BACHELOR OF ECONOMICS
THAMMASAT UNIVERSITY

Answer Sheet Cover Page
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(Readable handwriting and printed version are acceptable)

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Student Signature Chawt

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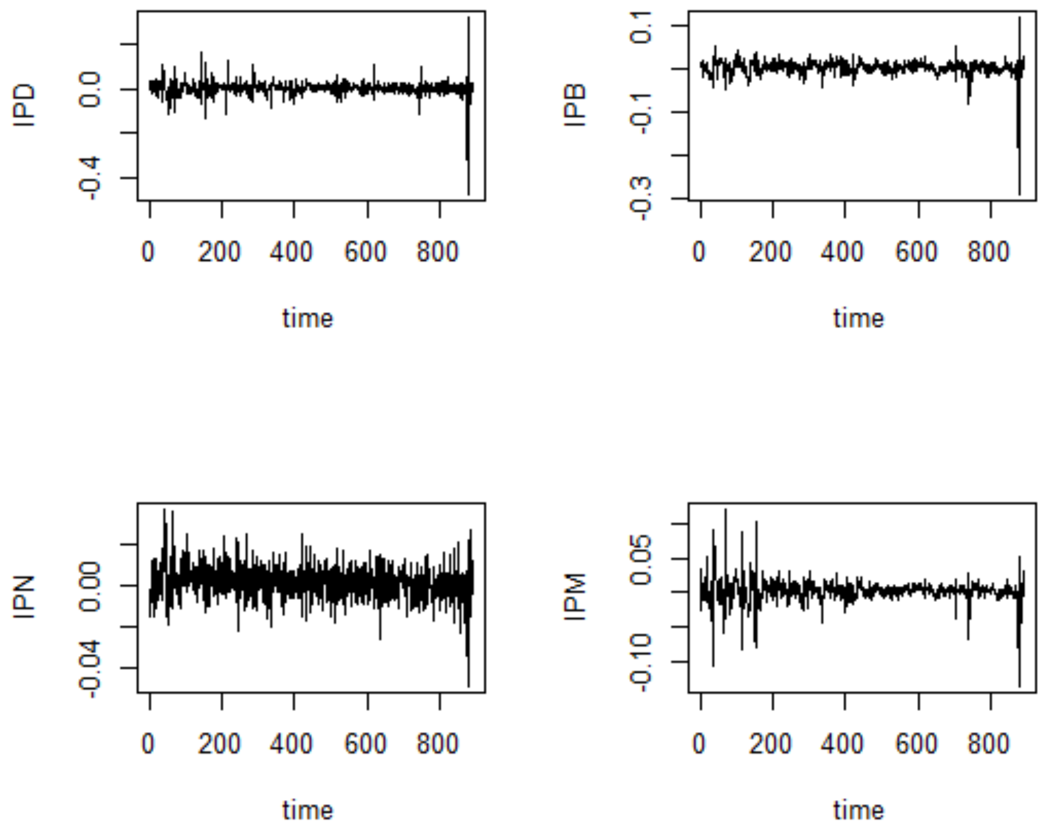
Question1

Q1.1



The graphs above seem to have a weakly stationarity and the average and variance of the graphs are quite constant but only at the end that has a significant spike. These spikes could be from the COVID.

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Q1.2

```
> VARorder(Q1zt1)
selected order: aic =  6
selected order: bic =  2
selected order: hq =  3
Summary table:
       p     AIC     BIC      HQ     M(p) p-value
 [1,]  0 -34.0260 -34.0260 -34.0260   0.0000  0.0000
 [2,]  1 -34.1944 -34.1083 -34.1615 178.2331  0.0000
 [3,]  2 -34.3289 -34.1567 -34.2631 147.9623  0.0000
 [4,]  3 -34.3844 -34.1262 -34.2857  79.0713  0.0000
 [5,]  4 -34.3851 -34.0408 -34.2535  31.4646  0.0117
 [6,]  5 -34.4369 -34.0066 -34.2724  75.1412  0.0000
 [7,]  6 -34.4582 -33.9418 -34.2608  48.7671  0.0000
 [8,]  7 -34.4429 -33.8405 -34.2127  17.5535  0.3507
 [9,]  8 -34.4246 -33.7361 -34.1614  14.8136  0.5383
[10,]  9 -34.4189 -33.6444 -34.1229  25.4492  0.0623
[11,] 10 -34.4146 -33.5540 -34.0857  26.3997  0.0487
[12,] 11 -34.4087 -33.4620 -34.0469  24.9845  0.0701
[13,] 12 -34.4155 -33.3829 -34.0209  35.4558  0.0034
[14,] 13 -34.4147 -33.2960 -33.9871  28.9289  0.0244
Warning messages:
```

BIC has the smallest value at period 2, therefore the optimal lag is 2 period

```
> Q1m2 = refVAR(Q1m1, thres = 1.645)
Constant term:
Estimates:  0.002152919 0.001773043 0.001842434 0.00124001
Std.Error:  0.00109649 0.0002686661 0.0005687657 0.0005346031
AR coefficient matrix
AR( 1 )-matrix
       [,1]   [,2]  [,3]  [,4]
[1,] 0.1023  0.000 0.000 0.347
[2,] 0.0348 -0.155 0.000 0.000
[3,] 0.0000  0.000 0.134 0.185
[4,] 0.0000  0.178 0.000 0.232
standard error
        [,1]   [,2]   [,3]   [,4]
[1,] 0.03733 0.0000 0.0000 0.0783
[2,] 0.00844 0.0351 0.0000 0.0000
[3,] 0.00000 0.0000 0.0378 0.0413
[4,] 0.00000 0.0672 0.0000 0.0337
AR( 2 )-matrix
       [,1]  [,2]   [,3]  [,4]
[1,] -0.129 0.000 -0.175 0.000
[2,]  0.000 0.000  0.000 0.000
[3,] -0.139 0.000  0.182 0.102
[4,]  0.000 0.144  0.000 0.000
standard error
       [,1]   [,2]   [,3]   [,4]
[1,] 0.0454 0.0000 0.0860 0.0000
[2,] 0.0000 0.0000 0.0000 0.0000
[3,] 0.0238 0.0000 0.0464 0.0425
[4,] 0.0000 0.0654 0.0000 0.0000

Residuals cov-mtx:
             [,1]        [,2]         [,3]         [,4]
[1,] 0.0010096231 8.27661e-05 0.0003701401 0.0002322786
[2,] 0.0000827661 6.14838e-05 0.0000439733 0.0000313845
[3,] 0.0003701401 4.39733e-05 0.0002684327 0.0001256237
[4,] 0.0002322786 3.13845e-05 0.0001256237 0.0002315673

det(SSE) =  1.175217e-15
AIC =  -34.3459
BIC =  -34.2706
HQ  =  -34.31712
```

