Financial Derivatives Toolbox

For Use with MATLAB®

Computation

Visualization

Programming

User's Guide

Version 1

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Financial Derivatives Toolbox User's Guide

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Contents

Preface

1 Tutorial

2 Function Reference

Preface

About this Book

This book describes the Financial Derivatives Toolbox for MATLAB®, a collection of tools for analyzing individual financial derivative instruments and portfolios of instruments.

Organization of the Document

Chapter	Description
"Tutorial"	Describes techniques for interest rate environment computations, instrument portfolio construction and manipulation, and Heath-Jarrow-Morton (HJM) modeling of fixed income derivatives.
"Function Reference"	Describes the functions used for interest rate environment computations, instrument portfolio construction and manipulation, and for Heath-Jarrow-Morton modeling.

Typographical Conventions

This manual uses some or all of these conventions.

Item	Convention	Example
Example code	`Monospace` font	To assign the value 5 to `A`, enter `A = 5`
Function names/syntax	`Monospace` font	The `cos` function finds the cosine of each array element. Syntax line example is `MLGetVar ML_var_name`
Keys	**Boldface** with an initial capital letter	Press the **Return** key.

Item	Convention	Example
Literal strings (in syntax descriptions in reference chapters)	**`Monospace bold`** for literals	`f = freqspace(n,'whole')`
Mathematical expressions	*Italics* for variables Standard text font for functions, operators, and constants	This vector represents the polynomial $p = x^2 + 2x + 3$

MATLAB output	`Monospace` font	MATLAB responds with
		`A =`
		`5`

Menu names, menu items, and controls	**Boldface** with an initial capital letter	Choose the **File** menu.
New terms	*Italics*	An *array* is an ordered collection of information.
String variables (from a finite list)	*`Monospace italics`*	`sysc = d2c(sysd, 'method')`

Related Products

The MathWorks provides several products relevant to the tasks you can perform with the Financial Derivatives Toolbox.

For more information about any of these products, see either:

- The online documentation for that product, if it is installed or if you are reading the documentation from the CD
- The MathWorks Web site, at `http://www.mathworks.com`; see the "products" section

Note The toolboxes listed below all include functions that extend MATLAB's capabilities.

Product	Description
Database Toolbox	Tool for connecting to, and interacting with, most ODBC/JDBC databases from within MATLAB
Datafeed Toolbox	MATLAB functions for integrating the numerical, computational, and graphical capabilities of MATLAB with financial data providers
Excel Link	Tool that integrates MATLAB capabilities with Microsoft Excel for Windows
Financial Time Series Toolbox	Tool for analyzing time series data in the financial markets
Financial Toolbox	MATLAB functions for quantitative financial modeling and analytic prototyping

Product	Description
GARCH Toolbox	MATLAB functions for univariate Generalized Autoregressive Conditional Heteroskedasticity (GARCH) volatility modeling
MATLAB	Integrated technical computing environment that combines numeric computation, advanced graphics and visualization, and a high-level programming language
MATLAB Compiler	Compiler for automatically converting MATLAB M-files to C and C++ code
MATLAB Report Generator	Tool for documenting information in MATLAB in multiple output formats
MATLAB Runtime Server	MATLAB environment in which you can take an existing MATLAB application and turn it into a stand-alone product that is easy and cost-effective to package and distribute. Users access only the features that you provide via your application's graphical user interface (GUI). They do not have access to your code or the MATLAB command line.
Optimization Toolbox	Tool for general and large-scale optimization of nonlinear problems, as well as for linear programming, quadratic programming, nonlinear least squares, and solving nonlinear equations
Spline Toolbox	Tool for the construction and use of piecewise polynomial functions
Statistics Toolbox	Tool for analyzing historical data, modeling systems, developing statistical algorithms, and learning and teaching statistics

Further Reading

Heath-Jarrow-Morton Modeling

An introduction to Heath-Jarrow-Morton (HJM) 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.

Financial Derivatives

Information on the creation of financial derivatives and their role in the marketplace can be found in numerous sources. Among those consulted in the development of the Financial Derivatives toolbox are:

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

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

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

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

1

Tutorial

Introduction

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

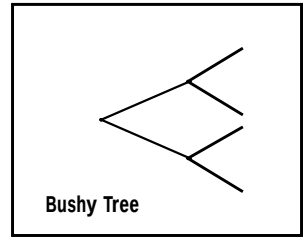
Interest Rate Models

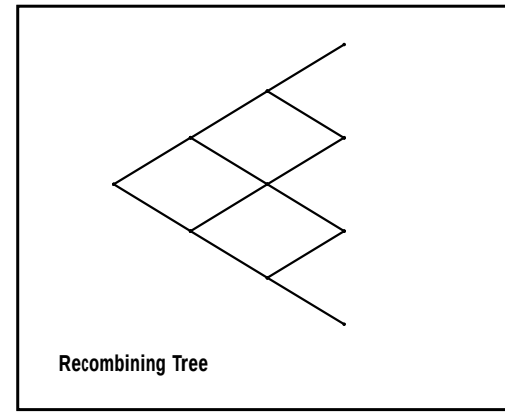
The Financial Derivatives Toolbox computes pricing and sensitivities of interest rate contingent claims based upon sets of zero coupon bonds or the Heath-Jarrow-Morton (HJM) evolution model of the interest rate term structure. For information, see:

- "Pricing and Sensitivity from Interest Term Structure" on page 1-30 for a discussion of price and sensitivity based upon portfolios of zero coupon bonds.
- "Pricing and Sensitivity from HJM" on page 1-48 for a discussion of price and sensitivity based upon the HJM model.

Trees

The Heath-Jarrow-Morton model works with a type of interest rate tree called a *bushy tree*. A bushy tree is a tree in which the number of branches increases exponentially relative to observation times; branches never recombine. The opposite of a bushy tree is a *recombining tree*, a tree in which branches recombine over time. From any given node, the node reached by taking the path up-down is the same node reached by taking the path down-up. A bushy and a recombining tree are both illustrated in the next figure.





Financial Instruments

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

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

Bond Options. Puts and calls on portfolios of bonds.

Fixed Rate Note. A long-term debt security with preset interest rate and maturity, by which the interest must be paid. The principal may or may not be paid at maturity. In this version of the Financial Derivatives Toolbox, the principal is always paid at maturity.

Floating Rate Note. A security similar to a bond, but in which the note's interest rate is reset periodically, relative to a reference index rate, to reflect fluctuations in market interest rates.

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

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

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

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

Hedging

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

- “Hedging” on page 1-64 for a discussion of the hedging process.
- “hedgeopt” on page 2-42 for a description of the function that allocates an optimal hedge.
- “hedgeslf” on page 2-45 for a description of the function that allocates a self-financing hedge.

Creating and Managing Instrument Portfolios

The Financial Derivatives Toolbox provides components for analyzing individual derivative instruments and portfolios containing several types of financial instruments. The toolbox provides functionality that supports the creation and management of these instruments:

- Bonds
- Bond Options
- Fixed Rate Notes
- Floating Rate Notes
- Caps
- Floors
- Swaps

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

The toolbox also provides pricing and sensitivity routines for these instruments. (See “Pricing and Sensitivity from Interest Term Structure” on page 1-30 and “Pricing and Sensitivity from HJM” on page 1-48.)

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: `'Bond'`, `'OptBond'`, `'CashFlow'`, `'Fixed'`, `'Float'`, `'Cap'`, `'Floor'`, or `'Swap'`. 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:

- 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)
```

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 NaN      NaN   NaN
2     Cap  0.07   08-Feb-2000 15-Jan-2003 NaN      NaN   NaN
```

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 NaN      NaN   NaN
2     Cap  0.07   08-Feb-2000 15-Jan-2003 NaN      NaN   NaN

Index Type CouponRate Settle      Maturity    Period Basis ...
3     Bond 0.04       08-Feb-2000 15-Jan-2003 NaN    NaN ...
```

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
Bond	`instbond`
Bond option	`instoptbnd`
Arbitrary cash flow	`instcf`
Fixed rate note	`instfixed`
Floating rate note	`instfloat`
Cap	`instcap`
Floor	`instfloor`
Swap	`instswap`

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

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

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

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

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

Creating New Instruments or Properties

Use the `instaddfield` function to create a *new kind of instrument* or to add *new parameters* 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)
```

And, 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};
```

Optionally, you can also specify the data types of the data cell array by creating another cell array containing this information.

```
FieldClass = {'date','dble'};
```

Finally, create the portfolio with a single instrument.

```
Port = instaddfield('Type', Type, 'FieldName', FieldName,...
'FieldClass', FieldClass, '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 NaN       NaN   NaN
3     Cap  0.07   08-Feb-2000 15-Jan-2003 NaN       NaN   NaN
```

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 example uses 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 0.01   01-Jan-2000 01-Jan-2004    1          NaN   NaN       1% Floor 40

Index Type LegRate   Settle        Maturity     LegReset Basis Principal LegType Name         Quantity
8     Swap [0.04 20] 01-Jan-2000   01-Jan-2003  [1  1]   NaN   NaN       [NaN]   4%/20BP Swap 10
```

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

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

```
Mat2003 =

     1
     4
     5
     8
```

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

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

CapFloor =

     6
     7
```

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

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

Pos50 =

     2
     3
```

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

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

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

   Mat2003 =

        1
        4
        5
        8
```

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

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

   instdisp(Select2003)
```

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

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

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

Index Type LegRate   Settle        Maturity     LegReset Basis Principal LegType Name         Quantity
4     Swap [0.04 20] 01-Jan-2000   01-Jan-2003  [1  1]   NaN   NaN       [NaN]   4%/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 Environment

The *interest rate environment* is the representation of the evolution of interest rates through time. In MATLAB, the interest rate environment is encapsulated in a structure called `RateSpec` (*rate specification*). This structure holds all information needed to identify completely the evolution of interest rates. Several functions included in the Financial Derivatives Toolbox are dedicated to the creation and management of the `RateSpec` structure. Many others take this structure as an input argument representing the evolution of interest rates.

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

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 rates 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 rates.

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 will be calculated. In this particular example, use February 15, 2000 as the beginning date for all interest rate terms.

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];
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 rates.

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`.

Find the corresponding values in the previous example.

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

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

```
Times = [StartTimes, EndTimes]

Times =

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

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

Alternative Syntax (rate2disc)

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

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

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

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

Disc =

    0.9756
    0.9463
    0.9151
    0.8799
    0.8319
```

Calculating Rates from Discounts

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

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

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

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

```
Rates =

    0.0500
    0.0560
    0.0600
    0.0650
    0.0750
```

Alternative Syntax (disc2rate)

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

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

Arrange the results in a matrix convenient to display.

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

Result =

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

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

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

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

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

Rates =

    0.0500
    0.0560
    0.0600
    0.0650
    0.0750
```

Interest Rate Term Conversions

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

Calculating Rates Applicable to Different Periods

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 will be interpolated.
- `StartDates` represent the starting dates for which the interest rates will be interpolated.
- `ValuationDate` is the date of observation, from which the `StartTimes` and `EndTimes` will be calculated. This date represents time = 0.

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

1. The initial or reference interest rates, including the terms for which they are valid
2. Terms for which the new interest rates will be calculated

As an example, consider the rate table specified earlier.

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

Assuming that the valuation date is February 15, 2000, these rates represent zero coupon bond rates with maturities specified in the second column. Use the function `ratetimes` to calculate the spot 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, EndTimes, StartTimes] = 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 spot 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 additional output arguments `StartTimes` and `EndTimes` represent the time factor equivalents to the `StartDates` and `EndDates` vectors. As with the functions `disc2rate` and `rate2disc`, `ratetimes` 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` also has an alternate syntax that uses time factors directly, and assumes 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 spot 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
```

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 1-25 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 1-27 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 User's Guide*.

Consider again the original table of interest rates.

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

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

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

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

```
rs =

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

Some of the properties filled in the structure were not passed explicitly in the call to `RateSpec`. The values of the automatically completed properties depend upon the properties that are explicitly passed. Consider for example the `StartTimes` and `EndTimes` vectors. Since the `StartDates` and `EndDates` vectors are passed in, as well as the `ValuationDate`, `intenvset` has all the information needed to calculate `StartTimes` and `EndTimes`. Hence, these two properties are read-only.

Obtaining Specific Properties (intenvget)

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

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

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

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

EndTimes =

     1
     2
     3
     4
     5
```

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

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

Disc =

    0.9756
    0.9463
    0.9151
    0.8799
    0.8319
```

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

Note Although it is possible to access directly these fields within the structure, instead of using intenvget, we strongly advise against this. The format of the interest rate term structure could change in future versions of the toolbox. Should that happen, any code accessing the RateSpec fields directly would stop working.

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

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

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

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

```
Times = [StartTimes, EndTimes]

Times =

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

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

Pricing and Sensitivity from Interest Term Structure

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

- "Pricing" on page 1-31 for a discussion on using the `intenvprice` function to price a portfolio of instruments based on a set of zero curves.
- "Sensitivity" on page 1-33 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) model to compute prices and sensitivities for financial instruments. The HJM model supports computations involving options and interest rate floors and caps. See "Pricing and Sensitivity from HJM" on page 1-48 for information on computing price and sensitivities of financial instruments using the Heath-Jarrow-Morton model.

Pricing

The main function used for pricing portfolios of instruments is `intenvprice`. This function is actually a wrapper for the family of functions that calculate the prices of individual types of instruments. `intenvprice` takes as input an interest rate term structure created with `intenvset`, and a portfolio of interest rate contingent derivatives instruments created with `instadd`. To learn more about `instadd`, see "Creating and Managing Instrument Portfolios" on page 1-5, and to learn more about the interest rate term structure see "Interest Rate Environment" on page 1-16.

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.

When called, `intenvprice` classifies the portfolio contained in `InstSet` by instrument type, and calls the appropriate pricing functions. The map between instrument types and the pricing function `intenvprice` calls is:

`bondbyzero`: Price bond by a set of zero curves

`fixedbyzero`: Price fixed rate note by a set of zero curves

`floatbyzero`: Price floating rate note by a set of zero curves

`swapbyzero`: Price swap by a set of zero curves

Each of these functions can be used individually to price an instrument. Consult the reference pages for specific information on the use of these functions.

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 [0.04  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 =

  105.77
  107.69
  105.77
  100.58
    5.19
```

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.

Sensitivity

The Financial Derivatives Toolbox can calculate two types of derivative price sensitivities, namely 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 of using `intenvsens` to calculate both sensitivities and prices.

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

Display the results in a single matrix in long format.

```
All = [Delta Gamma Price]

All =

  1.0e+003 *

-0.29971721334060   1.16033886010257   0.10576776654530
-0.39585159618412   1.90136650339994   0.10769123495924
-0.29971721334060   1.16033886010257   0.10576776654530
-0.00112373852341   0.00366003366949   0.10057677665453
-0.29859347481719   1.15667882643308   0.00519098989077
```

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

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

ans =

  1.0e+002 *

  -0.02833729245973   0.10970628368196   1.05767766545296
  -0.03675801436709   0.17655721973284   1.07691234959241
  -0.02833729245973   0.10970628368196   1.05767766545296
  -0.00011172942311   0.00036390445103   1.00576776654530
  -0.57521490332382   2.22824326529828   0.05190989890766
```

Heath-Jarrow-Morton (HJM) Model

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

Building an HJM Forward Rate Tree

The HJM 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 the HJM forward rate tree using the Financial Derivatives Toolbox.

