RQuantLib: Interfacing QuantLib from R

R / Finance 2010 Presentation

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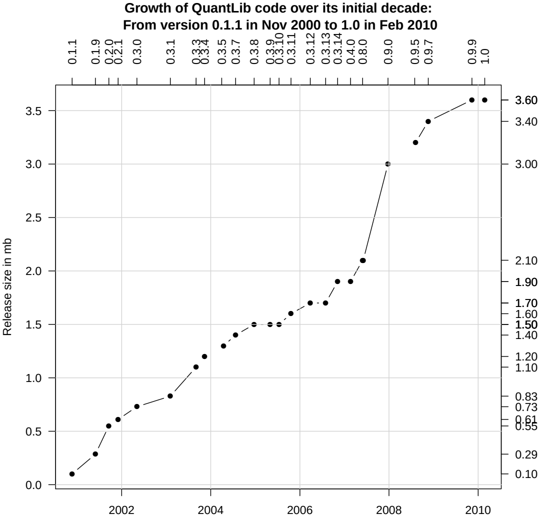
Outline

1. QuantLib
   - Overview
   - Timeline
   - Architecture
   - Examples
2. RQuantLib
   - Overview
   - Key components
   - Examples
3. Fixed Income
   - Overview and development
   - Examples
4. Summary

QuantLib releases

Showing the growth of QuantLib over time



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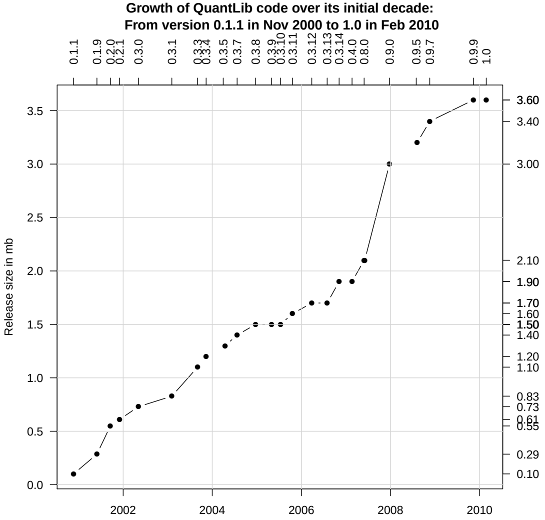

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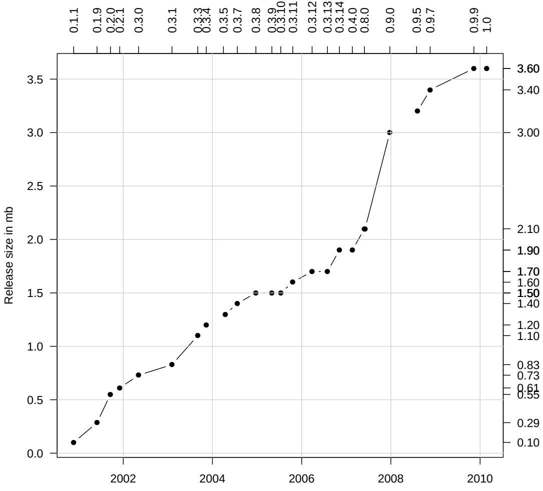

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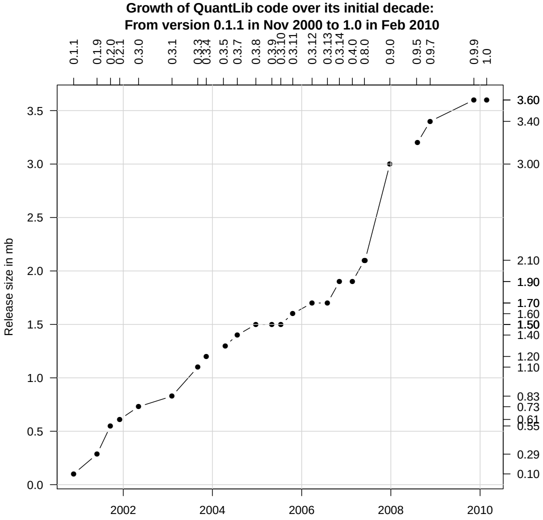

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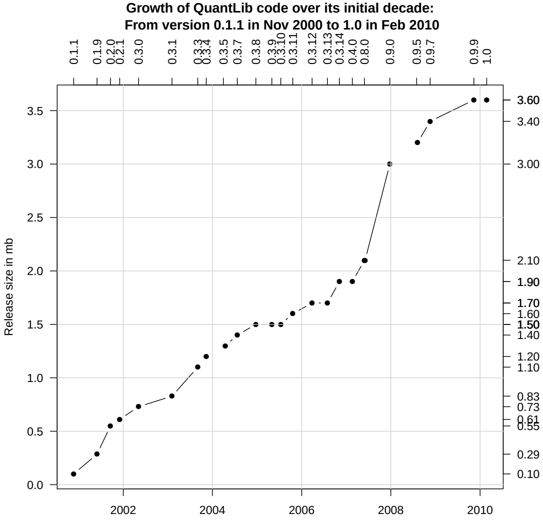

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- The long awaited QuantLib 1.0.0 release appeared in Feb 2010

