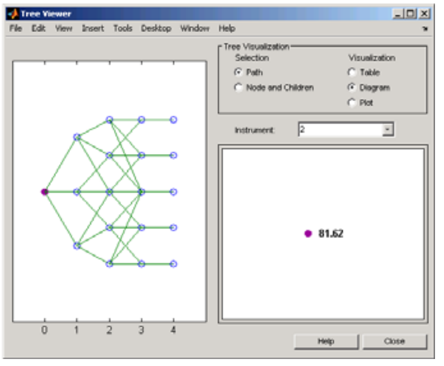
```
[Price, PriceTree] = cfbybk(BKTree, CFlowAmounts, CFlowDates,...
BKTree.RateSpec.ValuationDate)

Price =

   93.3600
```

```
   81.6218

PriceTree =

    FinObj: 'BKPriceTree'
       tObs: [0 1 2 3 4]
      PTree: {[2x1 double]  [2x3 double]  [2x5 double]  [2x5
double]                [2x5 double]}
    Connect: {[2]  [2 3 4]  [2 2 3 4 4]}
      Probs: {[3x1 double]  [3x3 double]  [3x5 double]}
```

You can visualize the prices of the two cash flow instruments with the `treeviewer` function.

```
treeviewer(PriceTree)
```





See Also

`bktree`, `bkprice`, `cfamounts`, `instcf`

Purpose

Price cash flows from 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 serial date number 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 instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`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`. The `HJMTree` structure contains the time and forward-rate information needed to price the instruments.

```
load deriv;
```

The valuation date (settle date) specified in `HJMTree` is January 1, 2000 (date number `730486`).

```
HWTree.RateSpec.ValuationDate

ans =

      730486
```

Provide values for the other required arguments.

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

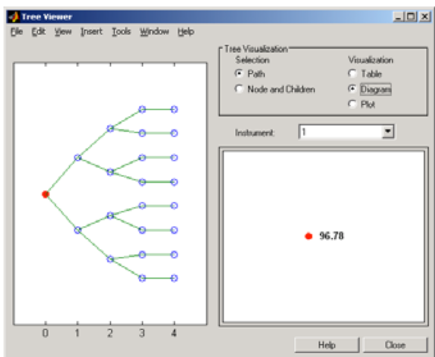
Use this information to compute the prices of the two cash flow instruments.

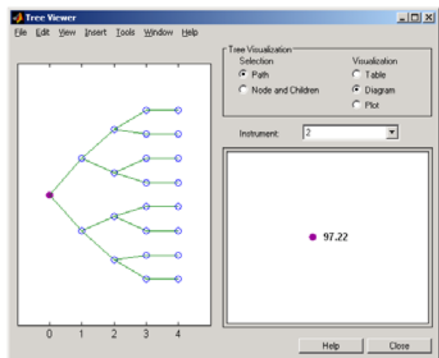
```
[Price, PriceTree] = cfbyhjm(HJMTree, CFlowAmounts,...
CFlowDates, HJMTree.RateSpec.ValuationDate)
```

```
Price =

   96.7805
   97.2188

PriceTree =

     FinObj: 'HJMPriceTree'
       tObs: [0 1.00 2.00 3.00 4.00]
      PBush: {1x5 cell}
```

You can visualize the prices of the two cash flow instruments with the `treeviewer` function.

```
treeviewer(PriceTree)
```





See Also

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

Purpose

Price cash flows from Hull-White interest-rate tree

Syntax

```
[Price, PriceTree] = cfbyhw(HWTree, CFlowAmounts, CFlowDates,
Settle, Basis, Options)
```

Arguments

HWTree	Forward-rate tree structure created by hwtree.
CFlowAmounts	Number of instruments (NINST) by maximum number of cash flows (MOSTCFS) matrix of cash flow amounts. Each row is a list of cash flow values for one instrument. If an instrument has fewer than MOSTCFS cash flows, the end of the row is padded with NaNs.
CFlowDates	NINST-by-MOSTCFS matrix of cash flow dates. Each entry contains the serial date number of the corresponding cash flow in CFlowAmounts.
Settle	Settlement date. A vector of serial date numbers or date strings. The Settle date for every cash flow is set to the ValuationDate of the HW tree. The cash flow argument, Settle, is ignored.
Basis	(Optional) Day-count basis of the instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).
Options	(Optional) Derivatives pricing options structure created with derivset.

Description

[Price, PriceTree] = cfbyhw(HWTree, CFlowAmounts, CFlowDates, Settle, Basis, Options) prices cash flows from a Hull-White interest-rate tree.

`Price` is an `NINST`-by-`1` vector of expected prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

Examples

Price a portfolio containing two cash flow instruments paying interest annually over the four-year period from January 1, 2005 to January 1, 2009.

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

```
load deriv;
```

The valuation date (settle date) specified in `HWTree` is January 1, 2004 (date number `731947`).

```
HWTree.RateSpec.ValuationDate

ans =

      731947
```

Provide values for the other required arguments.

```
CFlowAmounts =[5 NaN 5.5 105; 5 0 6 105];
CFlowDates = [732678, NaN, 733408, 733774;
              732678, 733034, 733408, 734774];
```

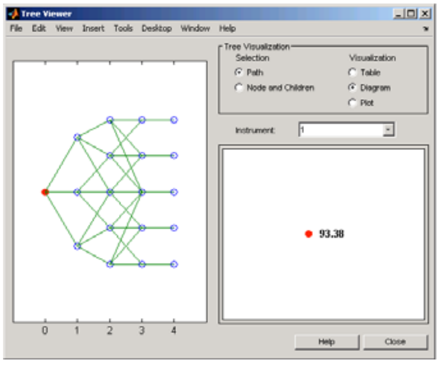
Use this information to compute the prices of the two cash flow instruments.

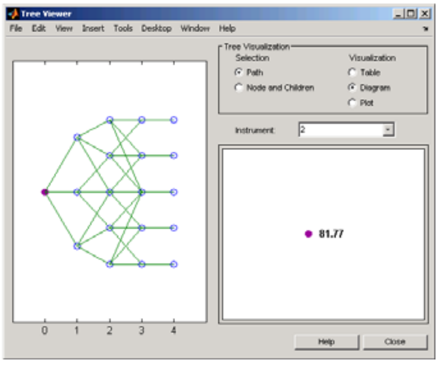
```
[Price, PriceTree] = cfbyhw(HWTree, CFlowAmounts, CFlowDates,...
HWTree.RateSpec.ValuationDate)

Price =

   93.3789
```

```
   81.7651

PriceTree =

    FinObj: 'HWPriceTree'
       tObs: [0 1 2 3 4]
      PTree: {[2x1 double]  [2x3 double]  [2x5 double]  [2x5
double]                [2x5 double]}
    Connect: {[2]  [2 3 4]  [2 2 3 4 4]}
      Probs: {[3x1 double]  [3x3 double]  [3x5 double]}
```

You can visualize the prices of the two cash flow instruments with the `treeviewer` function.

```
treeviewer(PriceTree)
```





See Also

`cfamounts`, `hwtree`, `hwprice`, `instcf`

Purpose

Price cash flows from set of zero curves

Syntax

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

Arguments

`RateSpec`	Structure containing the properties of an interest-rate structure. See `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 instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).

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 the name of a financial structure class.
Struct	MATLAB structure to be converted into a financial structure.
Obj	Name of a financial structure.

Description `Obj = classfin(ClassName)` and `Obj = classfin(Struct, ClassName)` create a financial structure of class `ClassName`.

`ClassName = classfin(Obj)` returns a string containing a financial structure's class name.

Examples 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

Purpose

Price compound option from 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 binomial 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.

```
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.

compoundbyeqp

Purpose

Price compound option from 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`. 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.

```
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 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 from a CRR tree.

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

Examples

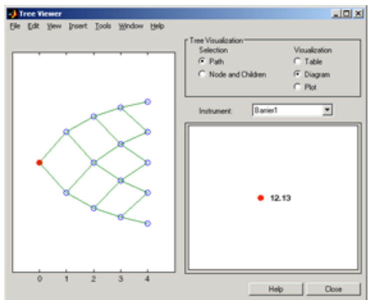
Load the CRR tree and instruments from the data file `deriv.mat`. Price the barrier and lookback options contained in the instrument set.

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

instdisp(CRRSubSet)

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}
```

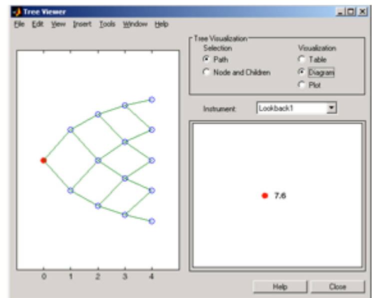
```
tObs: [0 1 2 3 4]
dObs: [731582 731947 732313 732678 733043]
```

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

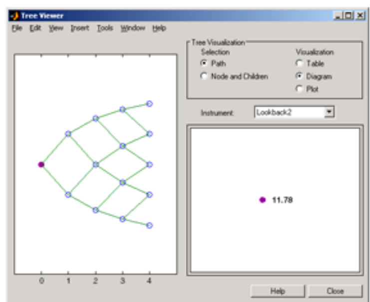
```
treeviewer(PriceTree, CRRSubSet)
```



Barrier1



Lookback1



Lookback2

See Also

`crrsens`, `crrtree`, `instadd`

Purpose

Instrument prices and sensitivities from CRR tree

Syntax

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

Purpose

Specify time structure for 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
tObs: [0 1 2 3 4]
dObs: [1x5 double]
```

See Also `crrtree`, `stockspec`

Purpose

Construct 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

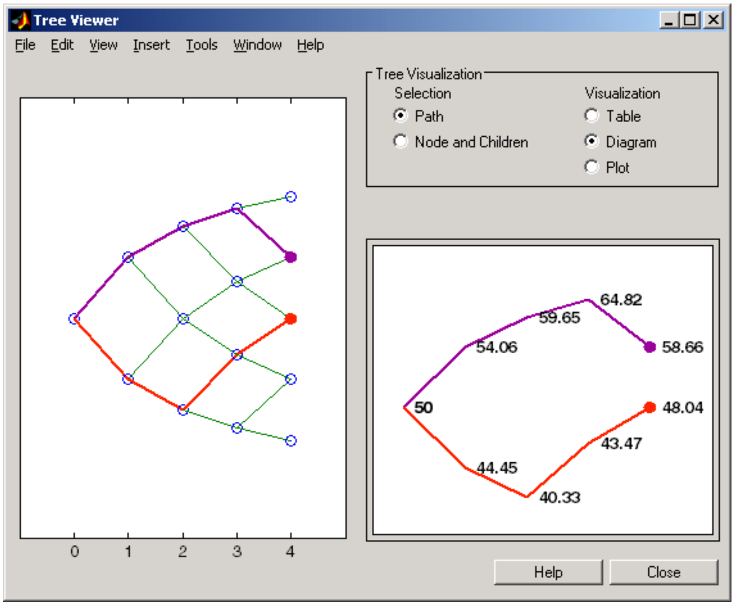
Using the data provided, create a stock specification (`StockSpec`), rate specification (`RateSpec`), and tree time layout specification (`TimeSpec`). Then use these specifications to create a CRR tree with `crrtree`.

```
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.



See Also

`crrtimespec`, `intenvset`, `stockspec`

Purpose

Convert inverse-discount tree to interest-rate tree

Syntax

```
RateTree = cvtree(Tree)
```

Arguments

`Tree`	Heath-Jarrow-Morton, Black-Derman-Toy, Hull-White, or Black-Karasinski tree structure using inverse-discount notation for forward rates.

Description

`RateTree = cvtree(Tree)` converts a tree structure using inverse-discount notation to a tree structure using rate notation for forward rates.

Examples

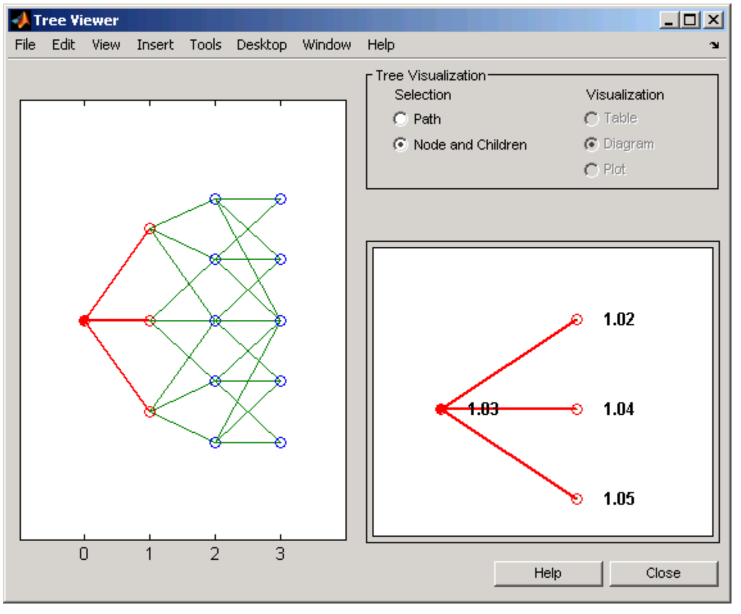
Convert a Hull-White tree using inverse-discount notation to a Hull-White tree displaying interest-rate notation.

```
load deriv;

HWTree

HWTree =

      FinObj: 'HWFwdTree'
     VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
        tObs: [0 1 2 3]
        dObs: [731947 732313 732678 733043]
      CFlowT: {[4x1 double]  [3x1 double]  [2x1 double]  [4]}
       Probs: {[3x1 double]  [3x3 double]  [3x5 double]}
     Connect: {[2]  [2 3 4]  [2 2 3 4 4]}
     FwdTree: {1x4 cell}

HWTree.FwdTree{1}
```

```
ans =
    1.0279

HWTree.FwdTree{2}

ans =
    1.0528    1.0356    1.0186
```

Use `treeviewer` to display the path of interest rates expressed in inverse-discount notation.

```
treeviewer(HWTree)
```

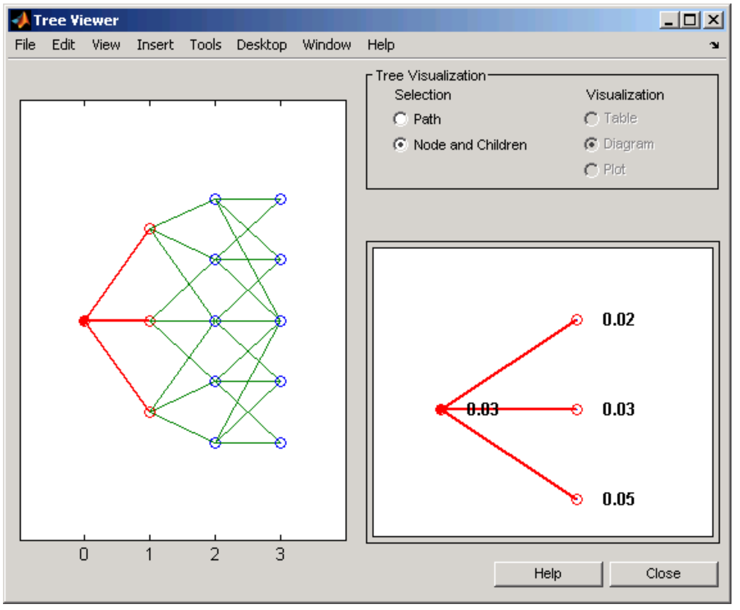


Use `cvtree` to convert the inverse-discount notation to interest-rate notation.

```
RTree = cvtree(HWTree)
```

```
RTree =

       FinObj: 'HWRateTree'
      VolSpec: [1x1 struct]
     TimeSpec: [1x1 struct]
     RateSpec: [1x1 struct]
         tObs: [0 1 2 3]
         dObs: [731947 732313 732678 733043]
       CFlowT: {[4x1 double]  [3x1 double]  [2x1 double]  [4]}
        Probs: {[3x1 double]  [3x3 double]  [3x5 double]}
      Connect: {[2]  [2 3 4]  [2 2 3 4 4]}
     RateTree: {1x4 cell}

RTree.RateTree{1}

ans =
    0.0275

RTree.RateTree{2}

ans =
    0.0514    0.0349    0.0185
```

Now use `treeviewer` to display the converted tree, showing the path of interest rates expressed as forward rates.



See Also

`disc2rate`, `rate2disc`

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`	Vector of dates corresponding to the compounding value.

`Compounding`	(Optional) Scalar value representing the rate at which the input zero rates were compounded when annualized. This argument determines the formula for the discount factors:
	`Compounding` = `1`, `2`, `3`, `4`, `6`, `12` (Default = `2`.)
	`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 instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).
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.

Note To obtain accurate results from this function, the Basis and Dates arguments must be consistent. If the Dates argument contains months that have 31 days, Basis must be one of the values that allow months to contain more than 30 days, e.g., Basis = 0, 3, or 7.

---

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

Examples

```
NumMat = [ 730730, 0.03, 1200, 730100;
           730731, 0.05, 1000, NaN]

NumMat =

   1.0e+05 *

    7.3073    0.0000    0.0120    7.3010
    7.3073    0.0000    0.0100       NaN

datedisp(NumMat)
    01-Sep-2000   0.03   1200   11-Dec-1998
    02-Sep-2000   0.05   1000       NaN
```

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

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

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`

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 a previous call to `derivset`.
`Parametern`	The parameter must be `'Diagnostics'`, `'Warnings'`, `'ConstRate'`, or `'BarrierMethod'`. Parameters can be entered in any order.
`Valuen`	(BDT, BK, HJM, or HW pricing only) 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`

disc2rate

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 EQP binomial tree

Syntax

```
[Price, PriceTree] = eqpprice(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 from an EQP tree.