The MATLAB function that creates the HJM forward rate tree is `hjmtree`. This function takes three structures as input arguments:

1. The volatility model `VolSpec`. (See "Specifying the Volatility Model (VolSpec)" on page 1-36.)
2. The interest rate term structure `RateSpec`. (See "Specifying the Interest Rate Term Structure (RateSpec)" on page 1-38.)
3. The tree time layout `TimeSpec`. (See "Specifying the Time Structure (TimeSpec)" on page 1-39.)

Creating the HJM Forward Rate Tree (hjmtree)

Calling the function `hjmtree` creates the structure, `HJMTree`, containing time and forward rate information of the bushy tree.

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

The calling syntax for `hjmtree` is

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

where:

- `VolSpec` is a structure that specifies the forward rate volatility process. `VolSpec` is created using the function `hjmvolspec`. The `hjmvolspec` function supports the specification of multiple factors, and it handles five 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.
- `RateSpec` is the interest rate specification of the initial rate curve. This structure is created with the function `intenvset`. (See "Interest Rate Term Structure" on page 1-25.)
- `TimeSpec` is the tree time layout specification. This variable is created with the function `hjmtimespec`. It represents the mapping between level times and level dates for rate quoting. This structure determines indirectly the number of levels of the tree generated in the call to `hjmtree`.

Specifying the Volatility Model (VolSpec)

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

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

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

VolSpec =

      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, `VolsSpec.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
VolSpec = hjmvolspec('Proportional', CurveProp, CurveTerm,...
1e6,'Exponential', Sigma_0, Lambda)
```

```
VolSpec =

      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.

Specifying the Interest Rate Term Structure (RateSpec)

The structure `RateSpec` is an interest term structure that defines the initial forward rate specification from which the tree rates are derived. The section “Interest Rate Term Structure” on page 1-25 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.

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 HJM tree. This structure defines the mapping between the observation times at each level of the tree and the corresponding dates.

`TimeSpec` is built using the function `hjmtimespec`. The `hjmtimespec` function requires three input arguments:

1. The valuation date `ValuationDate`
2. The maturity date `Maturity`
3. The compounding rate `Compounding`

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 will fall on tree nodes.
- Compounding is the frequency at which the rates are compounded when annualized.

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

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

TimeSpec =

       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 HJM tree, the rates in RateSpec will be interpolated to obtain the initial rates with maturities equal to those found in TimeSpec.

Example: Creating an HJM Tree

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

HJMTree = hjmtree(VolSpec, RateSpec, TimeSpec)

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]}
```

Using HJM Trees in MATLAB

When working with the HJM model, 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 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

HJMInstSet         1x1          22700  struct array
HJMTree            1x1           6302  struct array
ZeroInstSet        1x1          14442  struct array
ZeroRateSpec       1x1           1588  struct array
```

Structure of an HJM Tree

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

```
HJMTree

HJMTree =

  FinObj: 'HJMFwdTree'
 VolSpec: [1x1 struct]
TimeSpec: [1x1 struct]
RateSpec: [1x1 struct]
```

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

`FwdTree` contains the actual forward rate tree. It is represented in MATLAB as a cell array with each cell array element containing a tree level.

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

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

```
HJMTree.FwdTree{1}

ans =

    1.0200
    1.0200
    1.0200
    1.0200
```

This represents a constant rate curve of 2%.

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    0.0200
    1.0000    2.0000    0.0200
    2.0000    3.0000    0.0200
    3.0000    4.0000    0.0200
```

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 =
    1.0200
    1.0200
    1.0200
    1.0200
```

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 =

    0.9276
    0.9368
    0.9458
```

Now examine the corresponding down branch.

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

ans =

    1.1329
    1.1442
    1.1552
```

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 =

    0.8519    1.0405
    0.8686    1.0609
```

Next examine the corresponding down states.

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

ans =

    1.0405    1.2708
    1.0609    1.2958
```

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 =

    1.0200
    0.9276
    1.0405
    1.1784
```

`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 =

    1.1784
```

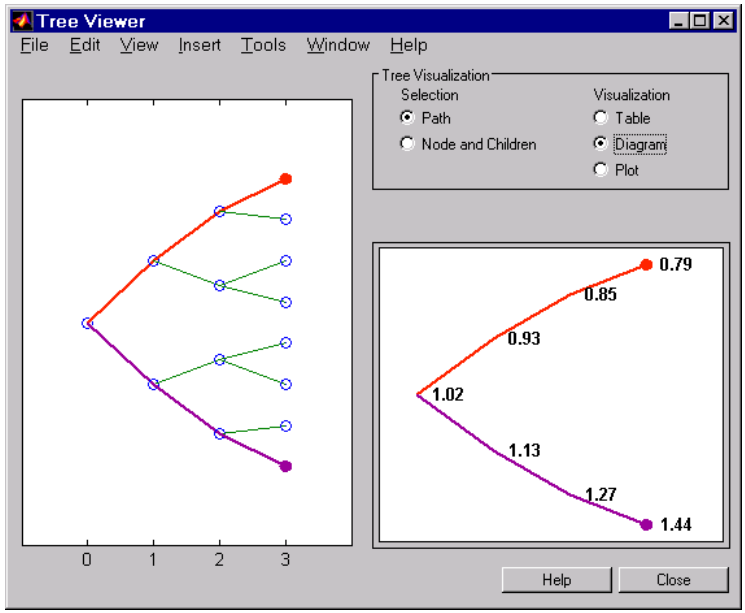
As expected, this single value corresponds to the last element of the rates returned by `bushpath`.

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

Graphical View of Forward Rate Tree

The function `treeviewer` provides a graphical view of the path of forward rates specified in `HJMTree`. For example, here is a `treeviewer` representation of the rates along both the up and the down branches of `HJMTree`.

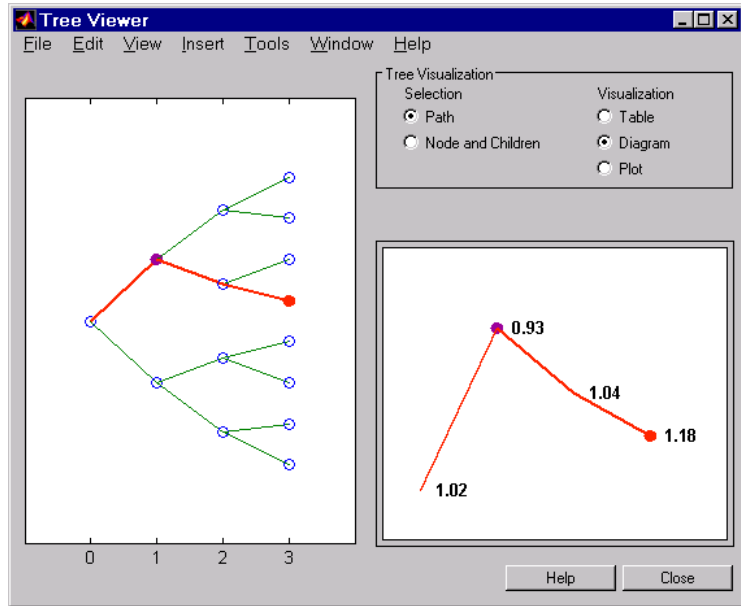
```
treeviewer(HJMTree)
```



A previous example used `bushpath` to find the path of forward rates taking the first branch up and then two branches down the rate tree.

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

FRates =

    1.0200
    0.9276
    1.0405
    1.1784
```

The `treeviewer` function displays the same information obtained by clicking along the sequence of nodes, as shown next.


Tree Viewer
File Edit View Insert Tools Window Help
Tree Visualization
Selection
Path
Node and Children
Visualization
Table
Diagram
Plot
0
1
2
3
0.93
1.04
1.18
1.02
Help
Close

Pricing and Sensitivity from HJM

This section explains how to use the Financial Derivatives Toolbox to compute prices and sensitivities of several financial instruments using the Heath-Jarrow-Morton (HJM) model. For information, see:

- "Pricing and the Price Tree" on page 1-48 for a discussion of using the `hjmprice` function to compute prices for a portfolio of instruments.
- "Calculating Prices and Sensitivities" on page 1-61 for a discussion of using the `hjmsens` function to compute delta, gamma, and vega portfolio sensitivities.

Pricing and the Price Tree

Using the HJM model, the function that calculates the price of any set of supported instruments, based on an interest rate tree, is `hjmprice`. The function is capable of pricing these instrument types:

- Bonds
- Bond options
- Arbitrary cash flows
- Fixed-rate notes
- Floating-rate notes
- Caps
- Floors
- Swaps

The syntax used for calling `hjmprice` is

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

This function requires two input arguments: the interest rate tree, `HJMTree`, and the set of instruments, `InstSet`. An optional argument `Options` further controls the pricing and the output displayed.

`HJMTree` is the Heath-Jarrow-Morton tree sampling of a forward rate process, created using `hjmtree`. See "Building an HJM Forward Rate Tree" on page 1-35 to learn how to create this structure based on the volatility model, the interest rate term structure, and the time layout.

`InstSet` is the set of instruments to be priced. This structure represents the set of instruments to be priced independently using the HJM model. The section "Creating and Managing Instrument Portfolios" on page 1-5 explains how to create this variable.

`Options` is an options structure created with the function `derivset`. This structure defines how the HJM 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. If this input argument is not specified in the call to `hjmprice`, a default `Options` structure is used.

In actuality, `hjmprice` is a *wrapper function* that classifies the instruments and calls appropriate pricing functions for each one of the instrument types. The calculation functions are `bondbyhjm`, `cfbyhjm`, `fixedbyhjm`, `floatbyhjm`, `optbndbyhjm`, and `swapbyhjm`. These functions may also be used directly to calculate the price of sets of instruments of the same type. See the documentation for these individual functions for further information.

Consider the following example, which uses the 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

HJMInstSet         1x1          22700  struct array
HJMTree            1x1           6302  struct array
ZeroInstSet        1x1          14442  struct array
ZeroRateSpec       1x1           1588  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 0.01   01-Jan-2000 01-Jan-2004    1          NaN   NaN       1% Floor 40

Index Type LegRate   Settle        Maturity     LegReset Basis Principal LegType Name         Quantity
8     Swap [0.04 20] 01-Jan-2000   01-Jan-2003  [1  1]   NaN   NaN       [NaN]   4%/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, PriceTree] = hjmprice(HJMTree, HJMInstSet)
Warning: Not all cash flows are aligned with the tree. Result will
be approximated.

Price =

105.7678
107.6773
  7.3217
105.7678
100.5768
 15.4367
 15.3938
  5.1910
```

```
PriceTree =

FinObj: 'HJMPriceTree'
 PBush: {1x5 cell}
AIBush: {1x5 cell}
  tObs: [0 1 2 3 4]
```

Note The warning shown above appears because some of the cash flows for the second bond do not fall exactly on a tree node. This situation is discussed further in "HJM Pricing Options Structure" on page 1-56.

Price Vector

The prices in the 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 the `Price` vector is the same as the indexing within `InstSet`. In this example, the prices in the `Price` vector correspond to the instruments in the following order.

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

InstNames =

4% bond
4% bond
Option 101
4% Fixed
20BP Float
3% Cap
1% Floor
4%/20BP Swap
```

Consequently, the price of the 3% cap is $15.4367, and the price for the 4% fixed-rate note is $105.7678

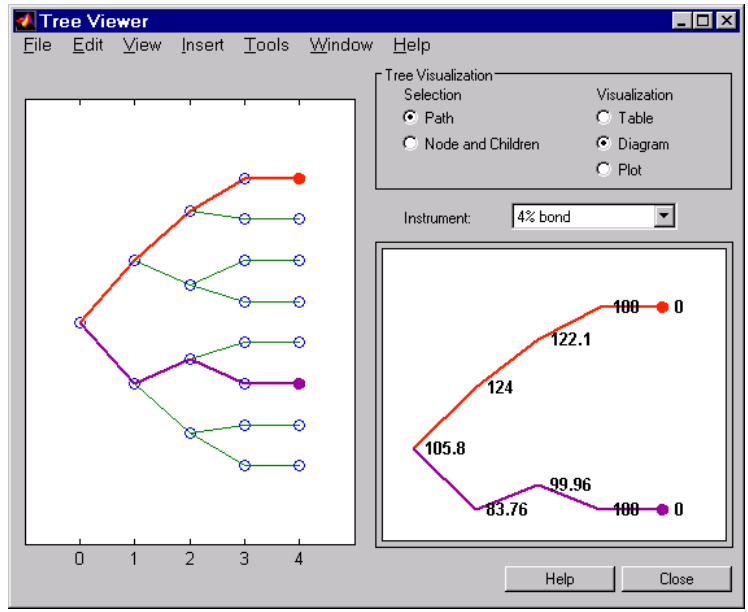
Price Tree Structure

The price tree structure holds all the pricing information. 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.

The function treeviewer can obtain a graphical representation of the tree, allowing you to examine interactively the values on the nodes of the tree.

```
treeviewer(PriceTree, HJMInstSet)
```

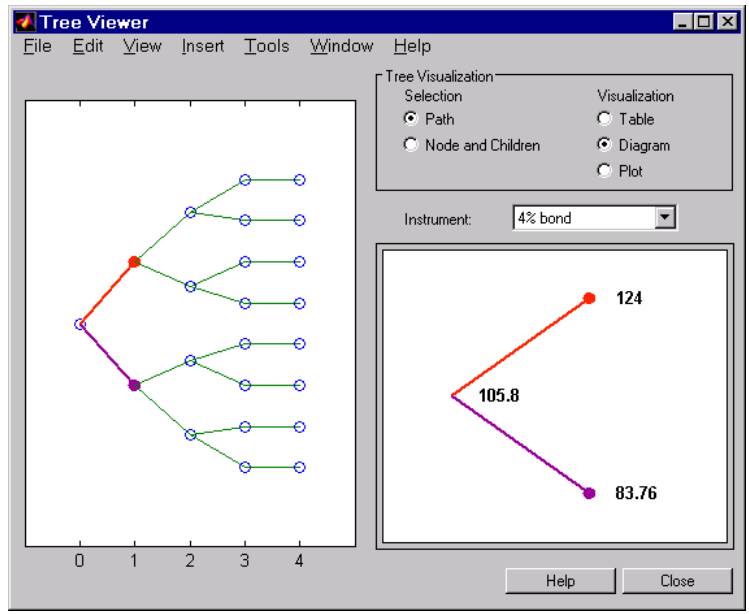


Alternatively, you can directly examine the field within the PriceTree structure, which contains the price tree with the price vectors at every state. The first node represents tObs = 0, corresponding to the valuation date.