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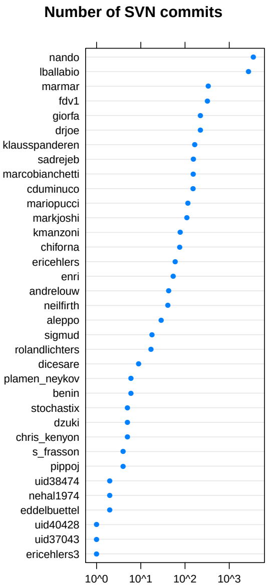

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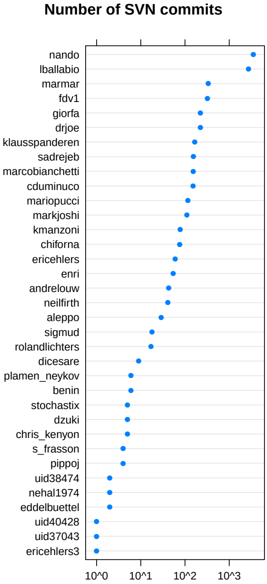

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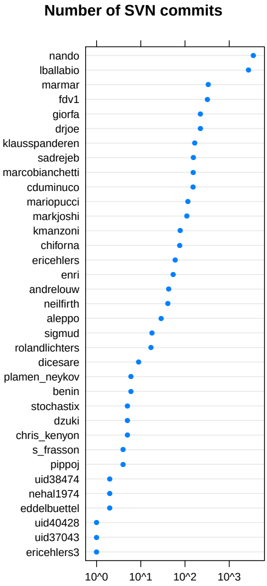

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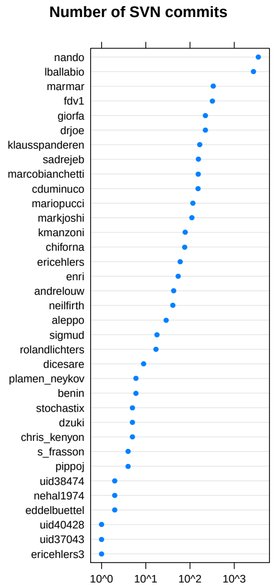

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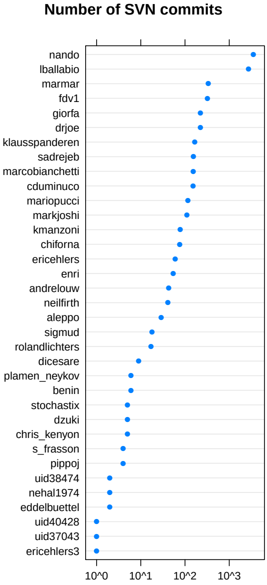

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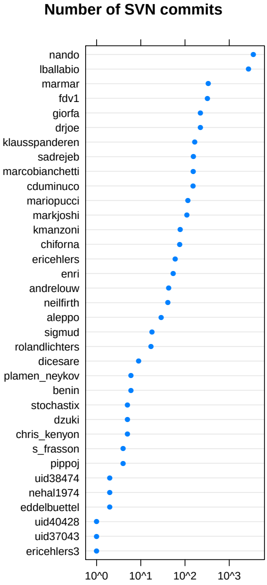

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- is sponsored by the Italian consultancy StatPro which derives consulting income from it.

QuantLib Architecture

How is it put togetherm and how do I use it?

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- QuantLibAddin exports a procedural interface to a number of platforms including Excel and Oo Calc.
- Several *manual* (non-SWIG) extension such as **RQuantLib** exist as well.

Key Modules

A rough guide, slight re-arranged from the QuantLib documentation

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- Utilities (Numeric types, Design patterns, Output manipulators)
- QuantLib macros (Numeric limits, Debugging)

Options: Fifteen solutions and three different exercises

```
$ EquityOption

Option type = Put
Maturity = May 17th, 1999
Underlying price = 36
Strike = 40
Risk-free interest rate = 6.000000 %
Dividend yield = 0.000000 %
Volatility = 20.000000 %
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Method                             European      Bermudan      American
Black-Scholes                      3.844308      N/A           N/A
Barone-Adesi/Whaley                N/A           N/A           4.459628
Bjerksund/Stensland                N/A           N/A           4.453064
Integral                           3.844309      N/A           N/A
Finite differences                 3.844342      4.360807      4.486118
Binomial Jarrow-Rudd               3.844132      4.361174      4.486552
Binomial Cox-Ross-Rubinstein       3.843504      4.360861      4.486415
Additive equiprobabilities         3.836911      4.354455      4.480097
Binomial Trigeorgis                3.843557      4.360909      4.486461
Binomial Tian                      3.844171      4.361176      4.486413
Binomial Leisen-Reimer             3.844308      4.360713      4.486076
Binomial Joshi                     3.844308      4.360713      4.486076
MC (crude)                         3.834522      N/A           N/A
QMC (Sobol)                        3.844613      N/A           N/A
MC (Longstaff Schwartz)            N/A           N/A           4.481675

Run completed in 5 s
```