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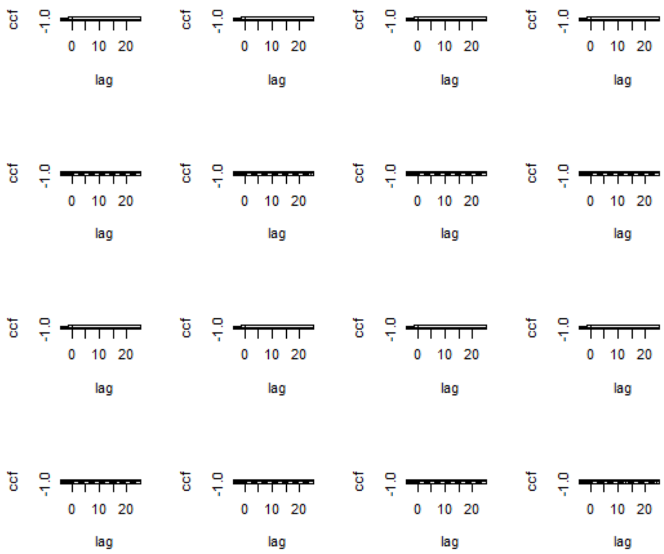
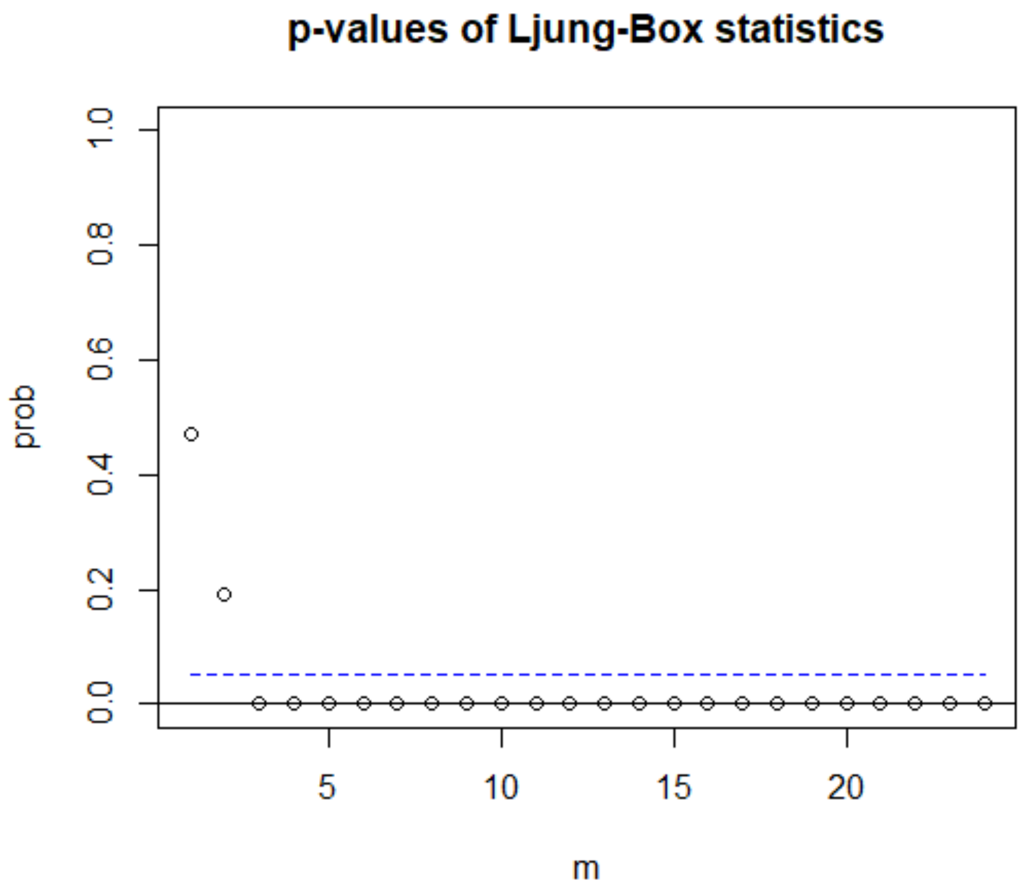
```
> MTSdiag(Q1m2)
[1] "Covariance matrix:"
         IPD      IPN      IPB      IPM
IPD 1.01e-03 8.29e-05 0.000371 2.33e-04
IPN 8.29e-05 6.16e-05 0.000044 3.14e-05
IPB 3.71e-04 4.40e-05 0.000269 1.26e-04
IPM 2.33e-04 3.14e-05 0.000126 2.32e-04
CCM at lag:  0
      [,1]  [,2]  [,3]  [,4]
[1,] 1.000 0.332 0.711 0.480
[2,] 0.332 1.000 0.342 0.263
[3,] 0.711 0.342 1.000 0.504
[4,] 0.480 0.263 0.504 1.000
Simplified matrix:
CCM at lag:  1
. . . .
. . . .
. . . .
. . . .
CCM at lag:  2
. . . .
. . . .
. . . .
. . . .
CCM at lag:  3
- . . .
. . . .
. . . .
. + . .
```





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The fitted model for the equation is

$$
\begin{bmatrix} \widehat{IPD} \\ \widehat{IPN} \\ \widehat{IPB} \\ \widehat{IPm} \end{bmatrix}
=
\begin{bmatrix} \underset{(0.00109649)}{0.002152919} \\ \underset{(0.0002686661)}{0.001773043} \\ \underset{(0.0005687657)}{0.001842434} \\ \underset{(0.0005346031)}{0.00124001} \end{bmatrix}
+
\begin{bmatrix}
\underset{(0.03733)}{0.1023} & \underset{(0.0000)}{0.000} & \underset{(0.0000)}{0.000} & \underset{(0.0783)}{0.347} \\
\underset{(0.00844)}{0.0348} & \underset{(0.0351)}{-0.155} & \underset{(0.0000)}{0.000} & \underset{(0.0000)}{0.000} \\
\underset{(0.00000)}{0.0000} & \underset{(0.0000)}{0.000} & \underset{(0.0378)}{0.134} & \underset{(0.0413)}{0.185} \\
\underset{(0.00000)}{0.0000} & \underset{(0.0672)}{0.178} & \underset{(0.0000)}{0.000} & \underset{(0.0337)}{0.232}
\end{bmatrix}
\begin{bmatrix} \widehat{IPD}_{t-1} \\ \widehat{IPN}_{t-1} \\ \widehat{IPB}_{t-1} \\ \widehat{IPm}_{t-1} \end{bmatrix}
$$

$$
+
\begin{bmatrix}
\underset{(0.0454)}{-0.129} & \underset{(0.0000)}{0.000} & \underset{(0.0860)}{-0.175} & \underset{(0.0000)}{0.000} \\
\underset{(0.0000)}{0.000} & \underset{(0.0000)}{0.000} & \underset{(0.0000)}{0.000} & \underset{(0.0000)}{0.000} \\
\underset{(0.0238)}{-0.139} & \underset{(0.0000)}{0.000} & \underset{(0.0464)}{0.182} & \underset{(0.0425)}{0.102} \\
\underset{(0.0000)}{0.000} & \underset{(0.0654)}{0.144} & \underset{(0.0000)}{0.000} & \underset{(0.0000)}{0.000}
\end{bmatrix}
\begin{bmatrix} \widehat{IPD}_{t-2} \\ \widehat{IPN}_{t-2} \\ \widehat{IPB}_{t-2} \\ \widehat{IPm}_{t-2} \end{bmatrix}
$$

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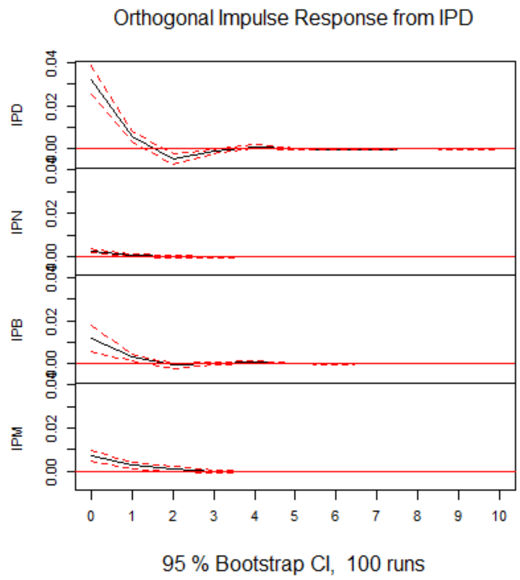
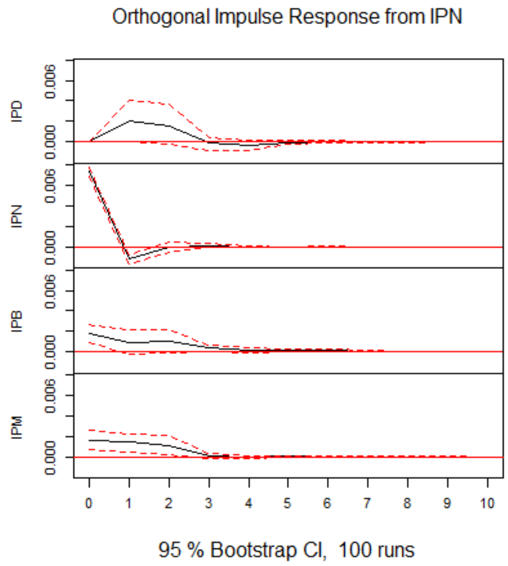
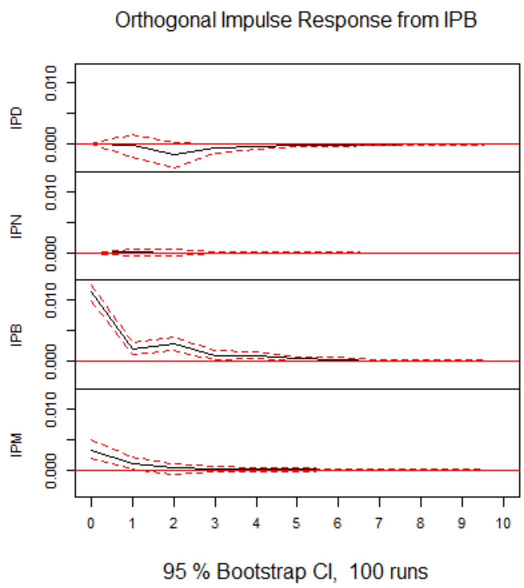
Q1.3

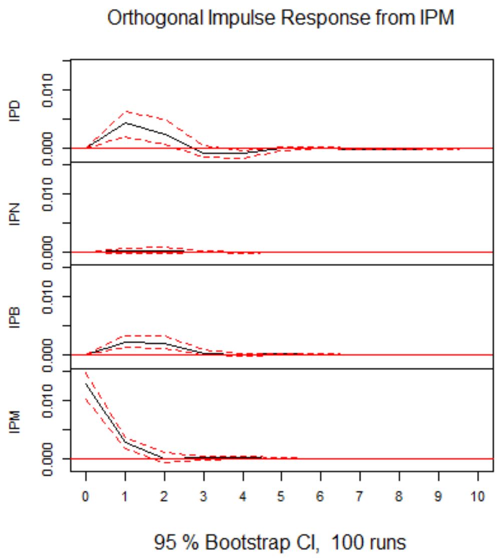
```
Covariance matrix of residuals:
          IPD       IPN       IPB       IPM
IPD 1.013e-03 8.423e-05 3.731e-04 2.364e-04
IPN 8.423e-05 6.194e-05 4.452e-05 3.173e-05
IPB 3.731e-04 4.452e-05 2.710e-04 1.270e-04
IPM 2.364e-04 3.173e-05 1.270e-04 2.328e-04

Correlation matrix of residuals:
       IPD    IPN    IPB    IPM
IPD 1.0000 0.3363 0.7120 0.4868
IPN 0.3363 1.0000 0.3436 0.2643
IPB 0.7120 0.3436 1.0000 0.5055
IPM 0.4868 0.2643 0.5055 1.0000
```









IPD does not seem to be affected by IPN, IPB, nor IPM for the same period.

