# Group 3-B Multivariate Analysis

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## 1 Group 3-B Multivariate analysis of FX equilibrium

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In [1]:
```
#import the necessary libraries
library(readxl)
library(vars)
library(timeSeries)
library(tidyverse)
library(stats)
library(tseries)
library(forecast)
library(tsDyn)
```

```
Warning message:
"package 'readxl' was built under R version 3.6.3"Warning message:
"package 'vars' was built under R version 3.6.3"Loading required package: MASS
Loading required package: strucchange
Warning message:
"package 'strucchange' was built under R version 3.6.3"Loading required package: zoo
Warning message:
"package 'zoo' was built under R version 3.6.3"
Attaching package: 'zoo'

The following objects are masked from 'package:base':

    as.Date, as.Date.numeric
```

```
Loading required package: sandwich
Warning message:
"package 'sandwich' was built under R version 3.6.3"Loading required package: urca
Warning message:
"package 'urca' was built under R version 3.6.3"Loading required package: lmtest
Warning message:
"package 'lmtest' was built under R version 3.6.3"Warning message:
"package 'timeSeries' was built under R version 3.6.3"Loading required package: timeDate
Warning message:
"package 'timeDate' was built under R version 3.6.2"
Attaching package: 'timeSeries'

The following object is masked from 'package:zoo':

    time<-

Warning message:
"package 'tidyverse' was built under R version 3.6.3"-- Attaching packages --------------------
v ggplot2 3.3.0     v purrr   0.3.3
v tibble  2.1.3     v dplyr   0.8.5
v tidyr   1.0.2     v stringr 1.4.0
v readr   1.3.1     v forcats 0.5.0
Warning message:
"package 'ggplot2' was built under R version 3.6.3"Warning message:
"package 'tibble' was built under R version 3.6.3"Warning message:
"package 'tidyr' was built under R version 3.6.3"Warning message:
"package 'readr' was built under R version 3.6.3"Warning message:
"package 'purrr' was built under R version 3.6.3"Warning message:
"package 'dplyr' was built under R version 3.6.3"Warning message:
"package 'stringr' was built under R version 3.6.3"Warning message:
"package 'forcats' was built under R version 3.6.3"-- Conflicts -------------------------------
x stringr::boundary() masks strucchange::boundary()
x dplyr::filter()     masks timeSeries::filter(), stats::filter()
x purrr::flatten()    masks jsonlite::flatten()
x dplyr::lag()        masks timeSeries::lag(), stats::lag()
x dplyr::select()     masks MASS::select()
Warning message:
"package 'tseries' was built under R version 3.6.3"Registered S3 method overwritten by 'quantmo
  method            from
  as.zoo.data.frame zoo
Warning message:
"package 'forecast' was built under R version 3.6.3"Warning message:
"package 'tsDyn' was built under R version 3.6.3"
```

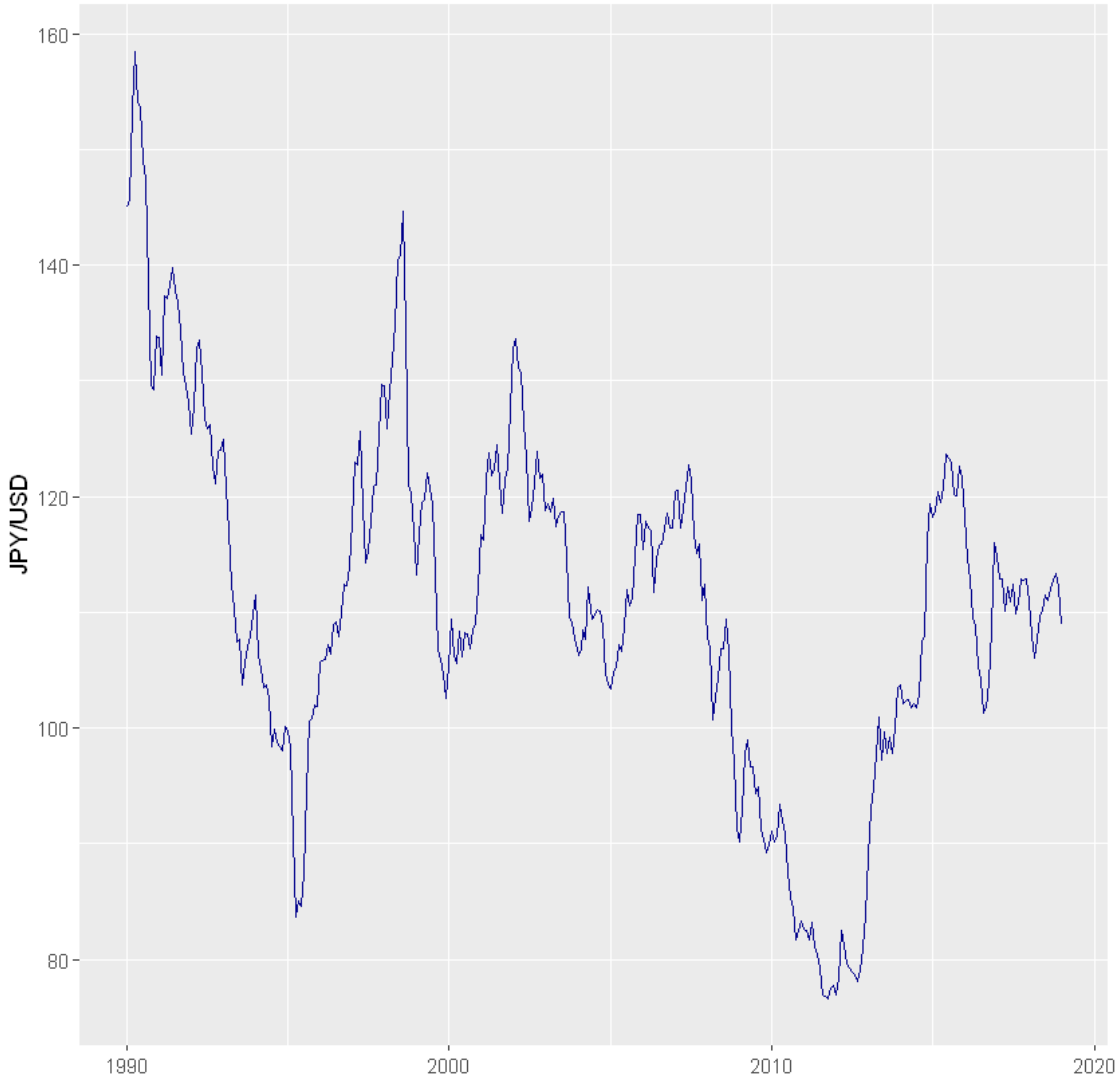
### 1.0.1 Equlibrium of US and Japan exchange rate using CPI and Interest rate of both countries. Data obtain from FRED

```
In [3]: JPY_USD <- read_excel("DEXJPUS (3).xls", col_types = c("date", "numeric"), skip = 10)
        JPY_CPI <- read_excel("JPNCPIALLMINMEI.xls", col_types = c("date", "numeric"), skip =
        JPY_IR <- read_excel("IRLTLT01JPM156N.xls", col_types = c("date", "numeric"), skip = 1
        US_CPI <- read_excel("CPIAUCSL.xls", col_types = c("date", "numeric"), skip = 10)
        US_IR <- read_excel("IRLTLT01USM156N.xls", col_types = c("date", "numeric"), skip =10)
```

### 1.0.2 Visualising the different Data

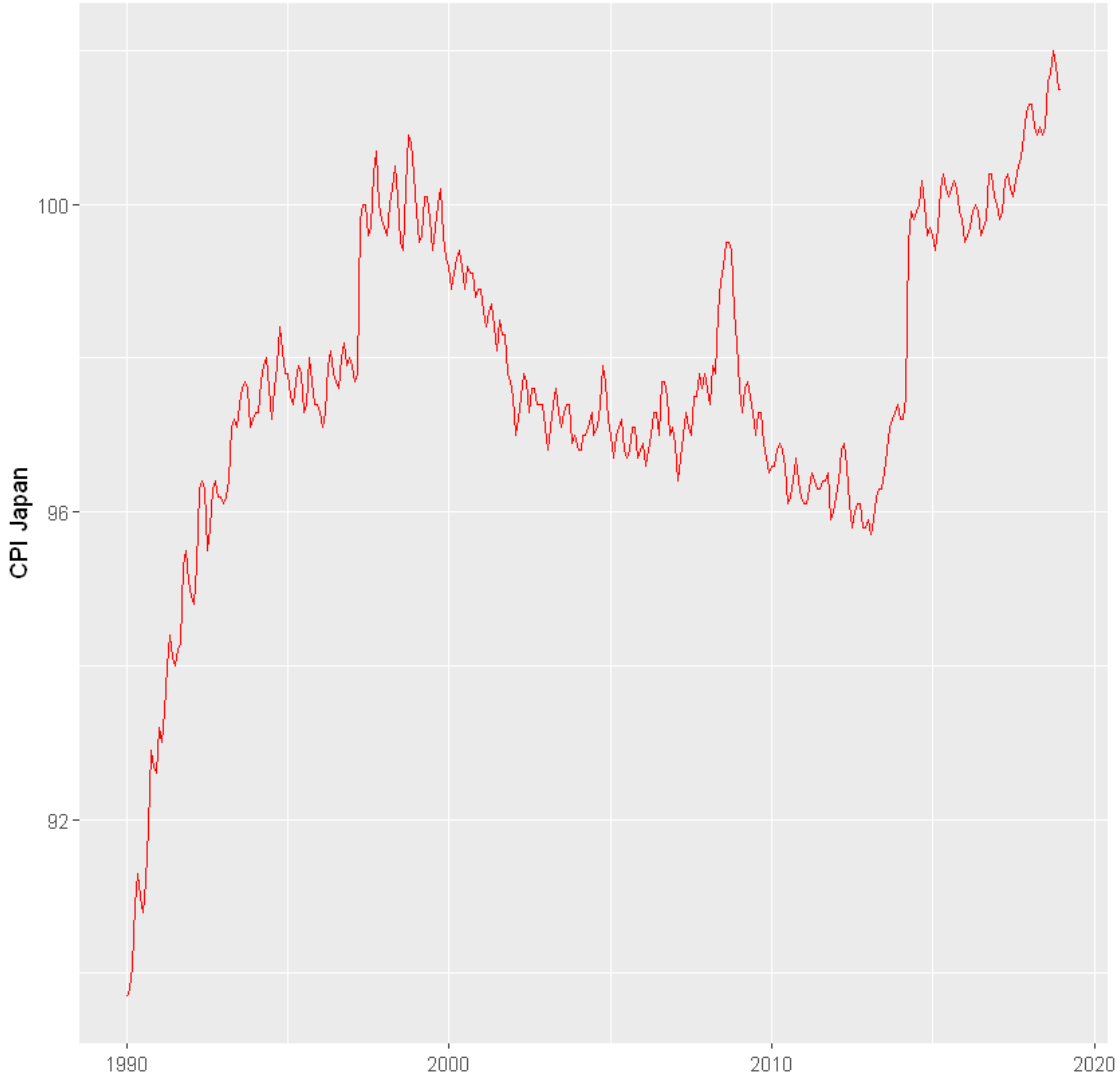
**Plot of Japan and US foreign exchange rate**

```
In [5]: ggplot(data = JPY_USD, mapping = aes(x=observation_date,y=DEXJPUS))+ geom_line(color ="
```