Errors from discrete hedging (Derman and Kamal)

```
$ DiscreteHedging

Option value: 2.51207

         |          |      P&L |      P&L | Derman&Kamal |      P&L |      P&L
 samples |   trades |     mean | std.dev. |      formula | skewness | kurtosis
------------------------------------------------------------------------------
   50000 |       21 |   -0.001 |     0.43 |         0.44 |    -0.33 |     1.56
   50000 |       84 |    0.000 |     0.22 |         0.22 |    -0.20 |     1.68

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Other examples include SwapValuation, Repo, Replication, FRA, FittedBondCurve, Bonds, BermudanSwaption, CDS, ConvertibleBonds, CallableBonds and MarketModels.

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Other examples include `SwapValuation`, `Repo`, `Replication`, `FRA`, `FittedBondCurve`, `Bonds`, `BermudanSwaption`, `CDS`, `ConvertibleBonds`, `CallableBonds` and `MarketModels`.
Also available are `quantlib-benchmark` (running 85 tests) and `quantlib-test-suite` (running 446 tests cases).

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Overview

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- Second external contribution (as Google Summer of Code): Fixed Income Functionality (more on this below)
- Other small extensions on date and holiday calculations.

Option Valuation and Greeks

Analytical results where available

```
R> example(EuropeanOption)

ErpnOpR> # simple call with unnamed parameters
ErpnOpR> EuropeanOption("call", 100, 100, 0.01, 0.03, 0.5, 0.4)
Concise summary of valuation for EuropeanOption
   value    delta    gamma     vega    theta      rho  divRho
 11.6365   0.5673   0.0138  27.6336 -11.8390  22.5475 -28.3657

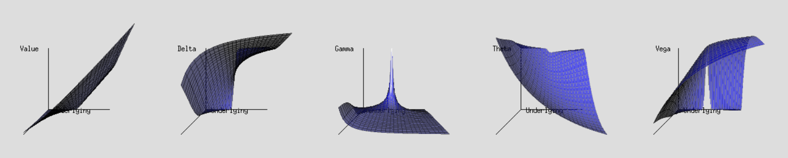
ErpnOpR> # simple call with some explicit parameters, and slightly increased vol:
ErpnOpR> EuropeanOption(type="call", underlying=100, strike=100, dividendYield=0.01,
ErpnOp+ riskFreeRate=0.03, maturity=0.5, volatility=0.5)
Concise summary of valuation for EuropeanOption
   value    delta    gamma     vega    theta      rho  divRho
 14.3927   0.5783   0.0110  27.4848 -14.4673  21.7206 -28.9169
R> example(BinaryOption)

BnryOpR> BinaryOption(binType="asset", type="call", excType="european",
BnryOp+               underlying=100, strike=100, dividendYield=0.02,
BnryOp+               riskFreeRate=0.03, maturity=0.5, volatility=0.4, cashPayoff=10)
Concise summary of valuation for BinaryOption
  value   delta   gamma    vega   theta     rho  divRho
 55.760   1.937   0.006  12.065  -5.090  68.944 -96.824
R> example(BarrierOption)