IPN at the current period is affected by IPD but not IPB and IPM.

IPB at the current period is only affected by IPM

IPM is affected by all variables at the same time. Th shocks seem to have positive value for most of the period in all variables.

The shock from IPD seems to last for 3 periods then concerts to long run growth.

The shock from IPN on IPD and IPB for about 3 periods of time but 4 periods for IPD

The shock from IPB seems to last about 4 periods on IPD and IPM

The shock from IPM on IPD and IPB for 2-3 periods.

All the shocks will convert into long run growth rate after at most 4 period. The shocks from each variable will exists for about 1-4 periods of time and then will convert to long run growth rate.

Q1.4

```
$IPD
            IPD         IPN          IPB        IPM
 [1,] 1.0000000 0.000000000 0.000000e+00 0.00000000
 [2,] 0.9786677 0.003677477 1.547554e-05 0.01763932
 [3,] 0.9681556 0.005825149 2.865465e-03 0.02315381
 [4,] 0.9673749 0.005826039 3.233717e-03 0.02356535
 [5,] 0.9664951 0.005913986 3.365580e-03 0.02422538
 [6,] 0.9664566 0.005918078 3.400740e-03 0.02422457
 [7,] 0.9664239 0.005917334 3.427742e-03 0.02423098
 [8,] 0.9664153 0.005917546 3.434368e-03 0.02423283
 [9,] 0.9664095 0.005918007 3.436407e-03 0.02423607
[10,] 0.9664087 0.005918072 3.437077e-03 0.02423614

$IPN
            IPD       IPN          IPB          IPM
 [1,] 0.1130659 0.8869341 0.0000000000 0.0000000000
 [2,] 0.1176617 0.8812807 0.0003848728 0.0006727082
 [3,] 0.1176060 0.8808902 0.0003857537 0.0011180226
 [4,] 0.1178793 0.8805521 0.0003980169 0.0011706388
 [5,] 0.1178761 0.8805347 0.0003990007 0.0011902249
 [6,] 0.1178942 0.8805099 0.0003989982 0.0011968518
 [7,] 0.1178942 0.8805093 0.0003991068 0.0011974314
 [8,] 0.1178956 0.8805076 0.0003991836 0.0011976850
 [9,] 0.1178956 0.8805075 0.0003991979 0.0011977477
[10,] 0.1178956 0.8805074 0.0003991997 0.0011977775

$IPB
            IPD        IPN       IPB        IPM
 [1,] 0.5069355 0.01224107 0.4808235 0.00000000
 [2,] 0.5048449 0.01432290 0.4624710 0.01836117
 [3,] 0.4828424 0.01696945 0.4679075 0.03228060
 [4,] 0.4812822 0.01727732 0.4688451 0.03259533
 [5,] 0.4808006 0.01725670 0.4694796 0.03246315
 [6,] 0.4806182 0.01727671 0.4695372 0.03256786
 [7,] 0.4804322 0.01729458 0.4696161 0.03265708
 [8,] 0.4803961 0.01729859 0.4696392 0.03266607
 [9,] 0.4803859 0.01729914 0.4696485 0.03266650
[10,] 0.4803820 0.01729948 0.4696507 0.03266778

$IPM
            IPD        IPN        IPB       IPM
 [1,] 0.2369914 0.01140501 0.04501385 0.7065897
 [2,] 0.2512518 0.01903374 0.04569678 0.6840177
 [3,] 0.2554440 0.02378324 0.04554842 0.6752243
 [4,] 0.2555947 0.02379966 0.04558903 0.6750166
 [5,] 0.2556231 0.02379681 0.04559513 0.6749849
 [6,] 0.2556249 0.02379765 0.04559845 0.6749790
 [7,] 0.2556289 0.02379741 0.04560048 0.6749732
 [8,] 0.2556296 0.02379737 0.04560115 0.6749719
 [9,] 0.2556295 0.02379740 0.04560134 0.6749718
[10,] 0.2556295 0.02379741 0.04560140 0.6749717
```

The shock on IPD on the 10th periods is consisted of 96.64%% from IPD, 0.59 % from IPN, 0.0003% from IPB and 2.42% from IPN.

The shock on IPN on the 10th periods is consisted of 11.79% from IPD, 88.05 % from IPN, 0.0004% from IPB and 0.12% from IPN.

The shock on IPB on the 10th periods is consisted of 48.38% from IPD, 1.73 % from IPN, 46.96% from IPB and 3.27% from IPN.

The shock on IPM on the 10th periods is consisted of 25.56% from IPD, 2.38 % from IPN, 4.56% from IPB and 67.50% from IPN.

```
> varfit.prd <- predict(Q1varfit,n.ahead=6,ci=0.95)
> varfit.prd
$IPD
              fcst       lower      upper         CI
[1,] -0.0006150473 -0.06300249 0.06177239 0.06238744
[2,]  0.0077907327 -0.05624736 0.07182883 0.06403809
[3,]  0.0018461230 -0.06318302 0.06687526 0.06502914
[4,]  0.0005341044 -0.06455561 0.06562382 0.06508971
[5,]  0.0018430627 -0.06330032 0.06698645 0.06514339
[6,]  0.0024660374 -0.06267897 0.06761105 0.06514501

$IPN
              fcst       lower      upper         CI
[1,] -0.0005426783 -0.01596737 0.01488201 0.01542469
[2,]  0.0015209749 -0.01415492 0.01719687 0.01567589
[3,]  0.0019159580 -0.01376365 0.01759557 0.01567961
[4,]  0.0015594667 -0.01412572 0.01724465 0.01568519
[5,]  0.0015469714 -0.01413842 0.01723237 0.01568540
[6,]  0.0016062462 -0.01407939 0.01729188 0.01568563

$IPB
            fcst       lower      upper         CI
[1,] 0.009027450 -0.02323714 0.04129204 0.03226459
[2,] 0.007194082 -0.02619747 0.04058564 0.03339155
[3,] 0.005411836 -0.02877592 0.03959959 0.03418775
[4,] 0.003508809 -0.03073996 0.03775757 0.03424877
[5,] 0.003737427 -0.03059243 0.03806729 0.03432986
[6,] 0.003594820 -0.03075094 0.03794058 0.03434576

$IPM
            fcst       lower      upper         CI
[1,] 0.003852687 -0.02604896 0.03375434 0.02990165
[2,] 0.003011154 -0.02805045 0.03407276 0.03106160
[3,] 0.002343799 -0.02891949 0.03360708 0.03126329
[4,] 0.002485357 -0.02878334 0.03375405 0.03126869
[5,] 0.002380792 -0.02888995 0.03365153 0.03127074
[6,] 0.002275148 -0.02899574 0.03354604 0.03127089
```