### Plot of Consumer Price Index of all Items in Japan

```
In [6]: ggplot(data = JPY_CPI, mapping = aes(x=observation_date,y=JPNCPIALLMINMEI))+ geom_line
```

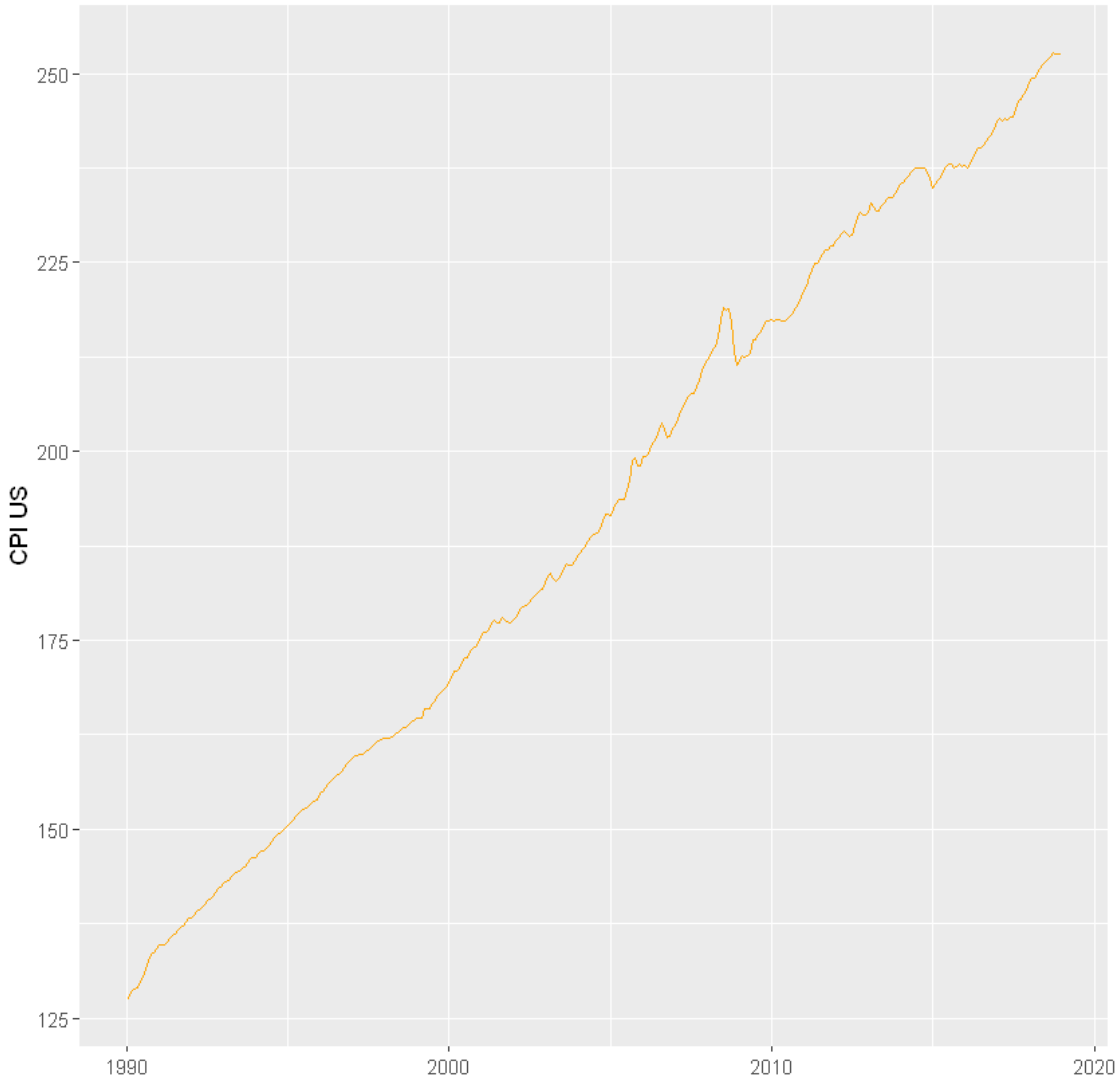



### Plot of Long Term Government Bond Yields Japan

```
In [8]: ggplot(data = JPY_IR, mapping = aes(x=observation_date,y=IRLTLT01JPM156N))+ geom_line(
```

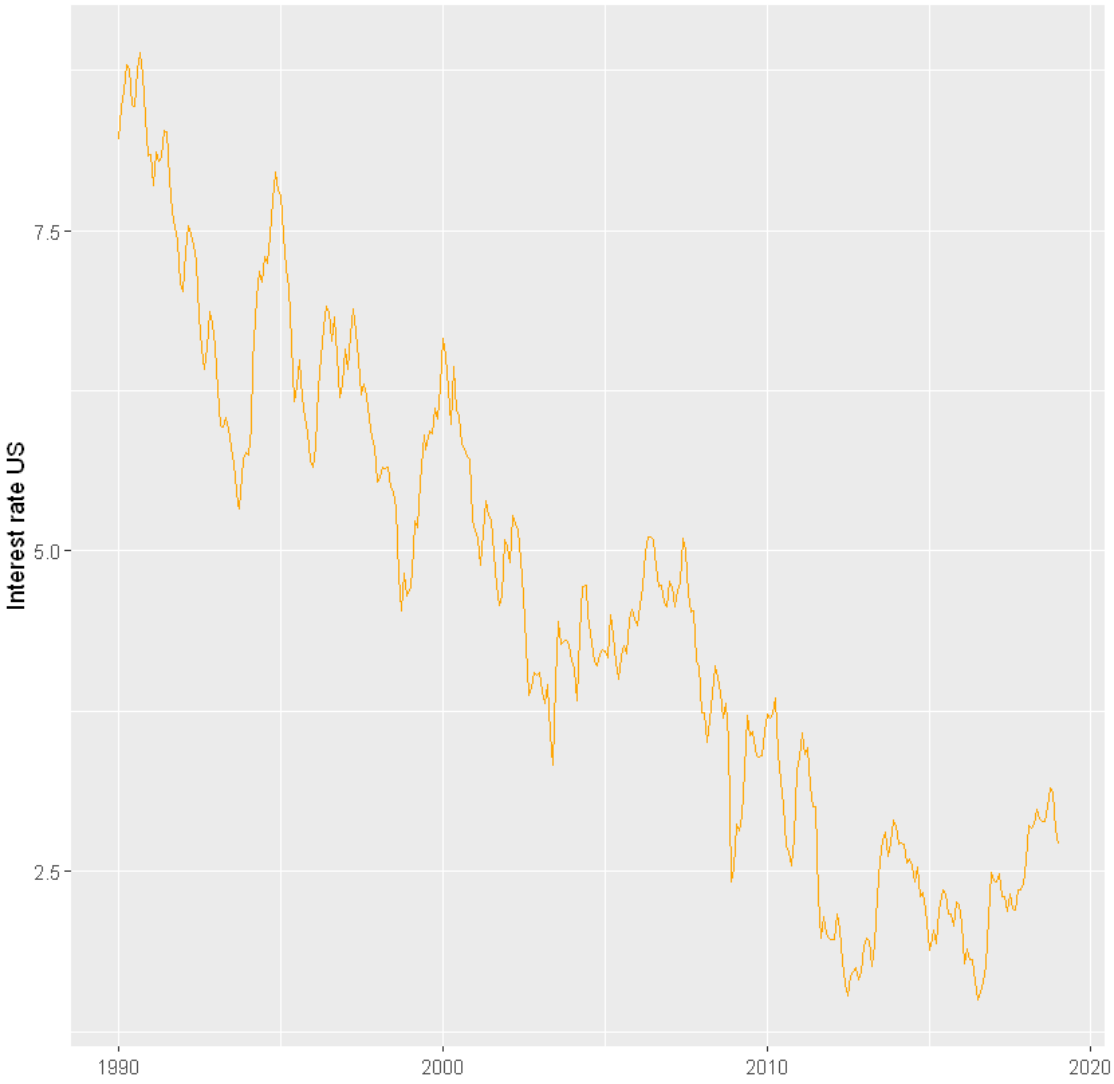

**Plot of Consumer Price Index for all Items in US**

```
In [10]: ggplot(data = US_CPI, mapping = aes(x=observation_date,y=CPIAUCSL))+ geom_line(color =
```




**Plot of Long Term Government Bond Yields in US**

```
In [12]: ggplot(data = US_IR, mapping = aes(x=observation_date,y=IRLTLT01USM156N))+ geom_line(
```