BrrrOpR> BarrierOption(barrType="downin", type="call", underlying=100,
BrrrOp+  strike=100, dividendYield=0.02, riskFreeRate=0.03,
BrrrOp+  maturity=0.5, volatility=0.4, barrier=90)
Concise summary of valuation for BarrierOption
 value  delta  gamma   vega  theta    rho divRho
 3.738    NaN    NaN    NaN    NaN    NaN    NaN
```

Option Valuation and Greeks

The `demo(OptionSurfaces)` provides some animation



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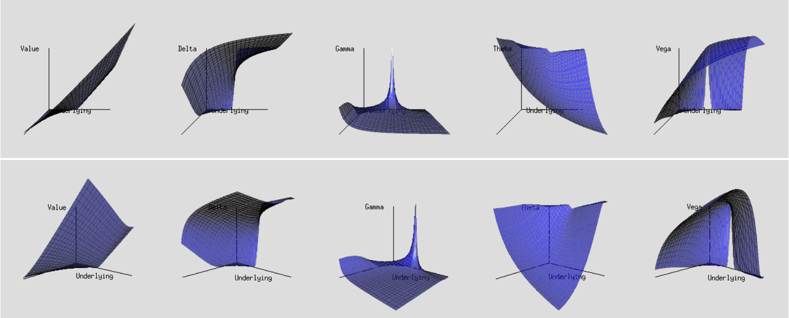

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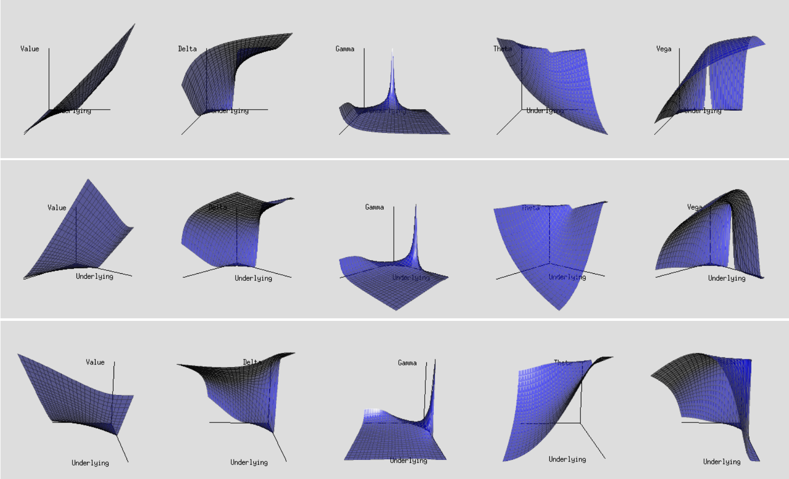

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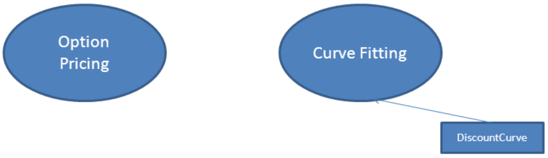
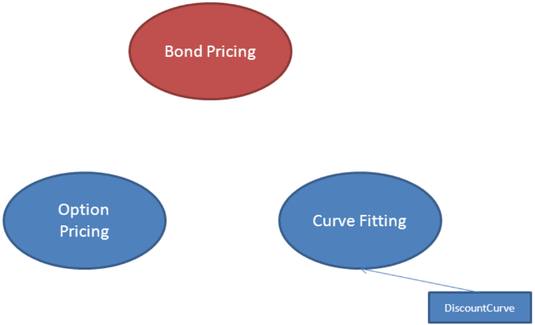
Fixed Income Development

RQuantLib before GSOC 2009...



Fixed Income Development

GSOC started. April 2009...



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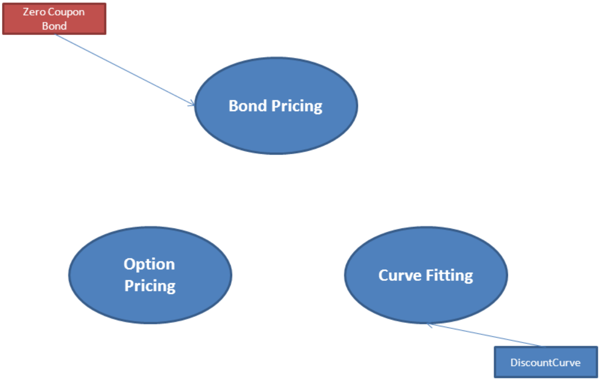

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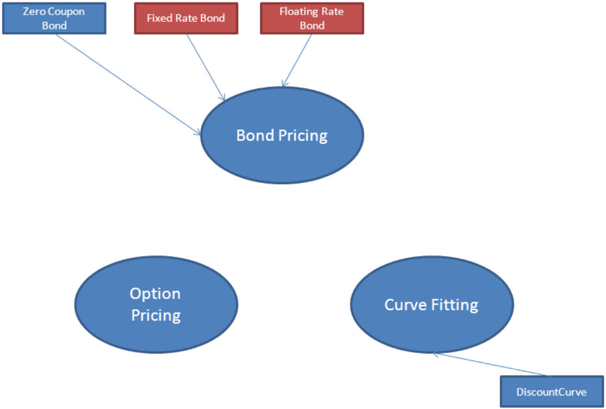
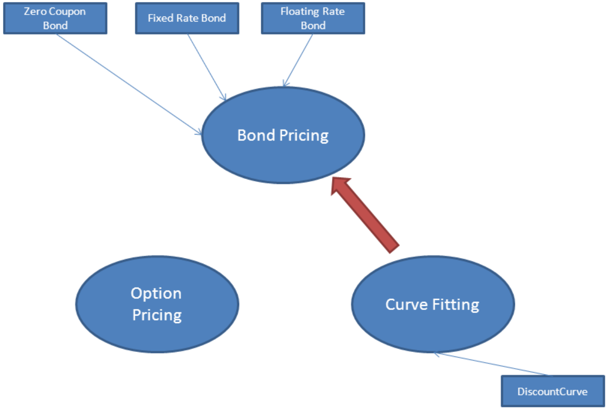


Fixed Income Development

Making curve fitting and bond pricing work together...



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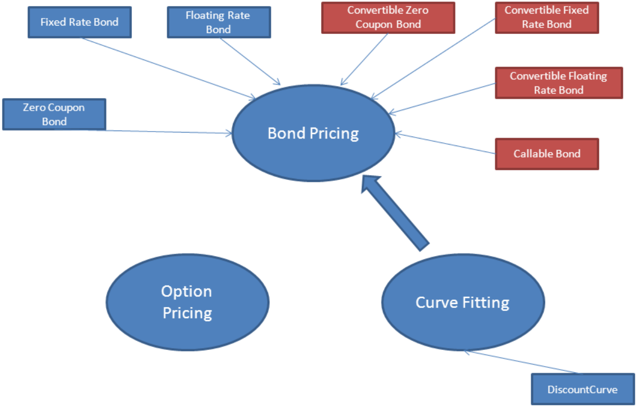

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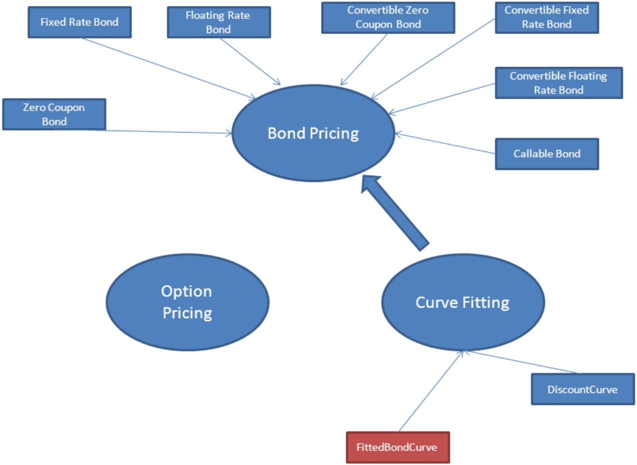
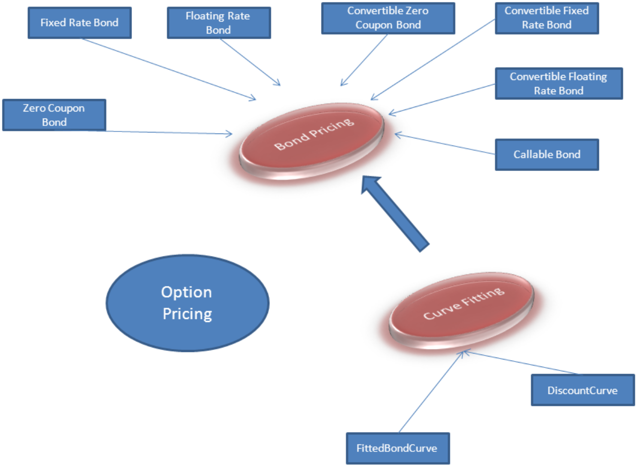


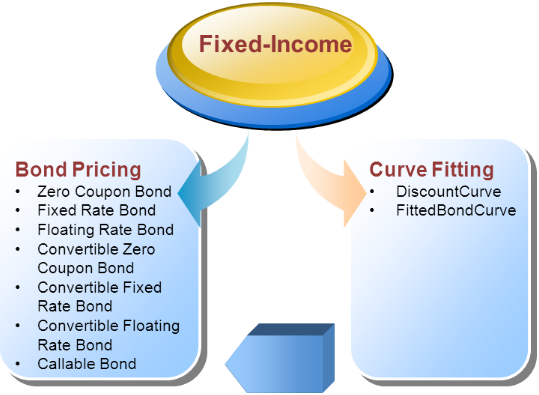
Fixed Income Development

And recently, we have started to add GUIs



Fixed Income Development

In summary



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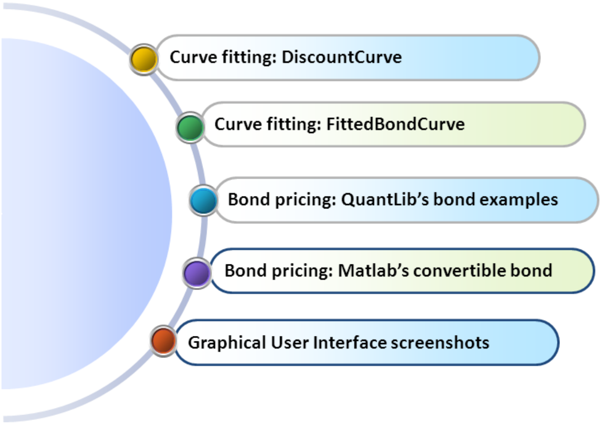


- Curve fitting: DiscountCurve
- Curve fitting: FittedBondCurve
- Bond pricing: QuantLib's bond examples
- Bond pricing: Matlab's convertible bond
- Graphical User Interface screenshots

Fixed Income in RQuantLib

Examples: Curve fitting with DiscountCurve function

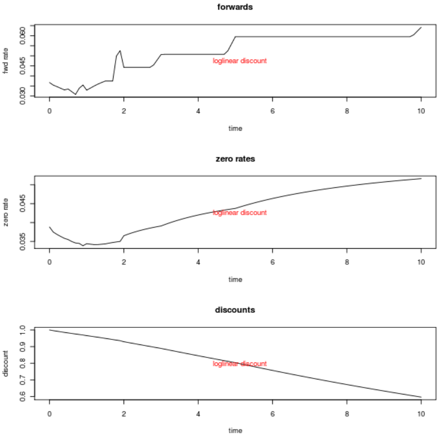
Building a discount curve from the market data. This data is taken from from examples included with QuantLib 0.9.7.

