a1

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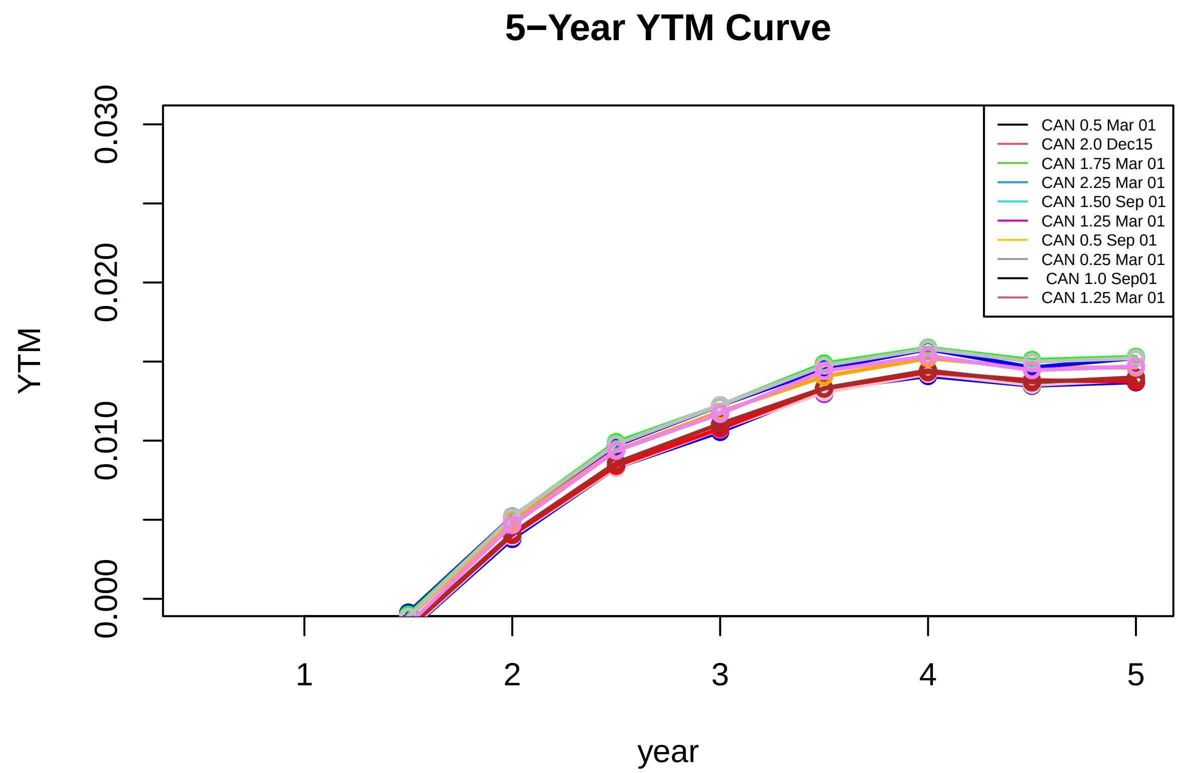
```r
##import data collelcted into Rstudio
library(readxl)
clean_price = read_excel("C:\\Users\\Rick\\Desktop\\clean price.xlsx")
dirty_price = read_excel("C:\\Users\\Rick\\Desktop\\dirty price.xlsx")
```

```r
##construct the matrix for the closed price of 10 days of selected bonds
coupon_paid <- dirty_price$Coupon
maturity_date <- dirty_price$`Maturity Date` ##extract corresponding data from dataset
date_of_data <- c("2022-01-10", "2022-01-11", "2022-01-12", "2022-01-13", "2022-01-14", "2022-01-17", "2
matrix_of_dirty_price = matrix(c(dirty_price$`01/10/2022`, dirty_price$`01/11/2022`, dirty_price$`01/12/
```

```r
##construct the matrix of YTM with maturity date derived from and matrix of close price in the last chu
library(jrvFinance)
matrix_of_YTM = matrix("numeric", nrow = 10, ncol = 10)
for (j in c(1:10)) {
  dirty_price = matrix_of_dirty_price[ ,j]
  for(i in c(1:10)){
    matrix_of_YTM[i,j] <- bond.yield(settle=date_of_data[i], mature = maturity_date[j], coupon=coupon_pa
  }
}
```

```r
##With the YTM matrix, we could plot the YTM curve for each each semi-year.
