cov matrix

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```
library(stringr)
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.2 --
## v ggplot2 3.4.0      v purrr   1.0.0
## v tibble  3.1.8      v dplyr   1.0.10
## v tidyr   1.2.1      v forcats 0.5.2
## v readr   2.1.3
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
YTM_data<-read.csv(file = "YTM_data_ad.csv", header = T)
```

```
X_11<-log(YTM_data$Jan_17[1]/YTM_data$Jan_16[1])
X_12<-log(YTM_data$Jan_18[1]/YTM_data$Jan_17[1])
X_13<-log(YTM_data$Jan_19[1]/YTM_data$Jan_18[1])
X_14<-log(YTM_data$Jan_20[1]/YTM_data$Jan_19[1])
X_15<-log(YTM_data$Jan_23[1]/YTM_data$Jan_20[1])
X_16<-log(YTM_data$Jan_24[1]/YTM_data$Jan_23[1])
X_17<-log(YTM_data$Jan_25[1]/YTM_data$Jan_24[1])
X_18<-log(YTM_data$Jan_26[1]/YTM_data$Jan_25[1])
X_19<-log(YTM_data$Jan_27[1]/YTM_data$Jan_26[1])

x_1 <-c(X_11, X_12, X_13, X_14, X_15, X_16, X_17, X_18, X_19)
```

```
X_21<-log(YTM_data$Jan_17[2]/YTM_data$Jan_16[2])
X_22<-log(YTM_data$Jan_18[2]/YTM_data$Jan_17[2])
X_23<-log(YTM_data$Jan_19[2]/YTM_data$Jan_18[2])
X_24<-log(YTM_data$Jan_20[2]/YTM_data$Jan_19[2])
X_25<-log(YTM_data$Jan_23[2]/YTM_data$Jan_20[2])
X_26<-log(YTM_data$Jan_24[2]/YTM_data$Jan_23[2])
X_27<-log(YTM_data$Jan_25[2]/YTM_data$Jan_24[2])
X_28<-log(YTM_data$Jan_26[2]/YTM_data$Jan_25[2])
X_29<-log(YTM_data$Jan_27[2]/YTM_data$Jan_26[2])

x_2 <-c(X_21, X_22, X_23, X_24, X_25, X_26, X_27, X_28, X_29)
```

```
X_31<-log(YTM_data$Jan_17[3]/YTM_data$Jan_16[3])
X_32<-log(YTM_data$Jan_18[3]/YTM_data$Jan_17[3])
X_33<-log(YTM_data$Jan_19[3]/YTM_data$Jan_18[3])
X_34<-log(YTM_data$Jan_20[3]/YTM_data$Jan_19[3])
X_35<-log(YTM_data$Jan_23[3]/YTM_data$Jan_20[3])
X_36<-log(YTM_data$Jan_24[3]/YTM_data$Jan_23[3])
```

```
X_37<-log(YTM_data$Jan_25[3]/YTM_data$Jan_24[3])
X_38<-log(YTM_data$Jan_26[3]/YTM_data$Jan_25[3])
X_39<-log(YTM_data$Jan_27[3]/YTM_data$Jan_26[3])

x_3 <-c(X_31, X_32, X_33, X_34, X_35, X_36, X_37, X_38, X_39)
```

```
X_41<-log(YTM_data$Jan_17[4]/YTM_data$Jan_16[4])
X_42<-log(YTM_data$Jan_18[4]/YTM_data$Jan_17[4])
X_43<-log(YTM_data$Jan_19[4]/YTM_data$Jan_18[4])
X_44<-log(YTM_data$Jan_20[4]/YTM_data$Jan_19[4])
X_45<-log(YTM_data$Jan_23[4]/YTM_data$Jan_20[4])
X_46<-log(YTM_data$Jan_24[4]/YTM_data$Jan_23[4])
X_47<-log(YTM_data$Jan_25[4]/YTM_data$Jan_24[4])
X_48<-log(YTM_data$Jan_26[4]/YTM_data$Jan_25[4])
X_49<-log(YTM_data$Jan_27[4]/YTM_data$Jan_26[4])