```
params <- list(tradeDate=as.Date(’2004-09-20’),
               settleDate=as.Date(’2004-09-22’),
               interpWhat="discount",
               interpHow="loglinear")
tsQuotes <- list(d1w=0.0382, d1m=0.0372,
                 d3m=0.0363, d6m=0.0353,
                 d9m=0.0348, d1y=0.0345,
                 fut2=96.7875, fut3=96.9875,
                 fut4=96.6875, fut5=96.4875,
                 fut7=96.2875, s2y=0.037125,
                 s3y=0.0398, s5y=0.0443,
                 s10y=0.05165, s15y=0.055175)
curves <- DiscountCurve(params, tsQuotes)
```

Fixed Income in RQuantLib

Examples: Curve fitting with DiscountCurve function

```
plot(curves)
```



Fixed Income in RQuantLib

Examples: Curve fitting with FittedBondCurve function

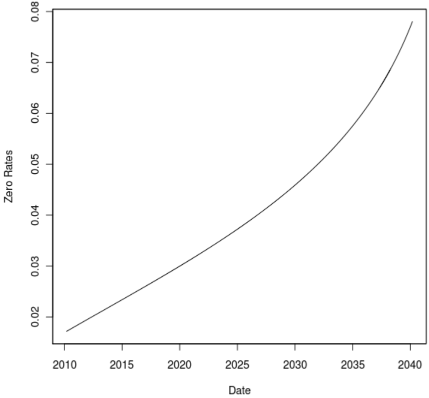
Fitting a curve to a set of bonds. The data is taken from examples included with QuantLib 0.9.7.