```
PriceTree.PBush{1}

ans =

105.7678
107.6773
```

```
    7.3217
  105.7678
  100.5768
   15.4367
   15.3938
    5.1910
```

You can also use `treeviewer` instrument-by-instrument to observe instrument prices. For the first 4% bond in the instrument portfolio, `treeviewer` indicates a valuation date price of 105.8, the same value obtained by accessing the `PriceTree` structure directly.

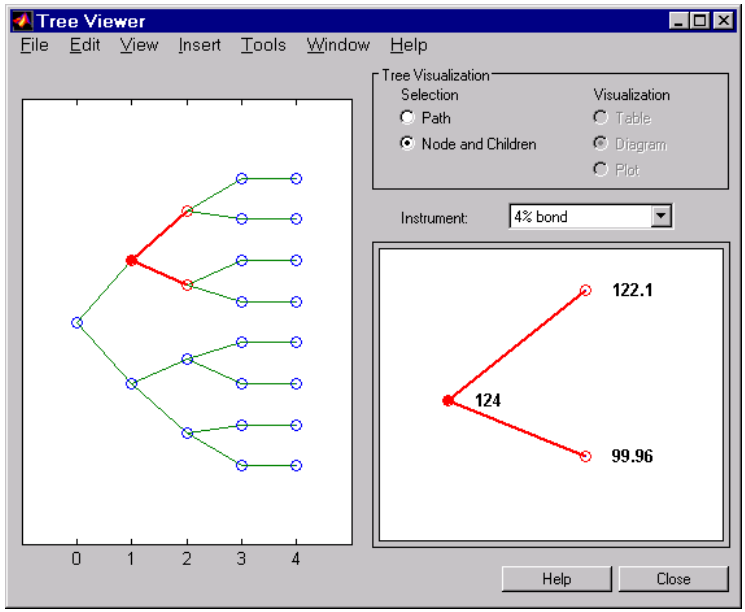


The second node represents the first rate observation time, `tObs = 1`. This node displays two states, one representing the branch going up and the other one representing the branch going down.

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

```
PriceTree.PBush{2}(:,:,1)

ans =

124.0039
135.2375
 13.5026
124.0039
100.4458
  3.8042
 30.4092
 23.5581
```

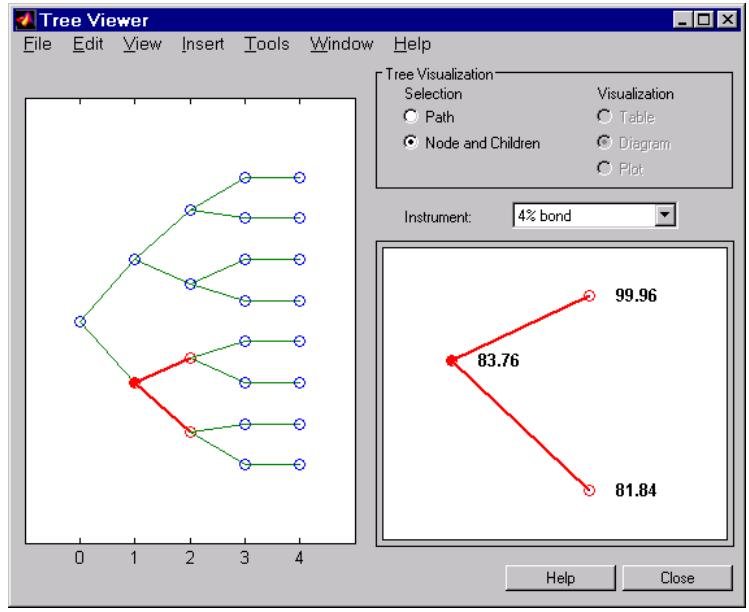
As before, you can use `treeviewer`, this time to examine the price for the 4% bond on the up branch. `treeviewer` displays a price of 124 for the first node of the up branch, as expected.



Now examine the corresponding down branch

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

ans =

 83.7623
 76.3844
  1.4337
 83.7623
100.3308
 27.6867
  0.9941
-16.5685
```

Use `treeviewer` once again, now to observe the price of the 4% bond on the down branch. The displayed price of 83.76 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.



HJM Pricing Options Structure

Default Structure. The HJM pricing `Options` structure defines how the HJM 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. If this input argument is not specified in the call to `hjmprice`, a default `Options` structure is used.

To observe the default structure, use the `derivset` function without any arguments.

```
Options = derivset

Options =

    Diagnostics: 'off'
       Warnings: 'on'
      ConstRate: 'on'
```

As seen, the `Options` structure is composed of three fields: `Diagnostics`, `Warnings`, and `ConstRate`.

`Diagnostics` indicates whether additional information is displayed if the HJM 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 HJM tree generated for pricing purposes.

`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` 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

HJM 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 HJM 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 an HJM tree grows exponentially with the number of tree dates. Consequently, setting `ConstRate 'off'` dramatically increases the memory and CPU demands on the computer.

Customizing the Structure. The `Options` structure is customized 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'
```

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 =

1.076773391800875e+002

BondPriceTree =
FinObj: 'HJMPriceTree'
 PBush: {1x5 cell}
AIBush: {1x5 cell}
  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 =

1.076912349592409e+002

BondPriceTreeNoCR =

FinObj: 'HJMPriceTree'
 PBush: {1x9 cell}
AIBush: {1x9 cell}
  tObs: [1x9 double]
```

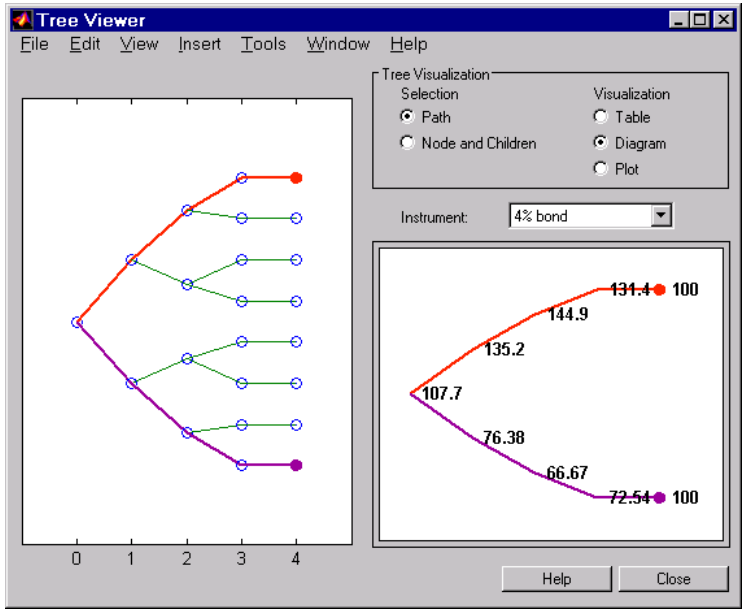
As indicated in the last warning, because the cash flows of the bond did not align with the tree dates, a new tree was generated for pricing the bond. This pricing method returns more accurate results since it guarantees that the process is arbitrage-free. It also takes longer to calculate and requires more memory. The `tObs` field of the price tree structure indicates the increased

memory usage. `BondPriceTree.tObs` has only five elements, while `BondPriceTreeNoCR` 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.

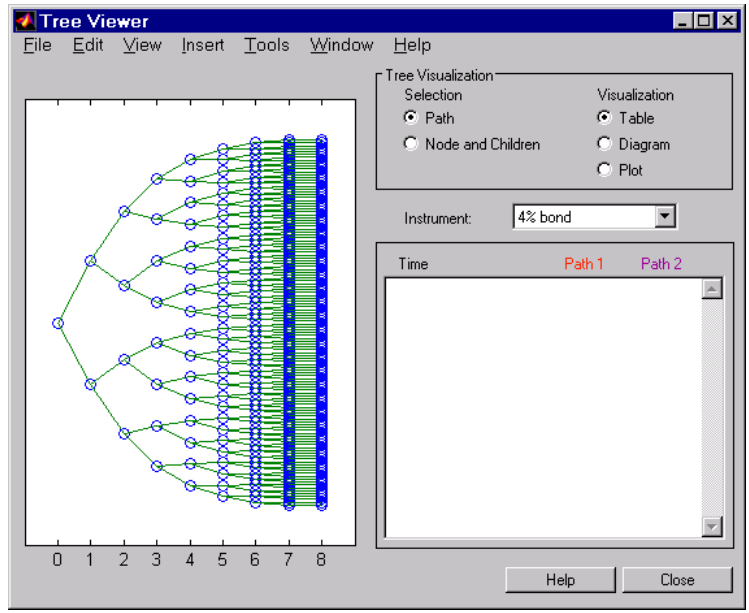
```
size(BondPriceTree.PBush{end})

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)
```



Calculating Prices and Sensitivities

The function `hjmsens` computes the delta, gamma, and vega sensitivities of instruments using an interest rate tree created with `hjmtree`. It also optionally returns the calculated price for each instrument. `hjmsens` requires the same two input arguments used by `hjmprice`, namely `HJMTree` and `InstSet`.

`hjmsens` calculates 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.

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. This situation was discussed in "HJM Pricing Options Structure" on page 1-56.

The sensitivities and the prices can be examined conveniently by arranging them into a single matrix.

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

All =

  1.0e+003 *

   -0.2997    1.1603   -0.0000    0.1058
   -0.3958    1.9012   -0.0003    0.1077
   -0.0818    0.5566    0.0610    0.0073
   -0.2997    1.1603   -0.0000    0.1058
   -0.0011    0.0037         0    0.1006
    0.1085   -0.6975    0.1665    0.0154
   -0.1741    0.9569    0.1615    0.0154
   -0.2986    1.1567   -0.0000    0.0052
```

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.

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

All =

   -2.8337   10.9706   -0.0000  105.7678
   -3.6759   17.6566   -0.0026  107.6773
  -11.1729   76.0234    8.3312    7.3217
   -2.8337   10.9706   -0.0000  105.7678
   -0.0112    0.0364         0  100.5768
    7.0273  -45.1870   10.7873   15.4367
  -11.3117   62.1593   10.4911   15.3938
  -57.5215  222.8243   -0.0000    5.1910
```

Hedging

Hedging is an important consideration in modern finance. The decision of 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.

Without 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.

The first function, `hedgeopt`, addresses the most general hedging problem. It allocates an optimal hedge to satisfy either of two goals:

1. Minimize the cost of hedging a portfolio given a set of target sensitivities
2. 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 1-65.

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 (hedgeslf)” on page 1-72.

Hedging with hedgeopt

To illustrate the hedging functions, consider the *delta*, *gamma*, and *vega* sensitivity measures. In the context of the Financial Derivatives Toolbox, 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. Note that the delta, gamma, and vega sensitivities calculated by the toolbox are dollar sensitivities. (See “Calculating Prices and Sensitivities” on page 1-61 for details.)

Note The numerical results in this section are displayed with 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. Load the 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])
```

```
       105.77       100.00      -299.72      1160.34        -0.00
       107.68        50.00      -395.81      1901.22        -0.28
         7.32       -50.00       -81.80       556.62        61.00
       105.77        80.00      -299.72      1160.34        -0.00
       100.58         8.00        -1.12         3.66            0
        15.44        30.00       108.48      -697.54       166.52
        15.39        40.00      -174.13       956.87       161.50
         5.19        10.00      -298.59      1156.68        -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 =
     -76355.34     305035.28       8391.37
```

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 =
     -76355.34     305035.28       8391.37

Cost =
             0

Quantity' =
        100.00
         50.00
        -50.00
         80.00
          8.00
         30.00
         40.00
         10.00
```

Note that our portfolio composition and sensitivities are unchanged and that 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 =
      25991.36

Value1 = Quantity * Price

Value1 =
      25991.36
```

Partially Hedged Portfolio

Building upon the previous example, suppose you want to know the cost to achieve an overall portfolio dollar sensitivity of `[-23000 -3300 3000]`, while

allowing trading only in instruments 2, 3, and 6 (holding the positions of instruments 1, 4, 5, 7, and 8 fixed.) To find the cost, first set the target portfolio dollar sensitivity.

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

Then, specify the instruments to be fixed.

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

Finally, call `hedgeopt`

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

and again examine the results

```
Sens =
     -23000.00      -3300.00       3000.00

Cost =
       8029.28

Quantity' =
        100.00
        -15.99
       -303.08
         80.00
          8.00
         90.22
         40.00
         10.00
```

Recompute `Value1`, the portfolio value after rebalancing.

```
Value1 = Quantity * Price

Value1 =
      17962.08
```

As expected, the cost, $8,029.28, is the difference between `Value0` and `Value1`, $25,991.36 - $17,962.08. Only the positions in instruments 2, 3, and 6 have been changed.

Fully Hedged Portfolio

The above example illustrates a partial hedge, but perhaps the most interesting case involves the cost associated with a fully-hedged portfolio (simultaneous delta, gamma, and vega neutrality). In this case, set the target sensitivity to a row vector of zeros and call `hedgeopt` again.

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

Examining the outputs, you obtain a fully-hedged portfolio

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

but at an expense of over $30,000,

```
Cost =
      30310.85
```

The positions needed to achieve a fully-hedged portfolio

```
Quantity' =
        100.00
       -227.78
        181.00
         80.00
          8.00
       -105.49
         40.00
         10.00
```

result in a negative portfolio value.

```
Value1 = Quantity * Price

Value1 =
      -4319.49
```

Minimizing Portfolio Sensitivities

The above examples illustrate how to use `hedgeopt` to determine the minimum cost of hedging a portfolio given a set of target sensitivities. In these examples, portfolio target sensitivities are treated as equality constraints during the

optimization process. You tell hedgeopt what sensitivities you want, and it tells you what it will cost to get those sensitivities.

A related problem involves minimizing portfolio sensitivities for a given set of maximum target costs. For this goal the target costs are treated as inequality constraints during the optimization process. You tell hedgeopt the most you are willing spend to insulate your portfolio, and it tells you the smallest portfolio sensitivities you can get for your money.

To illustrate this use of hedgeopt, compute the portfolio dollar sensitivities along the entire cost frontier. From the previous examples, you know that spending nothing simply replicates the existing portfolio, while spending $30,310.85 completely hedges the portfolio.

Assume, for example, you are willing to spend as much as $50,000, and want to see what portfolio sensitivities will result along the cost frontier. Assume the same instruments are held fixed, and that the cost frontier is evaluated from $0 to $50,000 at increments of $1000.

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

Now, call hedgeopt.

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

With this data, you can plot the required hedging cost versus the funds available (the amount you are willing to spend)

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

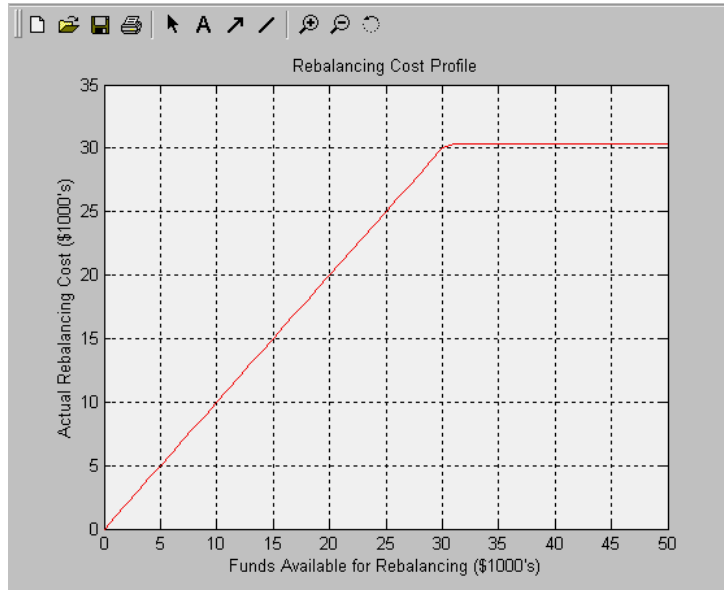


Figure 1-1: Rebalancing Cost Profile

and the portfolio dollar sensitivities versus the funds available

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

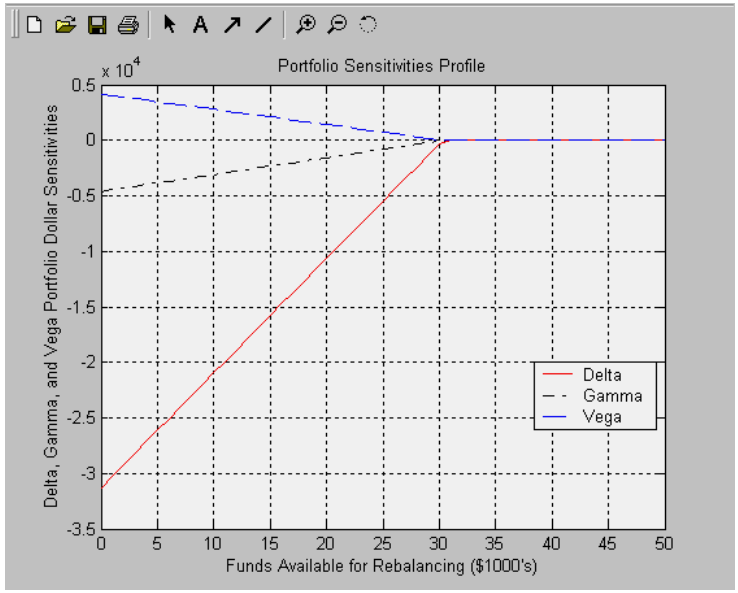


Figure 1-2: Funds Available for Rebalancing

Self Financing Hedges (hedgeslf)

Figure 1-1 and Figure 1-2 indicate that there is no benefit to be gained because the funds available for hedging exceed $30,310.85, 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 from `hedgeslf`.