x_4 <-c(X_41, X_42, X_43, X_44, X_45, X_46, X_47, X_48, X_49)
```

```
X_51<-log(YTM_data$Jan_17[5]/YTM_data$Jan_16[5])
X_52<-log(YTM_data$Jan_18[5]/YTM_data$Jan_17[5])
X_53<-log(YTM_data$Jan_19[5]/YTM_data$Jan_18[5])
X_54<-log(YTM_data$Jan_20[5]/YTM_data$Jan_19[5])
X_55<-log(YTM_data$Jan_23[5]/YTM_data$Jan_20[5])
X_56<-log(YTM_data$Jan_24[5]/YTM_data$Jan_23[5])
X_57<-log(YTM_data$Jan_25[5]/YTM_data$Jan_24[5])
X_58<-log(YTM_data$Jan_26[5]/YTM_data$Jan_25[5])
X_59<-log(YTM_data$Jan_27[5]/YTM_data$Jan_26[5])
x_5 <-c(X_51, X_52, X_53, X_54, X_55, X_56, X_57, X_58, X_59)
```

```
cov_data<-data.frame(X_1 = x_1, X_2= x_2, X_3 = x_3, X_4 = x_4, X_5=x_5)
```

```
YTM_cov_matrix<-cov(cov_data)
print(YTM_cov_matrix)
```

```
##              X_1          X_2          X_3          X_4          X_5
## X_1 0.0001398127 0.0001818287 0.0001766069 0.0002214283 0.0002215103
## X_2 0.0001818287 0.0003356997 0.0003508837 0.0004064613 0.0004002474
## X_3 0.0001766069 0.0003508837 0.0003873318 0.0004300666 0.0004189380
## X_4 0.0002214283 0.0004064613 0.0004300666 0.0005637715 0.0005647994
## X_5 0.0002215103 0.0004002474 0.0004189380 0.0005647994 0.0005721337
```

```
FWR_data<-read.csv(file = "Forward rate_ad.csv", header = T)
```

```
Y_11<-log(FWR_data$Jan_17[1]/FWR_data$Jan_16[1])
Y_12<-log(FWR_data$Jan_18[1]/FWR_data$Jan_17[1])
Y_13<-log(FWR_data$Jan_19[1]/FWR_data$Jan_18[1])
Y_14<-log(FWR_data$Jan_20[1]/FWR_data$Jan_19[1])
Y_15<-log(FWR_data$Jan_23[1]/FWR_data$Jan_20[1])
Y_16<-log(FWR_data$Jan_24[1]/FWR_data$Jan_23[1])
Y_17<-log(FWR_data$Jan_25[1]/FWR_data$Jan_24[1])
Y_18<-log(FWR_data$Jan_26[1]/FWR_data$Jan_25[1])
Y_19<-log(FWR_data$Jan_27[1]/FWR_data$Jan_26[1])

y_1 <-c(Y_11, Y_12, Y_13, Y_14, Y_15, Y_16, Y_17, Y_18, Y_19)
```

```
Y_21<-log(FWR_data$Jan_17[2]/FWR_data$Jan_16[2])
Y_22<-log(FWR_data$Jan_18[2]/FWR_data$Jan_17[2])
Y_23<-log(FWR_data$Jan_19[2]/FWR_data$Jan_18[2])
Y_24<-log(FWR_data$Jan_20[2]/FWR_data$Jan_19[2])
Y_25<-log(FWR_data$Jan_23[2]/FWR_data$Jan_20[2])
Y_26<-log(FWR_data$Jan_24[2]/FWR_data$Jan_23[2])
Y_27<-log(FWR_data$Jan_25[2]/FWR_data$Jan_24[2])
Y_28<-log(FWR_data$Jan_26[2]/FWR_data$Jan_25[2])
Y_29<-log(FWR_data$Jan_27[2]/FWR_data$Jan_26[2])