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

Examples

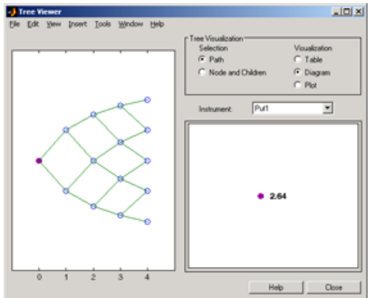
Load the EQP tree and instruments from the data file `deriv.mat`. Price the put options contained in the instrument set.

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

instdisp(EQPSubSet)

Index Type     OptSpec Strike Settle        ExerciseDates AmericanOpt Name...
1     OptStock put     105    01-Jan-2003 01-Jan-2006      0           Put 105...

Index Type  OptSpec Strike Settle     ExerciseDates AmericanOpt AvgType...
2     Asian put     110   01-Jan-2003 01-Jan-2006   0           arithmetic...
3     Asian put     110   01-Jan-2003 01-Jan-2007   0           arithmetic...

[Price, PriceTree] = eqpprice(EQPTree, EQPSubSet)

Price =

    2.6375
    4.7444
    3.9178

PriceTree =

    FinObj: 'BinPriceTree'
     PTree: {1x5 cell}
```

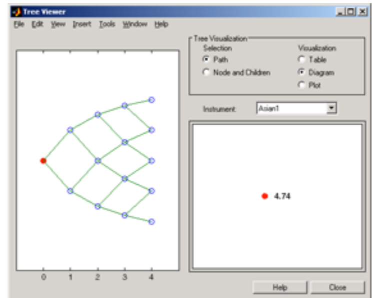
```
tObs: [0 1 2 3 4]
dObs: [731582 731947 732313 732678 733043]
```

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

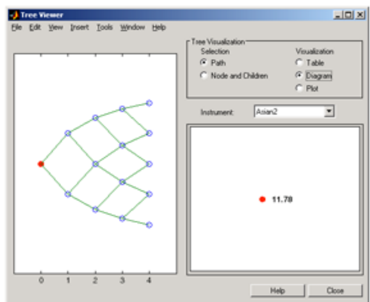
```
treeviewer(PriceTree, EQPSubSet)
```



Put1



Asian11



Asian2

See Also

`eqpsens`, `eqptimespec`, `eqptree`

Purpose

Instrument prices and sensitivities from 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`

Purpose Specify time structure for EQP binomial tree

Syntax

```
TimeSpec = eqptimespec(ValuationDate, Maturity, NumPeriods)
```

Arguments

`ValuationDate`	Scalar date indicating the pricing date and first observation in the tree. A serial date number or date string.
`Maturity`	Scalar date indicating depth of the tree.
`NumPeriods`	Scalar determining number of time steps in the tree.

Description `TimeSpec = eqptimespec(ValuationDate, Maturity, NumPeriods)` sets the number of levels and node times for an equal probabilities tree.

`TimeSpec` is a structure specifying the time layout for an equal probabilities tree.

Examples 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
tObs: [0 1 2 3 4]
dObs: [1x5 double]
```

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

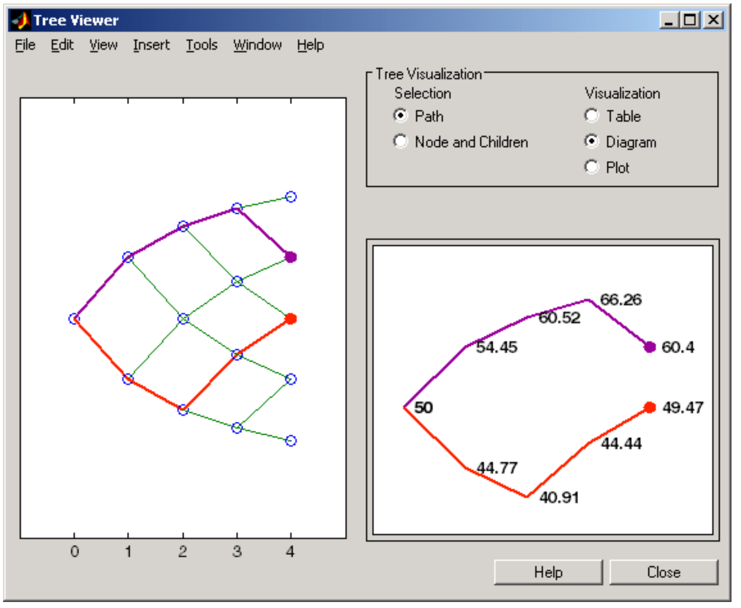
Using the data provided, create a stock specification (`StockSpec`), rate specification (`RateSpec`), and tree time layout specification (`TimeSpec`). Then use these specifications to create a CRR tree with `crrtree`.

```
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.



See Also

`eqptimespec`, `intenvset`, `stockspec`

Purpose

Price fixed-rate note from 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) Day-count basis of the instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).
Principal	(Optional) The notional principal amount. Default = 100.
Options	(Optional) Derivatives pricing options structure created with derivset.

Description

[Price, PriceTree] = fixedbybdt(BDTTree, 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. 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.

```
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

Purpose

Price fixed-rate note from Black-Karasinski interest-rate tree

Syntax

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

Arguments

`BKTree`	Interest-rate tree structure created by `bktree`.
`CouponRate`	Decimal annual rate.
`Settle`	Settlement dates. `NINST`-by-`1` vector of dates representing the settlement dates of the fixed-rate note.
`Maturity`	`NINST`-by-`1` vector of dates representing the maturity dates of the fixed-rate note.
`Reset`	(Optional) `NINST`-by-`1` vector representing the frequency of payments per year. Default = `1`.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`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] = fixedbybk(BKTree, CouponRate, Settle, Maturity, Reset, Basis, Principal, Options)` computes the price of a fixed-rate note from a Black-Karasinski 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 BK tree. The fixed-rate note argument Settle is ignored.

Examples

Price a 5% fixed-rate note using a Black-Karasinski interest-rate tree.

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

```
load deriv;
```

Set the required values. Other arguments will use defaults.

```
CouponRate = 0.05;
Settle = '01-Jan-2005';
Maturity = '01-Jan-2006';
```

Use fixedbybk to compute the price of the note.

```
Price = fixedbybk(BKTree, CouponRate, Settle, Maturity)

Price =

  103.5126
```

See Also

bktree, bondbybk, capbybk, cfbybk, floatbybk, floorbybk, swapbybk

Purpose

Price fixed-rate note from 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) Day-count basis of the instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`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. 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.

```
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

Purpose

Price fixed-rate note from Hull-White interest-rate tree

Syntax

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

Arguments

HWTree	Interest-rate tree structure created by hwtree.
CouponRate	Decimal annual rate.
Settle	Settlement dates. NINST-by-1 vector of dates representing the settlement dates of the fixed-rate note.
Maturity	NINST-by-1 vector of dates representing the maturity dates of the fixed-rate note.
Reset	(Optional) NINST-by-1 vector representing the frequency of payments per year. Default = 1.
Basis	(Optional) Day-count basis of the instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).
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] = floatbybj(HWTree, CouponRate, Settle, Maturity, Reset, Basis, Principal, Options) computes the price of a fixed-rate note from a Hull-White 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 HW tree. The fixed-rate note argument Settle is ignored.

Examples

Price a 5% fixed-rate note using a Hull-White interest-rate tree.

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

```
load deriv;
```

Set the required values. Other arguments will use defaults.

```
CouponRate = 0.05;
Settle = '01-Jan-2005';
Maturity = '01-Jan-2006';
```

Use fixedbyhw to compute the price of the note.

```
Price = fixedbyhw(HWTree, CouponRate, Settle, Maturity)

Price =

  103.5126
```

See Also

bondbyhw, capbyhw, cfbyhw, floatbyhw, floorbyhw, hwtree, swapbyhw

Purpose

Price fixed-rate note from set of zero curves

Syntax

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

Arguments

`RateSpec`	Structure containing the properties of an interest-rate structure. See `intenvset` for information on creating `RateSpec`.
`CouponRate`	Decimal annual rate.
`Settle`	Settlement date. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date.
`Reset`	(Optional) Frequency of payments per year. Default = `1`.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`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 from 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`

Purpose

Price floating-rate note from 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) Day-count basis of the instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`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] = floatbybdt(BDTTree, 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 =

  100.4865
```

See Also

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

Purpose

Price floating-rate note from Black-Karasinski interest-rate tree

Syntax

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

Arguments

`BKTree`	Interest-rate tree structure created by `bktree`.
`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) Day-count basis of the instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`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] = floatbybk(BKTree, Spread, Settle, Maturity,Reset, Basis, Principal, Options)` computes the price of a floating-rate note from a Black-Karasinski 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 BK tree. The floating-rate note argument Settle is ignored.

Examples

Price a 20 basis point floating-rate note using a Black-Karasinski interest-rate tree.

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

```
load deriv;
```

Set the required values. Other arguments will use defaults.

```
Spread = 20;
Settle = '01-Jan-2005';
Maturity = '01-Jan-2006';
```

Use floatbybk to compute the price of the note.

```
Price = floatbybk(BKTree, Spread, Settle, Maturity)

Price =

  100.3825
```

See Also

bktree, bondbybk, capbybk, cfbybk, fixedbybk, floorbybk, swapbybk

Purpose

Price floating-rate note from 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) Day-count basis of the instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`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

Purpose

Price floating-rate note from Hull-White interest-rate tree

Syntax

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

Arguments

HWTree	Interest-rate tree structure created by hwtree.
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) Day-count basis of the instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).
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] = floatbyhw(HWTree, Spread, Settle, Maturity, Reset, Basis, Principal, Options) computes the price of a floating-rate note from a Hull-White 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 HW tree. The floating-rate note argument Settle is ignored.

Examples

Price a 20 basis point floating-rate note using a Hull-White interest-rate tree.

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

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
Spread = 20;
Settle = '01-Jan-2005';
Maturity = '01-Jan-2006';
```

Use floatbyhw to compute the price of the note.

```
Price = floatbyhw(HWTree, Spread, Settle, Maturity)

Price =

  100.3825
```

See Also

bondbyhw, capbyhw, cfbyhw, fixedbyhw, floorbyhw, hwtree, swapbyhw

Purpose

Price floating-rate note from set of zero curves

Syntax

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

Arguments

RateSpec	Structure containing the properties of an interest-rate structure. See intenvset for information on creating RateSpec.
Spread	Number of basis points over the reference rate.
Settle	Settlement date. Settle must be earlier than or equal to Maturity.
Maturity	Maturity date.
Reset	(Optional) Frequency of payments per year. Default = 1.
Basis	(Optional) Day-count basis of the instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).
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 from 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`

Purpose

Price floor instrument from 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) Day-count basis of the instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`Principal`	(Optional) The notional principal amount. Default = `100`.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

floorbybdt

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. Remaining arguments will use defaults.

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

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`

floorbybk

Purpose

Price floor instrument from Black-Karasinski interest-rate tree

Syntax

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

Arguments

`HWTree`	Interest-rate tree structure created by `bktree`.
`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 BK 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) Day-count basis of the instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`Principal`	(Optional) The notional principal amount. Default = `100`.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

Description

`[Price, PriceTree] = floorbybk(BKTree, Strike, Settlement, Maturity, Reset, Basis, Principal, Options)` computes the price of a floor instrument from a Black-Karasinski tree.

Price is an NINST-by-1 vector of the expected prices of the floor at time 0.

PriceTree is the tree structure with values of the floor at each node.

Examples

Price a 3% floor instrument using a Black-Karasinski interest-rate tree.

Load the file deriv.mat, which provides BKTree. The BKTree structure contains the time and interest rate information needed to price the floor instrument.

```
load deriv;
```

Set the required values. Other arguments will use defaults.

```
Strike = 0.03;
Settle = '01-Jan-2005';
Maturity = '01-Jan-2009';
```

Use floorbyhw to compute the price of the floor instrument.

```
Price = floorbybk(BKTree, Strike, Settle, Maturity)

Price =

  0.2061
```

See Also

bktree, capbybk, cfbybk, swapbybk

floorbyhjm

Purpose

Price floor instrument from 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) Day-count basis of the instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).
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`. The `HJMTree` structure 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`

floorbyhw

Purpose Price floor instrument from Hull-White interest-rate tree

Syntax

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

Arguments

`HWTree`	Interest-rate tree structure created by `hwtree`.
`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 HW 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) Day-count basis of the instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`Principal`	(Optional) The notional principal amount. Default = `100`.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

Description

`[Price, PriceTree] = floorbyhw(HWTree, Strike, Settlement, Maturity, Reset, Basis, Principal, Options)` computes the price of a floor instrument from an HW tree.

`Price` is an `NINST-by-1` vector of the expected prices of the floor at time 0.

`PriceTree` is the tree structure with values of the floor at each node.

Examples

Price a 3% floor instrument using a Hull-White interest-rate tree.

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

```
load deriv;
```

Set the required values. Other arguments will use defaults.

```
Strike = 0.03;
Settle = '01-Jan-2005';
Maturity = '01-Jan-2009';
```

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

```
Price = floorbyhw(HWTree, Strike, Settle, Maturity)

Price =

  0.4616
```

See Also

`capbyhw`, `cfbyhw`, `hwtree`, `swapbyhw`

hedgeopt

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

The user-specified constraints included in `ConSet` may be created with the functions `pcalims` or `portcons`. However, the `portcons` default `PortHolds` positivity constraints are typically inappropriate for hedging problems since short-selling is usually required.

`NPOINTS`, the number of rows in `PortSens` and `PortHolds` and the length of `PortCost`, is inferred from the inputs. When the target sensitivities, `TargetSens`, is entered, `NPOINTS = 1`; otherwise `NPOINTS = NumCosts`, or is equal to the length of the `TargetCost` vector.

Not all problems are solvable (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 lets investors modify portfolio allocations among instruments to achieve either of the criteria. The chosen criterion is inferred from the input argument list. The problem is cast as a constrained linear least squares problem.

PortSens is a number of points (NPOINTS)-by-NSENS matrix of portfolio sensitivities. When a perfect hedge exists, PortSens is zeros. Otherwise, the best hedge possible is chosen.

PortCost is a 1-by-NPOINTS vector of total portfolio costs.

PortHolds is an NPOINTS-by-NINST matrix of contracts allocated to each instrument. These are the reallocated portfolios.

See Also

hedgeslf

pcalims, portcons, portopt in the Financial Toolbox documentation

lsqlin in the Optimization Toolbox documentation

hedgeslf

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

% WO(1) is not greater than 2.

[PortSens, PortValue, PortHolds] = hedgeslf(Sens, Price, WO,...
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];
WO = [1; 1];
ConSet = pcalims([2 2],[1 1]);

[PortSens, PortValue, PortHolds] = hedgeslf(Sens, Price, WO,...
[],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

Purpose

Instrument prices from HJM interest-rate tree

Syntax

```
Price = 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`. A subset of `NINST` instruments from a financial instrument variable, `InstSet`, are priced.

`Price` is a `NINST-by-1` vector of prices for each instrument. The prices are computed by backward dynamic programming on the interest-rate tree. If an instrument cannot be priced, `NaN` is returned.

`PriceTree` is a MATLAB structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node.

`PriceTree.PBush` contains the clean prices.

`PriceTree.AIBush` contains the accrued interest.

`PriceTree.tObs` contains the observation times.

`hjmprice` handles instrument types: `'Bond'`, `'CashFlow'`, `'OptBond'`, `'Fixed'`, `'Float'`, `'Cap'`, `'Floor'`, `'Swap'`. See `instadd` to construct defined types.