```
[Sens, Value1, Quantity] = hedgeslf(Sensitivities, Price,...
Holdings, FixedInd);

Sens =
         -0.00
          0.00
          0.00
Value1 =
       -4319.49
```

```
Quantity =
        100.00
       -227.78
        181.00
         80.00
          8.00
       -105.49
         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 =
      30310.85
```

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 =
     -31259.69      -4609.41       4161.86
     -27786.39      -4097.25       3699.43
     -24313.09      -3585.09       3237.00
     -20839.79      -3072.94       2774.57
     -17366.49      -2560.78       2312.14
     -13893.19      -2048.63       1849.71
     -10419.90      -1536.47       1387.29
```

```
      -6946.60      -1024.31        924.86
      -3473.30       -512.16        462.43
         -0.00         -0.00         -0.00
Cost =
             0
       3367.87
       6735.74
      10103.62
      13471.49
      16839.36
      20207.23
      23575.10
      26942.98
      30310.85
```

Now plot this data.

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

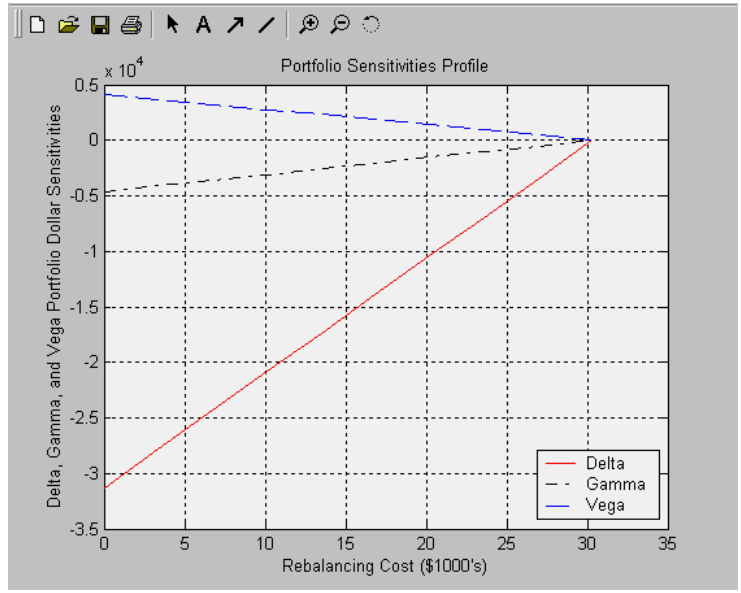


Figure 1-3: Rebalancing Cost

In this calling form, `hedgeopt` calls `hedgeslf` internally to determine the maximum cost needed to minimize the portfolio sensitivities ($30,310.85), and evenly samples the cost frontier between $0 and $30,310.85.

Note that both `hedgeopt` and `hedgeslf` cast the optimization problem as a constrained linear least-squares problem. Depending upon the instruments and constraints, neither function is guaranteed to converge to a solution. In some cases, the problem space may unbounded, and additional instrument equality constraints, or user-specified constraints, may be necessary for convergence. See “Hedging with Constrained Portfolios” on page 1-79 for additional information.

Specifying Constraints with ConSet

Both `hedgeopt` and `hedgeslf` accept an optional input argument, `ConSet`, that allows you to specify a set of linear inequality constraints for instruments in your portfolio. The examples in this section are quite brief. For additional information regarding portfolio constraint specifications, refer to the section “Analyzing Portfolios” found in the *Financial Toolbox User's Guide*.

For the first example of setting constraints, return to the fully-hedged portfolio example that used hedgeopt to determine the minimum cost of obtaining simultaneous delta, gamma, and vega neutrality (target sensitivities all zero). Recall that when hedgeopt computes the cost of rebalancing a portfolio, the input target sensitivities you specify are treated as equality constraints during the optimization process. The situation is reproduced below for convenience.

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

The outputs provide a fully-hedged portfolio

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

at an expense of over $30,000.

```
Cost =
      30310.85
```

The positions needed to achieve this fully-hedged portfolio are

```
Quantity' =
        100.00
       -227.78
        181.00
         80.00
          8.00
       -105.49
         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 +/- 200 contracts (for each instrument, you cannot short or long more than 200 contracts). Applying these constraints disallows the current position in the

second instrument (short 227.78). 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 = [-200 -200 -200 -200 -200 -200 -200 -200];
UpperBounds = [ 200  200  200  200  200  200  200  200];
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 =
      -3021.91
       -452.25
         74.17

Value1 =
      -1429.15

Quantity =
        100.00
       -200.00
        115.83
         80.00
          8.00
        -81.12
         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 =
       27420.51
```

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 =
     -10633.62      -1567.98       1415.74

Cost =
       20000.00

Quantity' =
          100.00
         -129.80
          -42.85
           80.00
            8.00
          -14.82
           40.00
           10.00
```

This result corresponds to the $20,000 point along the Portfolio Sensitivities Profile shown in Figure 1-3, Rebalancing Cost, on page 1-75.

Assume that, in addition to holding instruments 1, 4, 5, 7, and 8 fixed as before, you wish to bound the position of all instruments to within +/- 120 contracts (for

each instrument, you cannot short more than 120 contracts and you cannot long more than 120 contracts). These bounds disallow the current position in the second instrument (-129.80). 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 = [-120 -120 -120 -120 -120 -120 -120 -120];
UpperBounds = [ 120  120  120  120  120  120  120  120];
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 =
     -11724.04      -1754.57        287.75

Cost =
      19097.25

Quantity' =
        100.00
       -120.00
        -71.83
         80.00
          8.00
        -10.96
         40.00
         10.00
```

With these constraints `hedgeopt` enforces the lower bound for the second instrument. The cost incurred is $19,097.25.

Hedging with Constrained Portfolios

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

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

where *C*, *A*, and *Aeq* are matrices, and *d*, *b*, *beq*, *lb*, and *ub* are vectors. In all cases of interest 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. Depending upon the constraints and the number of assets in the portfolio, a solution to a particular problem may or may not exist. Furthermore, if a solution is found, the solution 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:

1. Minimize the cost of hedging a portfolio given a set of target sensitivities
2. 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 =
      30310.85
```

```
Quantity' =
        100.00
       -227.78
        181.00
         80.00
          8.00
       -105.49
         40.00
         10.00
```

This example finds a unique solution at a cost of just over $30,310. The matrix `C` (formed internally by `hedgeopt` and passed to `lsqlin`) is the asset `Price` vector expressed as a row vector.

```
C = Price' = [105.77 107.68 7.32 105.77 100.58 15.44 15.39 5.19]
```

The vector `d` is the current portfolio value `Value0 = 25991.36`. The example maintains, as closely as possible, a constant portfolio value subject to the specified constraints.

Additional Constraints. In the absence of any additional constraints, the least squares objective involves a single equation with eight unknowns. This is an under-determined system of equations. Because such systems generally have an infinite number of solutions, you need to specify additional constraints to achieve a solution with practical significance. The additional constraints can come from two sources:

- User-specified equality constraints
- Target sensitivity equality constraints imposed by `hedgeopt`

The fully-hedged portfolio example specifies five equality constraints associated with holding assets 1, 4, 5, 7, and 8 fixed. This reduces the number of unknowns from eight to three, which is still an under-determined system. However, when combined with the first goal of `hedgeopt`, the equality constraints associated with the target sensitivities in `TargetSens` produce an additional system of three equations with three unknowns. This additional system guarantees that the weighted average of the delta, gamma, and vega of assets 2, 3, and 6, together with the remaining assets held fixed, satisfy the overall portfolio target sensitivity requirements in `TargetSens`.

Combining the least squares objective equation with the three portfolio sensitivity equations provides an overall system of four equations with three

unknown asset holdings. This is no longer an under-determined system, and the solution is as shown.

If the assets held fixed are reduced, e.g., `FixedInd = [1 4 5 7]`, `hedgeopt` returns a no cost, fully-hedged portfolio (`Sens = [0 0 0]` and `Cost = 0`).

If you further reduce `FixedInd` (e.g., `[1 4 5]`, `[1 4]`, or even `[]`), `hedgeopt` always returns a no cost, fully-hedged portfolio. In these cases, insufficient constraints result in an under-determined system. Although `hedgeopt` identifies no cost, fully-hedged portfolios, there is nothing unique about them. These portfolios have little practical significance.

Constraints must be *sufficient* and *appropriately defined*. Additional constraints having no effect on the optimization are called *dependent constraints*. As a simple example, assume that parameter Z is constrained such that $Z \le 1$. 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 =
     -10633.62      -1567.98       1415.74

Cost =
      20000.00

Quantity' =
        100.00
       -129.80
        -42.85
         80.00
          8.00
        -14.82
```

```
    40.00
    10.00
```

This example corresponds to the $20,000 point along the cost axis in Figure 1-1, Figure 1-2, and Figure 1-3.

When minimizing sensitivities, the maximum target cost is treated as an inequality constraint; in this case, `MaxCost` is the most you are willing to spend to hedge a portfolio. The least squares objective matrix `C` is the matrix transpose of the input asset sensitivities

```
C = Sensitivities'
```

a 3-by-8 matrix in this example, and `d` is a 3-by-1 column vector of zeros, `[0 0 0]'`.

Without any additional constraints, the least squares objective results in an under-determined system of three equations with eight unknowns. By holding assets 1, 4, 5, 7, and 8 fixed, you reduce the number of unknowns from eight to three. Now, with a system of three equations with three unknowns, `hedgeopt` finds the solution shown.

Example: Under-Determined System

Reducing the number of assets held fixed creates an under-determined system with meaningless solutions. For example, see what happens with only four assets constrained.

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

[Sens, Cost, Quantity] = hedgeopt(Sensitivities, Price,...
Holdings, FixedInd, [], MaxCost)

Sens =
         -0.00          0.00          0.00

Cost =
      20000.00
```

```
Quantity' =
        100.00
       -126.00
         71.43
         80.00
          8.00
        -65.17
         40.00
        -80.25
```

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
       -422.13
        390.24
         80.00
          8.00
       -182.46
         40.00
        182.34
```

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`.

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.

2

Function Reference

Functions by Category

This chapter provides detailed descriptions of the functions in the Financial Derivatives Toolbox.

Table 2-1: Portfolio Hedge Allocation

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

Table 2-2: Fixed Income Pricing from Interest Term Structure

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

Table 2-3: Fixed Income Pricing and Sensitivity from Heath-Jarrow-Morton Tree

Function	Purpose
`hjmprice`	Fixed income instrument prices by HJM interest rate tree
`hjmsens`	Fixed income instrument price and sensitivities by HJM interest rate tree
`hjmtimespec`	Specify time structure for HJM interest rate tree
`hjmtree`	Construct HJM interest rate tree
`hjmvolspec`	Volatility process specification

Table 2-4: Heath-Jarrow-Morton Utilities

Function	Purpose
`bondbyhjm`	Price bond by HJM interest rate tree
`capbyhjm`	Price cap by HJM interest rate tree
`cfbyhjm`	Price arbitrary set of cash flows by HJM interest rate tree
`fixedbyhjm`	Price fixed rate note by HJM interest rate tree
`floatbyhjm`	Price floating rate note by HJM interest rate tree
`floorbyhjm`	Price floor by HJM interest rate tree
`mmktbyhjm`	Create money market tree
`optbndbyhjm`	Price bond option by HJM interest rate tree
`swapbyhjm`	Price swap by HJM interest rate tree

Table 2-5: Heath-Jarrow-Morton Bushy Tree Manipulation

Function	Purpose
`bushpath`	Extract entries from node of bushy tree
`bushshape`	Retrieve shape of bushy tree
`mkbush`	Create bushy tree
`treeviewer`	Display Heath-Jarrow-Morton (HJM) tree

Table 2-6: Heath-Jarrow-Morton Derivatives Pricing Options

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

Table 2-7: Instrument Portfolio Handling

Function	Purpose
`instadd`	Add types to instrument collection
`instaddfield`	Add new instruments to an instrument collection
`instbond`	Construct bond instrument
`instcap`	Construct cap instrument
`instcf`	Constructor for arbitrary cash flow instrument
`instdelete`	Complement of subset of instruments by matching conditions
`instdisp`	Display instruments

Table 2-7: Instrument Portfolio Handling (Continued)

Function	Purpose
instfields	List fieldnames
instfind	Search instruments for matching conditions
instfixed	Construct fixed-rate instrument
instfloat	Construct floating-rate instrument
instfloor	Construct floor instrument
instget	Retrieve data from instrument variable
instgetcell	Retrieve data and context from instrument variable
instlength	Count instruments
instoptbnd	Construct bond option
instselect	Create instrument subset by matching conditions
instsetfield	Add or reset data for existing instruments
instswap	Construct swap instrument
insttypes	List types

Table 2-8: Financial Object Structures

Function	Purpose
classfin	Create financial structure or return financial structure class name
isafin	True if financial structure type or financial object class

Table 2-9: Interest Term Structure

Function	Purpose
`date2time`	Fixed income time and frequency from dates
`disc2rate`	Interest rates from cash flow discounting factors
`intenvget`	Get properties of interest rate environment
`intenvset`	Set properties of interest rate environment
`rate2disc`	Discounting factors from interest rates
`ratetimes`	Change time intervals defining interest rate environment

Table 2-10: Date Functions

Function	Purpose
`datedisp`	Display date entries

Alphabetical List of Functions

Purpose

Price bond by HJM interest rate tree

Syntax

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

Arguments

`HJMTree`	Forward rate tree structure created by `hjmtree`.
`CouponRate`	Decimal annual rate.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are `1`, `2`, `3`, `4`, `6`, and `12`. Default = `2`.
`Basis`	(Optional) Day-count basis of the bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`EndMonthRule`	(Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. `0` = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. `1` = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
`IssueDate`	(Optional) Date when a bond was issued.
`FirstCouponDate`	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 will be 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 HJM tree. The bond argument `Settle` is ignored.

Description

`bondbyhjm` is a dynamic programming subroutine for `hjmprice`.

`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.