The forecast of the next 6 periods is in first column, fcst, for each variables

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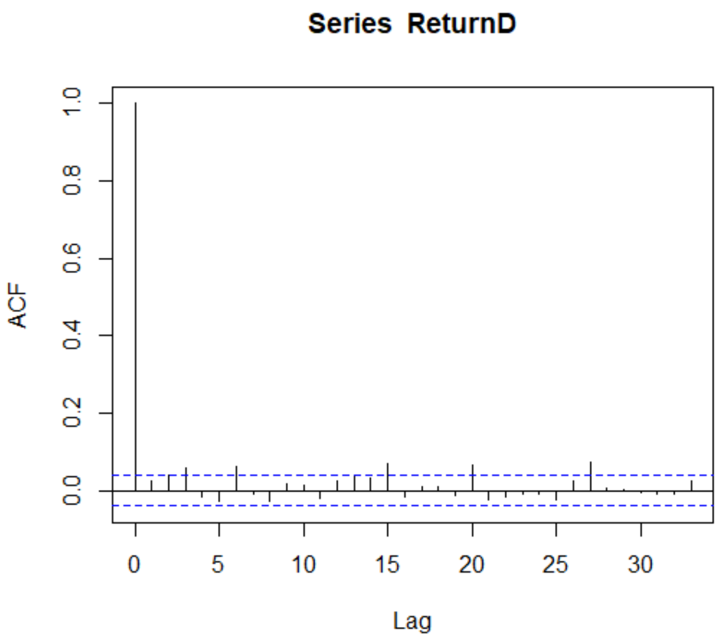
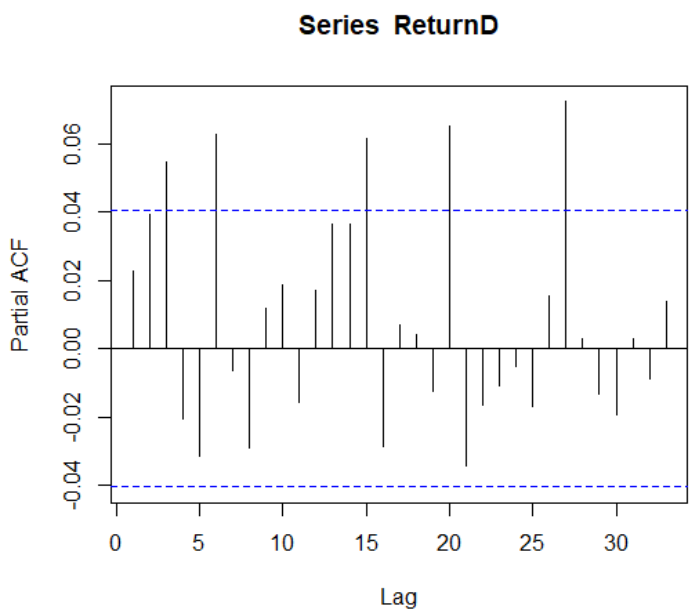
Question 2

```
        Box-Ljung test

data:  ReturnD
X-squared = 27.126, df = 10, p-value = 0.002487

> t.test(ReturnD)

        One Sample t-test

data:  ReturnD
t = 2.1217, df = 2330, p-value = 0.03397
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.0002470455 0.0062749150
sample estimates:
 mean of x
0.00326098
```

The p-value of t-test is less than 0.05, therefore we can reject the H-null hypothesis at 95% level of confidence interval. Hence the mean of return is not equal to 0.

From the Box-Ljung test, the serial- correlation of 10 lags period gives the p-value less than 0.05. Therefore, we can reject the H-null hypothesis that there is no serial correlation at 95% level of confidence interval. Hence, there is serial correlation.





According to the acf and pacf pictures, it shows the ARMA characteristic. The reduction in correlation is not exponential decreasing. As we can see that in ACF, there are multiple significance lags. As for PACF, it shows a similar story. There seems to have a significance lags at every 5-6 periods. When I try running all the possible models, the ARMA(3,2) has the least BIC value.

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```
        Box-Ljung test

data:  Q2m12$residuals
X-squared = 2.9659, df = 10, p-value = 0.9822
```

From Box-Ljung test, the p-value exceed 0.05, therefore. There is a possible serial correlation in residual term at 95% level of confidence interval. Hence, H-null cannot be rejected.

```
        Box-Ljung test

data:  Q2m12$residuals^2
X-squared = 262.34, df = 10, p-value < 2.2e-16
```

There seems to be no ARCH effect since the p-value is less than 0.05. It does have serial correlation between the residual squared. Hence, we can reject the H-null at 95% level of confidence interval.

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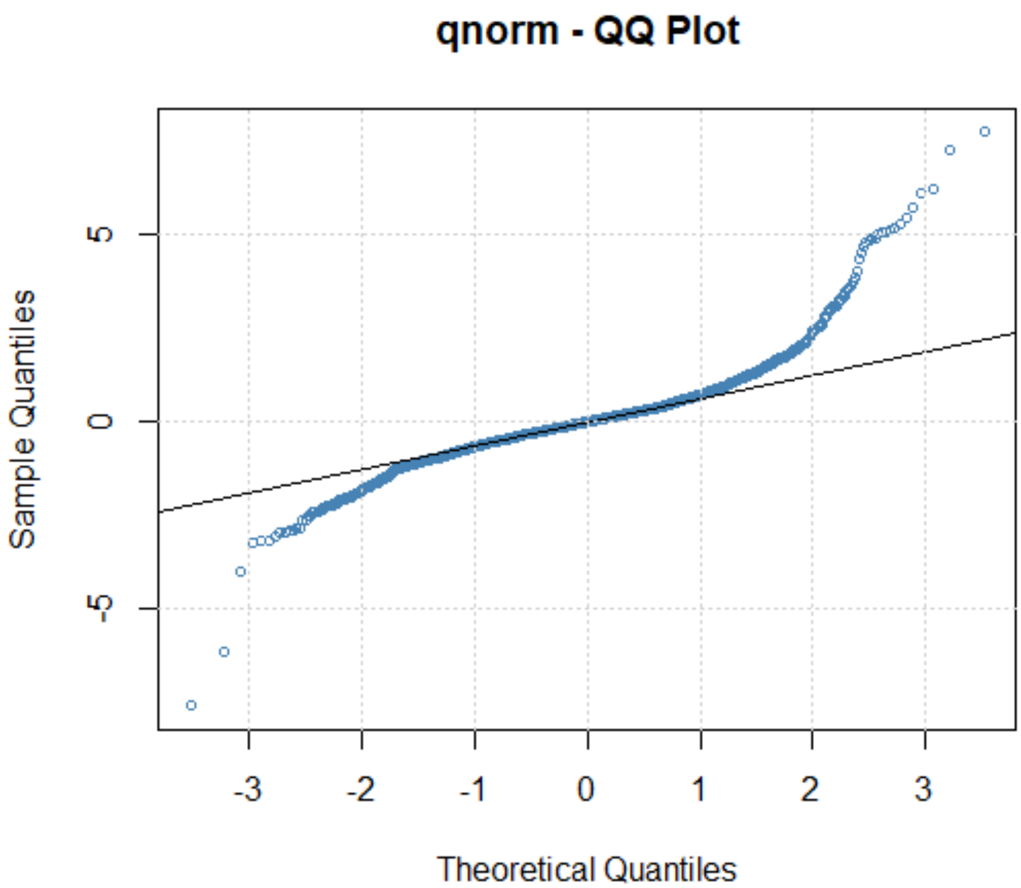
```
> summary(Q2m16)

Title:
 GARCH Modelling

Call:
 garchFit(formula = ~arma(3, 2) + garch(1, 1), data = ReturnD,
    trace = F)

Mean and Variance Equation:
 data ~ arma(3, 2) + garch(1, 1)
<environment: 0x0000023e9af1c120>
 [data = ReturnD]

Conditional Distribution:
 norm

Coefficient(s):
        mu         ar1         ar2         ar3         ma1         ma2       omega      alpha1       beta1
-0.0020485  -0.5346268  -0.7604528  -0.0229103   0.4819939   0.7655085   0.0001283   0.2936853   0.740806:

Std. Errors:
 based on Hessian

Error Analysis:
        Estimate  Std. Error  t value Pr(>|t|)
mu     -2.049e-03   1.774e-03   -1.155    0.248
ar1    -5.346e-01   9.226e-02   -5.795 6.85e-09 ***
ar2    -7.605e-01   9.999e-02   -7.605 2.84e-14 ***
ar3    -2.291e-02   2.718e-02   -0.843    0.399
ma1     4.820e-01   8.944e-02    5.389 7.08e-08 ***
ma2     7.655e-01   9.300e-02    8.231 2.22e-16 ***
omega   1.283e-04   1.785e-05    7.190 6.49e-13 ***
alpha1  2.937e-01   2.645e-02   11.104  < 2e-16 ***
beta1   7.408e-01   1.865e-02   39.723  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Log Likelihood:
 3680.067    normalized:  1.57875

Description:
 Fri Jun 11 21:55:42 2021 by user: Admin


Standardised Residuals Tests:
                                Statistic p-Value
 Jarque-Bera Test   R    Chi^2  9914.683  0
 Shapiro-Wilk Test  R    W      0.8755172 0
 Ljung-Box Test     R    Q(10)  25.25737  0.004878442
 Ljung-Box Test     R    Q(15)  44.56417  8.968722e-05
 Ljung-Box Test     R    Q(20)  46.80952  0.000623369
 Ljung-Box Test     R^2  Q(10)  16.49707  0.08625996
 Ljung-Box Test     R^2  Q(15)  17.09722  0.313086
 Ljung-Box Test     R^2  Q(20)  19.51363  0.4886998
 LM Arch Test       R    TR^2   16.2374   0.180603