semiyear = c(seq(0.5, 5, 0.5))
plot(semiyear, matrix_of_YTM[1,], main = "5-Year YTM Curve", col = "purple", xlab = "year", ylab = "YTM
color_of_bonds = c("blue", "pink", "red", "brown", "orange", "blue", "green", "grey", "violet","gold") #
for(i in c(2:10)){
  lines(semiyear, matrix_of_YTM[i,], type = "o", col=color_of_bonds[i-1], lwd=2)
}##set colors to each bond
legend("topright", legend = c("CAN 0.5 Mar 01", "CAN 2.0 Dec15", "CAN 1.75 Mar 01", "CAN 2.25 Mar 01",
```



##Now calculate spot rate

```
##to calculate spot rate, we need to know the cash flow of each period
cash_flow = list()
for (i in 1:10) {cash_flow=bond.TCF(date_of_data[i], maturity_date[i], coupon_paid[i], freq = 2, redemp
  print(cash_flow)
}
```

```
## [1] 100.25
## [1]   1 101
## [1]   0.875   0.875 100.875
## [1]   1.125   1.125   1.125   1.125 101.125
## [1]   0.75   0.75   0.75   0.75   0.75 100.75
## [1]   0.625   0.625   0.625   0.625   0.625   0.625 100.625
## [1]   0.25   0.25   0.25   0.25   0.25   0.25   0.25 100.25
## [1]   0.125   0.125   0.125   0.125   0.125   0.125   0.125   0.125 100.125
##  [1]   0.5   0.5   0.5   0.5   0.5   0.5   0.5   0.5   0.5 100.5
##  [1]   0.625   0.625   0.625   0.625   0.625   0.625   0.625   0.625   0.625
## [10]   0.625 100.625
```

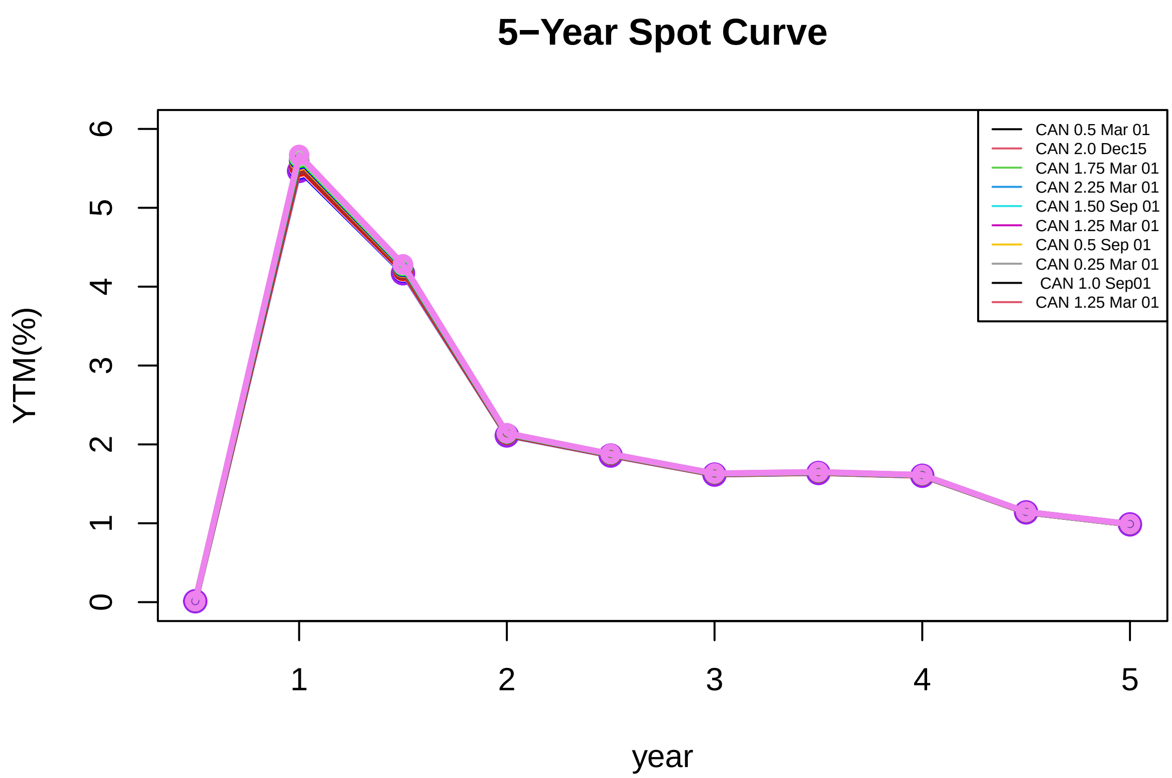
```
##to simplify further calculation, name cash flows as functions first
cash_flow1=c(100.25)
cash_flow2=c(1, 101)
cash_flow3=c(0.875, 0.875, 100.875)
cash_flow4=c(1.125, 1.125, 1.125, 101.125)
cash_flow5=c(0.75, 0.75, 0.75, 0.75, 100.75)
```

```r
cash_flow6=c(0.625, 0.625, 0.625, 0.625, 0.625, 100.625)
cash_flow7=c(0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 100.25)
cash_flow8=c(0.125, 0.125, 0.125, 0.125, 0.125, 0.125, 0.125, 100.125)
cash_flow9=c(0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 100.5)
cash_flow10=c(0.625, 0.625, 0.625, 0.625, 0.625, 0.625, 0.625, 0.625, 0.625, 100.625)
```

```r
##since time till mature, issue date of different bonds are not the same. For comparison, we need to co