Related single-type pricing functions are

- `bondbyhjm`: Price a bond from an HJM tree.
- `capbyhjm`: Price a cap from an HJM tree.
- `cfbyhjm`: Price an arbitrary set of cash flows from an HJM tree.
- `fixedbyhjm`: Price a fixed-rate note from an HJM tree.
- `floatbyhjm`: Price a floating-rate note from an HJM tree.
- `floorbyhjm`: Price a floor from an HJM tree.
- `optbndbyhjm`: Price a bond option from an HJM tree.
- `swapbyhjm`: Price a swap from an HJM tree.

Examples

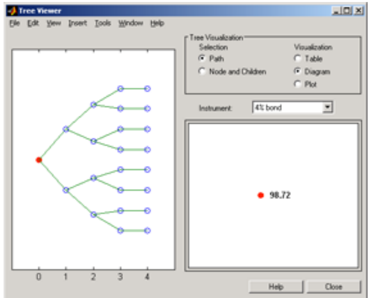
Load the HJM tree and instruments from the data file `deriv.mat`. Price the cap and bond instruments contained in the instrument set.

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

instdisp(HJMSubSet)

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.
```

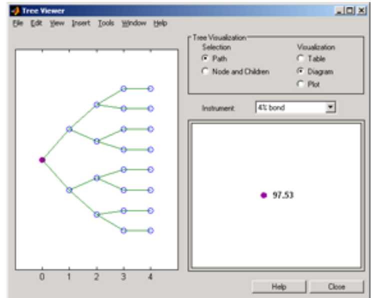
```
Price =

   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.

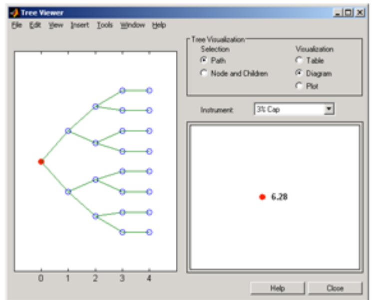
```
treeviewer(PriceTree, HJMSubSet)
```



First 4% Bond (Maturity 2003)



Second 4% Bond (Maturity 2004)



3% Cap

See Also

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

Purpose

Instrument prices and sensitivities from HJM interest-rate tree

Syntax

```
[Delta, Gamma, Vega, Price] = hjmsens(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

[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`

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.

hjmtimespec

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`

Purpose

Construct HJM interest-rate tree

Syntax

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

Arguments

`VolSpec`	Volatility process specification. Sets the number of factors and the rules for computing the volatility $\sigma(t, T)$ for each factor. See `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

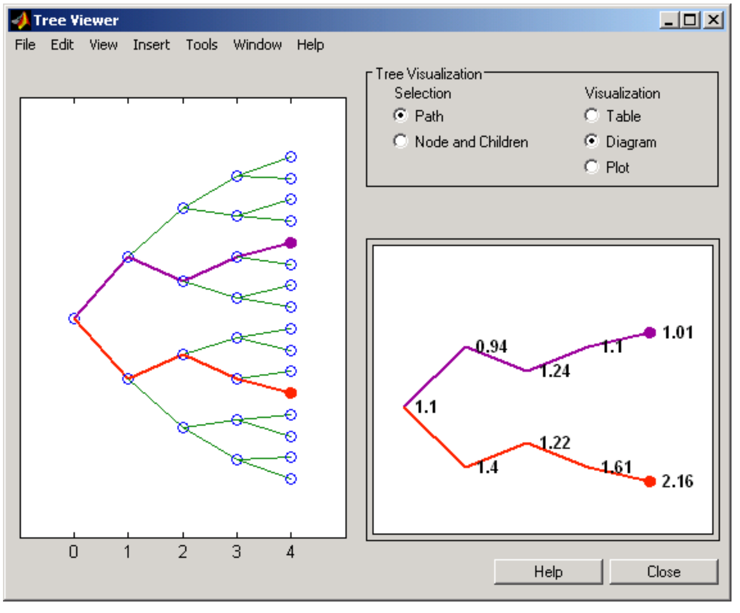
Using the data provided, create an HJM volatility specification (`VolSpec`), rate specification (`RateSpec`), and tree time layout specification (`TimeSpec`). Then use these specifications to create an HJM tree using `hjmtree`.

```
Compounding = 1;
ValuationDate = '01-01-2000';
StartDate = 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)
```



See Also

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

Purpose

Specify HJM interest-rate volatility process

Syntax

```
Volspec = hjmvolspec(varargin)
```

Arguments

The arguments to `hjmvolspec` vary according to the type and number of volatility factors specified when calling the function. Factors are specified by pairs of names and parameter sets. Factor names can be `'Constant'`, `'Stationary'`, `'Exponential'`, `'Vasicek'`, or `'Proportional'`. The parameter set is specific for each of these factor types:

- Constant volatility (Ho-Lee):
  `VolSpec = hjmvolspec('Constant', Sigma_0)`
- Stationary volatility:
  `VolSpec = hjmvolspec('Stationary', CurveVol, CurveTerm)`
- Exponential volatility:
  `VolSpec = hjmvolspec('Exponential', Sigma_0, Lambda)`
- Vasicek, Hull-White:
  `VolSpec = hjmvolspec('Vasicek', Sigma_0, CurveDecay, CurveTerm)`
- Nearly proportional stationary:
  `VolSpec = hjmvolspec('Proportional', CurveProp, CurveTerm, MaxSpot)`

You can specify more than one factor by concatenating names and parameter sets.

The following table defines the various arguments to `hjmvolspec`.

Argument	Description
Sigma_0	Scalar base volatility over a unit time.
Lambda	Scalar decay factor.
CurveVol	Number of curves (NCURVES)-by1 vector of Vol values at sample points.
CurveDecay	NCURVES-by-1 vector of Decay values at sample points.
CurveProp	NCURVES-by-1 vector of Prop values at sample points.
CurveTerm	NCURVES-by-1 vector of Term sample points.

Note See the volatility specifications formulas below for a description of Vol, Decay, Prop, and Term.

Description

Volspec = hjmvolspec(varargin) computes VolSpec, a structure that specifies the volatility model for hjmtree.

hjmvolspec specifies 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))

Volatility Specification	Formula
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

Instrument prices from Hull-White interest-rate tree

Syntax

```
[Price, PriceTree] = hwprice(HWTree, InstSet, Options)
```

Arguments

`HWTree`	Interest-rate tree structure created by `hwtree`.
`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] = hwprice(HWTree, InstSet, Options)` computes arbitrage free prices for instruments using an interest-rate tree created with `hwtree`. All instruments contained in a financial instrument variable, `InstSet`, are priced.

`Price` is a number of instruments `(NINST)`-by-1 vector of prices for each instrument. The prices are computed by backward dynamic programming on the interest-rate tree. If an instrument cannot be priced, `NaN` is returned.

`PriceTree` is a MATLAB structure of trees containing vectors of instrument prices and accrued interest, and a vector of observation times for each node.

`PriceTree.PTree` contains the clean prices.

`PriceTree.AITree` contains the accrued interest.

`PriceTree.tObs` contains the observation times.

`hwprice` handles instrument types: `'Bond'`, `'CashFlow'`, `'OptBond'`, `'Fixed'`, `'Float'`, `'Cap'`, `'Floor'`, `'Swap'`. See `instadd` to construct defined types.

Related single-type pricing functions are

- bondbyhw: Price a bond from a Hull-White tree.
- capbyhw: Price a cap from a Hull-White tree.
- cfbyhw: Price an arbitrary set of cash flows from a Hull-White tree.
- fixedbyhw: Price a fixed-rate note from a Hull-White tree.
- floatbyhw: Price a floating-rate note from a Hull-White tree.
- floorbyhw: Price a floor from a Hull-White tree.
- optbndbyhw: Price a bond option from a Hull-White tree.
- swapbyhw: Price a swap from a Hull-White tree.

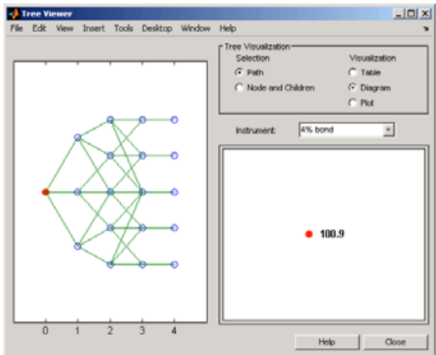
Examples

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

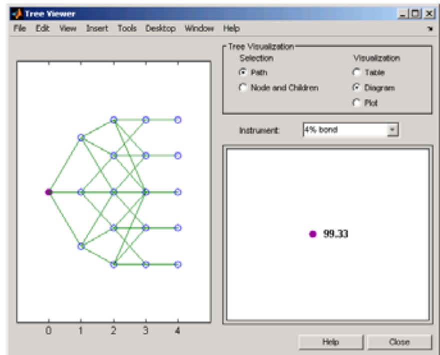
```
load deriv.mat;
HWSubSet = instselect(HWInstSet,'Type', {'Bond', 'Cap'});

instdisp(HWSubSet)

Index Type   CouponRate Settle      Maturity    Period  Name ...
1     Bond   0.04       01-Jan-2004 01-Jan-2007 1       4% bond
2     Bond   0.04       01-Jan-2004 01-Jan-2008 1       4% bond

Index Type Strike Settle      Maturity     CapReset...  Name ...
3     Cap  0.06   01-Jan-2004 01-Jan-2008  1            6% Cap

[Price, PriceTree] = hwprice(HWTree, HWSubSet);

Price =

  100.9188
   99.3296
    0.5837
```

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

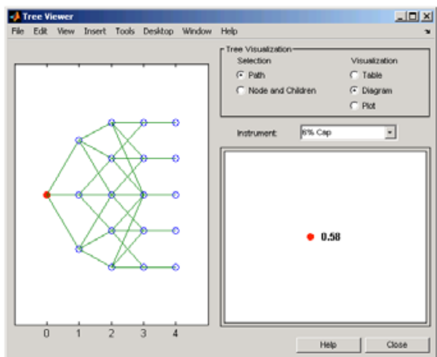
```
treeviewer(PriceTree, HWSubSet)
```



First 4% Bond (Maturity 2007)



Second 4% Bond (Maturity 2008)



6% Cap

See Also

`hwsens`, `hwtree`, `instadd`, `intenvprice`, `intenvsens`

hwsens

Purpose

Instrument prices and sensitivities from HW interest-rate tree

Syntax

```
[Delta, Gamma, Vega, Price] = hwsens(HWTree, InstSet,
   Options)
```

Arguments

`HWTree`	Interest-rate tree structure created by `hwtree`.
`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] = hwsens(HWTree, InstSet, Options)` computes instrument sensitivities and prices for instruments using an interest-rate tree created with the `hwtree` function. `NINST` instruments from a financial instrument variable, `InstSet`, are priced. `hwsens` handles instrument types: `'Bond'`, `'CashFlow'`, `'OptBond'`, `'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 `hwtree`. See `hwtree` for information on the observed yield curve.

`Gamma` is an `NINST`-by-`1` vector of gammas, representing the rate of change of instrument deltas with respect to the changes in the interest rate. `Gamma` is computed by finite differences in calls to `hwtree`.

`Vega` is an `NINST`-by-`1` vector of vegas, representing the rate of change of instrument prices with respect to the changes in the volatility $\sigma(t, T)$.

Vega is computed by finite differences in calls to hwtree. See hwvolspec for information on the volatility process.

Note All sensitivities are returned as dollar sensitivities. To find the per-dollar sensitivities, divide by the respective instrument price.

Price is an NINST-by-1 vector of prices of each instrument. The prices are computed by backward dynamic programming on the interest-rate tree. If an instrument cannot be priced, NaN is returned.

Delta and Gamma are calculated based on yield shifts of 100 basis points. Vega is calculated based on a 1% shift in the volatility process.

Examples

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;
HWSubSet = instselect(HWInstSet,'Type', {'Bond', 'Cap'});

instdisp(HWSubSet)

Index Type CouponRate Settle        Maturity     Period  Name ...
1     Bond 0.04       01-Jan-2004   01-Jan-2007  1       4% Bond
2     Bond 0.04       01-Jan-2004   01-Jan-2008  1       4% Bond

Index Type Strike Settle      Maturity     CapReset...  Name ...
3     Cap  0.06   01-Jan-2004 01-Jan-2008  1            6% Cap

[Delta, Gamma] = hwsens(HWTree, HWSubSet)

Delta =

       -291.26
       -374.64
         59.55
```

```
Gamma =

     858.41
    1460.88
    4843.65
```

See Also

hwprice, hwtree, hwvolspec, instadd

Purpose

Specify time structure for Hull-White tree

Syntax

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

Arguments

ValuationDate	Scalar date marking the pricing date and first observation in the tree. Specify as a serial date number or date string
Maturity	Number of levels (depth) of the tree. A number of levels (NLEVELS)-by-1 vector of dates marking the cash flow dates of the tree. Cash flows with these maturities fall on tree nodes. Maturity should be in increasing order.
Compounding	(Optional) Scalar value representing the rate at which the input zero rates were compounded when annualized. Default = -1 (continuous compounding). This argument determines the formula for the discount factors: 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.

hwtimespec

Description

`TimeSpec = hwtimespec(ValuationDate, Maturity, Compounding)` sets the number of levels and node times for a Hull-White tree and determines the mapping between dates and time for rate quoting.

`TimeSpec` is a structure specifying the time layout for `hwtree`. The state observation dates are `[Settle; Maturity(1:end-1)]`. Because a forward rate is stored at the last observation, the tree can value cash flows out to `Maturity`.

Examples

Specify a four-period tree with annual nodes. Use annual compounding to report rates.

```
ValuationDate = 'Jan-1-2004';
Maturity = ['12-31-2004'; '12-31-2005'; '12-31-2006';
'12-31-2007'];
Compounding = 1;
TimeSpec = hwtimespec(ValuationDate, Maturity, Compounding)

TimeSpec =

          FinObj: 'HWTimeSpec'
   ValuationDate: 731947
        Maturity: [4x1 double]
     Compounding: 1
           Basis: 0
```

See Also

`bktree`, `hwtree`, `hwvolspec`

Purpose

Construct Hull-White interest-rate tree

Syntax

`HWTree = hwtree(VolSpec, RateSpec, TimeSpec)`

Arguments

`VolSpec`	Volatility process specification. See `hwvolspec` for information on the volatility process.
`RateSpec`	Interest-rate specification for the initial rate curve. See `intenvset` for information on declaring an interest-rate variable.
`TimeSpec`	Tree time layout specification. Defines the observation dates of the HW tree and the compounding rule for date to time mapping and price-yield formulas. See `hwtimespec` for information on the tree structure.

Description

`HWTree = hwtree(VolSpec, RateSpec, TimeSpec)` creates a structure containing time and interest-rate information on a recombining tree.

Examples

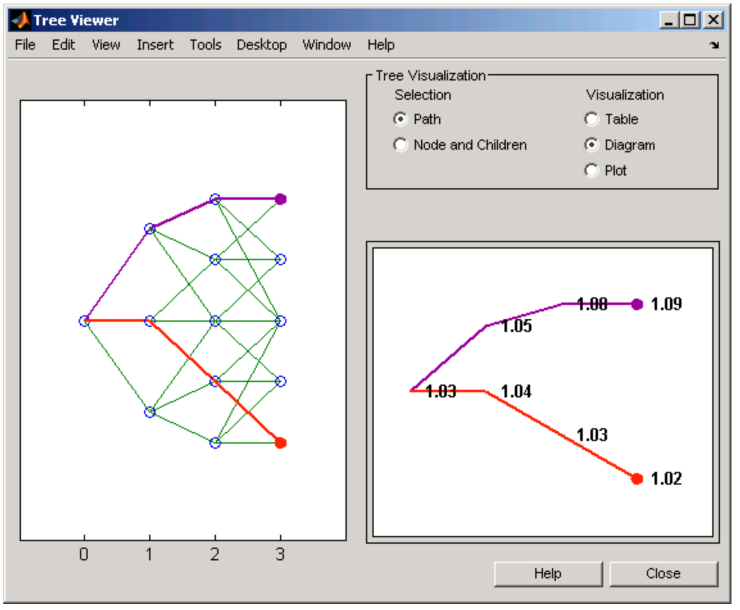
Using the data provided, create a Hull-White volatility specification (`VolSpec`), rate specification (`RateSpec`), and tree time layout specification (`TimeSpec`). Then use these specifications to create a Hull-White tree using `hwtree`.

```
Compounding = -1;
ValuationDate = '01-01-2004';
StartDate = ValuationDate;
VolDates = ['12-31-2004'; '12-31-2005'; '12-31-2006';
'12-31-2007'];
VolCurve = 0.01;
AlphaDates = '01-01-2008';
AlphaCurve = 0.1;
Rates = [0.0275; 0.0312; 0.0363; 0.0415];
```

```
HWVolSpec = hwvolspec(ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve);

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

HWTimeSpec = hwtimespec(ValuationDate, VolDates, Compounding);
HWTree = hwtree(HWVolSpec, RateSpec, HWTimeSpec)

HWTree =

      FinObj: 'HWFwdTree'
     VolSpec: [1x1 struct]
    TimeSpec: [1x1 struct]
    RateSpec: [1x1 struct]
        tObs: [0 0.9973 1.9973 2.9973]
        dObs: [731947 732312 732677 733042]
      CFlowT: {[4x1 double]  [3x1 double]  [2x1 double]  [3.9973]}
       Probs: {[3x1 double]  [3x3 double]  [3x5 double]}
     Connect: {[2]  [2 3 4]  [2 2 3 4 4]}
     FwdTree: {1x4 cell}
```

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

```
treeviewer(HWTree)
```



See Also

`hwprice`, `hwtimespec`, `hwvolspec`, `intenvset`

hwvolspec

Purpose

Specify Hull-White interest-rate volatility process

Syntax

```
Volspec = hwvolspec(ValuationDate, VolDates, VolCurve,
   AlphaDates, AlphaCurve, InterpMethod)
```

Arguments

`ValuationDate`	Scalar value representing the observation date of the investment horizon.
`VolDates`	Number of points (`NPOINTS`)-by-1 vector of yield volatility end dates.
`VolCurve`	`NPOINTS`-by-1 vector of yield volatility values in decimal form.
`AlphaDates`	`NPOINTS`-by-1 vector of mean reversion end dates.
`AlphaCurve`	`NPOINTS`-by-1 vector of positive mean reversion values in decimal form.
`InterpMethod`	(Optional) Interpolation method. Default is `'linear'`. See `interp1` for more information.