Information Criterion Statistics:
      AIC       BIC       SIC      HQIC
-3.149779 -3.127562 -3.149808 -3.141684
```

These result contains mostly serial correlation in all but not on lag10 amd 20th in standardized residuals. P-value is less than 0.05, therefore, we can conclude that there is serial correlation. Hence H-null can be rejected at 95%. The model is not adequate


qnorm - QQ Plot
Sample Quantiles
Theoretical Quantiles
5
0
-5
-3
-2
-1
0
1
2
3

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```
> summary(Q2m17)

Title:
 GARCH Modelling

Call:
 garchFit(formula = ~arma(3, 2) + garch(1, 1), data = ReturnD,
    cond.dist = "std", trace = F)

Mean and Variance Equation:
 data ~ arma(3, 2) + garch(1, 1)
<environment: 0x0000023ea612df18>
 [data = ReturnD]

Conditional Distribution:
 std

Coefficient(s):
         mu          ar1          ar2          ar3          ma1          ma2        omega       alpha1        beta1        shape
-0.00104599   0.85921922  -0.50634268  -0.09245642  -0.99999999   0.63848040   0.00017803   0.66376486   0.70671659   2.40734243

Std. Errors:
 based on Hessian

Error Analysis:
        Estimate  Std. Error  t value Pr(>|t|)
mu     -1.046e-03   5.645e-03   -0.185  0.85299
ar1     8.592e-01   5.894e+00    0.146  0.88409
ar2    -5.063e-01   1.750e+00   -0.289  0.77238
ar3    -9.246e-02   1.190e-01   -0.777  0.43711
ma1    -1.000e+00   5.943e+00   -0.168  0.86639
ma2     6.385e-01   2.468e+00    0.259  0.79586
omega   1.780e-04   6.569e-05    2.710  0.00672 **
alpha1  6.638e-01   2.029e-01    3.271  0.00107 **
beta1   7.067e-01   7.585e-02    9.317  < 2e-16 ***
shape   2.407e+00   2.901e-01    8.297  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Log Likelihood:
 4110.459    normalized:  1.763388

Description:
 Fri Jun 11 21:57:29 2021 by user: Admin


Standardised Residuals Tests:
                                Statistic p-Value
 Jarque-Bera Test   R    Chi^2  11623.06  0
 Shapiro-Wilk Test  R    W      0.8658699 0
 Ljung-Box Test     R    Q(10)  54.73854  3.533786e-08
 Ljung-Box Test     R    Q(15)  78.70475  1.203998e-10
 Ljung-Box Test     R    Q(20)  82.3241   1.577296e-09
 Ljung-Box Test     R^2  Q(10)  11.26594  0.3371777
 Ljung-Box Test     R^2  Q(15)  11.90993  0.6858334
 Ljung-Box Test     R^2  Q(20)  14.49435  0.8045732
 LM Arch Test       R    TR^2   11.62658  0.4761155

Information Criterion Statistics:
      AIC       BIC       SIC      HQIC
-3.518197 -3.493512 -3.518234 -3.509203
```

The results show that there is no serial correlation in the standarized residual and residuals squared in lag10th to 20^{th}. P-value is more than 0.05, therefore, we can conclude that there is no serial correlation. Hence H-null cannot be rejected at 95%. The model is adequate.

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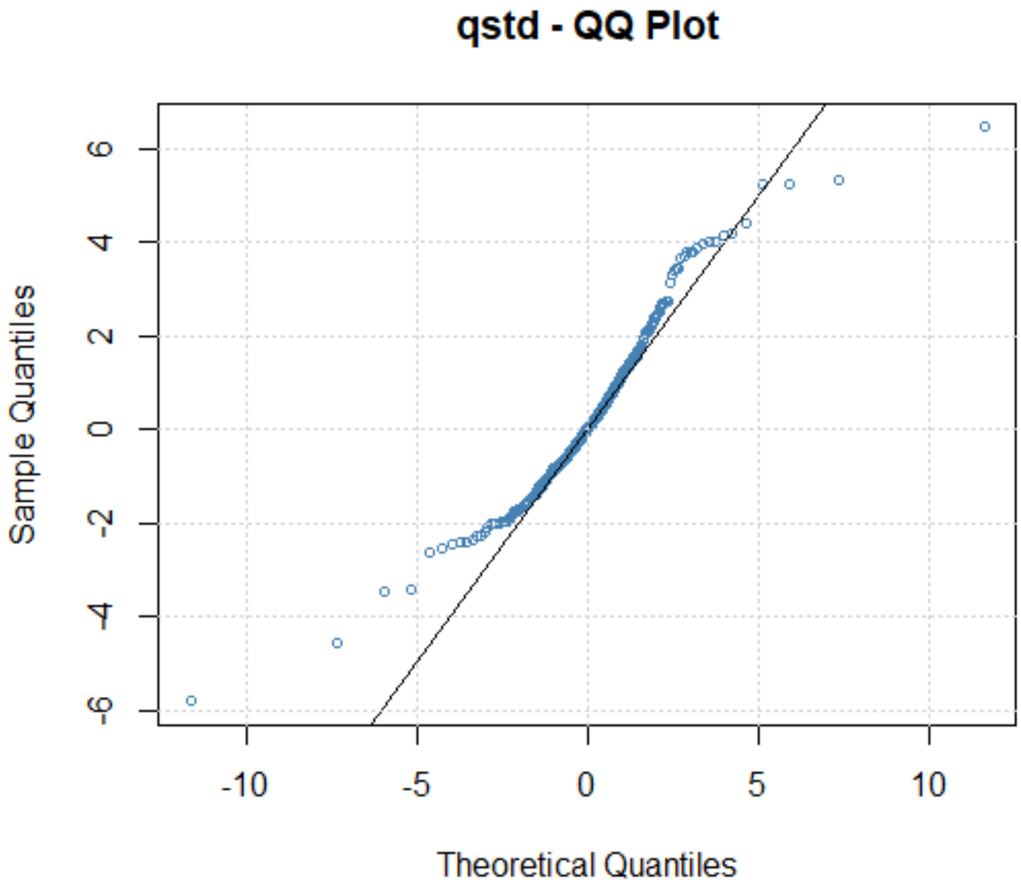

```
> summary(Q2m18)

Title:
 GARCH Modelling

Call:
 garchFit(formula = ~arma(3, 2) + garch(1, 1), data = ReturnD,
    cond.dist = "std", leverage = T, trace = F)

Mean and Variance Equation:
 data ~ arma(3, 2) + garch(1, 1)
<environment: 0x0000023ea32ff8b8>
 [data = ReturnD]

Conditional Distribution:
 std

Coefficient(s):
         mu          ar1          ar2          ar3          ma1          ma2        omega       alpha1       gamma1        beta1        shape
-0.00094837   0.86062214  -0.50718788  -0.09083899  -0.99999999   0.63794592   0.00017555   0.63196321  -0.07121605   0.70815983   2.4214778

Std. Errors:
 based on Hessian

Error Analysis:
         Estimate  Std. Error  t value Pr(>|t|)
mu     -9.484e-04          NA       NA       NA
ar1     8.606e-01          NA       NA       NA
ar2    -5.072e-01          NA       NA       NA
ar3    -9.084e-02   1.909e-02   -4.760 1.94e-06 ***
ma1    -1.000e+00          NA       NA       NA
ma2     6.379e-01          NA       NA       NA
omega   1.756e-04   5.868e-05    2.992 0.002774 **
alpha1  6.320e-01   1.860e-01    3.397 0.000681 ***
gamma1 -7.122e-02   4.379e-02   -1.626 0.103851
beta1   7.082e-01   2.782e-02   25.453  < 2e-16 ***
shape   2.421e+00   1.500e-01   16.142  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Log Likelihood:
 4111.789    normalized:  1.763959

Description:
 Fri Jun 11 21:58:22 2021 by user: Admin


Standardised Residuals Tests:
                                Statistic p-Value
 Jarque-Bera Test   R    Chi^2  12332.82  0
 Shapiro-Wilk Test  R    W      0.8668184 0
 Ljung-Box Test     R    Q(10)  51.08144  1.687022e-07
 Ljung-Box Test     R    Q(15)  75.48653  4.624139e-10
 Ljung-Box Test     R    Q(20)  79.19122  5.383256e-09
 Ljung-Box Test     R^2  Q(10)  10.86584  0.3680656
 Ljung-Box Test     R^2  Q(15)  11.60834  0.7083998
 Ljung-Box Test     R^2  Q(20)  14.11286  0.8247281
 LM Arch Test       R    TR^2   11.39411  0.4954787

Information Criterion Statistics:
      AIC       BIC       SIC      HQIC
-3.518481 -3.491327 -3.518525 -3.508588
```

The leverage results show that it is statistically insignificant at 95% for standardised residuals tests but not in squared residuals tests. P-value in gamma is more than 0.05. We can conclude that there is symmetry response in both postive and negative shocks.