```
lengths <- c(2,4,6,8,10,12,14,16,18,
             20,22,24,26,28,30)
coupons <- c(0.0200, 0.0225, 0.0250, 0.0275,
             0.0300, 0.0325, 0.0350, 0.0375,
             0.0400, 0.0425, 0.0450, 0.0475,
             0.0500, 0.0525, 0.0550 )
marketQuotes <- rep(100, length(lengths))
dateparams <- list(settlementDays=0,
                   period="Annual",
                   dayCounter="ActualActual",
                   businessDayConvention="Unadjusted")
curveparams <- list(method="ExponentialSplinesFitting",
                    origDate = Sys.Date())
curve <- FittedBondCurve(curveparams, lengths,
                         coupons, marketQuotes,
                         dateparams)
```

Fixed Income in RQuantLib

Examples: Curve fitting with FittedBondCurve function

```
library(zoo)
z <- zoo(curve$table$zeroRates, order.by=curve$table$date)
plot(z, xlab='Date', ylab='Zero Rates')
```



Fixed Income in RQuantLib

Examples: Bond pricing

We construct a bond discounting term structure and then use it to price a zero coupon bond and a fixed rate bond.

All the input data and dates are taken from the bond pricing example shipped with QuantLib.

```
#we start with date parameters
fixingDays <- 3
settlementDays <- 3
settlementDate <- as.Date('2008-09-18')
todaysDate <- settlementDate - fixingDays
```

Fixed Income in RQuantLib

Examples: Bond pricing

```
#set up bond discounting term structure
lengths <- c(5, 6, 7, 16, 48)
coupons <- c(0.02375, 0.04625, 0.03125,
             0.04000, 0.04500)
marketQuotes <- c(100.390625, 106.21875,
                  100.59375, 101.6875, 102.140625)
dateparams <- list(settlementDays=settlementDays,
                   period=2, dayCounter="ActualActual",
                   businessDayConvention ="Unadjusted")
curveparams <- list(method="ExponentialSplinesFitting",
                    origDate=todaysDate)
bondDsctTsr <- FittedBondCurve(curveparams, lengths,
                               coupons, marketQuotes,
                               dateparams)
```

Fixed Income in RQuantLib

Examples: Bond pricing

```
#Set up a Zero-Coupon Bond
zc.bond.param <- list(
              maturityDate=as.Date('2013-08-15'),
              issueDate=as.Date('2003-08-15'),
              redemption=116.92)
zc.bond.dateparam <- list(
              refDate=todaysDate,
              settlementDays=settlementDays,
              businessDayConvention='Following')
#Call the pricing function
ZeroCouponBond(zc.bond.param,
               bondDsctTsr,
               zc.bond.dateparam)
```

Fixed Income in RQuantLib

Examples: Bond pricing

```
#Set up a Fixed-Coupon Bond
fixed.bond.param <- list(
                  maturityDate=as.Date('2017-05-15'),
                  issueDate=as.Date('2007-05-15'),
                  redemption=100,
                  effectiveDate=as.Date('2007-05-15'))
fixed.bond.dateparam <- list(
                  settlementDays=settlementDays,
                  dayCounter='ActualActual',
                  period='Semiannual',
                  businessDayConvention='Unadjusted',
                  terminationDateConvention='Unadjusted',
                  dateGeneration='Backward',
                  endOfMonth=0)
fixed.bond.coupon <- c(0.045)
#Call the pricing function
FixedRateBond(fixed.bond.param, fixed.bond.coupon,
              bondDsctTsr, fixed.bond.dateparam)
```

Fixed Income in RQuantLib

Examples: Convertible Bond from Matlab's Fixed Income Toolbox

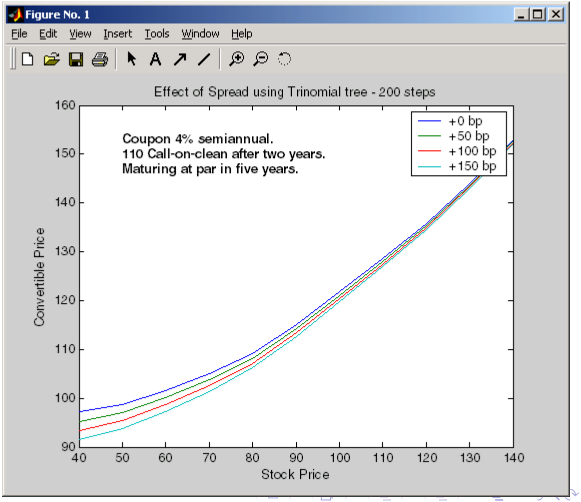
Perform a spread effect analysis of a 4%-coupon convertible bond callable at 110 at the end of the second year, maturing at par in 5 years, with yield to maturity of 5% and spread (of YTM versus 5-year treasury) of 0, 50, 100, and 150 basis points. The underlying stock pays no dividend.