Description

`Volspec = hwvolspec(ValuationDate, VolDates, VolCurve, AlphaDates, AlphaCurve, InterpMethod)` creates a structure specifying the volatility for `hwtree`.

Examples

Using the data provided, create a Hull-White volatility specification (`VolSpec`).

```
ValuationDate = '01-01-2004';
StartDate = ValuationDate;
VolDates = ['12-31-2004'; '12-31-2005'; '12-31-2006';
'12-31-2007'];
VolCurve = 0.01;
AlphaDates = '01-01-2008';
```

```
AlphaCurve = 0.1;

HWVolSpec = hwvolspec(ValuationDate, VolDates, VolCurve,...
AlphaDates, AlphaCurve)

HWVolSpec =

             FinObj: 'HWVolSpec'
      ValuationDate: 731947
           VolDates: [4x1 double]
           VolCurve: [4x1 double]
         AlphaCurve: 0.1000
         AlphaDates: 733408
    VolInterpMethod: 'linear'
```

See Also

bktree, interp1

instadd

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

`InstSetOld`	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.

For more information on instrument data parameters, see the reference entries for individual instrument types. For example, see `instcap` for additional information on the cap instrument.

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 instrument collection

Syntax

```
InstSet = instaddfield('FieldName', FieldList, '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 name `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 field names 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)`

`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

Purpose

Construct Asian option

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

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

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 instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).

`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

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) Day-count basis of the instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).
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

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 instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).

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

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 instrument set by matching conditions

Syntax

```
ISubSet = instdelete(InstSet, 'FieldName', FieldList, 'Data',
DataList, 'Index', IndexSet, 'Type', TypeList)
```

Arguments

`InstSet`	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
`FieldList`	String or number of fields (`NFIELDS`)-by-`1` cell array of strings listing the name of each data field to match with data values.
`DataList`	Number of values (`NVALUES`)-by-`M` array or `NFIELDS`-by-`1` cell array of acceptable data values for each field. Each row lists a data row value to search for in the corresponding `FieldList`. The number of columns is arbitrary and matching will ignore trailing `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`

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`

Purpose

List field names

Syntax

```
FieldList = instfields(InstSet, 'Type', TypeList)
```

Arguments

InstSet	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
TypeList	(Optional) String or number of types (NTYPES)-by-1 cell array of strings listing the instrument types to query.

Description

FieldList = instfields(InstSet, 'Type', TypeList) retrieves the list of fields stored in an instrument variable.

FieldList is a number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field corresponding to the listed types.

Examples

Retrieve the instrument set ExampleInst from the data file InstSetExamples.mat. ExampleInst contains three types of instruments: Option, Futures, and TBill.

```
load InstSetExamples;
instdisp(ExampleInst)

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

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

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

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

Get the fields listed for type 'Option'.

```
[FieldList, ClassList] = instfields(ExampleInst, 'Type',...
'Option')

FieldList =

    'Strike'
    'Price'
    'Opt'
    'Contracts'

ClassList =

    '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`

instfind

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`

Purpose

Construct fixed-rate instrument

Syntax

```
InstSet = instfixed(InstSet, Strike, 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) Day-count basis of the instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).
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`

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) Day-count basis of the instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`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`

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 instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`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

Purpose

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.

Argument value pairs can be entered in any order. The `InstSet` variable must be the first argument.

instget

Description

`[Data_1, Data_2,...,Data_n] = instget(InstSet, 'FieldName', FieldList, 'Index', IndexSet, 'Type', TypeList)` retrieves data arrays from an instrument variable.

`Data_1` is an `NINST`-by-`M` array of data contents for the first field in `FieldList`. Each row corresponds to a separate instrument in `IndexSet`. Unavailable data is returned as `NaN` or as spaces.

`Data_n` is an `NINST`-by-`M` array of data contents for the last field in `FieldList`.

Examples

Retrieve the instrument set `ExampleInst` from the data file. `InstSetExamples.mat`. `ExampleInst` contains three types of instruments: `Option`, `Futures`, and `TBill`.

```
load InstSetExamples;
instdisp(ExampleInst)

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

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

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

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

Extract the price from all instruments.

```
P = instget(ExampleInst,'FieldName','Price')

P =
```

```
   12.2000
    9.2000
    6.8000
       NaN
    7.4000
    2.9000
   99.0000
```

Get all the prices and the number of contracts held.

```
[P,C] = instget(ExampleInst, 'FieldName', {'Price', 'Contracts'})

P =

   12.2000
    9.2000
    6.8000
       Nan
    7.4000
    2.9000
   99.0000

C =

       0
       0
    1000
   -1000
   -1000
       0
       6
```

Compute a value `V`. Create a new variable `ISet` that appends `V` to `ExampleInst`.

```
V = P.*C
```

```
ISet = instsetfield(ExampleInst, 'FieldName', 'Value', 'Data',...
V);
instdisp(ISet)

Index Type   Strike Price Opt  Contracts Value
1     Option  95     12.2 Call    0          0
2     Option 100      9.2 Call    0          0
3     Option 105      6.8 Call  1000       6800

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

Index Type   Strike Price Opt  Contracts Value
5     Option 105     7.4 Put  -1000      -7400
6     Option  95     2.9 Put     0          0

Index Type Price Maturity       Contracts Value
7     TBill 99    01-Jul-1999   6         594
```

Look at only the instruments that have nonzero `Contracts`.

```
Ind = find(C ~= 0)

Ind =

     3
     4
     5
     7
```

Get the `Type` and `Opt` parameters from those instruments. (Only options have a stored `'Opt'` field.)

```
[T,O] = instget(ExampleInst, 'Index', Ind, 'FieldName',...
{'Type', 'Opt'})

T =
```

```
Option
Futures
Option
TBill

O =

Call

Put
```

Create a string report of holdings `Type`, `Opt`, and `Value`.

```
rstring = [T, O, num2str(V(Ind))]

rstring =

Option Call   6800
Futures        NaN
Option Put   -7400
TBill          594
```

See Also

`instaddfield`, `instdisp`, `instgetcell`

Purpose

Data and context from instrument variable

Syntax

```
[DataList, FieldList, ClassList] =
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.

Argument value pairs can be entered in any order. The `InstSet` variable must be the first argument.

Description

`[DataList, FieldList, ClassList] = instgetcell(InstSet, 'FieldName', FieldList, 'Index', IndexSet, 'Type', TypeList)` retrieves data and context from an instrument variable.

`DataList` is an `NFIELDS`-by-1 cell array of data contents for each field. Each cell is an `NINST`-by-`M` array, where each row corresponds to a separate instrument in `IndexSet`. Any data which is not available is returned as `NaN` or as spaces.

`FieldList` is an `NFIELDS`-by-1 cell array of strings listing the name of each field in `DataList`.

`ClassList` is an `NFIELDS`-by-1 cell array of strings listing the data class of each field. The class determines how arguments are parsed. Valid strings are `'dble'`, `'date'`, and `'char'`.

`IndexSet` is an `NINST`-by-1 vector of positions of instruments returned in `DataList`.

`TypeSet` is an `NINST`-by-1 cell array of strings listing the type of each instrument row returned in `DataList`.

Examples

Retrieve the instrument set `ExampleInst` from the data file `InstSetExamples.mat`. `ExampleInst` contains three types of instruments: `Option`, `Futures`, and `TBill`.

```
load InstSetExamples;
instdisp(ExampleInst)

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

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

Index Type   Strike Price Opt  Contracts
5     Option 105      7.4 Put  -1000
```

```
6     Option  95      2.9 Put      0

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

Get the prices and contracts from all instruments.

```
FieldList = {'Price'; 'Contracts'}
DataList = instgetcell(ExampleInst, 'FieldName', FieldList )
P = DataList{1}
C = DataList{2}

P =

   12.2000
    9.2000
    6.8000
       NaN
    7.4000
    2.9000
   99.0000

C =

       0
       0
    1000
   -1000
   -1000
       0
       6
```

Get all the option data: `Strike`, `Price`, `Opt`, `Contracts`.

```
[DataList, FieldList, ClassList] = instgetcell(ExampleInst,...
'Type','Option')
```

```
DataList =

    [5x1 double]
    [5x1 double]
    [5x4 char  ]
    [5x1 double]

FieldList =

    'Strike'
    'Price'
    'Opt'
    'Contracts'

ClassList =

    '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`

instlookback

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

instoptbnd

Purpose Construct bond option

Syntax

```
InstSet = instoptbnd(InstSet, BondIndex, OptSpec, Strike,
ExerciseDates)
InstSet = instoptbnd(InstSet, BondIndex, OptSpec, Strike,
ExerciseDates, AmericanOpt)
[FieldList, ClassList, TypeString] = instoptbnd
```

Arguments

`InstSet`	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
`BondIndex`	Number of instruments (`NINST`)-by-`1` vector of indices pointing to underlying instruments of Type `'Bond'` which are also stored in `InstSet`. See `instbond` for information on specifying the bond data.
`OptSpec`	`NINST`-by-`1` list of string values `'Call'` or `'Put'`.

Note 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, OptSpec, Strike,
ExerciseDates)
InstSet = instoptstock(InstSet, OptSpec, Strike,
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. This argument is specified only when adding stock instruments to an existing instrument set. See`instget` for more information on the `InstSet` variable.
`OptSpec`	`NINST`-by-`1` list of string values `'Call'` or `'Put'`.

Note 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, OptSpec, Strike, ExerciseDates)` specifies a European or Bermuda option.

`InstSet = instoptstock(InstSet, 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`

instselect

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.

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

Description

`InstSubSet = instselect(InstSet, 'FieldName', FieldList, 'Data', DataList, 'Index', IndexSet,'Type', TypeList)` creates an instrument subset (`InstSubSet`) from an existing set of instruments (`InstSet`).

`InstSubSet` is a variable containing instruments matching the input criteria. Instruments are returned in `InstSubSet` if all the `Field`, `Index`, and `Type` conditions are met. An instrument meets an individual `Field` condition if the stored `FieldName` data matches any of the rows listed in the `DataList` for that `FieldName`. See `instfind` for examples on matching criteria.

Examples

Retrieve the instrument set `ExampleInst` from the data file `InstSetExamples.mat`. The variable contains three types of instruments: `Option`, `Futures`, and `TBill`.

```
load InstSetExamples
instdisp(ExampleInst)

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

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

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

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

Make a new portfolio containing only options struck at 95.

```
Opt95 = instselect(ExampleInst, 'FieldName', 'Strike',...
'Data', '95')
```

```
instdisp(Opt95)

Opt95 =

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

Make a new portfolio containing only futures and Treasury bills.

```
FutTBill = instselect(ExampleInst,'Type',{'Futures';'TBill'})

instdisp(FutTBill) =

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

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

See Also

instaddfield, instdelete, instfind, instget, instgetcell

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`	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.

instsetfield

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`

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) Day-count basis of the instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).

`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`

Purpose

Properties of interest-rate 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`

Purpose

Price instruments from set of zero curves

Syntax

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

Arguments

RateSpec	A structure containing the properties of an interest-rate structure. See 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 from a set of zero curves.
cfbyzero	Price arbitrary cash flow instrument from a set of zero curves.
fixedbyzero	Fixed-rate note prices from a set of zero curves.
floatbyzero	Floating-rate note prices from a set of zero curves.
swapbyzero	Swap prices from 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
```

```
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 from set of zero curves

Syntax

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

Arguments

`RateSpec`	A structure containing the properties of an interest-rate structure. See `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 that use a zero coupon bond rate structure.

`Delta` is a number of instruments (`NINST`) by number of curves (`NUMCURVES`) matrix of deltas, representing the rate of change of instrument prices with respect to shifts in the observed 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

[Delta, Gamma] = intenvsens(ZeroRateSpec, ZeroInstSet)

Delta =

 -272.6403
 -347.4386
 -272.6403
   -1.0445
 -282.0405

Gamma =

  1.0e+003 *

    1.0298
    1.6227
```

```
1.0298
0.0033
1.0596
```

See Also

`hjmprice`, `hjmsens`, `instadd`, `intenvprice`, `intenvset`

intenvset

Purpose Set properties of interest-rate structure

Syntax

```
[RateSpec, RateSpecOld] = intenvset(RateSpec, 'Argument1',
   Value1, 'Argument2', Value2, ...)
[RateSpec, RateSpecOld] = intenvset
intenvset
```

Arguments

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

Arguments may be chosen from the following table 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 instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`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 argument names.

When creating a new `RateSpec`, the set of arguments passed to `intenvset` must include `StartDates`, `EndDates`, and either `Rates` or `Disc`.

Call `intenvset` with no input or output arguments to display a list of argument names and possible values.

Description

`[RateSpec, RateSpecOld] = intenvset(RateSpec, 'Argument1', Value1, 'Argument2', Value2, ...)` creates an interest term structure (`RateSpec`) in which the input argument list is specified as argument name /argument value pairs. The argument name portion of the pair must be recognized as a valid field of the output structure `RateSpec`; the argument value portion of the pair is then assigned to its paired field.

If the optional argument `RateSpec` is specified, `intenvset` modifies an existing interest term structure `RateSpec` by changing the named argument to the specified values and recalculating the arguments dependent on the new values.

`[RateSpec, RateSpecOld] = intenvset` creates an interest term structure `RateSpec` with all fields set to `[]`.

`intenvset` with no input or output arguments displays a list of argument names and possible values.

`RateSpecOld` is a structure containing the properties of an interest-rate structure 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 argument to 1 (annual).

```
RateSpec = intenvset(RateSpec, 'Compounding', 1)

RateSpec =

           FinObj: 'RateSpec'
      Compounding: 1
             Disc: 0.9518
            Rates: 0.0506
         EndTimes: 1
       StartTimes: 0
         EndDates: 730871
       StartDates: 730505
    ValuationDate: 730505
            Basis: 0
     EndMonthRule: 1
```

Calling intenvset with no input or output arguments displays a list of argument names and possible values.

```
intenvset

        Compounding: [ 1 | {2} | 3 | 4 | 6 | 12 | 365 | -1 ]
               Disc: [ scalar | vector (NPOINTS x 1) ]
              Rates: [ scalar | vector (NPOINTS x 1) ]
           EndDates: [ scalar | vector (NPOINTS x 1) ]
         StartDates: [ scalar | vector (NPOINTS x 1) ]
      ValuationDate: [ scalar ]
              Basis: [ {0} | 1 | 2 | 3 ]
       EndMonthRule: [ 0 | {1} ]
```

See Also

intenvget

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 the name of a 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 from 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 `[]`.

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 binomial 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 = 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 from EQP binomial 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 [].

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. 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 = 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.

mkbush

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`	(Optional) Scalar `0` or `1`. If `Trim = 1`, `NumPos` decreases by `1` when moving from one time level to the next. Otherwise, if `Trim = 0` (Default), `NumPos` does not decrease.
NodeVal	(Optional) Initial value at each node of the tree. Default = `NaN`.