The results show that there is serial correlation in the standarized residual but not in residuals squared terms. P-value is less than 0.05, therefore, we can conclude that there is serial correlation. Hence H-null can be rejected at 95%. The model is adequate.

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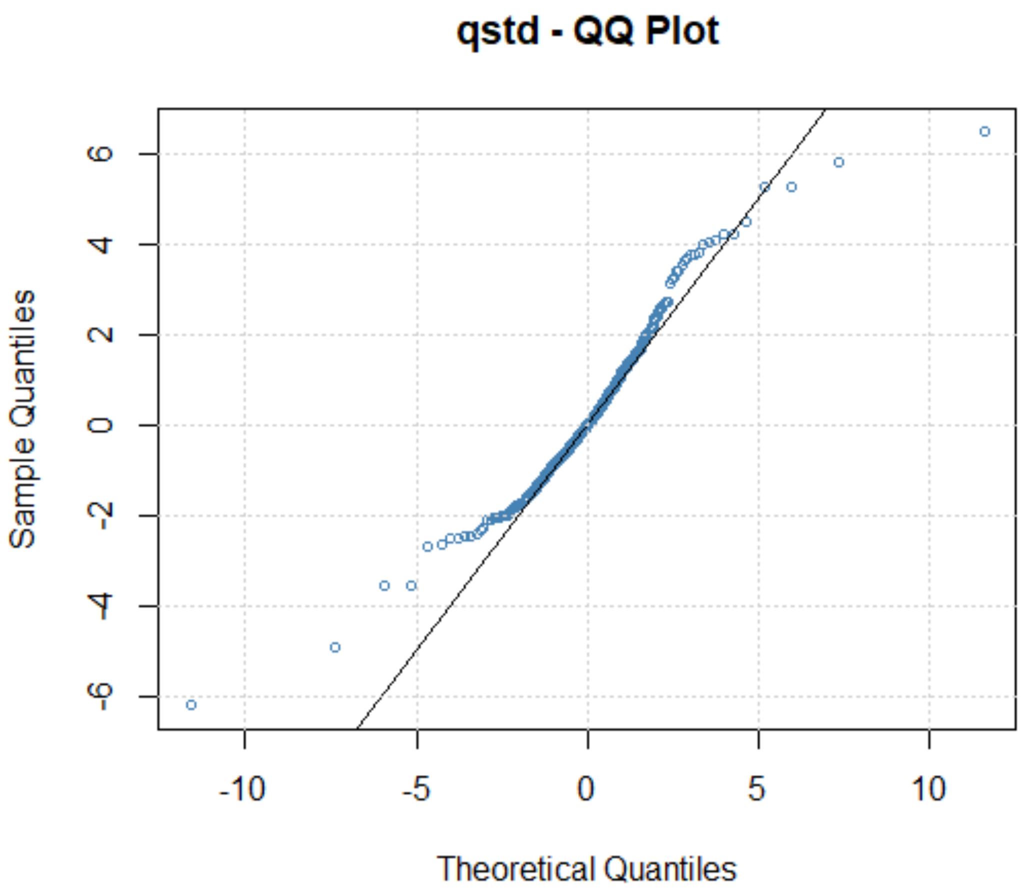

From The BIC criteria, is model Q2m17. Which is ARMA(3,2)+GARCH(1,1) with std t-statistic.

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Question3

Q3.1

```
> VARorder(Q3zt1)
selected order: aic =  2
selected order: bic =  2
selected order: hq =  2
Summary table:
       p     AIC      BIC       HQ      M(p) p-value
 [1,]  0 -19.1870 -19.1870 -19.1870    0.0000  0.0000
 [2,]  1 -30.8581 -30.6555 -30.7758 1281.8143  0.0000
 [3,]  2 -31.7835 -31.3783 -31.6189  112.7073  0.0000
 [4,]  3 -31.7746 -31.1669 -31.5277   13.7316  0.1322
 [5,]  4 -31.7090 -30.8986 -31.3798    7.6844  0.5662
 [6,]  5 -31.6656 -30.6526 -31.2540    9.5949  0.3843
 [7,]  6 -31.5926 -30.3771 -31.0988    6.5361  0.6853
 [8,]  7 -31.5344 -30.1163 -30.9583    7.6607  0.5687
 [9,]  8 -31.4368 -29.8160 -30.7783    3.9549  0.9144
[10,]  9 -31.4173 -29.5940 -30.6765   10.4266  0.3171
[11,] 10 -31.4933 -29.4674 -30.6702   17.8361  0.0371
[12,] 11 -31.4227 -29.1942 -30.5174    5.6773  0.7717
[13,] 12 -31.4948 -29.0637 -30.5071   16.2242  0.0623
[14,] 13 -31.4542 -28.8205 -30.3842    7.4155  0.5939
>
```

BIC lag 2 has the least value.

```
> Q3m1a=refVAR(Q3m1,thres = 1.645)
Constant term:
Estimates:  0.4819991 0 1.177618
Std.Error:  0.1449991 0 0.4377887
AR coefficient matrix
AR( 1 )-matrix
      [,1]  [,2]   [,3]
[1,] 1.427 0.000 0.0819
[2,] 0.291 1.222 0.3733
[3,] 0.384 0.199 0.9838
standard error
       [,1]   [,2]   [,3]
[1,] 0.0749 0.0000 0.0268
[2,] 0.0848 0.0854 0.0962
[3,] 0.0808 0.0760 0.0296
AR( 2 )-matrix
       [,1]   [,2]   [,3]
[1,] -0.525  0.000  0.000
[2,] -0.281 -0.225 -0.379
[3,] -0.284 -0.286  0.000
standard error
       [,1]   [,2]   [,3]
[1,] 0.0690 0.0000 0.0000
[2,] 0.0840 0.0869 0.0933
[3,] 0.0807 0.0734 0.0000

Residuals cov-mtx:
             [,1]         [,2]         [,3]
[1,] 3.038967e-05 1.026403e-06 5.549020e-06
[2,] 1.026403e-06 3.289782e-05 1.351117e-05
[3,] 5.549020e-06 1.351117e-05 3.229828e-05

det(SSE) =  2.584955e-14
AIC =  -31.06426
BIC =  -30.74912
HQ  =  -30.93623
>
```

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```
> summary(Q3varfit1)

VAR Estimation Results:
=========================
Endogenous variables: logUK, logCA, logUS
Deterministic variables: const
Sample size: 124
Log Likelihood: 1414.364
Roots of the characteristic polynomial:
0.9856 0.9563 0.8217 0.5202 0.5202 0.1523
Call:
VAR(y = Q3zt1, p = 2)


Estimation results for equation logUK:
======================================
logUK = logUK.l1 + logCA.l1 + logUS.l1 + logUK.l2 + logCA.l2 + logUS.l2 + const

         Estimate Std. Error t value Pr(>|t|)
logUK.l1  1.40140    0.08166  17.161  < 2e-16 ***
logCA.l1  0.03900    0.08309   0.469    0.640
logUS.l1  0.11577    0.09334   1.240    0.217
logUK.l2 -0.49628    0.08134  -6.101  1.4e-08 ***
logCA.l2 -0.03246    0.08465  -0.383    0.702
logUS.l2 -0.04250    0.09416  -0.451    0.653
const     0.34393    0.44609   0.771    0.442
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1


Residual standard error: 0.005656 on 117 degrees of freedom
Multiple R-Squared: 0.9995,     Adjusted R-squared: 0.9994
F-statistic: 3.565e+04 on 6 and 117 DF,  p-value: < 2.2e-16


Estimation results for equation logCA:
======================================
logCA = logUK.l1 + logCA.l1 + logUS.l1 + logUK.l2 + logCA.l2 + logUS.l2 + const

         Estimate Std. Error t value Pr(>|t|)
logUK.l1  0.28589    0.08432   3.391 0.000952 ***
logCA.l1  1.20185    0.08579  14.009  < 2e-16 ***
logUS.l1  0.35327    0.09638   3.665 0.000373 ***
logUK.l2 -0.26496    0.08399  -3.155 0.002042 **
logCA.l2 -0.24763    0.08741  -2.833 0.005432 **
logUS.l2 -0.33122    0.09723  -3.407 0.000902 ***
const     0.74342    0.46060   1.614 0.109218
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1