year_in_fraction = matrix("numeric", nrow=10, ncol = 10)
for (i in c(1:10)) {
  for (j in c(1:10)) {
    year_in_fraction[i,j]=yearFraction(date_of_data[i], maturity_date[j], freq=2, convention = c("30/36
```

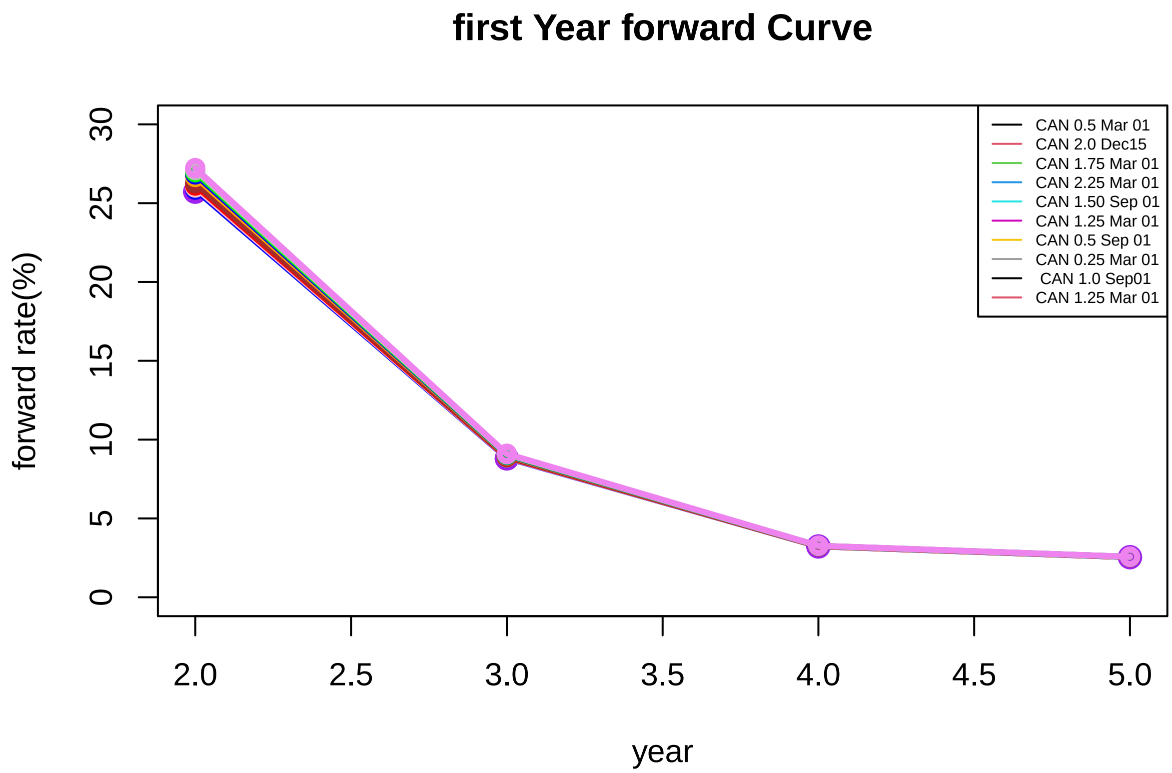
```r
##Now we can calculate spot rate for each period
matrix_of_spot_rate = matrix(nrow = 10, ncol = 10)
for (i in 1:10) {
  time_period1=as.numeric(year_in_fraction[i,1])
  spot_rate1=-log(cash_flow1[1]/matrix_of_dirty_price[i,1])/time_period1
  time_period2=as.numeric(year_in_fraction[i,2])
  spot_rate2=-log(cash_flow2[1]/matrix_of_dirty_price[i,2])/time_period2
  time_period3=as.numeric(year_in_fraction[i,3])
  spot_rate3=-log(cash_flow3[1]/matrix_of_dirty_price[i,3])/time_period3
  time_period4=as.numeric(year_in_fraction[i,4])
  spot_rate4=-log(cash_flow4[1]/matrix_of_dirty_price[i,4])/time_period4
  time_period5=as.numeric(year_in_fraction[i,5])
  spot_rate5=-log(cash_flow5[1]/matrix_of_dirty_price[i,5])/time_period5
  time_period6=as.numeric(year_in_fraction[i,6])
  spot_rate6=-log(cash_flow6[1]/matrix_of_dirty_price[i,6])/time_period6
  time_period7=as.numeric(year_in_fraction[i,7])
  spot_rate7=-log(cash_flow7[1]/matrix_of_dirty_price[i,7])/time_period7
  time_period8=as.numeric(year_in_fraction[i,8])
  spot_rate8=-log(cash_flow8[1]/matrix_of_dirty_price[i,8])/time_period8
  time_period9=as.numeric(year_in_fraction[i,9])
  spot_rate9=-log(cash_flow9[1]/matrix_of_dirty_price[i,9])/time_period9
  time_period10=as.numeric(year_in_fraction[i,10])
  spot_rate10=-log(cash_flow10[1]/matrix_of_dirty_price[i,10])/time_period10
  rates = rbind(spot_rate1, spot_rate2, spot_rate3, spot_rate4, spot_rate5, spot_rate6, spot_rate7, spo
  matrix_of_spot_rate[i, ] = rates
}
```

```r
##plot the spot curve
semiyear = c(seq(0.5, 5, 0.5))
plot(semiyear, matrix_of_spot_rate[1,], main = "5-Year Spot Curve", col = "purple", xlab = "year", ylab
color_of_bonds = c("blue", "pink", "red", "brown", "orange", "blue", "green", "grey", "violet","gold") #
for(i in c(2:10)){