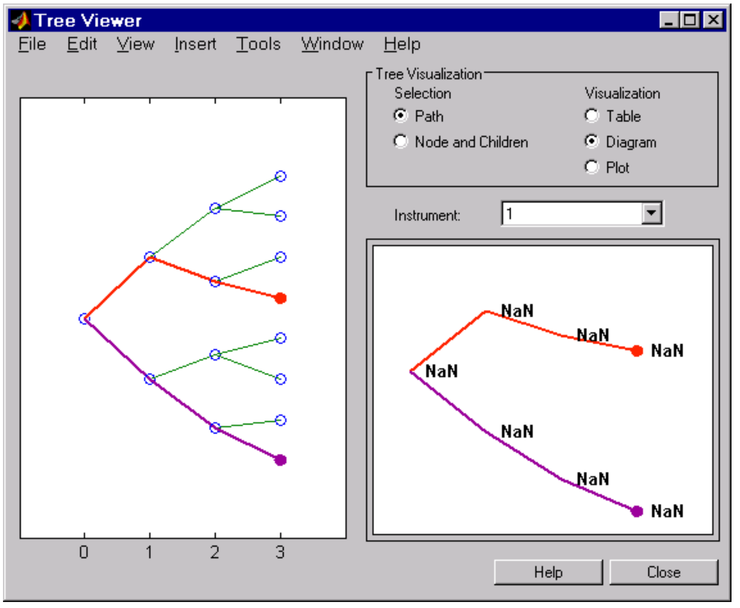
Description

`[Tree, NumStates] = mkbush(NumLevels, NumChild, NumPos, Trim, NodeVal)` creates a bushy tree `Tree` with initial values `NodeVal` at each node. `NumStates` is a `1`-by-`NUMLEVELS` vector containing the number of state vectors in each level.

Examples

Create a tree with four time levels, two branches per node, and a vector of three elements in each node with each element initialized to `NaN`.

```
Tree = mkbush(4, 2, 3);
treeviewer(Tree)
```



See Also

bushpath, bushshape

Purpose

Create recombining binomial tree

Syntax

```
Tree = mktree(NumLevels, NumPos, NodeVal, IsPriceTree)
```

Arguments

`NumLevels`	Number of time levels of the tree.
`NumPos`	`1`-by-`NUMLEVELS` vector containing the length of the state vectors in each time level.
`NodeVal`	(Optional) Initial value at each node of the tree. Default = `NaN`.
`IsPriceTree`	(Optional) Boolean determining if a final horizontal branch is added to the tree. Default = `0`.

Description

`Tree = mktree(NumLevels, NumPos, NodeVal, IsPriceTree)` creates a recombining tree `Tree` with initial values `NodeVal` at each node.

Examples

Create a recombining tree of four time levels with a vector of two elements in each node and each element initialized to `NaN`.

```
Tree = mktree(4, 2);
```

See Also

`treepath`, `treeshape`

Purpose

Create recombining trinomial tree

Syntax

```
TrinTree = mktrintree(NumLevels, NumPos, NumStates, NodeVal)
```

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.
`NumStates`	1-by-`NUMLEVELS` vector containing the number of state vectors in each time level.
`NodeVal`	(Optional) Initial value at each node of the tree. Default = `NaN`.

Description

`TrinTree = mktrintree(NumLevels, NumPos, NumStates, NodeVal)` creates a recombining tree `Tree` with initial values `NodeVal` at each node.

Examples

Create a recombining trinomial tree of four time levels with a vector of two elements in each node and each element initialized to `NaN`.

```
TrinTree = mktrintree(4, [2 2 2 2], [1 3 5 7]);
```

See Also

`trintreepath`, `trintreeshape`

mmktbybdt

Purpose

Create money-market tree from BDT interest-rate tree

Syntax

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

Arguments

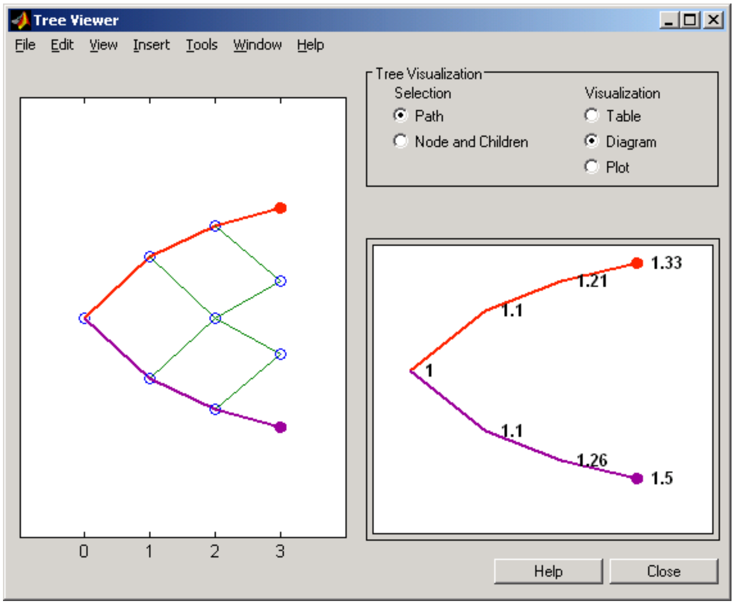
`BDTTree`	Interest-rate tree structure created by `bdttree`.

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`

mmktbyhjm

Purpose

Create money-market tree from HJM interest-rate tree

Syntax

`MMktTree = mmktbyhjm(HJMTree)`

Arguments

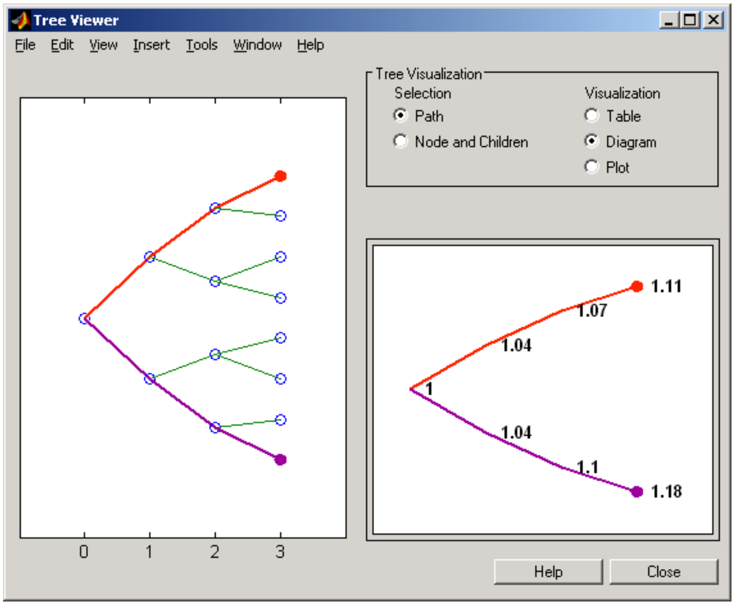
`HJMTree`	Forward-rate tree structure created by `hjmtree`.

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)
```



See Also

`hjmtree`

optbndbybdt

Purpose

Price bond option from BDT interest-rate tree

Syntax

```
[Price, PriceTree] = optbndbybdt(BDTTree, 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 instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`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(BDTTree, OptSpec, Strike, ExerciseDates, AmericanOpt, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face, Options)` computes the price of a bond option from a BDT interest-rate tree.

`Price` is an `NINST`-by-`1` matrix of expected prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

Examples

Example 1. Using the BDT interest-rate tree in the `deriv.mat` file, price a European call option on a 10% bond with a strike of 95. The exercise date for the option is Jan. 01, 2002. The settle date for the bond is Jan. 01, 2000, and the maturity date is Jan. 01, 2003.

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

```
load deriv;
```

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`

Purpose

Price bond option from Black-Karasinski interest-rate tree

Syntax

```
[Price, PriceTree] = optbndbybk(BKTree, OptSpec, Strike,
ExerciseDates, AmericanOpt, CouponRate, Settle, Maturity,
Period,  Basis, EndMonthRule, IssueDate, FirstCouponDate,
LastCouponDate,  StartDate, Face, Options)
```

Arguments

`BkTree`	Forward-rate tree structure created by `bktree`.
`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 instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`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 BK tree. The bond argument `Settle` is ignored.

Description

`[Price, PriceTree] = optbndbybk(BKTree, OptSpec, Strike, ExerciseDates, AmericanOpt, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face, Options)` computes the price of a bond option from a Black-Karasinski interest rate tree.

`Price` is an `NINST`-by-`1` matrix of expected prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

Examples

Example 1. Using the BK interest rate tree in the `deriv.mat` file, price a European call option on a 4% bond with a strike of 96. The exercise date for the option is Jan. 01, 2006. The settle date for the bond is Jan. 01, 2005, and the maturity date is Jan. 01, 2009.

Load the file `deriv.mat`, which provides `BKTree`. The `BKTree` structure contains the time and forward-rate information needed to price the bond.

```
load deriv;
```

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

```
Price = optbndbybk(BKTree,'Call','96','01-Jan-2006',...
'0','0.04','01-Jan-2005','01-Jan-2009')
Warning: Not all cash flows are aligned with the tree. Result will
be approximated.

Price =
```

```
    0.1512
```

Example 2. Now use `optbndbybk` to compute the price of a put option on the same bond.

```
Price = optbndbybk(BKTree,'Put','96','01-Jan-2006',...
'0','0.04','01-Jan-2005','01-Jan-2009')

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

Price =

    0.0272
```

See Also

`bkprice`, `bktree`, `instoptbnd`

optbndbyhjm

Purpose

Price bond option from 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 instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).

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. The HJMTree structure 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 bond option from Hull-White interest-rate tree

Syntax

```
[Price, PriceTree] = optbndbyhw(HWTree, OptSpec, Strike,
ExerciseDates, AmericanOpt, CouponRate, Settle, Maturity,
Period,  Basis, EndMonthRule, IssueDate, FirstCouponDate,
LastCouponDate,  StartDate, Face, Options)
```

Arguments

`HWTree`	Forward-rate tree structure created by `hwtree`.
`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 instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).
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 HW tree. The bond argument `Settle` is ignored.

Description

`[Price, PriceTree] = optbndbyhw(HWTree, OptSpec, Strike, ExerciseDates, AmericanOpt, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face, Options)` computes the price of a bond option from a Hull-White interest rate tree.

`Price` is an `NINST`-by-`1` matrix of expected prices at time 0.

`PriceTree` is a tree structure with a vector of instrument prices at each node.

Examples

Example 1. Using the HW interest rate tree in the `deriv.mat` file, price a European call option on a 4% bond with a strike of 96. The exercise date for the option is Jan. 01, 2006. The settle date for the bond is Jan. 01, 2005, and the maturity date is Jan. 01, 2009.

Load the file `deriv.mat`, which provides `HWTree`. The `HWTree` structure contains the time and forward-rate information needed to price the bond.

```
load deriv;
```

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

```
Price = optbndbyhw(HWTree,'Call','96','01-Jan-2006',...
'0','0.04','01-Jan-2005','01-Jan-2009')
Warning: Not all cash flows are aligned with the tree. Result will
be approximated.

Price =
```

```
    1.1556
```

Example 2. Now use `optbondbyhw` to compute the price of a put option on the same bond.

```
Price = optbndbyhw(HWTree,'Put','96','01-Jan-2006',...
'0','0.04','01-Jan-2005','01-Jan-2009')

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

Price =

    1.0150
```

See Also

`hwprice`, `hwtree`, `instoptbnd`

Purpose Price stock option from 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'`.

Note 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 binomial 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-2005';

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

Price =

 8.2863
```

See Also

`crrtree`, `instoptstock`

optstockbyeqp

Purpose

Price stock option from EQP binomial 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'`.

Note 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. 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-2005';

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

Price =

 8.4791
```

See Also

eqptree, instoptstock

Purpose

Discount 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.

You can specify the investment intervals either with input times (Usage 1) or with input dates (Usage 2). Entering `ValuationDate` invokes the date interpretation; omitting `ValuationDate` invokes the default time interpretations.

Examples

Example 1. Compute discounts from a zero curve at 6 months, 12 months, and 24 months. The times to the cash flows are 1, 2, and 4. You are computing the present value (at time 0) of the cash flows.

```
Compounding = 2;
Rates = [0.05; 0.06; 0.065];
EndTimes   = [1; 2; 4];
Disc = rate2disc(Compounding, Rates, EndTimes)

Disc =
    0.9756
    0.9426
    0.8799
```

Example 2. 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

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

Usage 1: `ValuationDate` not passed; third through sixth arguments are interpreted as times.

```
[Rates, EndTimes, StartTimes] = ratetimes(Compounding, RefRates, RefEn
```

Usage 2: `ValuationDate` passed and interval points input as dates.

```
[Rates, EndTimes, StartTimes] = ratetimes(Compounding, RefRates, RefEn
```

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.

You can specify the investment intervals either with input times (Usage 1) or with input dates (Usage 2). Entering the argument ValuationDate invokes the date interpretation; omitting `ValuationDate` invokes the default time interpretations.

Examples

Example 1. The reference environment is a collection of zero rates at 6, 12, and 24 months. Create a collection of one year forward rates beginning at 0, 6, and 12 months.

```
RefRates = [0.05; 0.06; 0.065];
RefEndTimes = [1; 2; 4];
StartTimes = [0; 1; 2];
EndTimes   = [2; 3; 4];
Rates = ratetimes(2, RefRates, RefEndTimes, 0, EndTimes,...
StartTimes)

Rates =
 0.0600
 0.0688
 0.0700
```

Example 2. Interpolate a zero yield curve to different dates. Zero curves start at the default date of `ValuationDate`.

```
RefRates = [0.04; 0.05; 0.052];
RefDates = [729756; 729907; 730121];
Dates    = [730241; 730486];
ValuationDate   = 729391;
Rates = ratetimes(2, RefRates, RefDates, [], Dates, [],...
ValuationDate)
Rates =
 0.0520
 0.0520
```

See Also

`disc2rate`, `rate2disc`

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 from 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) Day-count basis of the instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).
`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 0. 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 a tree structure with a vector of the swap values at each node.

CFTree is a tree structure with a vector of the swap cash flows at each node. This structure contains only NaNs because with binomial recombining trees, cash flows cannot be computed accurately at each node of a tree.

SwapRate is a NINST-by-1 vector of rates applicable to the fixed leg such that the swaps' values are zero at time 0. This rate is used in calculating the swaps' prices when the rate specified for the fixed leg in LegRate is NaN. SwapRate is padded with NaN for those instruments in which CouponRate is not set to NaN.

Examples

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 arguments are

- Coupon rate for fixed leg: 0.15 (15%)
- Spread for floating leg: 10 basis points
- Swap settlement date: Jan. 01, 2000
- Swap maturity date: Jan. 01, 2003

Based on the information above, set the required arguments and build the `LegRate`, `LegType`, and `LegReset` matrices.

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

Price the swap using the `BDTTree` included in the MAT-file `deriv.mat`. `BDTTree` contains the time and forward-rate information needed to price the instrument.

```
load deriv;
```

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

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

Price =

  7.4222
```

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 =

 -1.4211e-014

PriceTree =

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

    FinObj: 'BDTCFTree'
      tObs: [0 1 2 3 4]
    CFTree: {[NaN] [NaN NaN] [NaN NaN NaN] [NaN NaN NaN NaN] ...}

SwapRate =

    0.1205
```

See Also

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

Purpose

Price swap instrument from Black-Karasinski interest-rate tree

Syntax

```
[Price, PriceTree, CFTree, SwapRate] = swapbybk(BKTree,
   LegRate, Settle, Maturity, LegReset, Basis, Principal,
   LegType)
```

Arguments

`BKTree`	Interest-rate tree structure created by `bktree`.
`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) Day-count basis of the instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).
`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 BK tree. The swap argument Settle is ignored.

This function also calculates the SwapRate (fixed rate) so that the value of the swap is initially zero. To do this enter CouponRate as NaN.

Description

[Price, PriceTree, CFTree, SwapRate] = swapbybk(BKTree, LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType) computes the price of a swap instrument from a Black-Karasinski 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.

SwapRate is a NINST-by-1 vector of rates applicable to the fixed leg such that the swaps' values are zero at time 0. This rate is used in calculating the swaps' prices when the rate specified for the fixed leg in LegRate is NaN. The SwapRate output is padded with NaN for those instruments in which CouponRate is not set to NaN.