Residual standard error: 0.00584 on 117 degrees of freedom
Multiple R-Squared: 0.9994,     Adjusted R-squared: 0.9994
F-statistic: 3.394e+04 on 6 and 117 DF,  p-value: < 2.2e-16
```

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```
Estimation results for equation logUS:
======================================
logUS = logUK.l1 + logCA.l1 + logUS.l1 + logUK.l2 + logCA.l2 + logUS.l2 + const

         Estimate Std. Error t value Pr(>|t|)    
logUK.l1  0.36850    0.08432   4.370  2.7e-05 ***
logCA.l1  0.17407    0.08580   2.029  0.04474 *  
logUS.l1  1.04262    0.09639  10.817  < 2e-16 ***
logUK.l2 -0.26915    0.08399  -3.204  0.00174 ** 
logCA.l2 -0.25543    0.08741  -2.922  0.00417 ** 
logUS.l2 -0.06237    0.09723  -0.641  0.52250    
const     1.08791    0.46063   2.362  0.01984 *  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1


Residual standard error: 0.00584 on 117 degrees of freedom
Multiple R-Squared: 0.9996,     Adjusted R-squared: 0.9995 
F-statistic: 4.507e+04 on 6 and 117 DF,  p-value: < 2.2e-16



Covariance matrix of residuals:
          logUK     logCA     logUS
logUK 3.199e-05 1.229e-06 5.799e-06
logCA 1.229e-06 3.411e-05 1.441e-05
logUS 5.799e-06 1.441e-05 3.411e-05

Correlation matrix of residuals:
       logUK  logCA  logUS
logUK 1.0000 0.0372 0.1756
logCA 0.0372 1.0000 0.4225
logUS 0.1756 0.4225 1.0000
```

Fitted model

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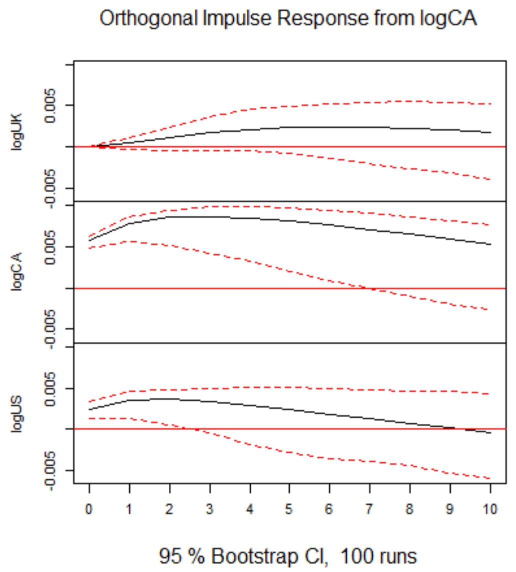
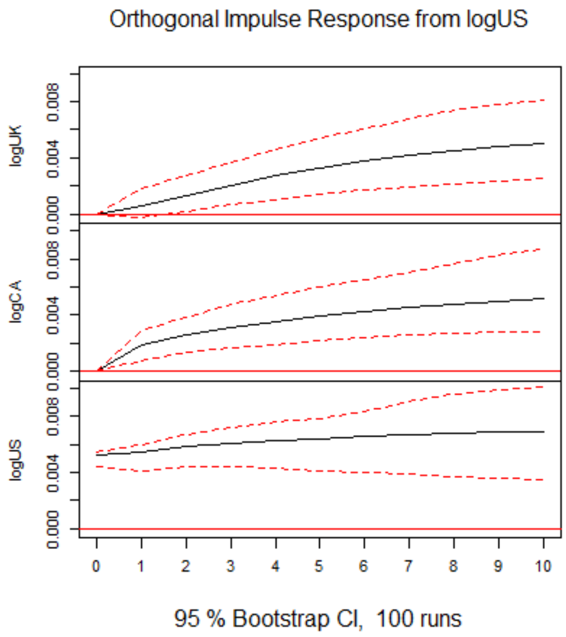
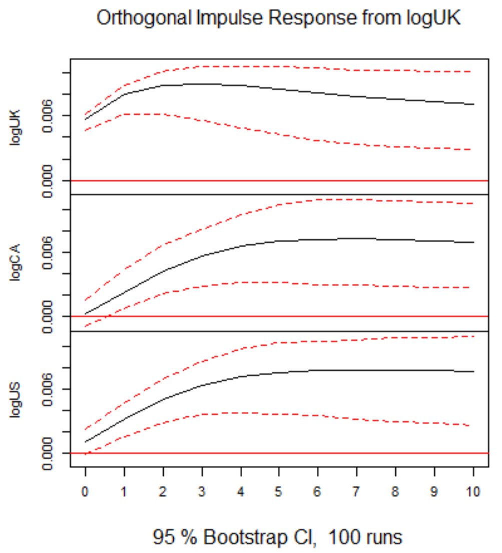
3.2







LogCA seem to be affected by LogUK, LogUS, for the same period.

LogUK seem to be affected by LogCA, LogUS, for the same period.

LogUS seem to be affected by LogUK, LogCA, for the same period.

The shocks on all variables seems to stay at the highest value but only logCA that the effects seem to slowly going down.

All the shocks does not seem to convert into long run growth rate at any period. The shocks from each variable will exists for more than 10 periods.

3.3

```
$logUK
        logUK       logCA       logUS
[1,] 1.0000000 0.000000000 0.000000000
[2,] 0.9936084 0.002658487 0.003733079
[3,] 0.9795272 0.008668888 0.011803939
[4,] 0.9598848 0.016514252 0.023600941
[5,] 0.9370456 0.024699954 0.038254430
[6,] 0.9130597 0.032062267 0.054878001

$logCA
           logUK     logCA      logUS
[1,] 0.001383986 0.9986160 0.00000000
[2,] 0.048483319 0.9190924 0.03242431
[3,] 0.113003304 0.8376129 0.04938382
[4,] 0.171528907 0.7664300 0.06204111
[5,] 0.218222486 0.7088233 0.07295426
[6,] 0.253972298 0.6625204 0.08350734

$logUS
          logUK     logCA     logUS
[1,] 0.03081983 0.1732760 0.7959042
[2,] 0.13000918 0.2142920 0.6556988
[3,] 0.22984824 0.1981156 0.5720362
[4,] 0.30964952 0.1720445 0.5183060
[5,] 0.36797968 0.1469672 0.4850531
[6,] 0.40940101 0.1254015 0.4651974
```

The shock on logUK on the 6th periods is consisted of 91.30% from logUK, 3.21% from logCA, and 5.48% from logUS.

The shock on logCA on the 6th periods is consisted of 25.39% from logUK, 66.25% from logCA, and 8.35% from logUS

The shock on logUS on the 6th periods is consisted of 40.94 from logUK, 12.54 % from logCA, and 46.51% from logUS

Q3.4

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

Test type: trace statistic , without linear trend and constant in cointegration

Eigenvalues (lambda):
[1] 2.318049e-01 1.235643e-01 3.351674e-02 3.281709e-15

Values of teststatistic and critical values of test:

          test 10pct  5pct  1pct
r <= 2 |  4.19  7.52  9.24 12.97
r <= 1 | 20.42 17.85 19.96 24.60
r = 0  | 52.85 32.00 34.91 41.07

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

            logUK.l1   logCA.l1  logUS.l1   constant
logUK.l1  1.0000000  1.0000000  1.000000   1.000000
logCA.l1 -0.5648314 -0.1152665 -5.218868 -12.868847
logUS.l1 -0.4027070 -0.7419682  4.009826   9.333177
constant  6.1082676 -2.6719556 88.276394 240.961896

Weights W:
(This is the loading matrix)

              logUK.l1     logCA.l1      logUS.l1      constant
logUK.d -0.0002218284 -0.115744686 -0.0001022373 -8.297789e-13
logCA.d  0.0173859220 -0.007592779  0.0065822220 -3.264252e-14
logUS.d  0.1538532992 -0.027939832  0.0019514847  7.838872e-13
```

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

Test type: maximal eigenvalue statistic (lambda max) , without linear trend and constant in cointegration

Eigenvalues (lambda):
[1] 2.318049e-01 1.235643e-01 3.351674e-02 3.281709e-15

Values of teststatistic and critical values of test:

          test 10pct  5pct  1pct
r <= 2 |  4.19  7.52  9.24 12.97
r <= 1 | 16.22 13.75 15.67 20.20
r = 0  | 32.44 19.77 22.00 26.81

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

            logUK.l1   logCA.l1  logUS.l1   constant
logUK.l1  1.0000000  1.0000000  1.000000   1.000000
logCA.l1 -0.5648314 -0.1152665 -5.218868 -12.868847
logUS.l1 -0.4027070 -0.7419682  4.009826   9.333177
constant  6.1082676 -2.6719556 88.276394 240.961896

Weights W:
(This is the loading matrix)

              logUK.l1     logCA.l1      logUS.l1      constant
logUK.d -0.0002218284 -0.115744686 -0.0001022373 -8.297789e-13
logCA.d  0.0173859220 -0.007592779  0.0065822220 -3.264252e-14
logUS.d  0.1538532992 -0.027939832  0.0019514847  7.838872e-13
```

```
> egcm(logUK, logCA)
NAEXKP01CAQ189S[i] =   1.0034 CLVMNACSCAB1GQUK[i] +  13.8177 + R[i], R[i] =   0.9858 R[i-1] + eps[i], eps ~ N(0,  0.0086^2)
                      (0.0079)                      (0.1000)                (0.0368)

R[2011-04-01] = 0.0458 (t = 2.167)

WARNING: CLVMNACSCAB1GQUK and NAEXKP01CAQ189S do not appear to be cointegrated.
> egcm(logUK, logUS)
GDPC1[i] =   1.1608 CLVMNACSCAB1GQUK[i] -   5.3326 + R[i], R[i] =   0.9491 R[i-1] + eps[i], eps ~ N(0,  0.0082^2)
            (0.0071)                      (0.0892)                (0.0388)

R[2011-04-01] = 0.0115 (t = 0.610)

WARNING: CLVMNACSCAB1GQUK and GDPC1 do not appear to be cointegrated.
> egcm(logCA, logUS)
GDPC1[i] =   1.1497 NAEXKP01CAQ189S[i] -  21.1281 + R[i], R[i] =   1.0000 R[i-1] + eps[i], eps ~ N(0,  0.0075^2)
            (0.0100)                     (0.2636)                (0.0252)

R[2011-04-01] = -0.0388 (t = -1.453)

WARNING: NAEXKP01CAQ189S and GDPC1 do not appear to be cointegrated.
```

The maximal eigenvalue statistic suggests that there are 2 cointegrating relationships among 3 variables. Since we can reject the hypothesis that r = 0 and r = 1 at 5%, and we accept the hypothesis that r = 2 at 5%. Therefore, we have 2 long-run relationships amongst these variables at 5% level.