```
RiskFreeRate = 0.05; Sigma        = 0.3;
ConvRatio    = 1;    NumSteps     = 200;
IssueDate    = datenum('2-Jan-2002');
Settle       = datenum('2-Jan-2002');
Maturity     = datenum('2-Jan-2007');
CouponRate   = 0.04;    Period       = 2; Basis        = 1; EndMonthRule = 1;
DividendType = 0; DividendInfo = [];
CallInfo     = [datenum('2-Jan-2004'), 110];
CallType     = 1; TreeType     = 1;
% Nested loop accross prices and static spread dimensions to compute convertible
      prices.
for j = 0:0.005:0.015;
StaticSpread = j;
      for i = 0:10:100
          Price = 40+i;
          [CbMatrix, UndMatrix, DebtMatrix, EqtyMatrix] =  cbprice(RiskFreeRate,
                StaticSpread, Sigma, Price, ConvRatio, NumSteps, IssueDate, Settle,
                Maturity, CouponRate, Period, Basis, EndMonthRule, DividendType,
                DividendInfo, CallType, CallInfo, TreeType);
           convprice(i/10+1,j*200+1) =  CbMatrix(1,1);
           stock(i/10+1,j*200+1)     =  Price;
        end
end
```

Fixed Income in RQuantLib
Examples: Convertible Bond from Matlab's Fixed Income Toolbox

Source: `http://www.mathworks.com/access/helpdesk/help/toolbox/finfixed/cbprice.html`

```
    plot(stock, convprice);
     legend({'+0 bp'; '+50 bp';
           '+100 bp'; '+150 bp
          '});
     title ('Effect of Spread
          using Trinomial tree
           - 200 steps')
     xlabel('Stock Price');
     ylabel('Convertible Price'
          );
     text(50, 150, ['Coupon 4%
          semiannual.',
          sprintf('\n'), ...
          '110 Call-on-clean
               after two years
               .' sprintf('\n'
               ), ...
          'Maturing at par in
               five years.'],'
               fontweight','
               Bold')
```



Fixed Income in RQuantLib

Examples: Convertible Bond from Matlab's Fixed Income Toolbox

Doing it in R using RQuantLib....

```
#set up a flat risk free curve
params <- list(tradeDate=as.Date("2002-01-02"), settleDate=as.Date("2002-01-02"),
               interpWhat="discount", interpHow="loglinear")
RiskFreeRate <- DiscountCurve(params, list(flat=0.05),times)
#parameters of the convertible bond
ConvRatio <- 1
issueDate <- as.Date("2002-01-02")
settleDate <- as.Date("2002-01-02")
maturityDate <- as.Date("2007-01-02")
dividendYield <- DiscountCurve(params, list(flat=0.01),times)
dividendSchedule <- data.frame(Type=character(0), Amount=numeric(0),
                               Rate=numeric(0), Date=as.Date(character(0)))
callabilitySchedule <- data.frame(Price=110, Type=0, Date=as.Date("2004-01-02"))
coupon <- 0.04
dateparams <- list(settlementDays=3, period="Semiannual", todayDate=issueDate)
bondparams <- list(exercise="eu", faceAmount=100,
                   divSch=dividendSchedule,
                   callSch=callabilitySchedule,
                   redemption=100,
                   creditSpread=0.005,
                   conversionRatio=ConvRatio,
                   issueDate=issueDate,
                   maturityDate=maturityDate)
```

Fixed Income in RQuantLib

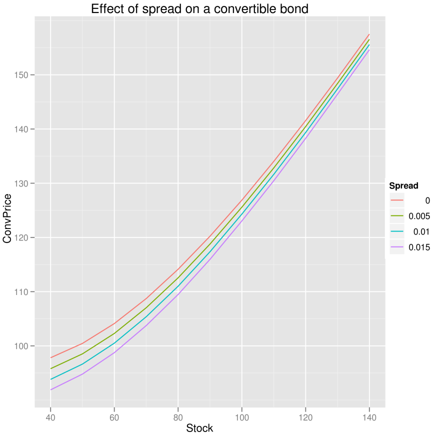
Examples: Convertible Bond from Matlab's Fixed Income Toolbox