Examples

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 arguments are

- Coupon rate for fixed leg: 0.15 (15%)

- Spread for floating leg: 10 basis points
- Swap settlement date: Jan. 01, 2005
- Swap maturity date: Jan. 01, 2008

Based on the information above, set the required arguments and build the LegRate, LegType, and LegReset matrices.

```
Settle = '01-Jan-2005';
Maturity = '01-Jan-2008';
Basis = 0;
Principal = 100;
LegRate = [0.15 10]; % [CouponRate Spread]
LegType = [1 0]; % [Fixed Float]
LegReset = [1 1]; % Payments once per year
```

Price the swap using the BKTree included in the MAT-file deriv.mat.The BKTree structure contains the time and forward-rate information needed to price the instrument.

```
load deriv;
```

Use swapbybk to compute the price of the swap.

```
Price  = swapbybk(BKTree, LegRate, Settle, Maturity, LegReset,...
Basis, Principal, LegType)

Price =

  39.1827
```

Example 2. Using the previous data, calculate the swap rate, which is the coupon rate for the fixed leg such that the swap price at time = 0 is zero.

```
LegRate = [NaN 20];

[Price, PriceTree, SwapRate] = swapbybk(BKTree, LegRate, ...
```

```
Settle, Maturity, LegReset, Basis, Principal, LegType)

Price =

     0

PriceTree =

     FinObj: 'BKPriceTree'
       tObs: [0 1 2 3 4]
      PTree: {1x5 cell}
    Connect: {[2]  [2 3 4]  [2 2 3 4 4]}
      Probs: {[3x1 double]  [3x3 double]  [3x5 double]}
SwapRate =

    0.0438
```

See Also

bktree, bondbybk, capbybk, fixedbybk, floorbybk

Purpose

Price swap instrument from HJM interest-rate tree

Syntax

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

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) Day-count basis of the instrument. A vector of integers. `0` = actual/actual (default), `1` = 30/360 (SIA), `2` = actual/360, `3` = actual/365, `4` = 30/360 (PSA), `5` = 30 360 (ISDA), `6` = 30/360 (European), `7` = actual/365 (Japanese).
`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. The SwapRate output 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 arguments are

- Coupon rate for fixed leg: 0.06 (6%)
- Spread for floating leg: 20 basis points
- Swap settlement date: Jan. 01, 2000
- Swap maturity date: Jan. 01, 2003

Based on the information above, set the required arguments and build the `LegRate`, `LegType`, and `LegReset` matrices.

```
Settle = '01-Jan-2000';
Maturity = '01-Jan-2003';
Basis = 0;
Principal = 100;
LegRate = [0.06 20]; % [CouponRate Spread]
LegType = [1 0]; % [Fixed Float]
LegReset = [1 1]; % Payments once per year
```

Price the swap using the `HJMTree` included in the MAT-file `deriv.mat`. The `HJMTree` structure contains the time and forward-rate information needed to price the instrument.

```
load deriv;
```

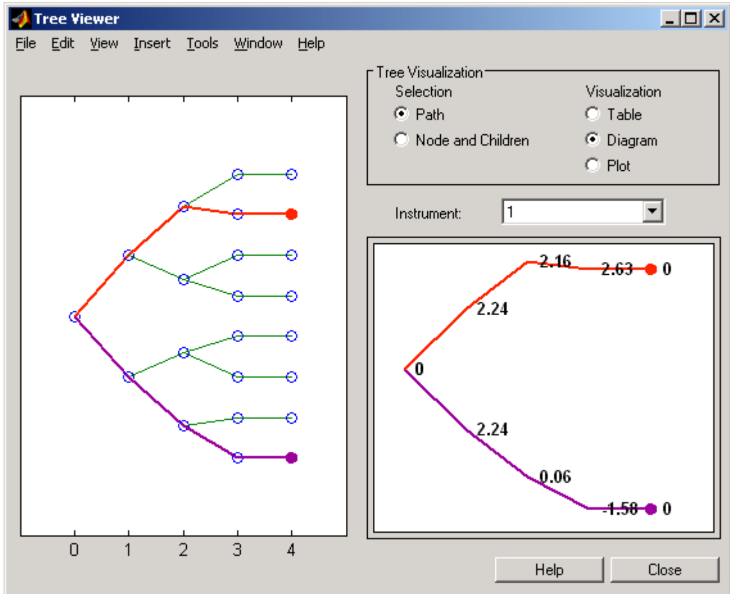
Use `swapbyhjm` to compute the price of the swap.

```
[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 rate and pay floating rate). At time `t = 3`, if interest rates go down, your cash flow is positive ($2.63), meaning that you will receive this amount. But if interest rates go up, your cash flow is negative (-$1.58), meaning that you owe this amount.

Example 2. Using the previous data, calculate the swap rate, which is the coupon rate for the fixed leg such that the swap price at time = 0 is zero.

```
LegRate = [NaN 20];

[Price, PriceTree, CFTree, SwapRate] = swapbyhjm(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 from Hull-White interest-rate tree

Syntax

```
[Price, PriceTree, SwapRate] = swapbyhw(HWTree, LegRate,
   Settle, Maturity, LegReset, Basis, Principal, LegType)
```

Arguments

HWTree	forward-rate tree structure created by hwtree.
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) Day-count basis of the instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).
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 HW tree. The swap argument Settle is ignored.

This function also calculates the SwapRate (fixed rate) so that the value of the swap is initially zero. To do this enter CouponRate as NaN.

Description

[Price, PriceTree, SwapRate] = swapbyhw(HWTree, LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType) computes the price of a swap instrument from a Hull-White 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.

SwapRate is a NINST-by-1 vector of rates applicable to the fixed leg such that the swaps' values are zero at time 0. This rate is used in calculating the swaps' prices when the rate specified for the fixed leg in LegRate is NaN. The SwapRate output is padded with NaN for those instruments in which CouponRate is not set to NaN.

Examples

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 arguments are

- Coupon rate for fixed leg: 0.06 (6%)

- Spread for floating leg: 20 basis points
- Swap settlement date: Jan. 01, 2005
- Swap maturity date: Jan. 01, 2008

Based on the information above, set the required arguments and build the LegRate, LegType, and LegReset matrices.

```
Settle = '01-Jan-2005';
Maturity = '01-Jan-2008';
Basis = 0;
Principal = 100;
LegRate = [0.06 20]; % [CouponRate Spread]
LegType = [1 0]; % [Fixed Float]
LegReset = [1 1]; % Payments once per year
```

Price the swap using the HWTree included in the MAT-file deriv.mat. The HWTree structure contains the time and forward-rate information needed to price the instrument.

```
load deriv;
```

Use swapbyhw to compute the price of the swap.

```
[Price, PriceTree, SwapRate] = swapbyhw(HWTree, LegRate, ...
Settle, Maturity, LegReset, Basis, Principal, LegType)

Price =

    5.9109

PriceTree =

     FinObj: 'HWPriceTree'
       tObs: [0 1 2 3 4]
      PTree: {1x5 cell}
    Connect: {[2]  [2 3 4]  [2 2 3 4 4]}
      Probs: {[3x1 double]  [3x3 double]  [3x5 double]}
```

```
SwapRate =

   NaN
```

Example 2. Using the previous data, calculate the swap rate, which is the coupon rate for the fixed leg such that the swap price at time = 0 is zero.

```
LegRate = [NaN 20];

[Price, PriceTree, SwapRate] = swapbyhw(HWTree, LegRate, ...
Settle, Maturity, LegReset, Basis, Principal, LegType)
Price =

   1.4211e-014

PriceTree =

FinObj: 'HWPriceTree'
       tObs: [0 1 2 3 4]
      PTree: {1x5 cell}
    Connect: {[2]  [2 3 4]  [2 2 3 4 4]}
      Probs: {[3x1 double]  [3x3 double]  [3x5 double]}

SwapRate =

   0.0438
```

See Also

bondbyhw, capbyhw, cfbyhw, floorbyhw, fixedbyhw, hwtree

Purpose

Price swap instrument from 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) Day-count basis of the instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360 (SIA), 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA), 5 = 30 360 (ISDA), 6 = 30/360 (European), 7 = actual/365 (Japanese).

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 from 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. The SwapRate output 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 arguments are:

- Coupon rate for fixed leg: 0.06 (6%)
- Spread for floating leg: 20 basis points
- Swap settlement date: Jan. 01, 2000
- Swap maturity date: Jan. 01, 2003

Based on the information above, set the required arguments and build the LegRate, LegType, and LegReset matrices.

```
Settle = '01-Jan-2000';
Maturity = '01-Jan-2003';
Basis = 0;
Principal = 100;
LegRate = [0.06 20]; % [CouponRate Spread]
LegType = [1 0]; % [Fixed Float]
LegReset = [1 1]; % Payments once per year
```

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

```
load deriv;
```

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, which is the coupon rate for the fixed leg such that the swap price at time = 0 is zero.

```
LegRate = [NaN 20];

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

Price =
   0

SwapRate =
   0.0466
```

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`	Vector of times corresponding to the compounding value. `Times` must be equal to or greater than 0.

`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 instrument. A vector of integers. 0 = actual/actual (default), 1 = 30/360, 2 = actual/360, 3 = actual/365, 4 = 30/360 (PSA compliant), 5 = 30/360 (ISDA compliant), 6 = 30/360 (European), 7 = actual/365 (Japanese).
`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.

Note To obtain accurate results from this function, the `Basis` and `Dates` arguments must be consistent. If the `Dates` argument contains months that have 31 days, `Basis` must be one of the values that allow months to contain more than 30 days, e.g., `Basis` = `0`, `3`, or `7`.

The `time2date` function is the inverse of `date2time`.

Examples

Show that `date2time` and `time2date` are the inverse of each other. First compute the time factors using `date2time`.

```
Settle = '1-Sep-2002';
Dates = datenum(['31-Aug-2005'; '28-Feb-2006'; '15-Jun-2006';
                 '31-Dec-2006']);
Compounding = 2;
```

```
Basis = 0;
EndMonthRule = 1;
Times = date2time(Settle, Dates, Compounding, Basis,...
                  EndMonthRule)

Times =

    5.9945
    6.9945
    7.5738
    8.6576
```

Now use the calculated `Times` in `time2date` and compare the calculated dates with the original set.

```
Dates_calc = time2date(Settle, Times, Compounding, Basis,...
                  EndMonthRule)

Dates_calc =

      732555
      732736
      732843
      733042

datestr(Dates_calc)

ans =

31-Aug-2005
28-Feb-2006
15-Jun-2006
31-Dec-2006
```

See Also

`cftimes` in the Financial Toolbox documentation

`date2time`, `disc2rate`, `rate2disc`

Purpose

Entries from node of recombining binomial tree

Syntax

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

Arguments

`Tree`	Recombining binomial tree.
`BranchList`	Number of paths (`NUMPATHS`) by path length (`PATHLENGTH`) matrix containing the sequence of branchings.

Description

`Values = treepath(Tree, BranchList)` extracts entries of a node of a recombining binomial tree. The node path is described by the sequence of branchings taken, starting at the root. The top branch is number one, the second-to-top is two, and so on. Set the branch sequence to zero to obtain the entries at the root node.

`Values` is a number of values (`NUMVALS`)-by-`NUMPATHS` matrix containing the retrieved entries of a recombining tree.

Examples

Create a BDT tree by loading the example file.

```
load deriv.mat;
```

Then

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

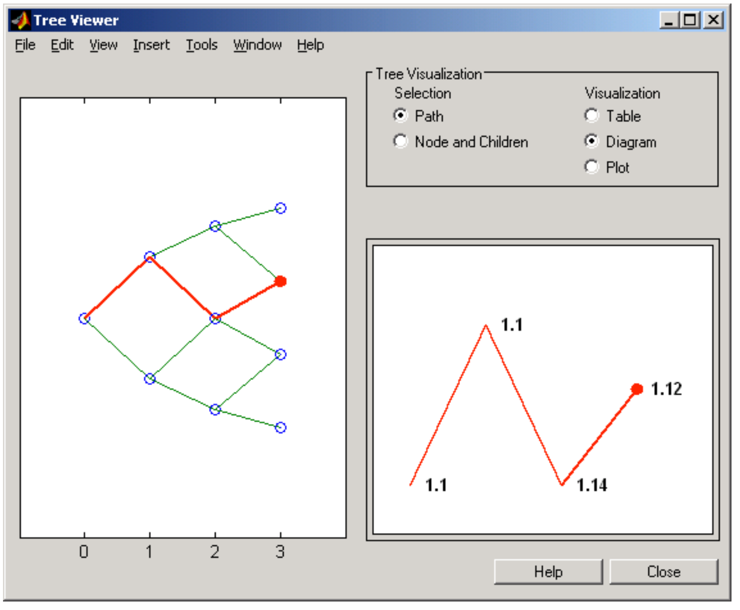
returns the rates at the tree nodes located by taking the up branch, then the down branch, and finally the up branch again.

```
FwdRates =

    1.1000
    1.0979
    1.1377
```

```
    1.1183
```

You can visualize this with the treeviewer function.

```
treeviewer(BDTTree)
```



See Also

mktree, treeshape

Purpose

Shape of recombining binomial tree

Syntax

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

Arguments

`Tree`	Recombining binomial tree.

Description

`[NumLevels, NumPos, IsPriceTree] = treeshape(Tree)` returns information on a recombining binomial tree's shape.

`NumLevels` is the number of time levels of the tree.

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

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

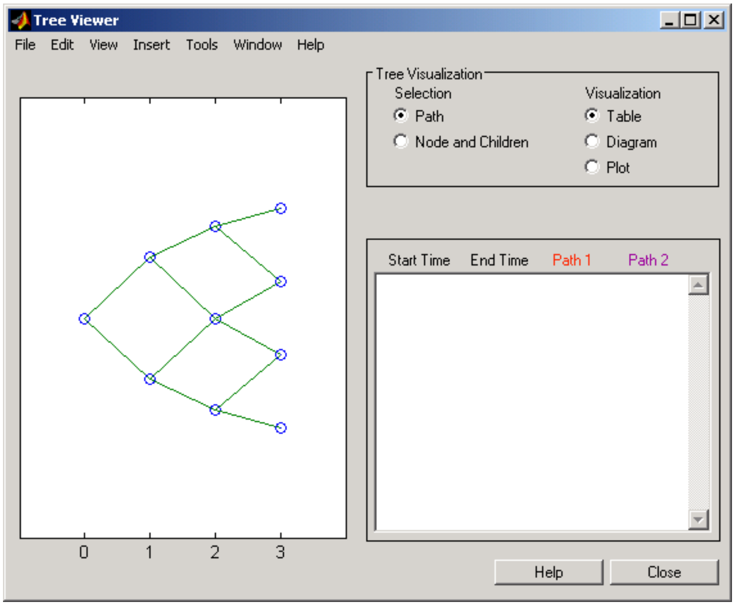
Examples

Create a BDT tree by loading the example file.

```
load deriv.mat;
```

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

```
treeviewer(BDTTree)
```



With this tree

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

returns

```
NumLevels   =
      4

NumPos      =
      1      1      1      1

IsPriceTree =
      0
```

See Also

`mktree`, `treepath`

Purpose Tree information

Syntax

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

Arguments

`Tree` — `Tree` can be any of the following types of trees.

Interest-rate trees:

- Black-Derman-Toy (`BDTTree`)
- Black-Karasinski (`BKTree`)
- Heath-Jarrow-Morton (`HJMTree`)
- Hull-White (`HWTree`)

For information on creating interest-rate trees, see

- `bktree` for information on creating `BKTree`.
- `bdttree` for information on creating `BDTTree`.
- `hjmtree` for information on creating `HJMTree`.
- `hwtree` for information on creating `HWTree`.

Money market trees:

- Money market tree (`MMktTree`)

For information on creating money-market trees, see

- `mmktbybdt` for information on creating a money-market tree from a BDT interest-rate tree.
- `mmktbyhjm` for information on creating a money-market tree from an HJM interest-rate tree.

> **Note** Money market trees cannot be created from BK or HW interest-rate trees.

Stock price trees:

- Cox-Ross-Rubinstein (`CRRTree`)
- Equal probabilities (`EQPTree`)

  For information on creating stock price trees, see

- `crrtree` for information on creating `CRRTree`.
- `eqptree` for information on creating `EQPTree`.

Cash flow trees:

- Black-Derman-Toy (`BDTCFTree`)
- Heath-Jarrow-Morton (`HJMCFTree`)

  Cash flow trees are created as outputs from the swap functions `swapbyhjm` and `swapbybdt`.

> **Note** For the function `swapbybdt`, which uses a recombining binomial tree, this structure contains only `NaN`s because cash flows cannot be accurately calculated at every tree node for floating rate notes.

`PriceTree` — `PriceTree` is a Black-Derman-Toy (`BDTPriceTree`), Black-Karasinski (`BKPriceTree`), Heath-Jarrow-Morton (`HJMPriceTree`), or Hull-White (`HWPriceTree`) tree of instrument prices.