**All plots display evidence of non-stationarity. This requires a first difference to be carried out as well as initial correlation examination**

```
In [13]: # differencing data of level 1
         JPY_USD <- diff(JPY_USD$DEXJPUS,trim=TRUE)
         JPY_CPI <- diff(JPY_CPI$JPNCPIALLMINMEI,trim=TRUE)
         JPY_IR <- diff(JPY_IR$IRLTLT01JPM156N,trim=TRUE)
         US_CPI <- diff(US_CPI$CPIAUCSL,trim=TRUE)
         US_IR <- diff(US_IR$IRLTLT01USM156N,trim=TRUE)
         # compiling the data in one data frame
         data <- cbind(JPY_USD, JPY_CPI, JPY_IR, US_CPI, US_IR)
         #data <- cbind(JPY_USD,JPY_IR, US_IR)
         head(data)
```

| JPY_USD | JPY_CPI | JPY_IR | US_CPI | US_IR |
|---|---|---|---|---|
| 0.7112531 | 0.1 | 0.329 | 0.5 | 0.26 |
| 7.6150239 | 0.3 | 0.121 | 0.6 | 0.12 |
| 5.1503896 | 0.8 | 0.007 | 0.3 | 0.20 |
| -4.4144805 | 0.4 | -0.398 | 0.2 | -0.03 |
| -0.3483766 | -0.3 | -0.087 | 0.8 | -0.28 |
| -4.6561905 | -0.2 | 0.351 | 0.6 | -0.01 |

**Examining for correlation among variables}**

```
In [14]: cor(data)
```

| | JPY_USD | JPY_CPI | JPY_IR | US_CPI | US_IR |
|---|---|---|---|---|---|
| JPY_USD | 1.000000000 | -0.07717107 | 0.06824398 | -0.004709053 | 0.30202885 |
| JPY_CPI | -0.077171072 | 1.00000000 | -0.06219357 | 0.183145164 | 0.07668705 |
| JPY_IR | 0.068243980 | -0.06219357 | 1.00000000 | 0.096317360 | 0.38294392 |
| US_CPI | -0.004709053 | 0.18314516 | 0.09631736 | 1.000000000 | 0.19363346 |
| US_IR | 0.302028854 | 0.07668705 | 0.38294392 | 0.193633456 | 1.00000000 |

**It is evident that the JPY/USD exchange rate has a strong correlation with US interest rate and weak correlation with Japanese Interest rate**

### 1.0.3 Building a VAR model for 12 Lags

```
In [15]: VAR_model = VAR(data, lag.max=12, type = "none", ic = "AIC")
         summary(VAR_model)
```

```
VAR Estimation Results:
=========================
Endogenous variables: JPY_USD, JPY_CPI, JPY_IR, US_CPI, US_IR
Deterministic variables: none
Sample size: 345
Log Likelihood: -848.614
Roots of the characteristic polynomial:
0.7688 0.6741 0.6741 0.6513 0.6513 0.5532 0.5532 0.5028 0.5007 0.5007 0.4765 0.4765 0.4192 0.41
Call:
VAR(y = data, type = "none", lag.max = 12, ic = "AIC")


Estimation results for equation JPY_USD:
========================================
JPY_USD = JPY_USD.l1 + JPY_CPI.l1 + JPY_IR.l1 + US_CPI.l1 + US_IR.l1 + JPY_USD.l2 + JPY_CPI.l2

           Estimate Std. Error t value Pr(>|t|)
JPY_USD.l1  0.25247    0.05796   4.356 1.77e-05 ***
JPY_CPI.l1 -1.44126    0.46909  -3.072  0.00230 **
JPY_IR.l1  -3.15756    1.05842  -2.983  0.00306 **
US_CPI.l1   0.29427    0.29590   0.994  0.32072
```

```
US_IR.l1    1.41095    0.81636   1.728  0.08486 .
JPY_USD.l2  0.08272    0.05911   1.399  0.16265
JPY_CPI.l2  0.97522    0.47200   2.066  0.03959 *
JPY_IR.l2   0.47535    1.11743   0.425  0.67083
US_CPI.l2   0.09052    0.35194   0.257  0.79718
US_IR.l2   -1.19010    0.81472  -1.461  0.14504
JPY_USD.l3 -0.01147    0.05536  -0.207  0.83598
JPY_CPI.l3 -0.08481    0.47293  -0.179  0.85778
JPY_IR.l3   0.55273    1.09686   0.504  0.61465
US_CPI.l3  -0.53243    0.30189  -1.764  0.07871 .
US_IR.l3   -1.33927    0.79721  -1.680  0.09391 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


Residual standard error: 2.697 on 330 degrees of freedom
Multiple R-Squared: 0.1613,Adjusted R-squared: 0.1231
F-statistic:  4.23 on 15 and 330 DF,  p-value: 3.527e-07


Estimation results for equation JPY_CPI:
========================================
JPY_CPI = JPY_USD.l1 + JPY_CPI.l1 + JPY_IR.l1 + US_CPI.l1 + US_IR.l1 + JPY_USD.l2 + JPY_CPI.l2

             Estimate Std. Error t value Pr(>|t|)
JPY_USD.l1  3.673e-03  6.739e-03   0.545 0.586094
JPY_CPI.l1  1.959e-01  5.454e-02   3.592 0.000379 ***
JPY_IR.l1  -2.219e-02  1.231e-01  -0.180 0.857022
US_CPI.l1   6.364e-02  3.440e-02   1.850 0.065211 .
US_IR.l1    9.939e-02  9.491e-02   1.047 0.295779
JPY_USD.l2 -2.640e-03  6.872e-03  -0.384 0.701075
JPY_CPI.l2 -2.121e-01  5.488e-02  -3.865 0.000134 ***
JPY_IR.l2   2.316e-01  1.299e-01   1.782 0.075606 .
US_CPI.l2   1.053e-02  4.092e-02   0.257 0.797108
US_IR.l2   -1.497e-01  9.472e-02  -1.580 0.115042
JPY_USD.l3  7.867e-05  6.436e-03   0.012 0.990255
JPY_CPI.l3 -1.861e-01  5.498e-02  -3.385 0.000797 ***
JPY_IR.l3  -6.565e-02  1.275e-01  -0.515 0.607027
US_CPI.l3   6.373e-02  3.510e-02   1.816 0.070292 .
US_IR.l3    4.591e-02  9.269e-02   0.495 0.620680
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


Residual standard error: 0.3135 on 330 degrees of freedom
Multiple R-Squared: 0.1797,Adjusted R-squared: 0.1424
F-statistic: 4.819 on 15 and 330 DF,  p-value: 1.769e-08
```

```
Estimation results for equation JPY_IR:
=======================================
JPY_IR = JPY_USD.l1 + JPY_CPI.l1 + JPY_IR.l1 + US_CPI.l1 + US_IR.l1 + JPY_USD.l2 + JPY_CPI.l2 +

             Estimate Std. Error t value Pr(>|t|)
JPY_USD.l1 -0.0006218  0.0031885  -0.195 0.845493
JPY_CPI.l1  0.0298339  0.0258048   1.156 0.248461
JPY_IR.l1   0.3454315  0.0582237   5.933 7.52e-09 ***
US_CPI.l1  -0.0068462  0.0162775  -0.421 0.674327
US_IR.l1    0.0573152  0.0449077   1.276 0.202752
JPY_USD.l2 -0.0051452  0.0032516  -1.582 0.114531
JPY_CPI.l2 -0.0328156  0.0259645  -1.264 0.207170
JPY_IR.l2  -0.2191174  0.0614695  -3.565 0.000418 ***
US_CPI.l2  -0.0240127  0.0193602  -1.240 0.215741
US_IR.l2    0.0752397  0.0448177   1.679 0.094139 .
JPY_USD.l3  0.0028318  0.0030452   0.930 0.353100
JPY_CPI.l3  0.0023740  0.0260160   0.091 0.927348
JPY_IR.l3  -0.1710985  0.0603382  -2.836 0.004855 **
US_CPI.l3   0.0005350  0.0166067   0.032 0.974321
US_IR.l3    0.0318297  0.0438545   0.726 0.468475
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


Residual standard error: 0.1483 on 330 degrees of freedom
Multiple R-Squared: 0.1961,Adjusted R-squared: 0.1596
F-statistic: 5.367 on 15 and 330 DF,  p-value: 1.09e-09


Estimation results for equation US_CPI:
=======================================
US_CPI = JPY_USD.l1 + JPY_CPI.l1 + JPY_IR.l1 + US_CPI.l1 + US_IR.l1 + JPY_USD.l2 + JPY_CPI.l2 +

            Estimate Std. Error t value Pr(>|t|)
JPY_USD.l1  0.007342   0.010639   0.690 0.490622
JPY_CPI.l1  0.044332   0.086104   0.515 0.606992
JPY_IR.l1   0.126205   0.194277   0.650 0.516392
US_CPI.l1   0.636692   0.054314  11.723  < 2e-16 ***
US_IR.l1    0.062426   0.149845   0.417 0.677239
JPY_USD.l2 -0.005755   0.010850  -0.530 0.596204
JPY_CPI.l2 -0.100821   0.086637  -1.164 0.245377
JPY_IR.l2  -0.025681   0.205107  -0.125 0.900435
US_CPI.l2  -0.147127   0.064600  -2.278 0.023394 *
US_IR.l2   -0.189562   0.149545  -1.268 0.205836
JPY_USD.l3 -0.017746   0.010161  -1.746 0.081660 .
JPY_CPI.l3 -0.054860   0.086808  -0.632 0.527845
JPY_IR.l3  -0.136983   0.201333  -0.680 0.496741
```

```
US_CPI.l3   0.184252   0.055412   3.325 0.000983 ***
US_IR.l3    0.010719   0.146331   0.073 0.941652
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


Residual standard error: 0.495 on 330 degrees of freedom
Multiple R-Squared: 0.4096,Adjusted R-squared: 0.3828
F-statistic: 15.26 on 15 and 330 DF,  p-value: < 2.2e-16


Estimation results for equation US_IR:
======================================
US_IR = JPY_USD.l1 + JPY_CPI.l1 + JPY_IR.l1 + US_CPI.l1 + US_IR.l1 + JPY_USD.l2 + JPY_CPI.l2 +

             Estimate Std. Error t value Pr(>|t|)
JPY_USD.l1  0.0004102  0.0043468   0.094 0.924877
JPY_CPI.l1 -0.0309942  0.0351788  -0.881 0.378932
JPY_IR.l1   0.2647563  0.0793745   3.336 0.000948 ***
US_CPI.l1   0.0643322  0.0221905   2.899 0.003993 **
US_IR.l1    0.2130768  0.0612213   3.480 0.000568 ***
JPY_USD.l2  0.0041404  0.0044329   0.934 0.350978
JPY_CPI.l2  0.0487526  0.0353965   1.377 0.169345
JPY_IR.l2   0.0232227  0.0837993   0.277 0.781860
US_CPI.l2  -0.0362993  0.0263931  -1.375 0.169962
US_IR.l2   -0.1702915  0.0610985  -2.787 0.005625 **
JPY_USD.l3  0.0002830  0.0041515   0.068 0.945697
JPY_CPI.l3 -0.0598649  0.0354667  -1.688 0.092372 .
JPY_IR.l3   0.0113411  0.0822571   0.138 0.890424
US_CPI.l3  -0.0275637  0.0226393  -1.218 0.224278
US_IR.l3    0.0920621  0.0597854   1.540 0.124549
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


Residual standard error: 0.2022 on 330 degrees of freedom
Multiple R-Squared: 0.1748,Adjusted R-squared: 0.1373
F-statistic: 4.659 on 15 and 330 DF,  p-value: 3.99e-08



Covariance matrix of residuals:
         JPY_USD   JPY_CPI    JPY_IR    US_CPI    US_IR
JPY_USD  7.26224 -0.072081  0.049289 -0.057586 0.178629
JPY_CPI -0.07208  0.098212 -0.004152  0.015220 0.001744
JPY_IR   0.04929 -0.004152  0.021950  0.003326 0.010700
US_CPI  -0.05759  0.015220  0.003326  0.230876 0.007635
US_IR    0.17863  0.001744  0.010700  0.007635 0.040836
```

```
Correlation matrix of residuals:
         JPY_USD  JPY_CPI   JPY_IR   US_CPI   US_IR
JPY_USD  1.00000 -0.08535  0.12345 -0.04447 0.32802
JPY_CPI -0.08535  1.00000 -0.08943  0.10108 0.02754
JPY_IR   0.12345 -0.08943  1.00000  0.04673 0.35738
US_CPI  -0.04447  0.10108  0.04673  1.00000 0.07864
US_IR    0.32802  0.02754  0.35738  0.07864 1.00000
```