`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`. `HJMTree` 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 =

  107.6773
```

See Also

hjmtree, hjmprice, instbond

bondbyzero

Purpose

Price bond by a set of zero curves

Syntax

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

Arguments

`RateSpec`	A structure encapsulating the properties of an interest rate structure. See `intenvset` for information on creating `RateSpec`.
`CouponRate`	Decimal annual rate.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are `1`, `2`, `3`, `4`, `6`, and `12`. Default = `2`.
`Basis`	(Optional) Day-count basis of the bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`EndMonthRule`	(Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. `0` = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. `1` = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
`IssueDate`	(Optional) Date when a bond was issued.
`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

`LastCouponDate`	(Optional) Last coupon date of a bond prior to the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.
`StartDate`	Ignored.
`Face`	(Optional) Face value. Default is `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 =

  107.6912
```

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.

Example

Create an HJM tree by loading the example file.

```
load deriv.mat;
```

Then

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

returns the rates at the tree node located by taking the first branch, then the second branch, and finally the first branch again.

```
FwdRates =

    1.0200
    0.9276
    1.0405
    0.9648
```

See Also

`bushshape`, `mkbush`

bushshape

Purpose

Retrieve shape of bushy tree

Syntax

```
[NumLevels, NumChild, NumPos, NumStates, Trim] = bushshape(Tree)
```

Arguments

`Tree`	Bushy tree.

Description

`[NumLevels, NumChild, NumPos, NumStates, Trim] = bushshape(Tree)` returns information on a bushy tree's shape.

`NumLevels` is the number of time levels of the tree.

`NumChild` is a `1` by number of levels (`NUMLEVELS`) vector with the number of branches (children) of the nodes in each level.

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

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

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

Example

Create an HJM tree by loading the example file.

```
load deriv.mat;
```

Then

```
[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
```

Recreate the tree using the mkbush function:

```
Tree = mkbush(NumLevels, NumChild(1), NumPos(1), Trim);
Tree = mkbush(NumLevels, NumChild, NumPos);
```

See Also

bushpath, mkbush

capbyhjm

Purpose

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

Description

`[Price, PriceTree] = capbyhjm(HJMTree, Strike, Settle, Maturity, Reset, Basis, Principal, Options)` computes the price of a cap instrument from an HJM tree.

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

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

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

Examples

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

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

```
load deriv
```

Set the required values. Other arguments will use defaults.

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

Use capbyhjm to compute the Price of the cap instrument.

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

Price =

  15.4367
```

See Also

cfbyhjm, floorbyhjm, hjmtree, swapbyhjm

cfbyhjm

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 date of the corresponding cash flow in `CFlowAmounts`.
`Settle`	Settlement date. A vector of serial date numbers or date strings. The `Settle` date for every cash flow is set to the `ValuationDate` of the HJM tree. The cash flow argument, `Settle`, is ignored.
`Basis`	(Optional) Day-count basis of the bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

Description

`[Price, PriceTree] = cfbyhjm(HJMTree, CFlowAmounts, CFlowDates, Settle, Basis, Options)` prices cash flows from an HJM interest rate tree.

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

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

See Also

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

Purpose

Price cash flows by a set of zero curves

Syntax

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

Arguments

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

Description

`Price = cfbyzero(RateSpec, CFlowAmounts, CFlowDates, Settle, Basis)` computes `Price`, an `NINST`-by-`NUMCURVES` matrix of cash flows prices. Each column arises from one of the zero curves.

See Also

`bondbyzero`, `fixedbyzero`, `floatbyzero`, `swapbyzero`

classfin

Purpose

Create financial structure or return financial structure class name

Syntax

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

Arguments

`ClassName`	String containing name of financial structure class.
`Struct`	MATLAB structure to be converted into a financial structure.
`Obj`	Name of a financial structure.

Description

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

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

Examples

Example 1.

Create a `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-10-2000');
TimeSpec.Compounding = 2;
TimeSpec.Basis = 0;
TimeSpec.EndMonthRule = 1;
```

```
TimeSpec =

    FinObj: 'HJMTimeSpec'
```

Example 2.

Convert an existing MATLAB structure into a financial structure.

```
TSpec.ValuationDate = datenum('Dec-10-1999');
TSpec.Maturity = datenum('Dec-10-2000');
TSpec.Compounding = 2;
```

```
TSpec.Basis = 0;
TSpec.EndMonthRule = 0;

TimeSpec = classfin(TSpec, 'HJMTimeSpec')

TimeSpec =

    ValuationDate: 730464
         Maturity: 730830
      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

date2time

Purpose

Fixed income time and frequency from dates

Syntax

```
[Times, F] = date2time(Settle, Maturity, Compounding, Basis,
   EndMonthRule)
```

Arguments

`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.

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

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

`EndMonthRule`
(Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. `0` = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. `1` = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

Description

`[Times, F] = date2time(Settle, Dates, Compounding, Basis, EndMonthRule)` computes time factors appropriate to compounded rate quotes between `Settle` and `Maturity` dates.

`Times` is as vector of time factors.

`F` is a scalar of related compounding frequencies.

See Also

`cftimes` in the *Financial Toolbox User's Guide*

`disc2rate`, `rate2disc`

datedisp

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.

Example

```
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 User's Guide*

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'`, or `'ConstRate'`. 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'`.

Examples

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
```

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'`.

See Also

`derivset`

derivset

Purpose

Set or modify derivatives pricing options

Syntax

```
Options = derivset(Options, 'Parameter1', Value1, 'Parameter2',
   Value2,'Parameter3', Value3)
Options = derivset(OldOptions, NewOptions)
Options = derivset
derivset
```

Arguments

`Options`	(Optional) Existing options specification structure, probably created from previous call to `derivset`.
`Parameter`*n*	Must be `'Diagnostics'`, `'Warnings'`, or `'ConstRate'`. Parameters can be entered in any order. Parameter values can be `'on'` or `'off'`. `'Diagnostics' 'on'` generates diagnostic information. The default is `'Diagnostics' 'off'`. `'Warnings' 'on'` (default) displays a warning message when executing an HJM function. `'ConstRate' 'on'` (default) assumes a constant rate between tree nodes.
`OldOptions`	Existing options specification structure.
`NewOptions`	New options specification structure.

Description

`Options = derivset(Options, 'Parameter1', Value1, 'Parameter2', Value2,'Parameter3', Value3)` 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 HJM 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 HJM 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   ]
```

See Also

`derivget`

disc2rate

Purpose

Interest rates from cash flow discounting factors

Syntax

Usage 1: Interval points input as times in periodic units

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

Usage 2: `ValuationDate` passed and interval points 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 curve 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.

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

See Also

`rate2disc`, `ratetimes`

fixedbyhjm

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`	`NINST`-by-`1` vector representing the reset frequency per year. Default = `1`.
`Basis`	`NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	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)` is a dynamic programming subroutine for `hjmprice`.

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

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

`PriceTree.PBush` contains the clean prices.

`PriceTree.AIBush` contains the accrued interest.

`PriceTree.tObs` contains the observation times.

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

Examples

Price a 4% fixed rate note using an HJM forward rate tree.

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

```
load deriv
```

Set the required values. Other arguments will use defaults.

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

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

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

Price =

  105.7678
```

See Also

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

fixedbyzero

Purpose

Price fixed rate note by a set of zero curves

Syntax

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

Arguments

`RateSpec`	A structure encapsulating 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 settlements per year. Default = `1`.
`Basis`	(Optional) Day count basis. Default = `0` (actual/actual).
`Principal`	(Optional) The notional principal amount. Default = `100`.

All inputs are either scalars or `NINST`-by-`1` vectors unless otherwise specified. Any date may be a serial date number or date string. An optional argument may be passed as an empty matrix `[]`.

Description

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

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

Examples

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

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

```
load deriv
```

Set the required values. Other arguments will use defaults.

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

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

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

Price =

  105.7678
```

See Also

`bondbyzero`, `cfbyzero`, `floatbyzero`, `swapbyzero`

floatbyhjm

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

Description

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

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

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

`PriceTree.PBush` contains the clean prices.

`PriceTree.AIBush` contains the accrued interest.

PriceTree.tObs contains the observation times.

The Settle date for every floating rate note is set to the ValuationDate of the HJM tree. The floating rate note argument Settle is ignored.

Examples

Price a 20 basis point floating rate note using an HJM forward rate tree.

Load the file deriv.mat, which provides HJMTree. HJMTree 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 =

  100.5768
```

See Also

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

floatbyzero

Purpose

Price floating rate note prices by a set of zero curves

See Also

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

Arguments

`RateSpec`	A structure encapsulating 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 settlements per year. Default = `1`.
`Basis`	(Optional) Day count basis. Default = `0` (actual/actual).
`Principal`	(Optional) The notional principal amount. Default = `100`.

All inputs are either scalars or `NINST`-by-`1` vectors unless otherwise specified. Any date may be a serial date number or date string. An optional argument may be passed as an empty matrix `[]`.

Description

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

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

Examples

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

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

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
Spread = 20;
Settle = '01-Jan-2000';
Maturity = '01-Jan-2003';
```

Use `floatbyzero` to compute the `Price` of the note.

```
Price = floatbyzero(ZeroRateSpec, Spread, Settle, Maturity)

Price =

  100.5768
```

See Also

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

floorbyhjm

Purpose

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

Description

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

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

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

Examples

Price a 1% floor instrument using an HJM forward rate tree.

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

```
load deriv
```

Set the required values. Other arguments will use defaults.

```
Strike = 0.01;
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 =

  15.3938
```

See Also

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

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

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

3. Not all problems are solvable (e.g., the solution space may be infeasible or unbounded, or the solution may fail to converge). When a valid solution is not found, the corresponding rows of PortSens and PortHolds and the elements of PortCost are padded with NaN's as placeholders.

Description

[PortSens, PortCost, PortHolds] = hedgeopt(Sensitivities, Price, CurrentHolds, FixedInd, NumCosts, TargetCost, TargetSens, ConSet) allocates an optimal hedge by one of two criteria:

1. Minimize portfolio sensitivities (exposure) for a given set of target costs
2. Minimize the cost of hedging a portfolio given a set of target sensitivities.

Hedging involves the fundamental tradeoff between portfolio insurance and the cost of insurance coverage. This function allows investors to modify

portfolio allocations among instruments to achieve either of the criteria. The chosen criterion is inferred from the input argument list. The problem is cast as a constrained linear least-squares problem.

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

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

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

See Also

`hedgeslf`

`pcalims`, `portcons`, `portopt` in the *Financial Toolbox User's Guide*

`lsqlin` in the *Optimization Toolbox User's Guide*

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 will be 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 hedge possible is chosen.

PortValue is the total portfolio value (scalar). When a perfectly self-financing hedge exists, PortValue is equal to the value, 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 Unreachable.

```
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. Conflicting Constraints.

```
Sens = [0.44  0.32; 1.0 0.0]
Price = [1.2; 1.0]
W0 = [1; 1]
ConSet = pcalims([2 2])

% O.K. if nothing fixed.

[PortSens, PortValue, PortHolds]= hedgeslf(Sens, Price, W0,...
[], ConSet)

PortSens =

    2.8800
    0.6400

PortValue =

    4.4000

PortHolds =

     2
     2

% W0(1) is not greater than 2.

[PortSens, PortValue, PortHolds] = hedgeslf(Sens, Price, W0,...
1, ConSet)

??? Error using ==> hedgeslf
Overly restrictive allocation constraints implied by ConSet and
by fixing the weight of instruments(s): 1
```

Example 3. Impossible Constraints.

```
Sens = [0.44  0.32; 1.0 0.0]
Price = [1.2; 1.0]
W0 = [1; 1]
ConSet = pcalims([2 2],[1 1])

[PortSens, PortValue, PortHolds] = hedgeslf(Sens, Price, W0,...
[],ConSet)

??? Error using ==> hedgeslf
Overly restrictive allocation constraints specified in ConSet
```

See Also

`hedgeopt`

`lsqlin` in the *Optimization Toolbox User's Guide*

`portcons` in the *Financial Toolbox User's Guide*

Purpose

Fixed income instrument prices by HJM interest rate tree

Syntax

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

Arguments

`HJMTree`	Heath-Jarrow-Morton tree sampling a forward rate process. See `hjmtree` for information on creating `HJMTree`.
`InstSet`	Variable containing a collection of instruments. Instruments are categorized by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

Description

`Price = hjmprice(HJMTree, InstSet, Options)` computes arbitrage free prices for instruments using an interest rate tree created with `hjmtree`. `NINST` instruments from a financial instrument variable, `InstSet`, are priced.

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

`PriceTree` is a structure containing a bushy tree with `NINST`-by-`1` price vectors at every state.

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

See single-type pricing functions to retrieve state by state pricing tree information.

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

- optbndbyhjm: Price a bond option by an HJM tree.
- swapbyhjm: Price a swap by an HJM tree.

Example

Load the tree and instruments from a data file. 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 = hjmprice(HJMTree, HJMSubSet)

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

Price =

  105.7678
  107.6773
   15.4367
```

See Also

hjmsens, hjmtree, hjmvolspec, instadd, intenvprice, intenvsens

Purpose

Fixed income instrument prices and sensitivities by 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.

Example

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 =

 -299.7172
 -395.8132
  108.4780
```

```
Gamma =

  1.0e+003 *

    1.1603
    1.9012
   -0.6975
```

See Also

hjmprice, hjmtree, hjmvolspec, instadd

hjmtimespec

Purpose

Specify time structure for HJM interest rate tree

Syntax

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

Arguments

`ValuationDate` — Scalar date marking the pricing date and first observation in the tree. Specify as serial date number or date string

`Maturity` — Number of levels (depth) of the tree. A number of levels (`NLEVELS`)-by-`1` vector of dates marking the cash flow dates of the tree. Cash flows with these maturities fall on tree nodes. Maturity should be in increasing order.

`Compounding` — (Optional) Scalar value representing the rate at which the input zero rates were compounded when annualized. Default = `1`. This argument determines the formula for the discount factors:

`Compounding` = `1`, `2`, `3`, `4`, `6`, `12`
`Disc = (1 + Z/F)^(-T)`, where `F` is the compounding frequency, `Z` is the zero rate, and `T` is the time in periodic units, e.g. `T = F` is one year.

`Compounding` = `365`
`Disc = (1 + Z/F)^(-T)`, where `F` is the number of days in the basis year and `T` is a number of days elapsed computed by basis.

`Compounding` = `-1`
`Disc = exp(-T*Z)`, where `T` is time in years.

Description

`TimeSpec = hjmtimespec(ValuationDate, Maturity, Compounding)` sets the number of levels and node times for an HJM tree and determines the mapping between dates and time for rate quoting.

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

Example

Specify an eight period tree with semiannual nodes (every six months). Use exponential compounding to report rates.