CFTree	CFTree is a tree of swap cash flows. You create cash flow trees when executing the Black-Derman-Toy and Heath-Jarrow-Morton swap functions. (Black-Derman-Toy cash flow trees contain only NaNs.)
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 for a description.) If you do not provide the optional InstSet argument, the instruments are identified by their sequence number in the instrument set. (See Example 6 for a description.)

treeviewer(CFTree, InstSet) displays a cash flow tree that has been created with swapbybdt or swapbyhjm. If you provide the name of an instrument set (InstSet) containing cash flow names, the treeviewer display identifies the instrument being displayed with its name. (See Example 3 for a description.) If the optional InstSet argument is not present, the instruments are identified by their sequence number in the instrument set. See Example 6 for a description.)

treeviewer price tree diagrams follow the convention that increasing prices appear on the upper branch of a tree and, consequently, decreasing prices appear on the lower branch. Conversely, for interest rate displays, *decreasing* interest rates appear on the upper branch (prices are rising) and *increasing* interest rates on the lower branch (prices are falling).

`treeviewer` provides an interactive display of prices or interest rates. The display is activated by clicking the nodes along the price or interest rate path shown in the left pane when the function is called. For HJM trees you select the end points of the path, and `treeviewer` displays all data from beginning to end. With recombining trees, such as BDT, BK and HW, you must click *each* node in succession from the beginning (`t = 1`) to the last node (`t = n`). Do not include the *root node*, the node at `t = 0`. If you do not click the nodes in the proper order, you are reminded with the message

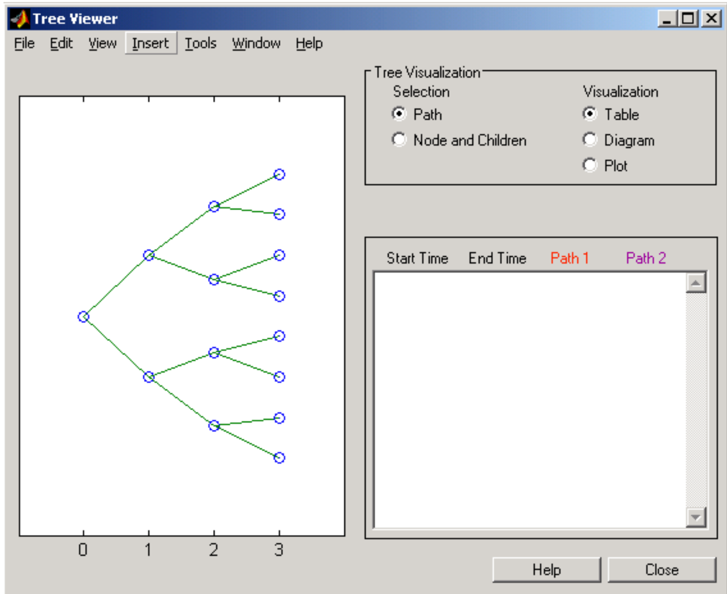
```
Parent of selected node must be selected.
```

Examples

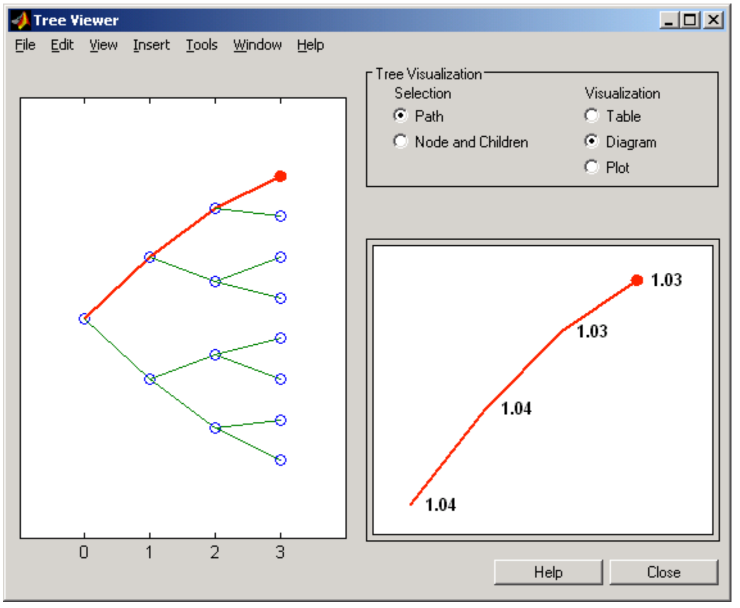
Example 1. Display an HJM Interest-Rate Tree.

```
load deriv.mat
treeviewer(HJMTree)
```

The `treeviewer` function displays the structure of an HJM tree in the left pane. The tree visualization in the right pane is blank.

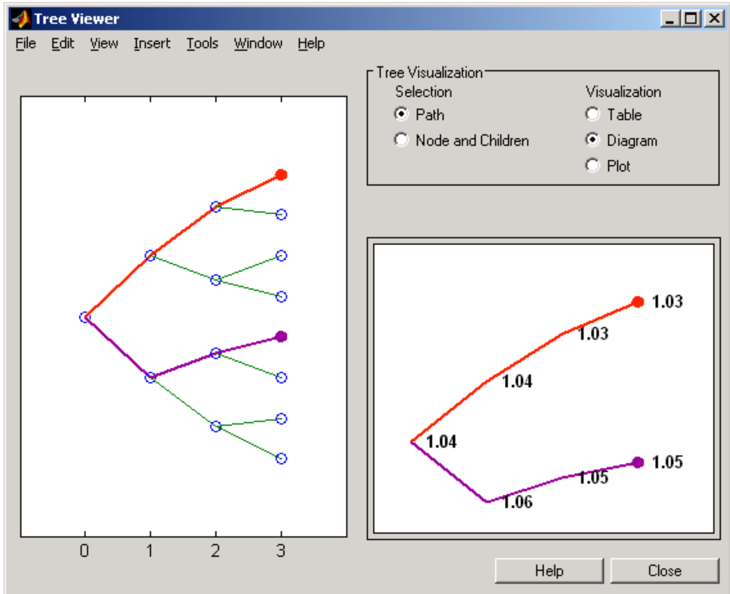


To visualize the actual interest-rate tree, go to the **Tree Visualization** pane and click on **Path** (the default) and **Diagram.** Now, select the first path by clicking on the last node (`t = 3`) of the upper branch.



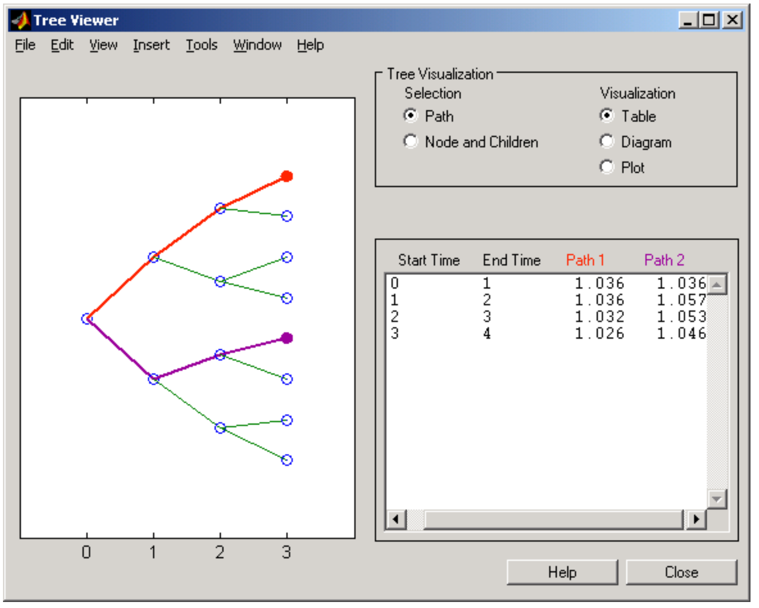
Note that the entire upper path is highlighted in red.

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

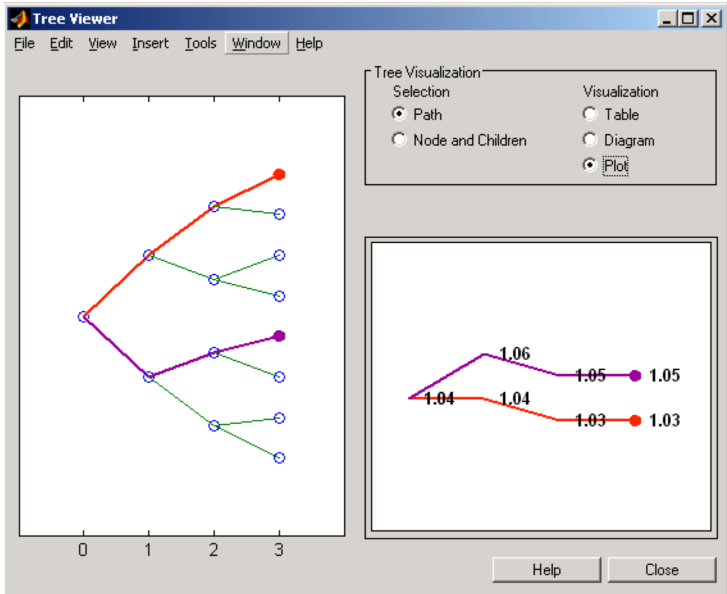


Alternative Forms of Display

The **Tree Visualization** pane allows you to select alternative ways to display tree data. For example, if you select **Path** and **Table** as your visualization choices, the final display above instead appears in tabular form.

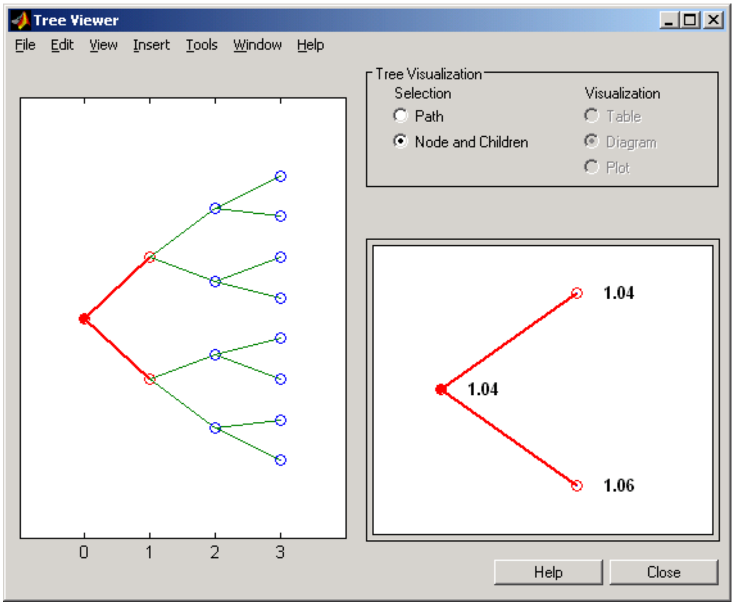


To see a plot of interest rates along the chosen branches, click **Path** and **Plot** in the **Tree Visualization** pane.



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

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

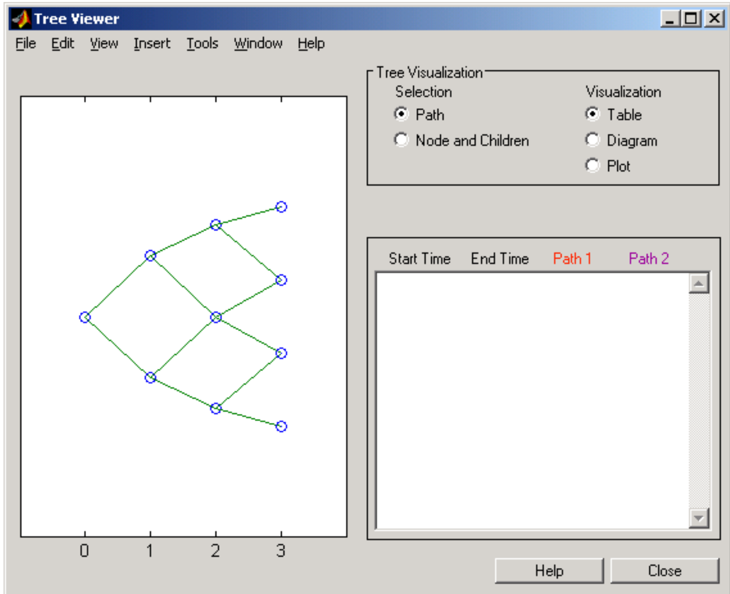


With **Node and Children** selected, the choices under **Visualization** are unavailable.

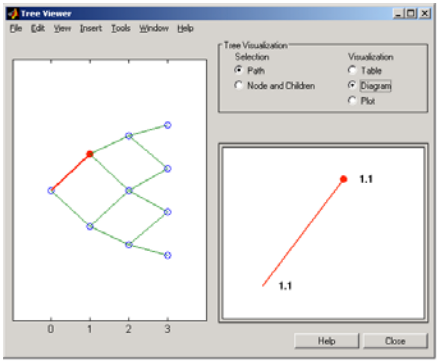
Example 2. Display a BDT Interest-Rate Tree.

```
load deriv.mat
treeviewer(BDTTree)
```

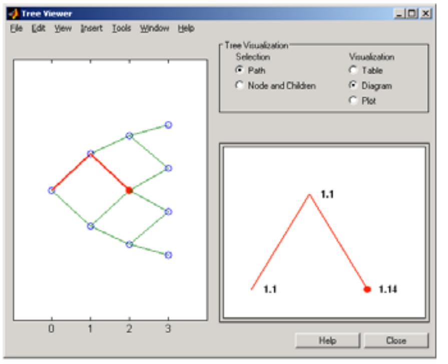
The `treeviewer` function displays the structure of a BDT tree in the left pane. The tree visualization in the right pane is blank.



To visualize the actual interest-rate tree, go to the **Tree Visualization** pane and click **Path** (the default) and **Diagram**. Now, select the first path by clicking on the first node of the up branch (`t = 1`). Continue by clicking the down branch at the next node (`t = 2`). The two figures below show the treeviewer path diagrams for these selections.



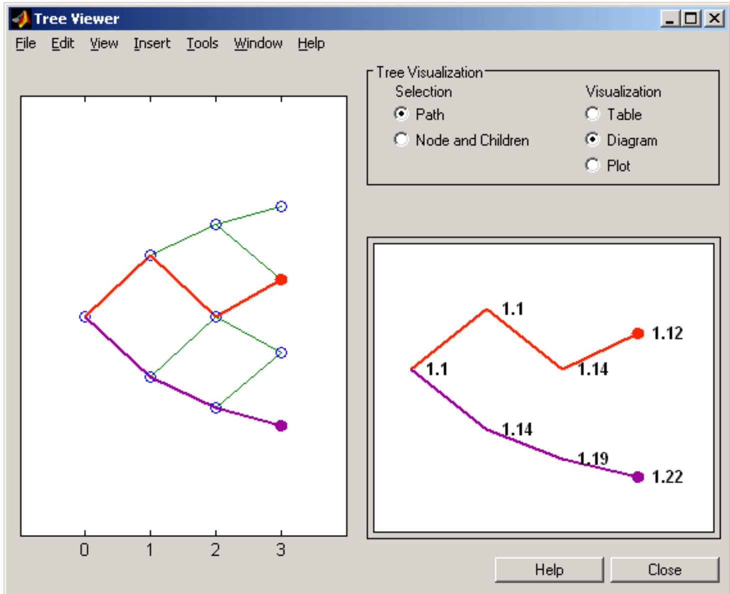
t = 1



t = 2

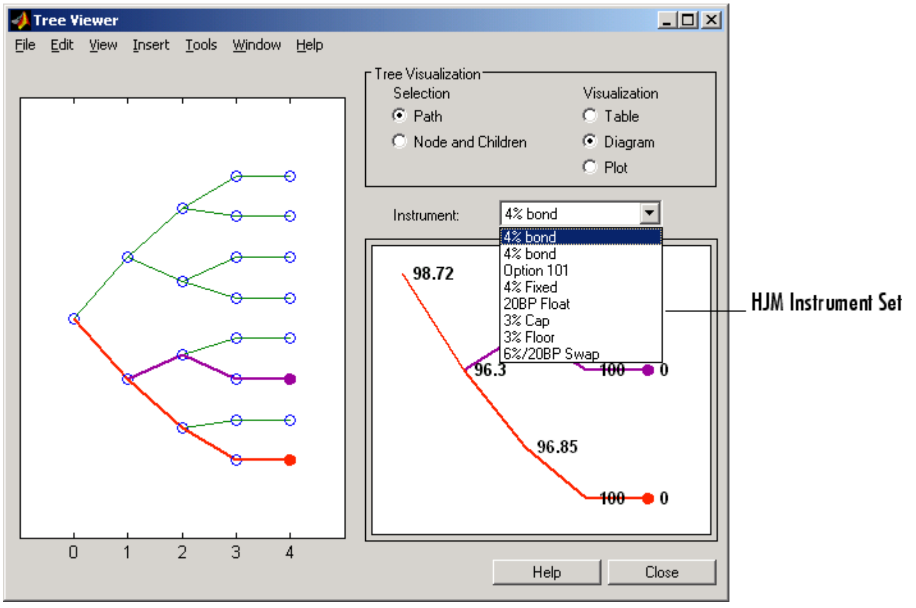
Continue clicking all nodes in succession until you reach the end of the branch. Note that the entire path you have selected is highlighted in red.