**The VAR model displays a significant effect of US and Japanese CPI and IR with the JPY/USD exchange rate**

### 1.0.4 Implementing the Granger causality test

**Granger Casuality test for Japanese CPI**

```
In [17]: causality(VAR_model, cause="JPY_CPI")$Granger
```

```
Granger causality H0: JPY_CPI do not Granger-cause JPY_USD JPY_IR
US_CPI US_IR

data:  VAR object VAR_model
F-Test = 1.8803, df1 = 12, df2 = 1650, p-value = 0.0325
```

**Granger Causality test for Japanese Interest rate**

```
In [18]: causality(VAR_model, cause="JPY_IR")$Granger
```

```
Granger causality H0: JPY_IR do not Granger-cause JPY_USD JPY_CPI
US_CPI US_IR

data:  VAR object VAR_model
F-Test = 3.2316, df1 = 12, df2 = 1650, p-value = 0.0001298
```

**Granger Causality test for US CPI**

```
In [19]: causality(VAR_model, cause="US_CPI")$Granger
```

```
Granger causality H0: US_CPI do not Granger-cause JPY_USD JPY_CPI
JPY_IR US_IR

data:  VAR object VAR_model
F-Test = 2.774, df1 = 12, df2 = 1650, p-value = 0.0009485
```

**Granger Causality test for US IR**

```
In [20]: causality(VAR_model, cause="US_IR")$Granger
```

```
Granger causality H0: US_IR do not Granger-cause JPY_USD JPY_CPI
JPY_IR US_CPI

data:  VAR object VAR_model
F-Test = 1.7436, df1 = 12, df2 = 1650, p-value = 0.05254
```

**Granger Causality test for JPY/USD**

```
In [21]: causality(VAR_model, cause="JPY_USD")$Granger
```

```
Granger causality H0: JPY_USD do not Granger-cause JPY_CPI JPY_IR
US_CPI US_IR

data:  VAR object VAR_model
F-Test = 0.91659, df1 = 12, df2 = 1650, p-value = 0.5293
```

**Using Granger Causality test we can see that Japanese CPI, Japanese interest rate and US CPI have the most causal effect for these estimations**

### 1.0.5 Plotting the VAR model

**JPY/USD foreign exchange data shows a stationary process according to the ACF and PACF**

```
In [22]: plot(VAR_model)
```

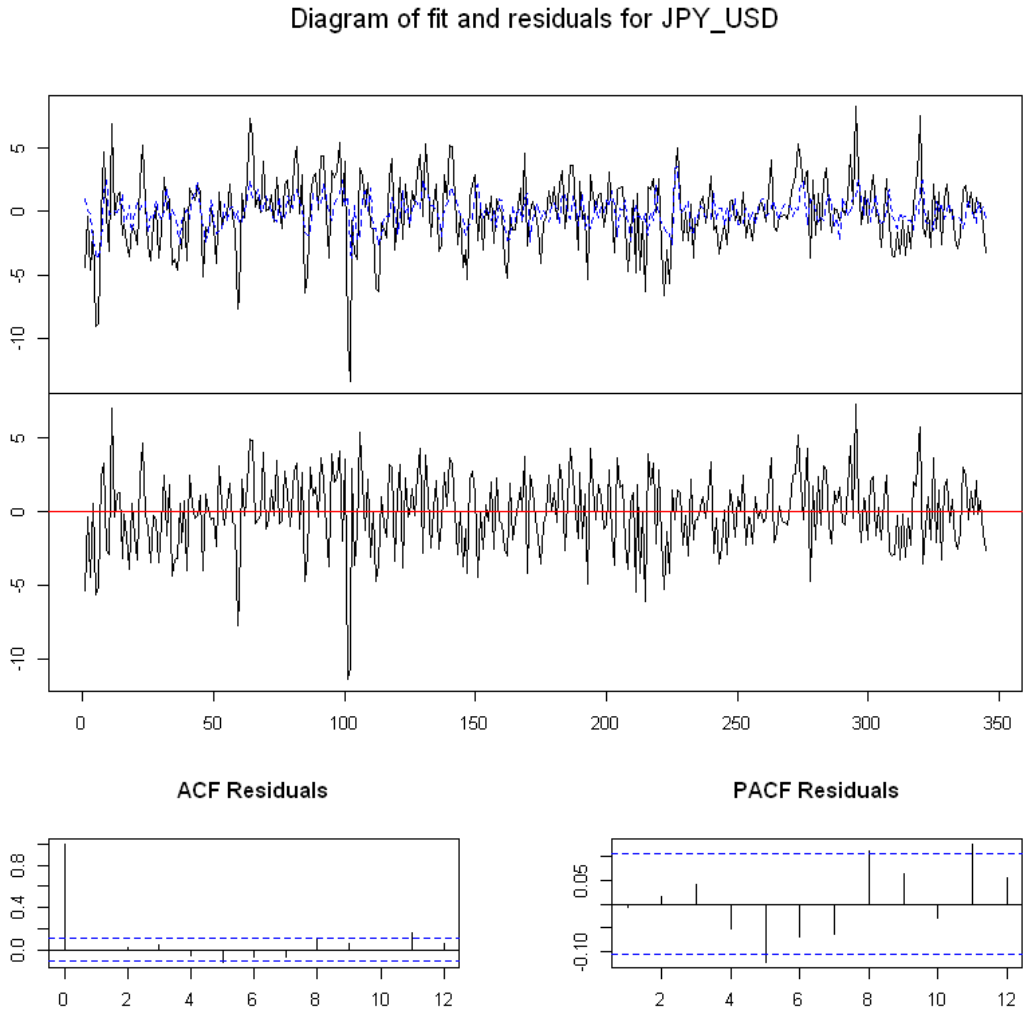


Diagram of fit and residuals for JPY_USD
5
0
-5
-10
5
0
-5
-10
0
50
100
150
200
250
300
350


ACF Residuals
0.8
0.4
0.0
0
2
4
6
8
10
12


PACF Residuals
0.05
-0.10
2
4
6
8
10
12

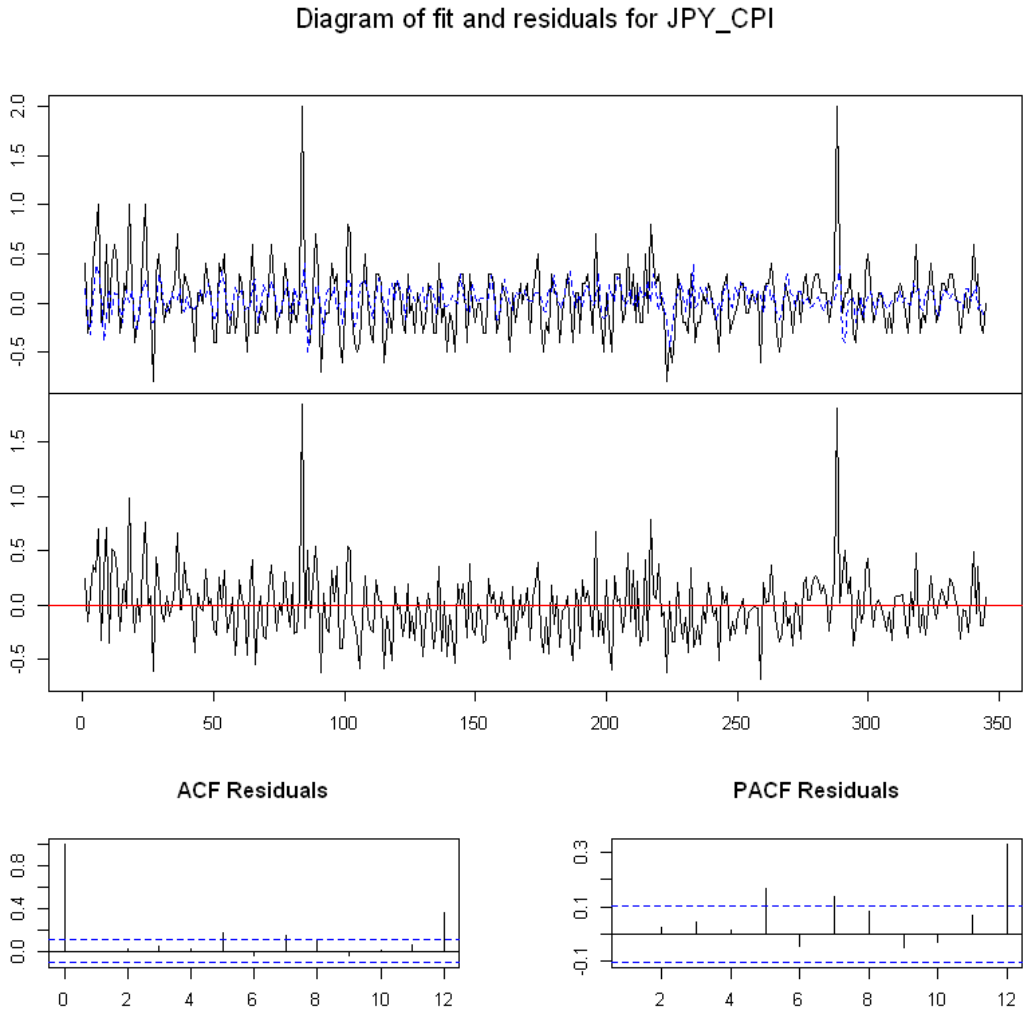


Diagram of fit and residuals for JPY_CPI
2.0
1.5
1.0
0.5
0.0
-0.5
1.5
1.0
0.5
0.0
-0.5
0
50
100
150
200
250
300
350