  lines(semiyear, matrix_of_spot_rate[i,], type = "o", col=color_of_bonds[i-1], lwd=3)
}##set colors to each bond
legend("topright", legend = c("CAN 0.5 Mar 01", "CAN 2.0 Dec15", "CAN 1.75 Mar 01", "CAN 2.25 Mar 01",
```




```
##set the matrix of first year forward rate of each bond
matrix_of_forward_rate = matrix(nrow = 10, ncol = 4)
for (j in c(1:10)) {
  for (i in c(1:4)) {
    formula_of_forward = function(x)((1+matrix_of_spot_rate[j,1]/2)^2)*((1+x/2)^(2*i))-(1+matrix_of_spo
    matrix_of_forward_rate[j,i]=uniroot(formula_of_forward,c(0,100))$root
  }
}
```

```
##plot the graph of first year forward rate
year=c(2,3,4,5)
plot(year, matrix_of_forward_rate[1,], main = "first Year forward Curve", col = "purple", xlab = "year"
color_of_bonds = c("blue", "pink", "red", "brown", "orange", "blue", "green", "grey", "violet","gold")
for(i in c(2:10)){
  lines(year, matrix_of_forward_rate[i,], type = "o", col=color_of_bonds[i-1], lwd=3)
}##set colors to each bond
legend("topright", legend = c("CAN 0.5 Mar 01", "CAN 2.0 Dec15", "CAN 1.75 Mar 01", "CAN 2.25 Mar 01",
```




```r
##calculate the log function of ytm matrix, and then compute the covariance matrix of it.
log_matrix_of_forward = matrix(nrow = 9, ncol=4)
for (i in c(1:4)) {
  for (j in c(1:9)) {
    log_matrix_of_forward[j,i] = log(matrix_of_forward_rate[(j+1),i]/matrix_of_forward_rate[j,i])
  }
}
covariance_of_forward = cov(log_matrix_of_forward,log_matrix_of_forward)
```

```r
##calculate the log function of ytm matrix, and then compute the covariance matrix of it.
ytm <- matrix(as.numeric(matrix_of_YTM), ncol = 10)
log_matrix_of_ytm = matrix(nrow = 9, ncol=10)
for (i in c(1:10)) {
  for (j in c(1:9)) {
    log_matrix_of_ytm[j,i] = log(ytm[(j+1),i]/ytm[j,i])
  }
}
covariance_of_ytm=cov(log_matrix_of_ytm,log_matrix_of_ytm)
```

```r
eigenvalue_of_forward = eigen(covariance_of_forward)$value
eigenvector_of_forward = eigen(covariance_of_forward)$vector
eigenvalue_of_ytm = eigen(covariance_of_ytm)$value
eigenvector_of_ytm = eigen(covariance_of_ytm)$vector
```