y_2 <-c(Y_21, Y_22, Y_23, Y_24, Y_25, Y_26, Y_27, Y_28, Y_29)
```

```
Y_31<-log(FWR_data$Jan_17[3]/FWR_data$Jan_16[3])
Y_32<-log(FWR_data$Jan_18[3]/FWR_data$Jan_17[3])
Y_33<-log(FWR_data$Jan_19[3]/FWR_data$Jan_18[3])
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Y_37<-log(FWR_data$Jan_25[3]/FWR_data$Jan_24[3])
Y_38<-log(FWR_data$Jan_26[3]/FWR_data$Jan_25[3])
Y_39<-log(FWR_data$Jan_27[3]/FWR_data$Jan_26[3])

y_3 <-c(Y_31, Y_32, Y_33, Y_34, Y_35, Y_36, Y_37, Y_38, Y_39)
```

```
Y_41<-log(FWR_data$Jan_17[4]/FWR_data$Jan_16[4])
Y_42<-log(FWR_data$Jan_18[4]/FWR_data$Jan_17[4])
Y_43<-log(FWR_data$Jan_19[4]/FWR_data$Jan_18[4])
Y_44<-log(FWR_data$Jan_20[4]/FWR_data$Jan_19[4])
Y_45<-log(FWR_data$Jan_23[4]/FWR_data$Jan_20[4])
Y_46<-log(FWR_data$Jan_24[4]/FWR_data$Jan_23[4])
Y_47<-log(FWR_data$Jan_25[4]/FWR_data$Jan_24[4])
Y_48<-log(FWR_data$Jan_26[4]/FWR_data$Jan_25[4])
Y_49<-log(FWR_data$Jan_27[4]/FWR_data$Jan_26[4])

y_4 <-c(Y_41, Y_42, Y_43, Y_44, Y_45, Y_46, Y_47, Y_48, Y_49)
```

```
cov_data_2<-data.frame(Y_1 = y_1, Y_2= y_2, Y_3 = y_3, Y_4 = y_4)
```

```
FWR_cov_matrix<-cov(cov_data_2)
print(FWR_cov_matrix)
```

```
##              Y_1          Y_2          Y_3          Y_4
## Y_1 0.0011753427 0.0009782119 0.0010085821 0.0009186159
## Y_2 0.0009782119 0.0008708379 0.0008522547 0.0007645874
## Y_3 0.0010085821 0.0008522547 0.0010900257 0.0010270144
## Y_4 0.0009186159 0.0007645874 0.0010270144 0.0009847083
```

```
X_ev<- eigen(YTM_cov_matrix)
print(X_ev$values)
```

```
## [1] 1.870977e-03 7.223598e-05 4.813322e-05 5.836133e-06 1.566906e-06
```

```
print(X_ev$vectors)
```

```
##            [,1]       [,2]        [,3]        [,4]        [,5]
## [1,] -0.2265797  0.2352190  0.90380742 -0.27584653  0.01935213
```

```
## [2,] -0.4116453  0.4563480  0.01913504  0.78392493 -0.08596584
## [3,] -0.4351091  0.5637353 -0.42008812 -0.52395117  0.20465516
## [4,] -0.5438480 -0.3550698 -0.07635780 -0.15814536 -0.73980690
## [5,] -0.5423275 -0.5408756  0.02148143  0.09917467  0.63485225
```

```
Y_ev<- eigen(FWR_cov_matrix)
print(Y_ev$values)
```

```
## [1] 3.820279e-03 2.632799e-04 3.308862e-05 4.267387e-06
```

```
print(Y_ev$vectors)
```

```
##            [,1]       [,2]        [,3]        [,4]
## [1,] -0.5352801  0.4984213  0.68054974 -0.04362817
## [2,] -0.4539979  0.5023628 -0.71345034  0.18029462
## [3,] -0.5218272 -0.4214707 -0.14834642 -0.72667198
## [4,] -0.4848273 -0.5670716  0.07638058  0.66146675
```