ACF Residuals
0.8
0.4
0.0
0
2
4
6
8
10
12


PACF Residuals
0.3
0.1
-0.1
2
4
6
8
10
12

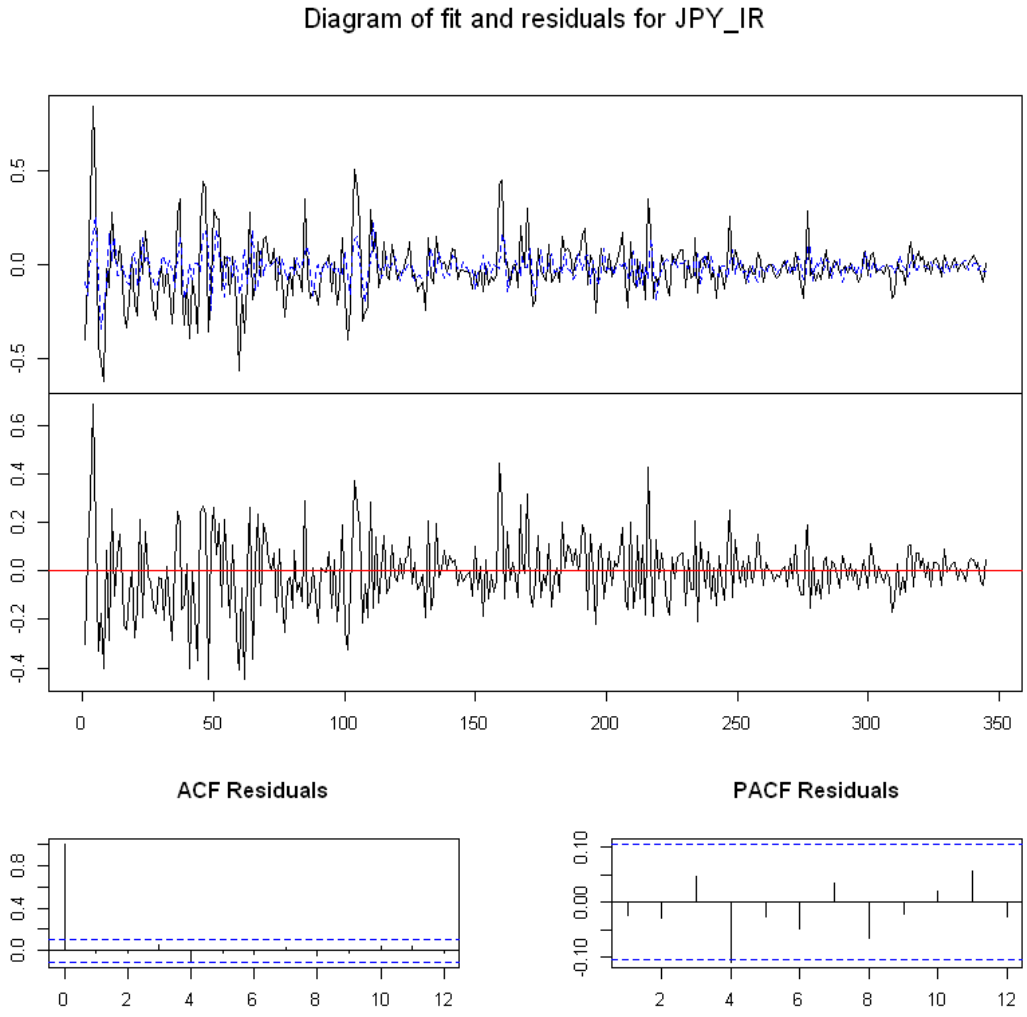


Diagram of fit and residuals for JPY_IR
0.5
0.0
-0.5
0.6
0.4
0.2
0.0
-0.2
-0.4
0
50
100
150
200
250
300
350


ACF Residuals
0.0
0.4
0.8
0
2
4
6
8
10
12


PACF Residuals
0.10
0.00
-0.10
2
4
6
8
10
12

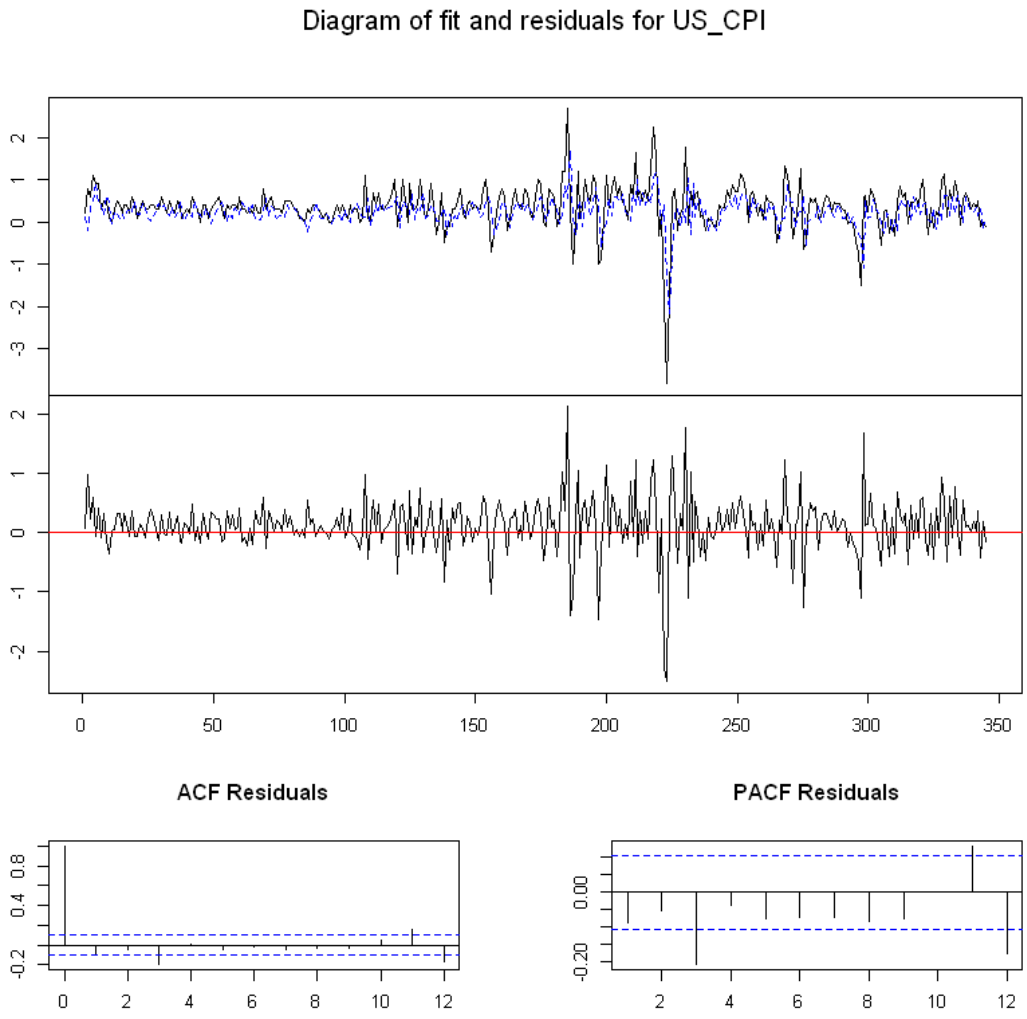
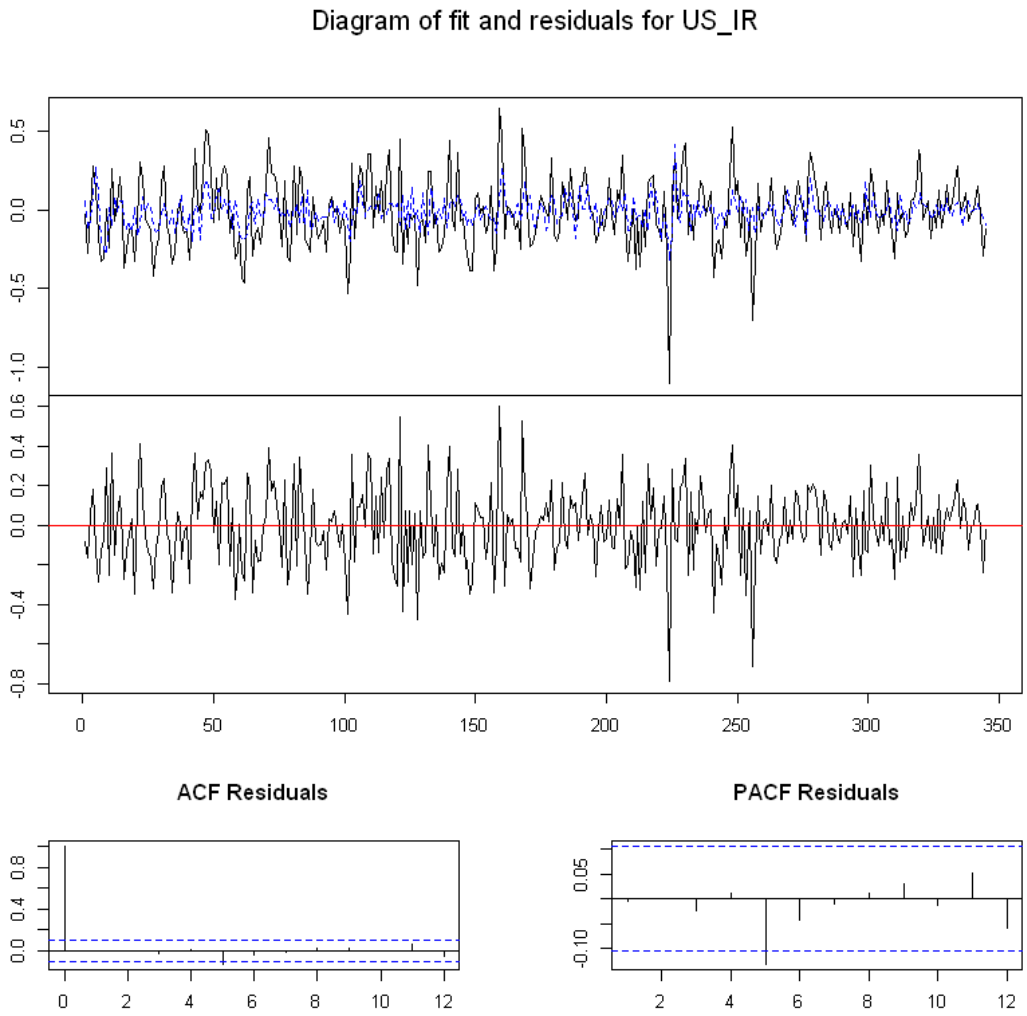