```
Compounding = -1
ValuationDate = '15-Jan-1999'
Maturity = datemnth(ValuationDate, 6*(1:8)')
TimeSpec = hjmtimespec(ValuationDate, Maturity, Compounding)

TimeSpec =

           FinObj: 'HJMTimeSpec'
    ValuationDate: 730135
         Maturity: [8x1 double]
      Compounding: -1
            Basis: 0
     EndMonthRule: 1
```

See Also

hjmtree, hjmvolspec

hjmtree

Purpose

Build an HJM forward rate tree

Syntax

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

Arguments

`VolSpec`	Volatility process specification. Sets the number of factors and the rules for computing the volatility `sigma(t,T)` for each factor. See `hjmvolspec` for information on the volatility process.
`RateSpec`	Interest rate specification for the initial rate curve. See `intenvset` for information on declaring an interest rate variable.
`TimeSpec`	Tree time layout specification. Defines the observation dates of the HJM tree and the `Compounding` rule for date to time mapping and price-yield formulas. See `hjmtimespec` for information on the tree structure.

Description

`HJMTree = hjmtree(VolSpec, RateSpec, TimeSpec)` creates a structure containing time and forward rate information on a bushy tree.

See Also

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

Purpose

Specify an HJM forward rate volatility process

Syntax

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

Arguments

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

`Sigma_0` is the scalar base volatility over a unit time.

`Lambda` is the scalar decay factor.

`CurveVol` is a number of curves (`NCURVE`) -by-`1` vector of `Vol` values at sample points.

`CurveDecay` is an `NCURVE`-by-`1` vector of `Decay` values at sample points.

`CurveProp` is an `NCURVE`-by-`1` vector of `Prop` values at sample points.

`CurveTerm` is an `NCURVE`-by-`1` vector of term sample points `T-t`.

The time values `T`, `t`, and `Term` are in coupon interval units specified by the `Compounding` input of `hjmtimespec`. For instance if `Compounding` is `2`, `Term = 1` is a semiannual period (six months).

Description

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

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)
```

`VolSpec` is a structure specifying the volatility model for `hjmtree`.

Example

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]
```

Two-factor exponential and constant

```
VolSpec = hjmvolspec('Exponential', 0.1, 1, 'Constant', 0.2)
```

```
VolSpec =
          FinObj: 'HJMVolSpec'
    FactorModels: {'Exponential'  'Constant'}
      FactorArgs: {{1x2 cell}  {1x1 cell}}
      SigmaShift: 0
      NumFactors: 2
       NumBranch: 3
         PBranch: [0.2500 0.2500 0.5000]
     Fact2Branch: [2x3 double]
```

See Also

`hjmtimespec`, `hjmtree`

Purpose

Add types to instrument collection

Syntax

Bond instrument. (See also `instbond`.)

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

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

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

Bond option. (See also `instoptbnd`.)

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

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 )
```

Cap instrument. (See also `instcap`.)

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

Floor instrument. (See also `instfloor`.)

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

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, ...)
```

instadd

Arguments

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

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

Description

`instadd` stores instruments of types `'Bond'`, `'CashFlow'`, `'OptBond'`, `'Fixed'`, `'Float'`, `'Cap'`, `'Floor'`, or `'Swap'`. Pricing and sensitivity routines are provided for these instruments.

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

Example

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

`instbond`, `instcap`, `instcf`, `instfixed`, `instfloat`, `instfloor`, `instoptbnd`, `instswap`

Purpose

Add new instruments to an instrument collection

Syntax

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

Arguments

`FieldList`	String or number of fields (`NFIELDS`)-by-`1` cell array of strings listing the name of each data field. `FieldList` cannot be named with the reserved names `Type` or `Index`.
`DataList`	Number of instruments (`NINST`)-by-`M` array or `NFIELDS`-by-`1` cell array of data contents for each field. Each row in a data array corresponds to a separate instrument. Single rows are copied to apply to all instruments to be worked on. The number of columns is arbitrary, and data will be 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` will be parsed. Valid strings are `'dble'`, `'date'`, and `'char'`. The `'FieldClass', ClassList` pair is always optional. `ClassList` will be inferred from existing fieldnames or from the data if not entered.
`TypeString`	String specifying the type of instrument added. Instruments of different types can have different fieldname collections.
`InstSet`	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.

instaddfield

Description

Use `instaddfield` to create your own types of instruments or to append new instruments to an existing collection. Argument value pairs can be entered in any order.

`InstSet = instaddfield('FieldName', FieldList, 'Data', DataList, 'Type', TypeString)` and
`InstSet = instaddfield('FieldName', FieldList, 'FieldClass', ClassList, 'Data', DataList, 'Type', TypeString)` create an instrument variable.

`InstSetNew = instaddfield(InstSet, 'FieldName', FieldList, 'Data', DataList,'Type',TypeString)` adds instruments to an existing instrument set, `InstSet`. The output `InstSetNew` is a new instrument set containing the input data.

Examples

Build a portfolio around July options.

```
Strike  Call    Put
 95     12.2    2.9
100      9.2    4.9
105      6.8    7.4

Strike = (95:5:105)'
CallP = [12.2; 9.2; 6.8]
```

Enter three call options with data fields `Strike`, `Price`, and `Opt`.

```
InstSet = instaddfield('Type','Option','FieldName',...
{'Strike','Price','Opt'}, 'Data',{ Strike, CallP, 'Call'});
 instdisp(InstSet)

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

Add a futures contract and set the input parsing class.

```
InstSet = instaddfield(InstSet,'Type','Futures',...
'FieldName',{'Delivery','F'},'FieldClass',{'date','dble'},...
'Data' ,{'01-Jul-99',104.4 });
instdisp(InstSet)
```

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

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

Add a put option.

```
FN = instfields(InstSet,'Type','Option')
InstSet = instaddfield(InstSet,'Type','Option',...
'FieldName',FN, 'Data',{105, 7.4, 'Put'});
instdisp(InstSet)

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

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

Index Type   Strike Price Opt
5     Option 105     7.4  Put
```

Make a placeholder for another put.

```
InstSet = instaddfield(InstSet,'Type','Option',...
'FieldName','Opt','Data','Put')
instdisp(InstSet)

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

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

```
Index Type   Strike Price Opt
5     Option 105     7.4  Put
6     Option NaN     NaN  Put
```

Add a cash instrument.

```
InstSet = instaddfield(InstSet, 'Type', 'TBill',
'FieldName','Price','Data',99)
instdisp(InstSet)

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

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

Index Type   Strike Price Opt
5     Option 105     7.4  Put
6     Option NaN     NaN  Put

Index Type  Price
7     TBill 99
```

See Also

`instdisp`, `instget`, `instgetcell`, `instsetfield`

Purpose

Construct bond instrument

Syntax

```
InstSet = instbond(InstSet, CouponRate, Settle, Maturity, Period,
   Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate,
   StartDate, Face)
[FieldList, ClassList, TypeString] = instbond
```

Arguments

`InstSet`	Instrument variable. This argument is specified only when adding bond instruments to an existing instrument set. See `instget` for more information on the `InstSet` variable.
`CouponRate`	Decimal number indicating the annual percentage rate used to determine the coupons payable on a bond.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are `1`, `2`, `3`, `4`, `6`, and `12`. Default = `2`.
`Basis`	(Optional) Day-count basis of the bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`EndMonthRule`	(Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. `0` = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. `1` = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
`IssueDate`	(Optional) Date when a bond was issued.

`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.
`LastCouponDate`	(Optional) Last coupon date of a bond prior to the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be 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 will be 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 reset frequency per year. Default = `1`.
`Basis`	(Optional) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) The notional principal amount. Default = `100`.

Description

`InstSet = instcap(InstSet, Strike, Settle, Maturity, Reset, Basis, Principal)` creates a new instrument set containing cap instruments or adds cap instruments to an existing instrument set.

`[FieldList, ClassList, TypeString] = instcap` displays the classes.

`FieldList` is a number of fields (`NFIELDS`)-by-`1` cell array of strings listing the name of each data field for this instrument type.

`ClassList` is an `NFIELDS`-by-`1` cell array of strings listing the data class of each field. The class determines how arguments will be 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 bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.

Only one data argument is required to create an instrument. Other arguments can be omitted or passed as empty matrices `[]`. Dates can be input as serial date numbers or date strings.

Description

`InstSet = instcf(InstSet, CFlowAmounts, CFlowDates, Settle, Basis)` creates a new instrument set from data arrays or adds instruments of type `CashFlow` to an instrument set.

`[FieldList, ClassList, TypeString] = instcf` lists field meta-data for an instrument of type `CashFlow`.

`FieldList` is a number of fields (`NFIELDS`)-by-`1` cell array of strings listing the name of each data field for this instrument type.

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

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

See Also

hjmprice, instaddfield, instdisp, instget, intenvprice

Purpose

Complement of a subset of instruments found by matching conditions

Syntax

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

Arguments

`InstSet`	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
`FieldList`	String or number of fields (`NFIELDS`)-by-`1` cell array of strings listing the name of each data field to match with data values.
`DataList`	Number of values (`NVALUES`)-by-`M` array or `NFIELDS`-by-`1` cell array of acceptable data values for each field. Each row lists a data row value to search for in the corresponding `FieldList`. The number of columns is arbitrary and matching will ignore trailing `NaN`s or spaces.
`IndexSet`	(Optional) Number of instruments (`NINST`)-by-`1` vector restricting positions of instruments to check for matches. The default is all indices available in the instrument variable.
`TypeList`	(Optional) String or number of types (`NTYPES`)-by-`1` cell array of strings restricting instruments to match one of `TypeList` types. The default is all types in the instrument variable.

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

Description

The output argument `ISubSet` contains instruments *not* matching the input criteria. Instruments are deleted from `ISubSet` if all the `Field`, `Index`, and `Type` conditions are met. An instrument meets an individual `Field` condition if the stored `FieldName` data matches any of the rows listed in the `DataList` for that `FieldName`. See `instfind` for more examples on matching criteria.

Example

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.

Example

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 User's Guide*

`num2str` in the online MATLAB reference

`instaddfield`, `instget`

Purpose

List fields

Syntax

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

Arguments

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

Description

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

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

Example

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.

Example

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, CouponRate, Settle, Maturity, Reset,
   Basis, Principal)
[FieldList, ClassList, TypeString] = instfixed
```

Arguments

`InstSet`	Instrument variable. This argument is specified only when adding fixed rate note instruments to an existing instrument set. See `instget` for more information on the `InstSet` variable.
`CouponRate`	Decimal annual rate.
`Settle`	Settlement date. Date string or serial date number representing the settlement date of the fixed rate note.
`Maturity`	Date string or serial date number representing the maturity date of the fixed rate note.
`Reset`	(Optional) `NINST`-by-`1` vector representing the reset frequency per year. Default = `1`.
`Basis`	(Optional) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) The notional principal amount. Default = `100`.

Data arguments are number of instruments (`NINST`)-by-`1` vectors, scalar, or empty. Fill unspecified entries in vectors with `NaN`. Only one data argument is required to create the instrument. The others may be omitted or passed as empty matrices `[]`.

Description

`InstSet = instfixed(InstSet, Strike, Settle, Maturity, Reset, Basis, Principal)` creates a new instrument set containing fixed rate instruments or adds fixed rate instruments to an existing instrument set.

`[FieldList, ClassList, TypeString] = instfixed` displays the classes.

`FieldList` is a number of fields (`NFIELDS`)-by-`1` cell array of strings listing the name of each data field for this instrument type.

ClassList is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments will be 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 reset frequency per year. Default = `1`.
`Basis`	(Optional) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) The notional principal amount. Default = `100`.

Data arguments are number of instruments (`NINST`)-by-`1` vectors, scalar, or empty. Fill unspecified entries in vectors with `NaN`. Only one data argument is required to create the instrument. The others may be omitted or passed as empty matrices `[]`.

Description

`InstSet = instfloat(InstSet, Spread, Settle, Maturity, Reset, Basis, Principal)` creates a new instrument set containing floating rate instruments or adds floating rate instruments to an existing instrument set.

`[FieldList, ClassList, TypeString] = instfloat` displays the classes.

`FieldList` is a number of fields (`NFIELDS`)-by-`1` cell array of strings listing the name of each data field for this instrument type.

ClassList is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments will be 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 reset frequency per year. Default = `1`.
`Basis`	(Optional) Day-count basis of the bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`Principal`	(Optional) The notional principal amount. Default = `100`.

Description

`InstSet = instfloor(InstSet, Strike, Settle, Maturity, Reset, Basis, Principal)` creates a new instrument set containing floor instruments or adds floor instruments to an existing instrument set.

`[FieldList, ClassList, TypeString] = instfloor` displays the classes.

`FieldList` is a number of fields (`NFIELDS`)-by-`1` cell array of strings listing the name of each data field for this instrument type.

ClassList is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments will be 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

Retrieve data from instrument variable

Syntax

```
[Data_1, Data_2,...,Data_n] = instget(InstSet, 'FieldName',
  FieldList,  'Index', IndexSet, 'Type', TypeList)
```

Arguments

`InstSet`	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
`FieldList`	(Optional) String or number of fields (`NFIELDS`)-by-`1` cell array of strings listing the name of each data field to match with data values. `FieldList` entries can also be either `'Type'` or `'Index'`; these return type strings and index numbers respectively. The default is all fields available for the returned set of instruments.
`IndexSet`	(Optional) Number of instruments (`NINST`)-by-`1` vector of positions of instruments to work on. If `TypeList` is also entered, instruments referenced must be one of `TypeList` types and contained in `IndexSet`. The default is all indices available in the instrument variable.
`TypeList`	(Optional) String or number of types (`NTYPES`)-by-`1` cell array of strings restricting instruments to match one of `TypeList` types. The default is all types in the instrument variable.

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

Description

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

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

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

Examples

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

```
load InstSetExamples;
instdisp(ExampleInst)

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

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

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

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

Extract the price from all instruments.

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

P =

   12.2000
    9.2000
    6.8000
       NaN
    7.4000
    2.9000
   99.0000
```

Get all the prices and the number of contracts held.

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

```
P =

   12.2000
    9.2000
    6.8000
       Nan
    7.4000
    2.9000
   99.0000

C =

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

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

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

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

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

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

Index Type Price Maturity       Contracts Value
```

```
7     TBill 99    01-Jul-1999   6         594
```

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

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

Ind =

     3
     4
     5
     7
```

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

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

T =

Option
Futures
Option
TBill

O =

Call

Put
```

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

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

rstring =

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

See Also `instaddfield`, `instdisp`, `instgetcell`

instgetcell

Purpose

Retrieve data and context from instrument variable

Syntax

```
[DataList, FieldList, ClassList, IndexSet, TypeSet] =
  instgetcell(InstSet, 'FieldName', FieldList,  'Index', IndexSet,
  'Type', TypeList)
```

Arguments

`InstSet`	Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.
`FieldList`	(Optional) String or number of fields (`NFIELDS`)-by-`1` cell array of strings listing the name of each data field to match with data values. FieldList should not be either `Type` or `Index`; these field names are reserved. The default is all fields available for the returned set of instruments.
`IndexSet`	(Optional) Number of instruments (`NINST`)-by-`1` vector of positions of instruments to work on. If `TypeList` is also entered, instruments referenced must be one of `TypeList` types and contained in `IndexSet`. The default is all indices available in the instrument variable.
`TypeList`	(Optional) String or number of types (`NTYPES`)-by-`1` cell array of strings restricting instruments to match one of `TypeList` types. The default is all types in the instrument variable.

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

Description

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

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

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

ClassList is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments will be 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.

Example

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

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`

instoptbnd

Purpose

Construct bond option

Syntax

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

Arguments

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

`BondIndex` Number of instruments (`NINST`)-by-`1` vector of indices pointing to underlying instruments of Type `'Bond'` which are also stored in `InstSet`. See `instbond` for information on specifying the bond data.

`OptSpec` `NINST`-by-`1` list of string values `'Call'` or `'Put'`.

The interpretation of the `Strike` and `ExerciseDates` arguments depends upon the setting of the `AmericanOpt` argument. If `AmericanOpt = 0`, `NaN`, or is unspecified, the option is a European or Bermuda option. If `AmericanOpt = 1`, the option is an American option.

`Strike` For a European or 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` For a European or Bermuda option:
`NINST`-by-`NSTRIKES` matrix of exercise dates. Each row is the schedule for one option. For a European option, there is only one 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` 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 will be 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`, `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.