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



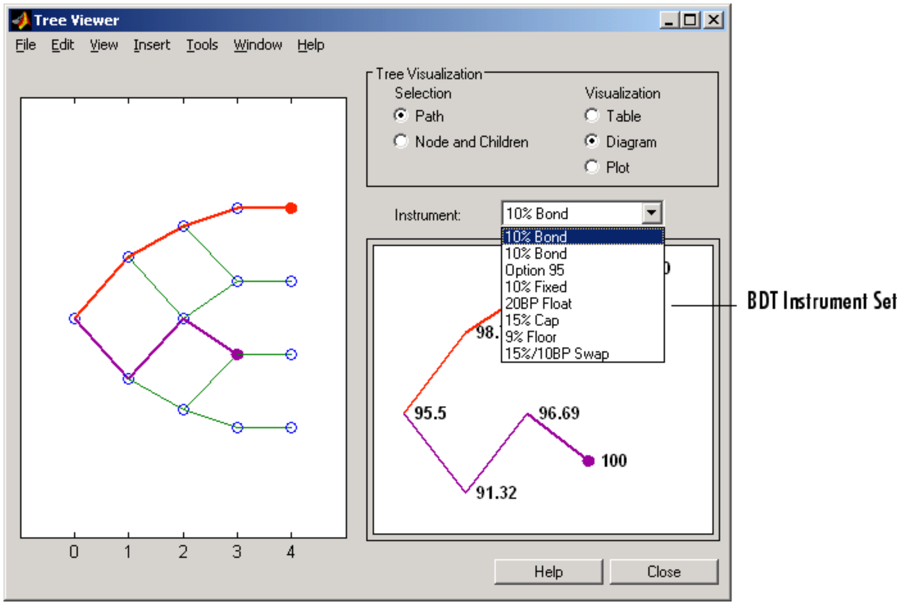
Example 3. Display an HJM Price Tree for Named Instruments.

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



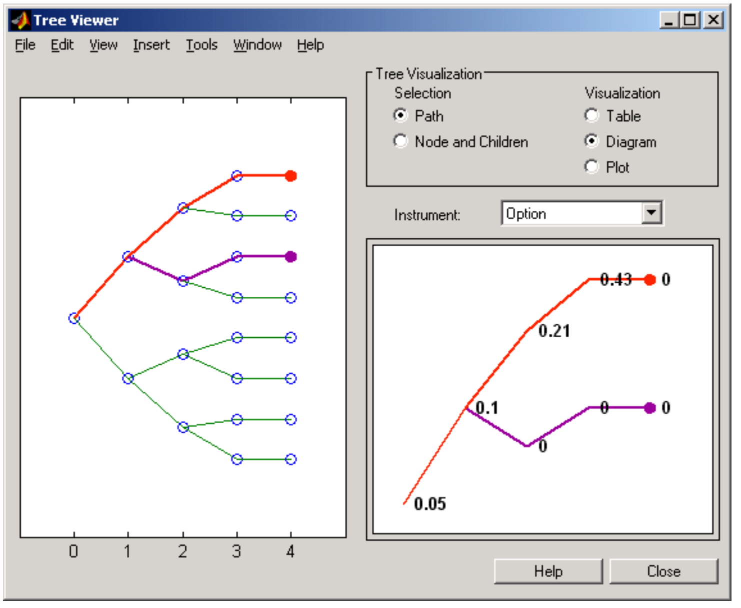
Example 4. Display a BDT Price Tree for Named Instruments.

```
load deriv.mat
[Price, PriceTree] = bdtprice(BDTTree, BDTInstSet);
treeviewer(PriceTree, BDTInstSet)
```



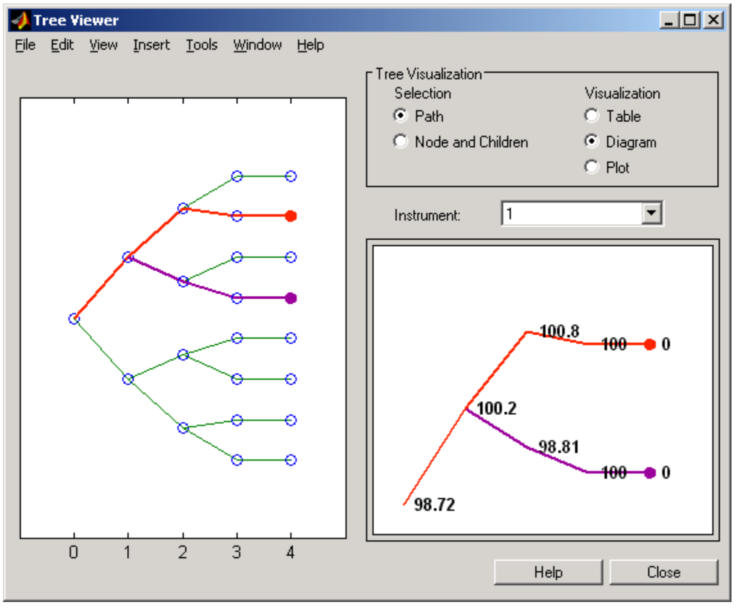
Example 5. Display an HJM Price Tree with Renamed Instruments.

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



Example 6. Display an HJM Price Tree Using Default Instrument Names (Numbers).

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



See Also

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

trintreepath

Purpose

Entries from node of recombining trinomial tree

Syntax

```
Values = trintreepath(TrinTree, BranchList)
```

Arguments

`TrinTree`	Recombining price or interest-rate trinomial tree.
`BranchList`	Number of paths (`NUMPATHS`) by path length (`PATHLENGTH`) matrix containing the sequence of branchings.

Description

`Values = trintreepath(TrinTree, BranchList)` extracts entries of a node of a recombining trinomial tree. The node path is described by the sequence of branchings taken, starting at the root. The top branch is number 1, the middle branch is 2, and the bottom branch is 3. Set the branch sequence to 0 to obtain the entries at the root node.

`Values` is a number of values (`NUMVALS`)-by-`NUMPATHS` matrix containing the retrieved entries of a recombining tree.

Examples

Create a Hull-White tree by loading the example file.

```
load deriv.mat;
```

Then, for example

```
FwdRates = trintreepath(HWTree, [1 2 3])
```

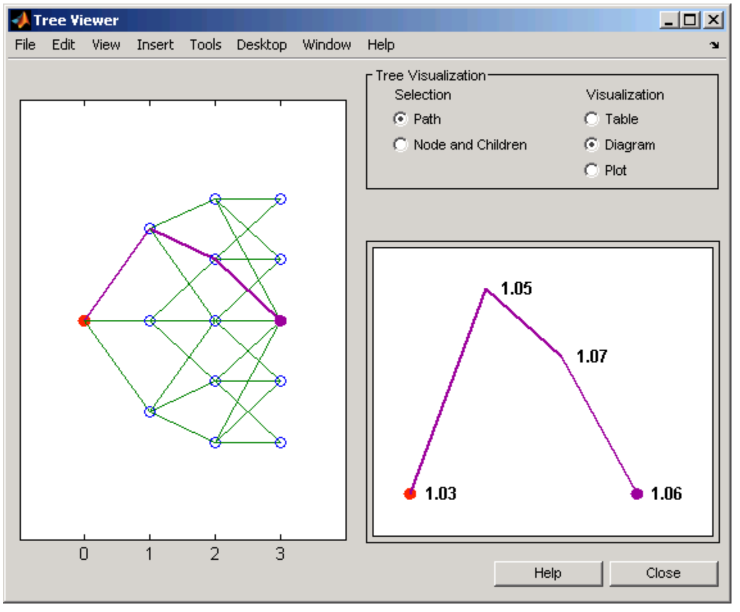
returns the rates at the tree nodes located by starting at 0, taking the up branch at the first node, the middle branch at the second node, and finally the bottom branch at the third node.

```
FwdRates =
```

```
1.0279
1.0528
1.0652
1.0591
```

You can visualize this with the `treeviewer` function.

```
treeviewer(HWTree)
```



See Also

`mktrintree`, `trintreeshape`

trintreeshape

Purpose

Shape of recombining trinomial tree

Syntax

```
[NumLevels, NumPos, NumStates] = trintreeshape(TrinTree)
```

Arguments

`TrinTree`	Recombining price or interest-rate trinomial tree.

Description

`[NumLevels, NumPos, NumStates] = trintreeshape(TrinTree)` returns information on a recombining trinomial tree's shape.

`NumLevels` is the number of time levels of the tree.

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

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

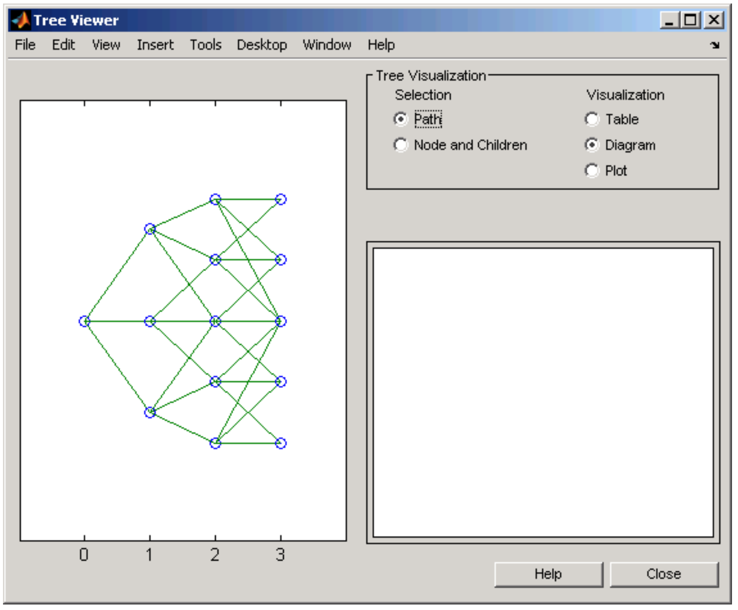
Examples

Create a Hull-White tree by loading the example file.

```
load deriv.mat;
```

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

```
treeviewer(HWTree)
```



With this tree

```
[NumLevels, NumPos, NumStates] = trintreeshape(HWTree)
```

returns

```
NumLevels  =
     4

NumPos     =
     1     1     1     1

NumStates =
     1     3     5     5
```

See Also

`mktrintree`, `trintreepath`

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]
```

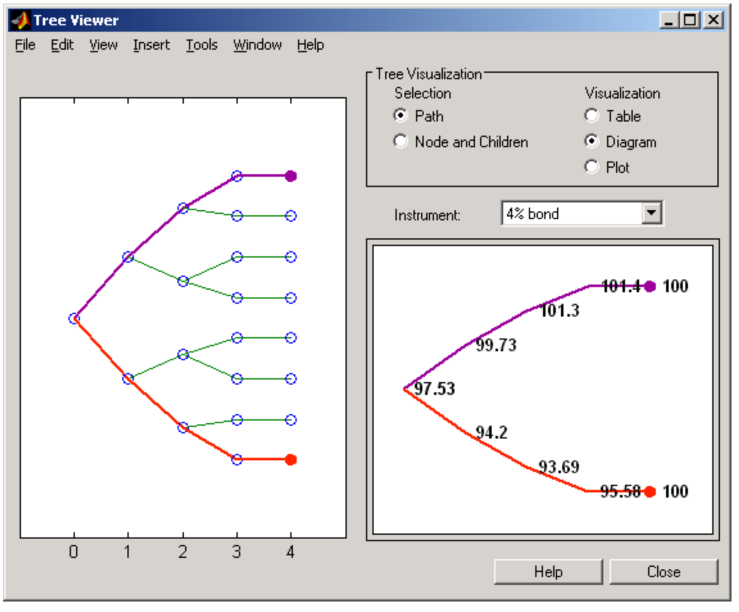
As indicated in the last warning, because the cash flows of the bond did not align with the tree dates, a new tree was generated for pricing the bond. This pricing method returns more accurate results since it guarantees that the process is arbitrage-free. It also takes longer to calculate and requires 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})
```

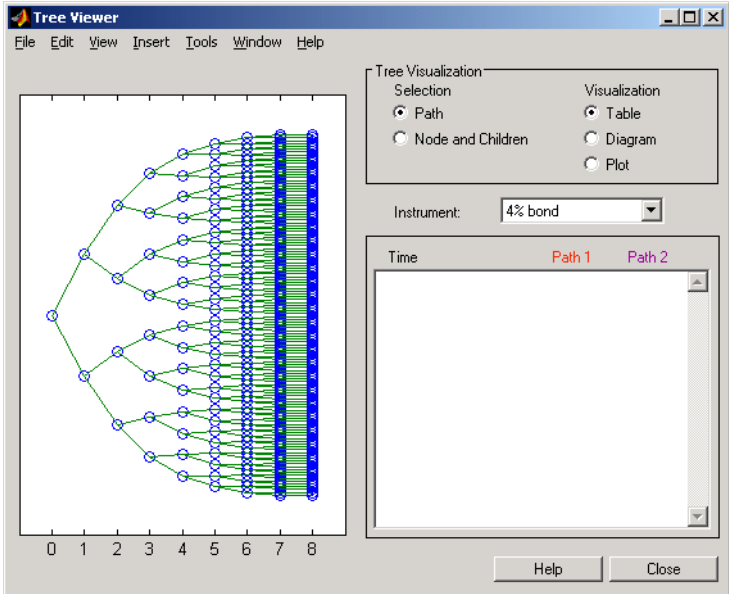
```
ans =

     1  8

size(BondPriceTreeNoCR.PBush{end})

ans =

     1  128
```

The differences become more obvious by examining the price trees with `treeviewer`.

```
treeviewer(BondPriceTree, BondPort)
```




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




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

All =

      -2.76        10.43        0.00        98.72
      -3.56        16.64       -0.00        97.53
    -166.18     13235.59      700.96         0.05
      -2.76        10.43        0.00        98.72
      -0.01         0.03           0       100.55
      46.95      1090.63       14.91         6.28
    -969.85    173969.77     1926.72         0.05
     -76.39       287.00        0.00         3.690
```

Bibliography

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.

Hull-White (HW) and Black-Karasinski (BK) Modeling

A description of the Hull-White model and its Black-Karasinski modification can be found in

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

You can find additional information about the Hull-White single-factor model used in this toolbox in these papers

Hull, J., and A. White, “Numerical Procedures for Implementing Term Structure Models I: Single-Factor Models,” *Journal of Derivatives,* 1994

Hull, J., and A. White, “Using Hull-White Interest Rate Trees,” *Journal of Derivatives,* 1996.

Cox-Ross-Rubinstein (CRR) Modeling

To learn about the Cox-Ross-Rubinstein 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 Equal Probabilities 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.

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

Examples

Use this list to find examples in the documentation.

Instrument Portfolio Examples

Interest Rate Environment Examples

HJM Examples

Volatility Modelling

BDT Examples

Rate Specification Creation

Time Specification

Sensitivity

Treeviewer Examples

Creating Equity Derivatives

Pricing Equity Derivatives

Hedging Examples

Hedging with Constrained Portfolios

Glossary

American option

An option that can be exercised any time until its expiration date. Contrast with European option.

arbitrary cash flow instrument

A set of generic cash flow amounts for which a price needs to be established.

Asian option

An option whose payoff depends upon the average price of the underlying asset over a certain period of time.

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.

Bermuda option

An option that can be exercised on predetermined dates only, usually every month. See also American option and European option.

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 in which the probability over time of each possible price or rate follows a binomial distribution. The basic assumption is that prices or rates can move to only two values (one higher and one lower) over any short time period. See also trinomial model.

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
1. An option to buy a certain quantity of a stock or commodity for a specified price within a specified time. See also put.

2. 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 also 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.

mean reversion
The tendency of a variable to return to its mean value after reaching a point of excessive positive or negative valuation relative to the mean.

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 also 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 also 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.

trinomial model
: A method in which the basic assumption is that prices or rates can move to one of three possible values over any short time period. At any time step the price or rate direction can be upward, neutral, or downward. See also binomial model.

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.

Index

T

U

V