Diagram of fit and residuals for US_CPI
2
1
0
-1
-2
-3
2
1
0
-1
-2
0
50
100
150
200
250
300
350


ACF Residuals
0.8
0.4
-0.2
0
2
4
6
8
10
12

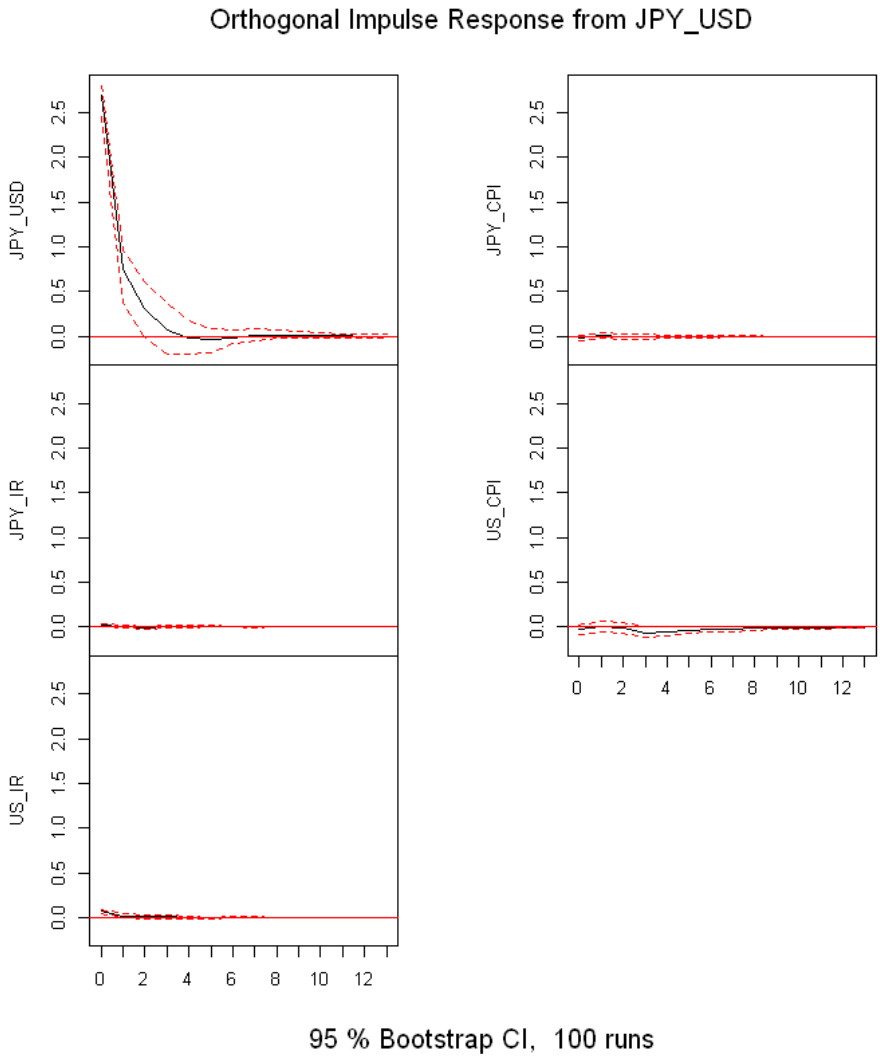

PACF Residuals
0.00
-0.20
2
4
6
8
10
12

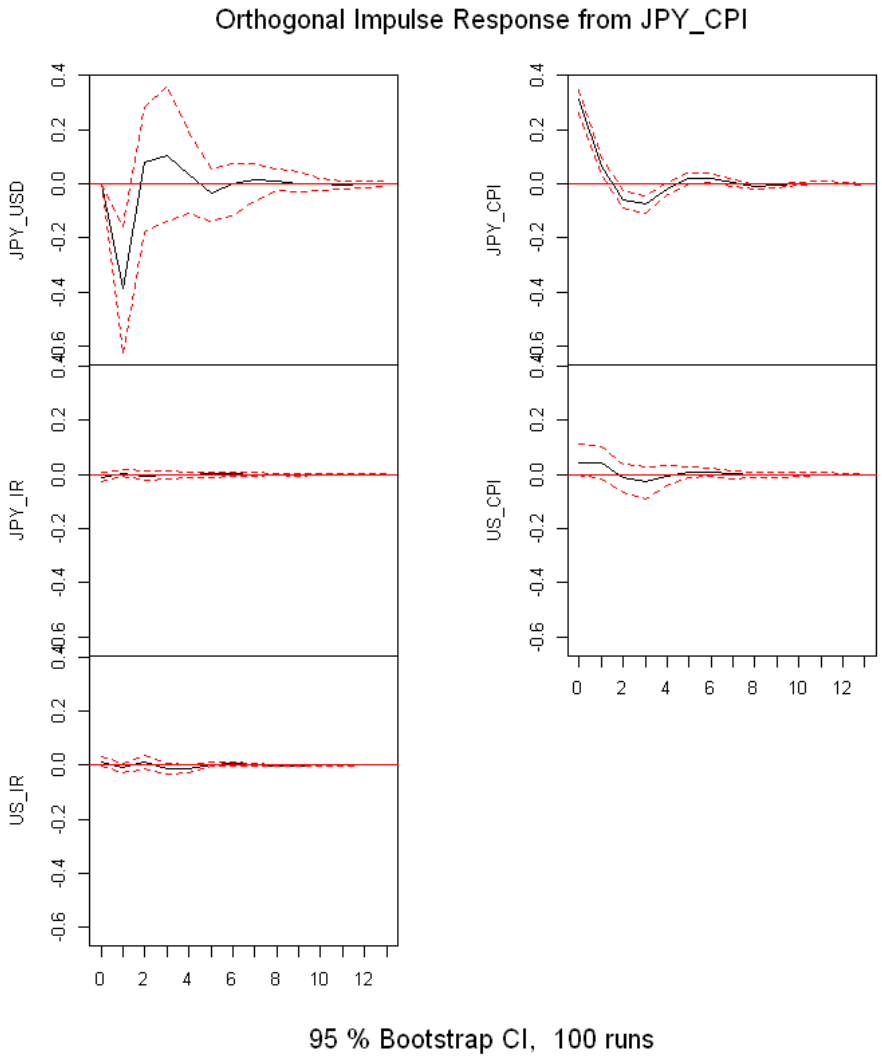


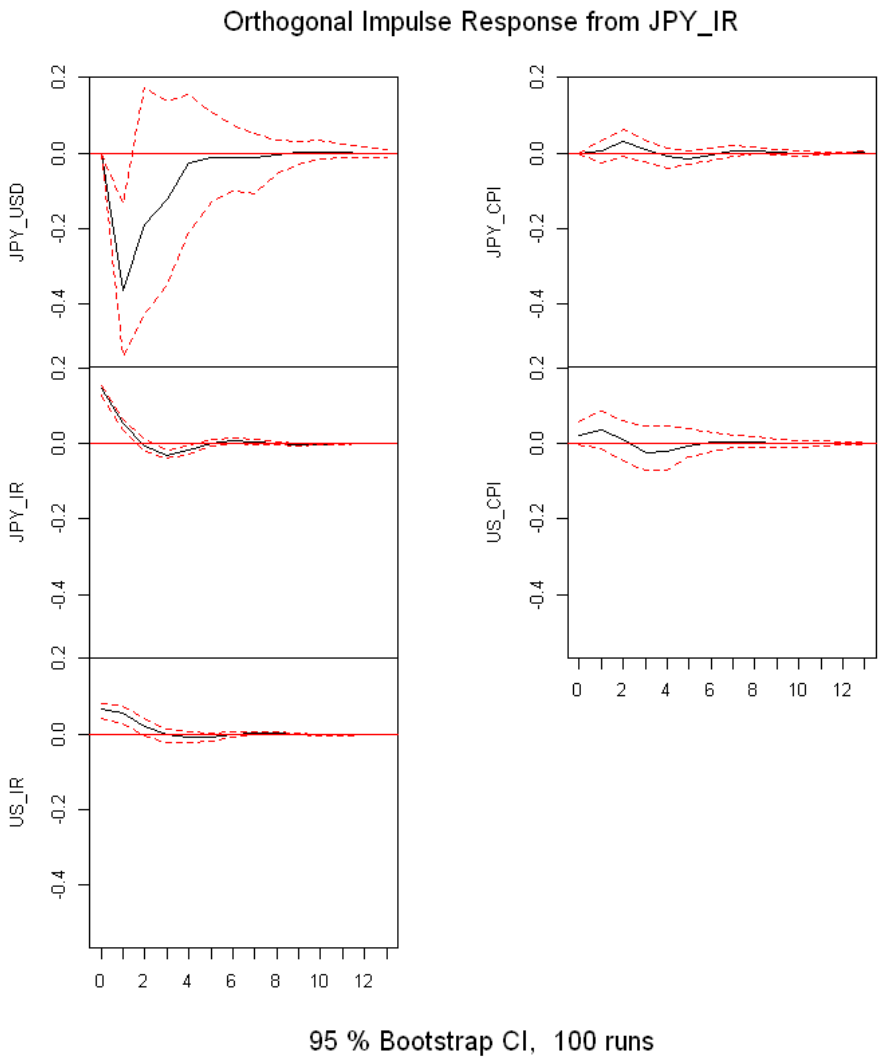

### 1.0.6 Impulse response functions

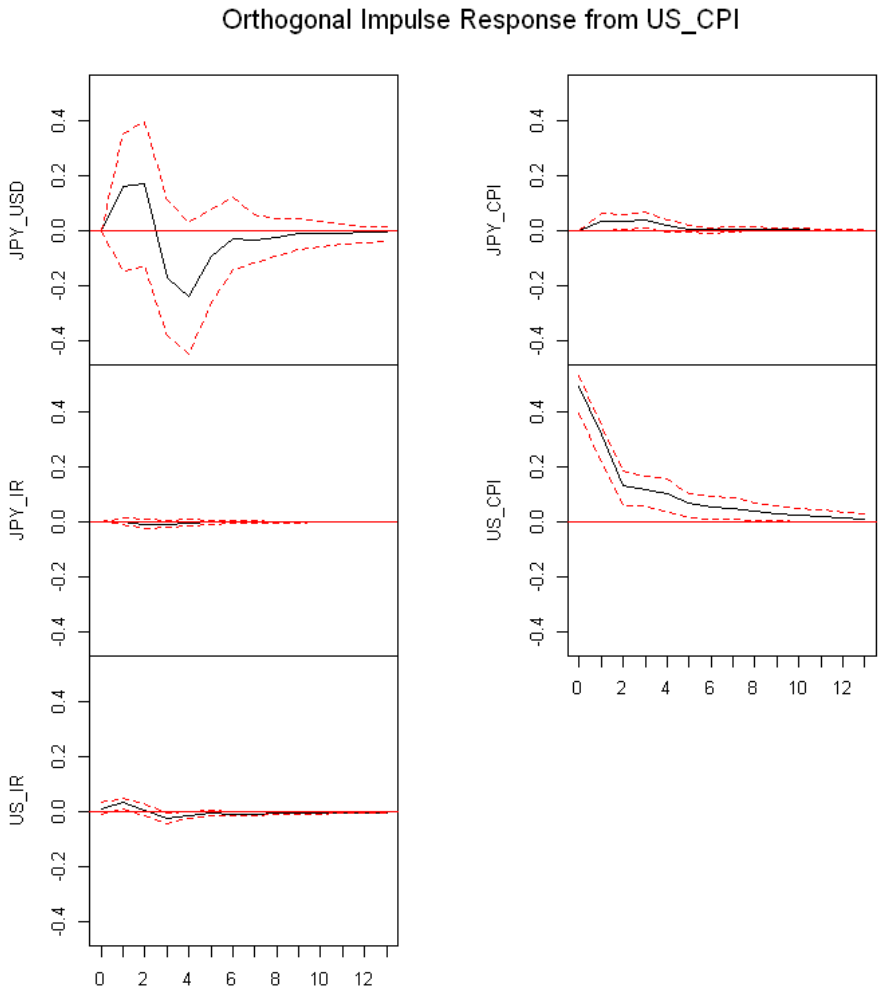
**We can see the impulse function of JPY/USD responds to its own innovation positively but the respose to other innovation seems to ocillate between positive and negative but mostly negative and finally returns to its mean in the longrun.**

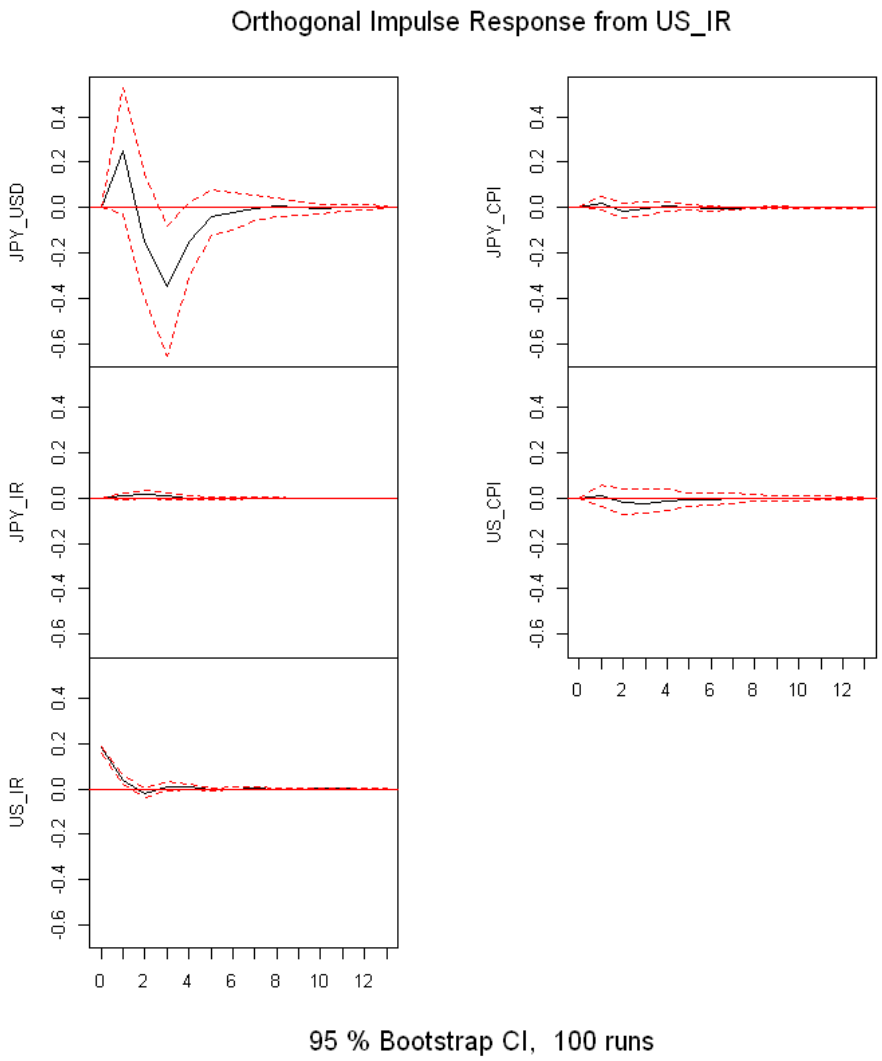
```
In [24]: VAR_irf = irf(VAR_model, n.ahead = 13,boot = TRUE, ci = 0.95)
         plot(VAR_irf)
```


Orthogonal Impulse Response from JPY_USD
JPY_USD
JPY_IR
US_IR
JPY_CPI
US_CPI
0.0
0.5
1.0
1.5
2.0
2.5
0
2
4
6
8
10
12
95 % Bootstrap CI, 100 runs


Orthogonal Impulse Response from JPY_CPI
JPY_USD
JPY_IR
US_IR
JPY_CPI
US_CPI
95 % Bootstrap CI, 100 runs


Orthogonal Impulse Response from JPY_IR
JPY_USD
JPY_IR
US_IR
JPY_CPI
US_CPI
0.2
0.0
-0.2
-0.4
0
2
4
6
8
10
12
95 % Bootstrap CI, 100 runs