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

Description

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

`InstSubSet` is a variable containing instruments matching the input criteria. Instruments are returned in `InstSubSet` if all the `Field`, `Index`, and `Type`

conditions are met. An instrument meets an individual `Field` condition if the stored `FieldName` data matches any of the rows listed in the `DataList` for that `FieldName`. See `instfind` for examples on matching criteria.

Example

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

```
load InstSetExamples
instdisp(ExampleInst)

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

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

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

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

Make a new portfolio containing only options struck at 95.

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

instdisp(Opt95)

Opt95 =

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

Make a new portfolio containing only futures and Treasury bills.

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

instdisp(FutTBill) =

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

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

See Also instaddfield, instdelete, instfind, instget, instgetcell

Purpose

Add or reset data for existing instruments

Syntax

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

Arguments

`InstSet`	(Required) Variable containing a collection of instruments. Instruments are classified by type; each type can have different data fields. The stored data field is a row vector or string for each instrument. `InstSet` must be the first argument in the list.
`FieldList`	String or number of fields (`NFIELDS`)-by-`1` cell array of strings listing the name of each data field. `FieldList` cannot be named with the reserved names `Type` or `Index`.
`DataList`	Number of instruments (`NINST`)-by-`M` array or `NFIELDS`-by-`1` cell array of data contents for each field. Each row in a data array corresponds to a separate instrument. Single rows are copied to apply to all instruments to be worked on. The number of columns is arbitrary, and data will be padded along columns.
`IndexSet`	`NINST`-by-`1` vector of positions of instruments to work on. If `TypeList` is also entered, instruments referenced must be one of `TypeList` types and contained in `IndexSet`.
`TypeList`	String or number of types (`NTYPES`)-by-`1` cell array of strings restricting instruments worked on to match one of `TypeList` types.

Argument value pairs can be entered in any order.

Description

`instsetfield` sets data for existing instruments in a collection variable.

`InstSet = instsetfield(InstSet, 'FieldName', FieldList, 'Data', DataList)` resets or adds fields to every instrument.

instsetfield

`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.

Example

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) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) `NINST`-by-`1` vector of the notional principal amounts. Default = `100`.
`LegType`	(Optional) `NINST`-by-`2` matrix. Each row represents an instrument. Each column indicates if the corresponding leg is fixed (`1`) or floating (`0`). This matrix defines the interpretation of the values entered in `LegRate`. Default is `[1,0]` for each instrument.

Data arguments are number of instruments (NINST)-by-1 vectors, scalar, or empty. Fill unspecified entries in vectors with NaN. Only one data argument is required to create the instrument; the others may be omitted or passed as empty matrices [].

Description

`InstSet = instswap(InstSet, LegRate, Settle, Maturity, LegReset, Basis, Principal, LegType)` creates a new instrument set containing swap instruments or adds swap instruments to an existing instrument set.

`[FieldList, ClassList, TypeString] = instswap` displays the classes.

`FieldList` is a number of fields (NFIELDS)-by-1 cell array of strings listing the name of each data field for this instrument type.

`ClassList` is an NFIELDS-by-1 cell array of strings listing the data class of each field. The class determines how arguments will be 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.

Example

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
```

insttypes

List all of the types included in `ExampleInst`.

```
TypeList = insttypes(ExampleInst)
TypeList =
         'Futures'
         'Option'
         'TBill'
```

See Also

`instdisp`, `instfields`, `instlength`

Purpose

Obtain properties of an interest term structure

Syntax

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

Arguments

`RateSpec`	A structure encapsulating 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`.

Example

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 fixed income instruments by a set of zero curves

Syntax

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

Arguments

`RateSpec`	A structure encapsulating the properties of an interest rate structure. See `intenvset` for information on creating `RateSpec`.
`InstSet`	Variable containing a collection of instruments. Instruments are categorized by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.

Description

`Price = intenvprice(RateSpec, InstSet)` computes arbitrage free prices for instruments against a set of zero coupon bond rate curves.

`Price` is a number of instruments (`NINST`) by number of curves (`NUMCURVES`) matrix of prices of each instrument. If an instrument cannot be priced, a `NaN` is returned in that entry.

`intenvprice` handles the following instrument types: `'Bond'`, `'CashFlow'`, `'Fixed'`, `'Float'`, `'Swap'`. See `instadd` for information about constructing defined types.

See single-type pricing functions to retrieve pricing information.

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

Example

Load the zero curves and instruments from a data file.

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

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

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

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

Index Type LegRate    Settle       Maturity     LegReset Basis Principal LegType Name         Quantity
5     Swap 0.04       01-Jan-2000  01-Jan-2003  1  1     NaN   NaN       NaN     4%/20BP Swap 10
```

```
Price = intenvprice(ZeroRateSpec, ZeroInstSet)

Price =

  105.7678
  107.6912
  105.7678
  100.5768
    5.1910
```

See Also hjmprice, hjmsens, instadd, intenvsens, intenvset,

Purpose

Instrument price and sensitivities by a set of zero curves

Syntax

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

Arguments

`RateSpec`	A structure encapsulating the properties of an interest rate structure. See `intenvset` for information on creating `RateSpec`.
`InstSet`	Variable containing a collection of instruments. Instruments are categorized by type; each type can have different data fields. The stored data field is a row vector or string for each instrument.

Description

`[Delta, Gamma, Price] = intenvsens(RateSpec, InstSet)` computes dollar prices and price sensitivities for instruments using a zero coupon bond rate term structure.

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

`Gamma` is an `NINST`-by-`NUMCURVES` matrix of gammas, representing the rate of change of instrument deltas with respect to shifts in the observed forward yield curve. `Gamma` is computed by finite differences.

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

`Price` is an `NINST`-by-`NUMCURVES` matrix of prices of each instrument. If an instrument cannot be priced, a `NaN` is returned.

`intenvsens` handles the following instrument types: `'Bond'`, `'CashFlow'`, `'Fixed'`, `'Float'`, `'Swap'`. See `instadd` for information about constructing defined types.

Example

Load the tree and instruments from a data file.

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

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

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

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

Index Type LegRate    Settle       Maturity     LegReset Basis Principal LegType Name         Quantity
5     Swap 0.04       01-Jan-2000  01-Jan-2003  1  1     NaN   NaN       NaN     4%/20BP Swap 10
```

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

Delta =

 -299.7172
 -395.8516
 -299.7172
   -1.1237
 -298.5935

Gamma =

  1.0e+003 *

    1.1603
    1.9014
    1.1603
    0.0037
    1.1567
```

See Also hjmprice, hjmsens, instadd, intenvprice, intenvset

Purpose

Set properties of interest rate environment

Syntax

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

Arguments

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

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

`Compounding` Scalar value representing the rate at which the input zero rates were compounded when annualized. Default = 2. This argument determines the formula for the discount factors:

`Compounding` = 1, 2, 3, 4, 6, 12
`Disc = (1 + Z/F)^(-T)`, where `F` is the compounding frequency, `Z` is the zero rate, and `T` is the time in periodic units, e.g. `T = F` is one year.

`Compounding` = 365
`Disc = (1 + Z/F)^(-T)`, where `F` is the number of days in the basis year and `T` is a number of days elapsed computed by basis.

`Compounding` = -1
`Disc = exp(-T*Z)`, where `T` is time in years.

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

`Rates` Number of points (`NPOINTS`) by number of curves (`NCURVES`) matrix of rates in decimal form. For example, 5% is 0.05 in `Rates`. `Rates` are the yields over investment intervals from `StartDates`, when the cash flow is valued, to `EndDates`, when the cash flow is received.

`EndDates`	`NPOINTS`-by-`1` vector or scalar of serial maturity dates ending the interval to discount over.
`StartDates`	`NPOINTS`-by-`1` vector or scalar of serial dates starting the interval to discount over. Default = `ValuationDate`.
`ValuationDate`	(Optional) Scalar value in serial date number form representing the observation date of the investment horizons entered in `StartDates` and `EndDates`. Default = `min(StartDates)`.
`Basis`	(Optional) Day-count basis of the bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`EndMonthRule`	(Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. `0` = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. `1` = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

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

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

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

Description

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

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

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

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

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

Example

Use intenvset to create a RateSpec.

```
RateSpec = intenvset('Rates', 0.05, 'StartDates',...
'20-Jan-2000', 'EndDates', '20-Jan-2001')

RateSpec =

           FinObj: 'RateSpec'
      Compounding: 2
             Disc: 0.9518
            Rates: 0.0500
         EndTimes: 2
       StartTimes: 0
         EndDates: 730871
       StartDates: 730505
    ValuationDate: 730505
            Basis: 0
     EndMonthRule: 1
```

Now change the Compounding parameter to 1 (annual).

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


RateSpec =

           FinObj: 'RateSpec'
      Compounding: 1
```

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

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

```
intenvset
```

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

See Also

`intenvget`

Purpose

True if financial structure type or financial object class

Syntax

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

Arguments

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

Description

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

Example

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

```
IsFinObj =

     1
```

See Also

`classfin`

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

Description

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

Example

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)
```

See Also

`bushpath`, `bushshape`

Purpose

Create money market tree

Syntax

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

Arguments

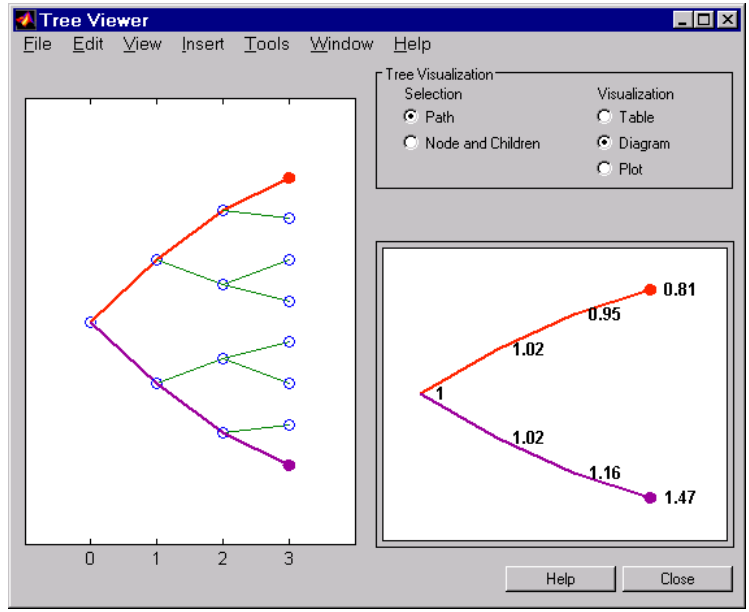
`HJMTree`	Forward rate tree structure created by `hjmtree`.

Description

`MMktTree = mmktbyhjm(HJMTree)` creates a money market tree from a forward rate tree structure created by `hjmtree`.

Example

```
load deriv.mat;
MMktTree = mmktbyhjm(HJMTree);
treeviewer(MMktTree)
```



See Also

`hjmtree`

optbndbyhjm

Purpose

Price bond option by 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`	For a European or 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`	For a European or Bermuda option: `NINST`-by-`NSTRIKES` matrix of exercise dates. Each row is the schedule for one option. A European option has only one exercise date, the option expiry date. For an American option: `NINST`-by-`2` vector of exercise date boundaries. For each instrument, the option can be exercised on any coupon date between or including the pair of dates on that row. If only one non-`NaN` date is listed, or if `ExerciseDates` is `NINST`-by-`1`, the option can be exercised between the underlying bond `Settle` and the single listed exercise date.
`AmericanOpt`	`NINST`-by-`1` vector of flags: `0` (European/Bermuda) or `1` (American)
`CouponRate`	Decimal annual rate.

`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are `1`, `2`, `3`, `4`, `6`, and `12`. Default = `2`.
`Basis`	(Optional) Day-count basis of the bond. A vector of integers. `0` = actual/actual (default), `1` = 30/360, `2` = actual/360, `3` = actual/365.
`EndMonthRule`	(Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. `0` = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. `1` = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
`IssueDate`	(Optional) Date when a bond was issued.
`FirstCouponDate`	Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.
`LastCouponDate`	Last coupon date of a bond prior to the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be 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 HJM tree. The bond argument Settle is ignored.

Description

optbondbyhjm is a dynamic programming subroutine for hjmprice.

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 101. The exercise date for the option is Jan. 01, 2003. The settle date for the bond is Jan. 01, 2000, and the maturity date is Jan. 01, 2004.

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

```
load deriv
```

Use optbondbyhjm to compute the Price of the option.

```
Price = optbndbyhjm(HJMTree,'Call','101','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 =

    7.3217
```

See Also

hjmprice, hjmtree, instoptbnd

Purpose

Discounting factors from interest rates

Syntax

Usage 1: Interval points input as times in periodic units

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

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

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

Arguments

`Compounding` — Scalar value representing the rate at which the input zero rates were compounded when annualized. This argument determines the formula for the discount factors:

`Compounding` = `1`, `2`, `3`, `4`, `6`, `12`
`Disc = (1 + Z/F)^(-T)`, where `F` is the compounding frequency, `Z` is the zero rate, and `T` is the time in periodic units, e.g. `T = F` is one year.

`Compounding` = `365`
`Disc = (1 + Z/F)^(-T)`, where `F` is the number of days in the basis year and `T` is a number of days elapsed computed by basis.

`Compounding` = `-1`
`Disc = exp(-T*Z)`, where `T` is time in years.

`Rates` — Number of points (`NPOINTS`) by number of curves (`NCURVES`) matrix of rates in decimal form. For example, 5% is 0.05 in `Rates`. `Rates` are the yields over investment intervals from `StartTimes`, when the cash flow is valued, to `EndTimes`, when the cash flow is received.

`EndTimes` — `NPOINTS`-by-`1` vector or scalar of times in periodic units ending the interval to discount over.

`StartTimes` — (Optional) `NPOINTS`-by-`1` vector or scalar of times in periodic units starting the interval to discount over. Default = `0`.

EndDates	NPOINTS-by-1 vector or scalar of serial maturity dates ending the interval to discount over.
StartDates	(Optional) NPOINTS-by-1 vector or scalar of serial dates starting the interval to discount over. Default = ValuationDate.
ValuationDate	Scalar value in serial date number form representing the observation date of the investment horizons entered in StartDates and EndDates. Required in Usage 2. Omitted or passed as an empty matrix to invoke Usage 1.

Description

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

`[Disc, EndTimes, StartTimes] = rate2disc(Compounding, Rates, EndDates, StartDates, ValuationDate)` convert interest rates to cash flow discounting factors. `rate2disc` computes the discounts over a series of `NPOINTS` time intervals given the annualized yield over those intervals. `NCURVES` different rate curves can be translated at once if they have the same time structure. The time intervals can represent a zero curve or a forward curve.

`Disc` is an `NPOINTS`-by-`NCURVES` column vector of discount factors in decimal form representing the value at time `StartTime` of a unit cash flow received at time `EndTime`.

`StartTimes` is an `NPOINTS`-by-1 column vector of times starting the interval to discount over, measured in periodic units.

`EndTimes` is an `NPOINTS`-by-1 column vector of times ending the interval to discount over, measured in periodic units.

If `Compounding = 365` (daily), `StartTimes` and `EndTimes` are measured in days. The arguments otherwise contain values, `T`, computed from SIA semiannual time factors, `Tsemi`, by the formula `T = Tsemi/2*F`, where `F` is the compounding frequency.

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

Example

Example 1. Compute discounts from a zero curve at six months, 12 months, and 24 months. The time to the cash flows is 1, 2, and 4. We 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 six 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 six months, and in 12 months. Use monthly compounding. The times to the cash flows are 12, 18, 24, and the forward times are 0, 6, 12.