```
#arguments to construct a BlackScholes process and set up the binomial pricing process
#engine for this bond.
Sigma <- 0.3
process <- list(underlying=40, divYield=dividendYield,
                rff=RiskFreeRate, volatility=Sigma)
#loop through underlying price and spread to produce similar analysis to Matlab
ret <- data.frame()
for (s in c(0, 0.005, 0.010, 0.015)){
   x <- c()
   y <- c()
   i <- 1
   for (p in seq(0, 100, by = 10)) {
      process$underlying <- 40+p
      bondparams$creditSpread <- s
      t <- ConvertibleFixedCouponBond(bondparams,
                                      coupon,
                                      process,
                                      dateparams)
      x[i] <- p + 40
      y[i] <- t$cleanPrice
      i <- i + 1
   }
   z <- rep(s, 11)
   ret <- rbind(ret, data.frame(Stock=x,ConvPrice=y,z))
}
```

Fixed Income in RQuantLib

Examples: Convertible Bond from Matlab's Fixed Income Toolbox

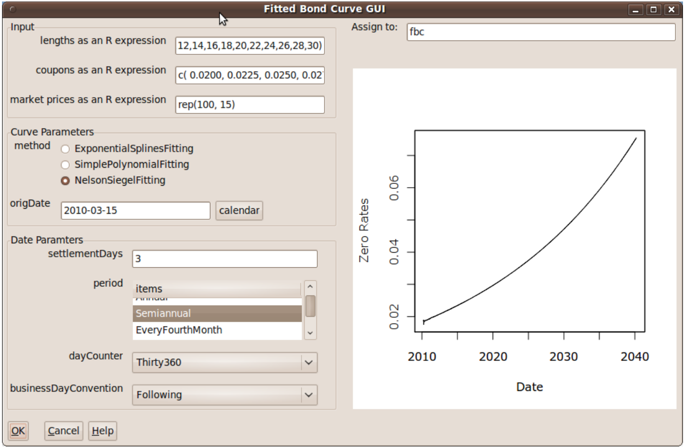
```
#plot the result
>library(ggplot2)
>p <- ggplot(ret, aes(Stock,ConvPrice, colour=factor(z)))
>p + geom_line() + scale_colour_discrete("Spread")
+ opts(title='Effect of spread on a convertible bond'
```



Fixed Income in RQuantLib

Graphical User Interface: Fitted Curve

RQuantLibGUI provides a graphical user interface via the 'traitr' package by John Verzani.



Fitted Bond Curve GUI

Input

lengths as an R expression: 12,14,16,18,20,22,24,26,28,30)

coupons as an R expression: c(0.0200, 0.0225, 0.0250, 0.02

market prices as an R expression: rep(100, 15)

Assign to: fbc

Curve Parameters

method
○ ExponentialSplinesFitting
○ SimplePolynomialFitting
● NelsonSiegelFitting

origDate: 2010-03-15 calendar

Date Paramters

settlementDays: 3

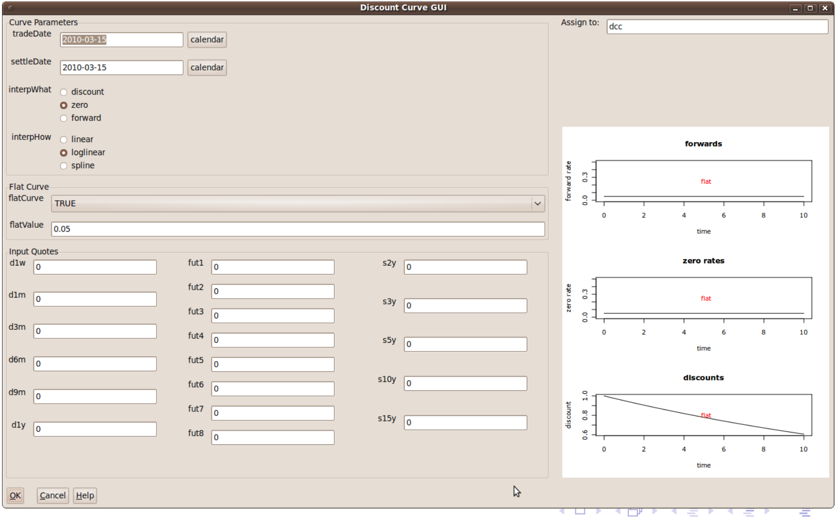
period: items
Annual
Semiannual
EveryFourthMonth

dayCounter: Thirty360

businessDayConvention: Following

Fixed Income in RQuantLib

Graphical User Interface: Discount Curve



Discount Curve GUI

Curve Parameters

tradeDate 2010-03-15

settleDate 2010-03-15

interpWhat ○ discount ● zero ○ forward

interpHow ○ linear ● loglinear ○ spline

Flat Curve

flatCurve TRUE

flatValue 0.05

Input Quotes

d1w 0

d1m 0

d3m 0

d6m 0

d9m 0

d1y 0

fut1 0

fut2 0

fut3 0

fut4 0

fut5 0

fut6 0

fut7 0

fut8 0

s2y 0

s3y 0

s5y 0

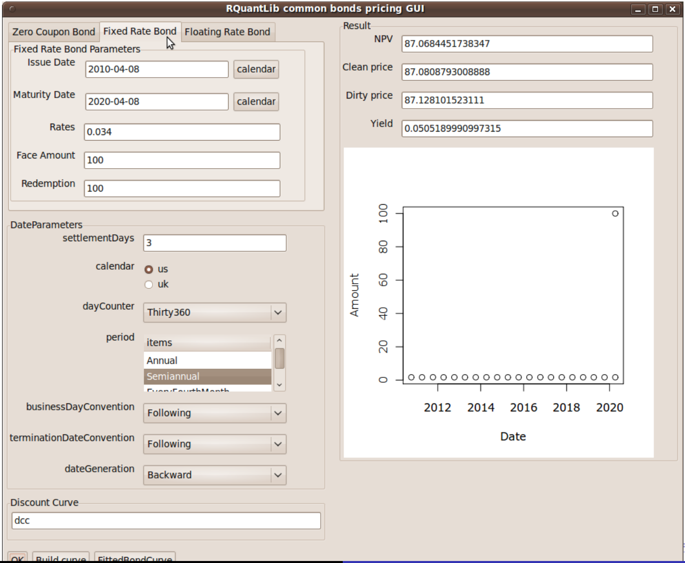
s10y 0

s15y 0

Assign to: dcc

Fixed Income in RQuantLib

Graphical User Interface: Bonds



RQuantLib common bonds pricing GUI

Fixed Rate Bond Parameters

Issue Date: 2010-04-08

Maturity Date: 2020-04-08

Rates: 0.034

Face Amount: 100

Redemption: 100

DateParameters

settlementDays: 3

calendar: ● us ○ uk

dayCounter: Thirty360

period: items, Annual, Semiannual, EveryFourthMonth

businessDayConvention: Following

terminationDateConvention: Following

dateGeneration: Backward

Discount Curve: dcc

Result

NPV: 87.0684451738347

Clean price: 87.0808793008888

Dirty price: 87.128101523111

Yield: 0.0505189990997315

Outline

1. QuantLib
   - Overview
   - Timeline
   - Architecture
   - Examples
2. RQuantLib
   - Overview
   - Key components
   - Examples
3. Fixed Income
   - Overview and development
   - Examples
4. Summary

Summary and Outlook

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- Thank you!