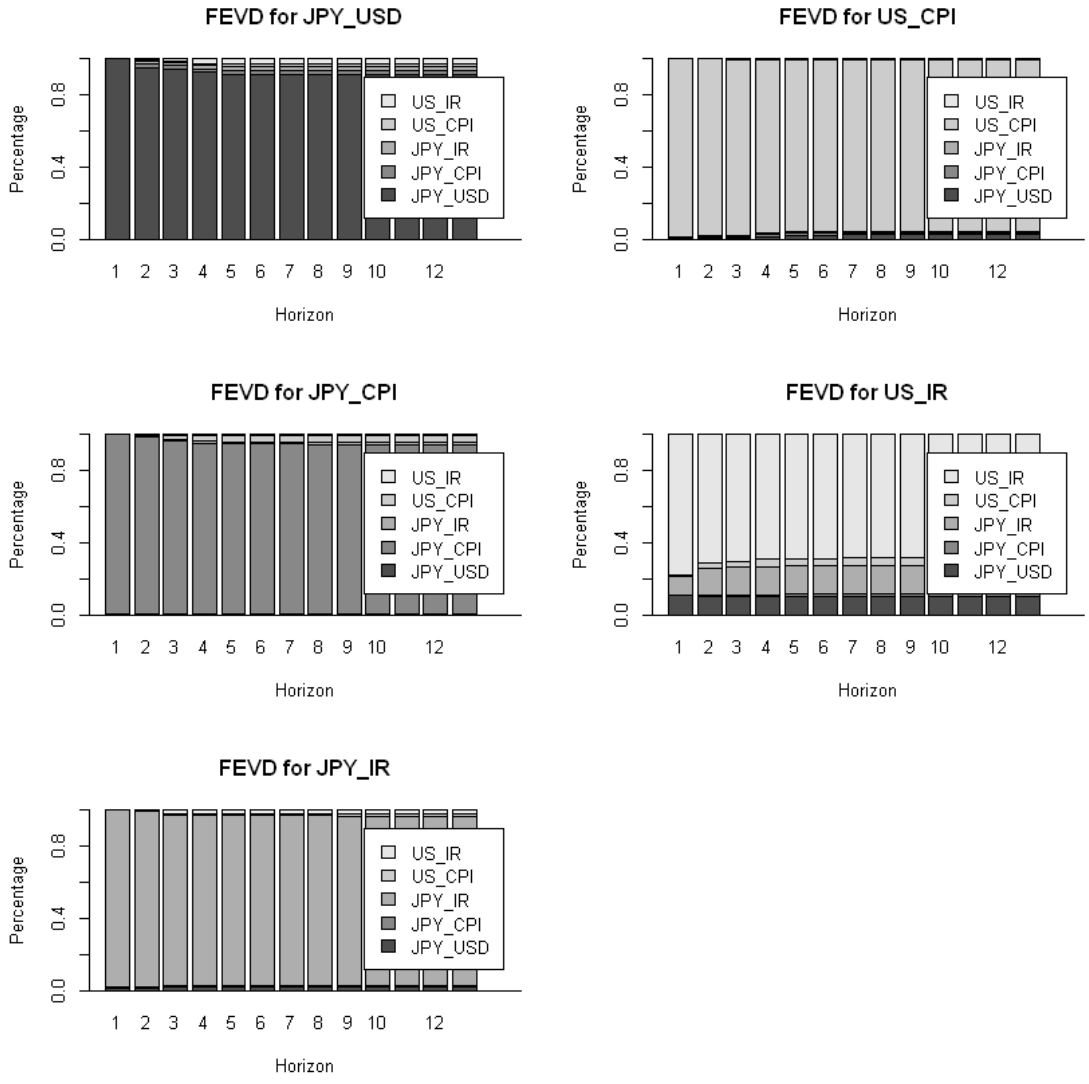

Orthogonal Impulse Response from US_CPI
JPY_USD
JPY_IR
US_IR
JPY_CPI
US_CPI
0.4
0.2
0.0
-0.2
-0.4
0
2
4
6
8
10
12
95 % Bootstrap CI, 100 runs




## 1.1 Forecast Variance Decompositon

**Forecast error decomposition shows that the JPY/USD is determined mostly by itself but in the long run it seems to be explained by all off the included variables equally**

```
In [25]: VAR_fevd <- fevd(VAR_model,n.ahead = 13)
         plot(VAR_fevd)
```




### 1.1.1 Johnson test with eigen value

```
In [26]: jotest1=ca.jo(data, type="eigen", K=2, ecdet="none", spec="longrun")
         summary(jotest1)
```

```
######################
# Johansen-Procedure #
######################

Test type: maximal eigenvalue statistic (lambda max) , with linear trend

Eigenvalues (lambda):
```

```
[1] 0.4296476 0.4031881 0.3172940 0.3067387 0.2432555

Values of teststatistic and critical values of test:

           test 10pct  5pct  1pct
r <= 4 |  96.44  6.50  8.18 11.65
r <= 3 | 126.76 12.91 14.90 19.19
r <= 2 | 132.07 18.90 21.07 25.75
r <= 1 | 178.59 24.78 27.14 32.14
r = 0  | 194.28 30.84 33.32 38.78

Eigenvectors, normalised to first column:
(These are the cointegration relations)

           JPY_USD.l2 JPY_CPI.l2 JPY_IR.l2  US_CPI.l2   US_IR.l2
JPY_USD.l2   1.000000   1.000000  1.000000   1.000000  1.0000000
JPY_CPI.l2 -12.868902  45.292045  7.188671  -1.360866  0.7213208
JPY_IR.l2   60.210002  49.904364 55.769351  53.486389 -4.0046183
US_CPI.l2    4.701533  -5.205188 13.296758 -75.238716  0.2093643
US_IR.l2   -39.040513 -38.591200 95.562599  64.678876 -3.0890532

Weights W:
(This is the loading matrix)

             JPY_USD.l2    JPY_CPI.l2     JPY_IR.l2     US_CPI.l2      US_IR.l2
JPY_USD.d -0.0353882017 -0.0086167403 -0.0285241849 -0.0136278546 -0.5813851703
JPY_CPI.d  0.0181590830 -0.0169074539 -0.0006904107  0.0007564309  0.0040323912
JPY_IR.d  -0.0087682642 -0.0024324105 -0.0028225228 -0.0006430958  0.0115536576
US_CPI.d  -0.0005925015  0.0006081467 -0.0052626773  0.0083840459 -0.0054902961
US_IR.d    0.0078368260  0.0033096585 -0.0048330278 -0.0010992580  0.0002701193
```

### 1.1.2 Johnson test with trace

```
In [27]: jotest2=ca.jo(data, type="trace", K=2, ecdet="none", spec="longrun")
         summary(jotest2)
```

```
######################
# Johansen-Procedure #
######################

Test type: trace statistic , with linear trend

Eigenvalues (lambda):
[1] 0.4296476 0.4031881 0.3172940 0.3067387 0.2432555
```

```
Values of teststatistic and critical values of test:

           test 10pct  5pct  1pct
r <= 4 |  96.44  6.50  8.18 11.65
r <= 3 | 223.20 15.66 17.95 23.52
r <= 2 | 355.26 28.71 31.52 37.22
r <= 1 | 533.85 45.23 48.28 55.43
r = 0  | 728.13 66.49 70.60 78.87

Eigenvectors, normalised to first column:
(These are the cointegration relations)

           JPY_USD.12 JPY_CPI.12 JPY_IR.12  US_CPI.12   US_IR.12
JPY_USD.12   1.000000   1.000000  1.000000   1.000000  1.0000000
JPY_CPI.12 -12.868902  45.292045  7.188671  -1.360866  0.7213208
JPY_IR.12   60.210002  49.904364 55.769351  53.486389 -4.0046183
US_CPI.12    4.701533  -5.205188 13.296758 -75.238716  0.2093643
US_IR.12   -39.040513 -38.591200 95.562599  64.678876 -3.0890532

Weights W:
(This is the loading matrix)

             JPY_USD.12    JPY_CPI.12     JPY_IR.12     US_CPI.12      US_IR.12
JPY_USD.d -0.0353882017 -0.0086167403 -0.0285241849 -0.0136278546 -0.5813851703
JPY_CPI.d  0.0181590830 -0.0169074539 -0.0006904107  0.0007564309  0.0040323912
JPY_IR.d  -0.0087682642 -0.0024324105 -0.0028225228 -0.0006430958  0.0115536576
US_CPI.d  -0.0005925015  0.0006081467 -0.0052626773  0.0083840459 -0.0054902961
US_IR.d    0.0078368260  0.0033096585 -0.0048330278 -0.0010992580  0.0002701193
```

**Both tests fail to reject the hypothesis that we have at most 4 cointegration relationships between the variables. Thus, we have more than four common stochastic trends or conintegration between the variables**

### 1.1.3 Constructing Vector error correction model with r = 4

```
In [28]: fit = VECM(data, 1, r = 4, include = "const",estim = "ML", LRinclude = "none")
         summary(fit)
```

```
##############
###Model VECM
##############
Full sample size: 348  End sample size: 346
Number of variables: 5  Number of estimated slope parameters 50
AIC -3004.952  BIC -2797.244  SSR 3190.935
Cointegrating vector (estimated by ML):
        JPY_USD       JPY_CPI       JPY_IR        US_CPI       US_IR
```

```
r1 1.000000e+00 -8.615331e-14 1.705303e-13  1.136868e-13 5368.345997
r2 1.387779e-17  1.000000e+00 4.440892e-16  0.000000e+00  -15.834006
r3 4.163336e-17 -1.942890e-15 1.000000e+00 -1.776357e-15  -93.527987
r4 0.000000e+00  1.387779e-17 1.110223e-16  1.000000e+00    4.289557
```

| | ECT1 | ECT2 | ECT3 |
|---|---|---|---|
| Equation JPY_USD | -0.0862(0.0247)*** | -0.1214(0.6441) | -4.8804(1.4065)*** |
| Equation JPY_CPI | 0.0013(0.0026) | -1.0055(0.0680)*** | 0.2516(0.1485). |
| Equation JPY_IR | -0.0147(0.0012)*** | -0.0167(0.0323) | -0.8411(0.0705)*** |
| Equation US_CPI | 0.0031(0.0038) | -0.0141(0.0987) | 0.1496(0.2156) |
| Equation US_IR | 0.0052(0.0017)** | 0.0158(0.0431) | 0.3087(0.0942)** |
| | ECT4 | Intercept | JPY_USD -1 |
| Equation JPY_USD | 0.5245(0.3969) | -0.3502(0.2182) | -0.3559(0.0499)*** |
| Equation JPY_CPI | 0.1073(0.0419)* | -0.0015(0.0230) | 0.0014(0.0053) |
| Equation JPY_IR | -0.0177(0.0199) | -0.0089(0.0109) | 0.0084(0.0025)*** |
| Equation US_CPI | -0.7067(0.0608)*** | 0.2575(0.0334)*** | 0.0062(0.0076) |
| Equation US_IR | 0.0381(0.0266) | -0.0239(0.0146) | -0.0051(0.0033) |
| | JPY_CPI -1 | JPY_IR -1 | US_CPI -1 |
| Equation JPY_USD | -1.3440(0.5037)** | -0.3828(1.1818) | 0.1676(0.3588) |
| Equation JPY_CPI | 0.2526(0.0532)*** | -0.2152(0.1248). | -0.0393(0.0379) |
| Equation JPY_IR | 0.0403(0.0252) | 0.2616(0.0592)*** | 0.0151(0.0180) |
| Equation US_CPI | 0.0934(0.0772) | 0.0509(0.1812) | 0.1936(0.0550)*** |
| Equation US_IR | -0.0354(0.0337) | -0.0372(0.0792) | 0.0401(0.0240). |
| | US_IR -1 | | |
| Equation JPY_USD | 2.9243(0.8621)*** | | |
| Equation JPY_CPI | 0.1216(0.0910) | | |
| Equation JPY_IR | -0.0727(0.0432). | | |
| Equation US_CPI | 0.0670(0.1322) | | |
| Equation US_IR | 0.1599(0.0577)** | | |

**ECT1 and ECT3 are both negative and significant, indicating there is error correction in the long run which are linked to the Japanness and US CPI. this can help construct a more parsiomonous model**

**Short run dynamics of JPY CPI and US interest rate shows significant signs**