```
Compounding = 12;
Rates = [0.05; 0.04; 0.06];
EndTimes = [12; 18; 24];
StartTimes = [0; 6; 12];
Disc = rate2disc(Compounding, Rates, EndTimes, StartTimes)
```

```
Disc =
    0.9513
    0.9609
    0.9419
```

See Also

disc2rate, ratetimes

Purpose

Change time intervals defining interest rate environment

Syntax

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

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

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

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

Arguments

`Compounding` — Scalar value representing the rate at which the input zero rates were compounded when annualized. This argument determines the formula for the discount factors:

`Compounding` = `1`, `2`, `3`, `4`, `6`, `12`
`Disc = (1 + Z/F)^(-T)`, where `F` is the compounding frequency, `Z` is the zero rate, and `T` is the time in periodic units, e.g. `T = F` is one year.

`Compounding` = `365`
`Disc = (1 + Z/F)^(-T)`, where `F` is the number of days in the basis year and `T` is a number of days elapsed computed by basis.

`Compounding` = `-1`
`Disc = exp(-T*Z)`, where `T` is time in years.

`RefRates` — `NREFPTS`-by-`NCURVES` matrix of reference rates in decimal form. `RefRates` are the yields over investment intervals from `RefStartTimes`, when the cash flow is valued, to `RefEndTimes`, when the cash flow is received.

`RefEndTimes` — `NREFPTS`-by-`1` vector or scalar of times in periodic units ending the intervals corresponding to `RefRates`.

`RefStartTimes` — (Optional) `NREFPTS`-by-`1` vector or scalar of times in periodic units starting the intervals corresponding to `RefRates`. Default = `0`.

EndTimes	NPOINTS-by-1 vector or scalar of times in periodic units ending the interval to discount over.
StartTimes	(Optional) NPOINTS-by-1 vector or scalar of times in periodic units starting the interval to discount over. Default = 0.
RefEndDates	NREFPTS-by-1 vector or scalar of serial dates ending the intervals corresponding to RefRates.
RefStartDates	(Optional) NREFPTS-by-1 vector or scalar of serial dates starting the intervals corresponding to RefRates. Default = ValuationDate.
EndDates	NPOINTS-by-1 vector or scalar of serial maturity dates ending the interval to discount over.
StartDates	(Optional) NPOINTS-by-1 vector or scalar of serial dates starting the interval to discount over. Default = ValuationDate.
ValuationDate	Scalar value in serial date number form representing the observation date of the investment horizons entered in StartDates and EndDates. Required in usage 2. Omitted or passed as an empty matrix to invoke usage 1.

Description

`[Rates, EndTimes, StartTimes] = ratetimes(Compounding, RefRates, RefEndTimes, RefStartTimes, EndTimes, StartTimes)` and `[Rates, EndTimes, StartTimes] = ratetimes(Compounding, RefRates, RefEndDates, RefStartDates, EndDates, StartDates, ValuationDate)` change time intervals defining an interest rate environment.

`ratetimes` takes an interest rate environment defined by yields over one collection of time intervals and computes the yields over another set of time intervals. The zero rate is assumed to be piecewise linear in time.

`Rates` is an `NPOINTS`-by-`NCURVES` matrix of rates implied by the reference interest rate structure and sampled at new intervals.

`StartTimes` is an `NPOINTS`-by-`1` column vector of times starting the new intervals where rates are desired, measured in periodic units.

EndTimes is an NPOINTS-by-1 column vector of times ending the new intervals, measured in periodic units.

If Compounding = 365 (daily), StartTimes and EndTimes are measured in days. The arguments otherwise contain values, T, computed from SIA semiannual time factors, Tsemi, by the formula T = Tsemi/2 * F, where F is the compounding frequency.

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

Examples

Example 1:

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

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

Rates =
   0.0600
   0.0688
   0.0700
```

Example 2:

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

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

```
Rates =
   0.0520
   0.0520
```

See Also disc2rate, rate2disc

Purpose

Price swap by HJM interest rate tree

Syntax

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

Arguments

`HJMTree`	Forward rate tree structure created by `hjmtree`.
`LegRate`	Number of instruments (`NINST`)-by-`2` matrix, with each row defined as: `[CouponRate Spread]` or `[Spread CouponRate]` `CouponRate` is the decimal annual rate. `Spread` is the number of basis points over the reference rate. The first column represents the receiving leg, while the second column represents the paying leg.
`Settle`	Settlement date. `NINST`-by-`1` vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. `NINST`-by-`1` vector of dates representing the maturity date for each swap.
`LegReset`	(Optional) `NINST`-by-`2` matrix representing the reset frequency per year for each swap. Default = `[1 1]`.
`Basis`	(Optional) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) `NINST`-by-`1` vector of the notional principal amounts. Default = `100`.
`LegType`	(Optional) `NINST`-by-`2` matrix. Each row represents an instrument. Each column indicates if the corresponding leg is fixed (`1`) or floating (`0`). This matrix defines the interpretation of the values entered in `LegRate`. Default is `[1,0]` for each instrument.
`Options`	(Optional) Derivatives pricing options structure created with `derivset`.

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

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 swap's values are zero at time 0. This rate is used in calculating the swap's prices when the rate specified for the fixed leg in LegRate is NaN. SwapRate is padded with NaN for those instruments in which CouponRate is not set to NaN.

Examples

Example 1: Price an interest rate swap with a fixed receiving leg and a floating paying leg. Payments are made once a year, and the notional principal amount is $100. The values for the remaining parameters are:

- Coupon rate for fixed leg: 0.04 (4%)
- Spread for floating leg: 20 basis points
- Swap settlement date: Jan. 01, 2000
- Swap maturity date: Jan. 01, 2003

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

```
Settle = '01-Jan-2000';
Maturity = '01-Jan-2003';
Basis = 0;
Principal = 100;
LegRate = [0.04 20]; % [CouponRate Spread]
LegType = [1 0]; % [Fixed Float]
LegReset = [1 1]; % Payments once per year
```

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

```
load deriv
```

Use swapbyhjm to compute the price of the swap.

```
Price = swapbyhjm(HJMTree, LegRate, Settle, Maturity,...
LegReset, Basis, Principal, LegType)

Price =
5.1910
```

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

```
LegRate = [NaN 20];

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

Price =
-1.4211e-014

PriceTree =
FinObj: 'HJMPriceTree'
tObs: [0 1 2 3 4]
PBush: {1x5 cell}

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

SwapRate =
0.0220
```

See Also

capbyhjm, cfbyhjm, floorbyhjm, hjmtree

swapbyzero

Purpose

Price swap by a set of zero curves

Syntax

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

Arguments

`RateSpec`	A structure encapsulating the properties of an interest rate structure. See `intenvset` for information on creating `RateSpec`.
`LegRate`	Number of instruments (`NINST`)-by-`2` matrix, with each row defined as: `[CouponRate Spread]` or `[Spread CouponRate]` `CouponRate` is the decimal annual rate. `Spread` is the number of basis points over the reference rate. The first column represents the receiving leg, while the second column represents the paying leg.
`Settle`	Settlement date. `NINST`-by-`1` vector of serial date numbers or date strings representing the settlement date for each swap. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. `NINST`-by-`1` vector of dates representing the maturity date for each swap.
`LegReset`	(Optional) `NINST`-by-`2` matrix representing the reset frequency per year for each swap. Default = `[1 1]`.
`Basis`	(Optional) `NINST`-by-`1` vector representing the basis used when annualizing the input forward rate tree. Default = `0` (actual/actual).
`Principal`	(Optional) `NINST`-by-`1` vector of the notional principal amounts. Default = `100`.
`LegType`	(Optional) `NINST`-by-`2` matrix. Each row represents an instrument. Each column indicates if the corresponding leg is fixed (`1`) or floating (`0`). This matrix defines the interpretation of the values entered in `LegRate`. Default is `[1,0]` for each instrument.

Description

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

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

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

Examples

Example 1: Price an interest rate swap with a fixed receiving leg and a floating paying leg. Payments are made once a year, and the notional principal amount is $100. The values for the remaining parameters are:

- Coupon rate for fixed leg: 0.04 (4%)
- Spread for floating leg: 20 basis points
- Swap settlement date: Jan. 01, 2000
- Swap maturity date: Jan. 01, 2003

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

```
Settle = '01-Jan-2000';
Maturity = '01-Jan-2003';
Basis = 0;
Principal = 100;
LegRate = [0.04 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 =
5.1910
```

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

```
LegRate = [NaN 20];

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

Price =
0

SwapRate =
0.0220
```

See Also

`bondbyzero`, `cfbyzero`, `fixedbyzero`, `floatbyzero`

Purpose

Display Heath-Jarrow-Morton (HJM) tree

Syntax

```
treeviewer(HJMTree)
treeviewer(HJMTree, InstSet)
```

Arguments

`HJMTree`	Heath-Jarrow-Morton tree containing forward rates, prices, or cash flows. See `hjmtree` for information on creating `HJMTree`.
`InstSet`	(Optional) Variable containing a collection of instruments whose prices or cash-flows are contained in `HJMTree`. 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

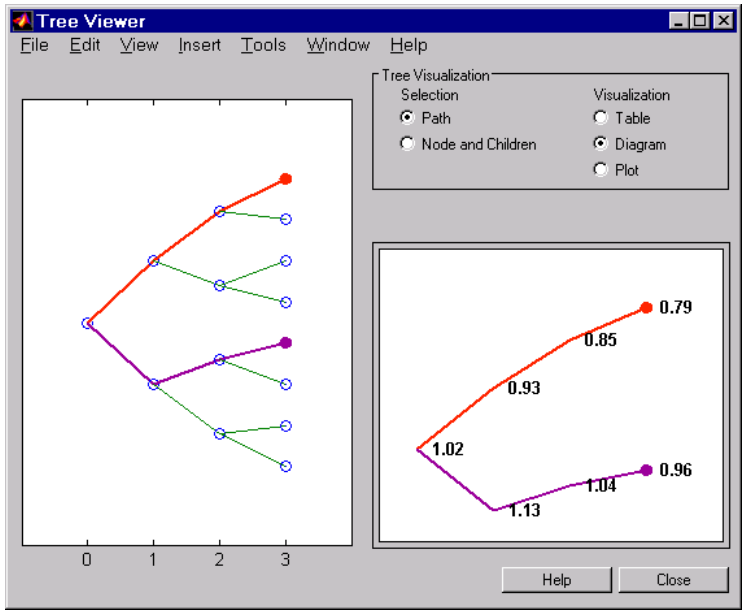
`treeviewer(HJMTree)` displays an HJM tree using default instrument names.

`treeviewer(HJMTree, InstSet)` displays an HJM forward rate, price, or cash flow tree including instrument names.

Examples

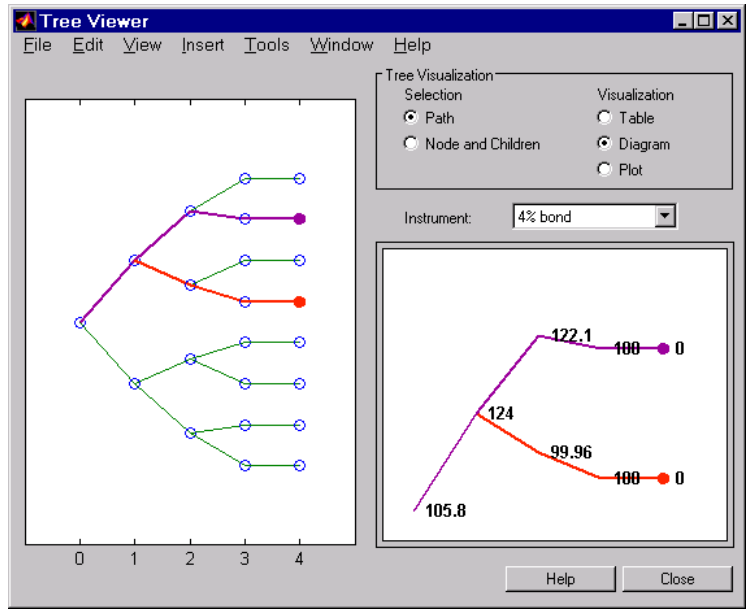
Display an HJM forward rate tree.

```
load deriv.mat
treeviewer(HJMTree)
```



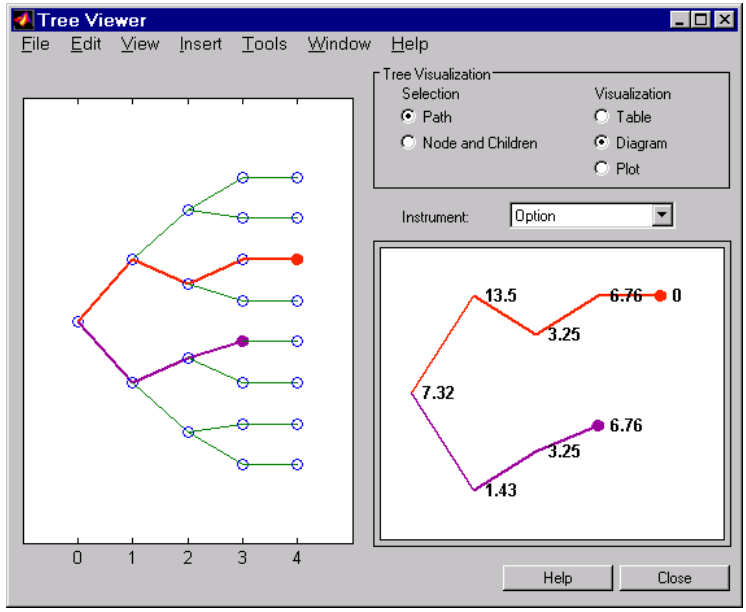
Display HJM price tree including instrument set.

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



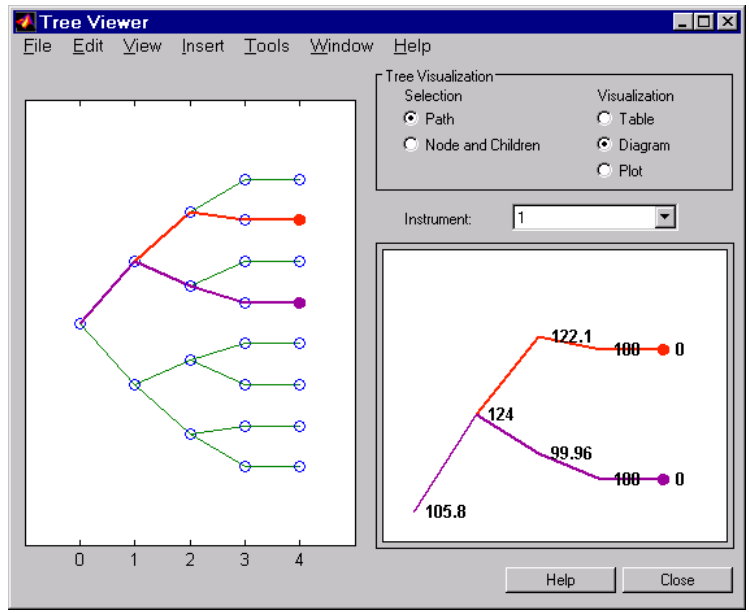
Display HJM price tree with renamed instruments.

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



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

```
load deriv.mat
treeviewer(PriceTree)
```



See Also

`hjmtree`, `instadd`

Index