However, after using the Engle-Granger cointegration test it suggests otherwise that there is no relationship among these 3 returns.

The cointegrating vectors should be

Q3wt=Q3zt1[,1] - 0.5648314*Q3zt1[,2] - 0.4027070*Q3zt1[,3]

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3.5

```
> Q3wt=Q3zt1[,1]*0.9646514+Q3zt1[,2]*0.4627676+Q3zt1[,
> adf.test(Q3wt)
Augmented Dickey-Fuller Test
alternative: stationary

Type 1: no drift no trend
     lag   ADF p.value
[1,]   0 0.825   0.879
[2,]   1 0.519   0.791
[3,]   2 0.525   0.793
[4,]   3 0.238   0.711
[5,]   4 0.197   0.699
Type 2: with drift no trend
     lag   ADF p.value
[1,]   0 -2.07  0.3001
[2,]   1 -2.67  0.0868
[3,]   2 -3.00  0.0408
[4,]   3 -2.79  0.0672
[5,]   4 -2.06  0.3054
Type 3: with drift and trend
     lag   ADF p.value
[1,]   0 -2.61  0.3214
[2,]   1 -3.46  0.0488
[3,]   2 -3.85  0.0190
[4,]   3 -4.15  0.0100
[5,]   4 -3.76  0.0231
----
Note: in fact, p.value = 0.01 means p.value <= 0.01
>
```

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```
> Q3m7=ECMvar1(Q3zt1,3,Q3wt,include.const = T)
alpha:
      logUK  logCA logUS
[1,] -0.042 0.0289 0.143
standard error
       [,1]   [,2]   [,3]
[1,] 0.0334 0.0332 0.0328
constant term:
 logUK  logCA  logUS
-0.254  0.177  0.875
standard error
[1] 0.204 0.202 0.199
AR coefficient matrix
AR( 1 )-matrix
      logUK   logCA  logUS
logUK 0.424 -0.0372 0.0851
logCA 0.357  0.3703 0.3856
logUS 0.358  0.3447 0.1070
standard error
       [,1]   [,2]   [,3]
[1,] 0.0870 0.0994 0.0904
[2,] 0.0864 0.0986 0.0897
[3,] 0.0852 0.0973 0.0886
AR( 2 )-matrix
       logUK   logCA    logUS
logUK  0.143  0.0499  0.00662
logCA -0.176 -0.0823 -0.07195
logUS -0.277  0.0238 -0.01181
standard error
       [,1]   [,2]   [,3]
[1,] 0.0937 0.0875 0.0962
[2,] 0.0930 0.0868 0.0955
[3,] 0.0918 0.0857 0.0942
-----
Residuals cov-mtx:
             logUK        logCA        logUS
logUK 3.151944e-05 2.473845e-06 7.430923e-06
logCA 2.473845e-06 3.103492e-05 1.227119e-05
logUS 7.430923e-06 1.227119e-05 3.022843e-05

det(sse) =  2.337575e-14
AIC =  -31.00612
BIC =  -30.46588
```

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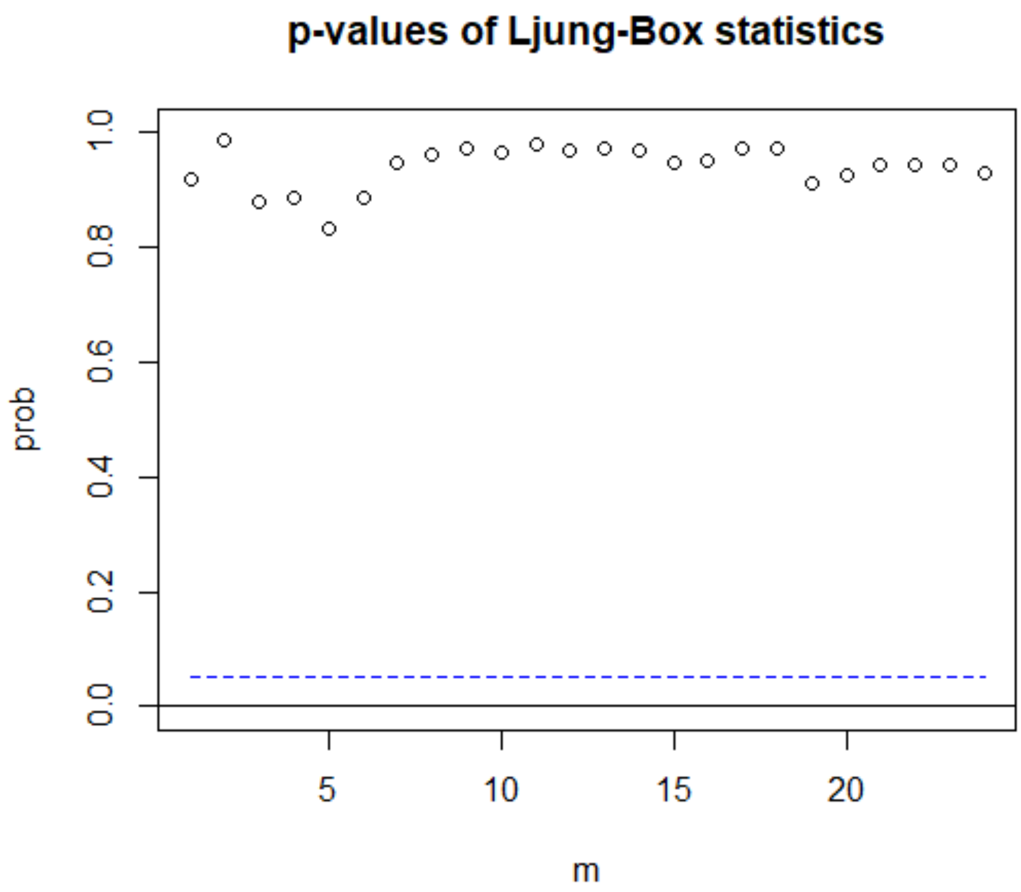
```
[1] "Covariance matrix:"
        logUK    logCA    logUS
logUK 3.22e-05 2.13e-06 7.53e-06
logCA 2.13e-06 3.24e-05 1.23e-05
logUS 7.53e-06 1.23e-05 3.05e-05
CCM at lag:  0
       [,1]   [,2]  [,3]
[1,] 1.0000 0.0661 0.240
[2,] 0.0661 1.0000 0.391
[3,] 0.2404 0.3913 1.000
Simplified matrix:
CCM at lag:  1
. . .
. . .
. . .
CCM at lag:  2
. . .
. . .
```



The model is adequate. The Ljung-box suggests that CCM of residuals are insignificant for long times.

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Fitted model

$$\begin{bmatrix}\Delta \log \hat{UK} \\ \Delta \log \hat{CA} \\ \Delta \log \hat{US}\end{bmatrix} \quad \begin{bmatrix} -0.254 \\ (0.204) \\ 0.177 \\ (0.202) \\ 0.875 \\ (0.199)\end{bmatrix} + \begin{bmatrix} -0.042 \\ 0.0334 \\ .0289 \\ 0.0332 \\ 0.143 \\ 0.0328 \end{bmatrix} wt + \begin{bmatrix} 0.424 & -0.0372 & 0.0851 \\ 0.0870 & 0.0994 & 0.0904 \\ 0.357 & 0.3703 & 0.3856 \\ 0.0864 & 0.0986 & 0.0897 \\ 0.358 & 0.3447 & 0.1070 \\ 0.0852 & 0.0973 & 0.0886 \end{bmatrix} \begin{bmatrix}\Delta \log \hat{UK}_{t-1} \\ \Delta \log \hat{CA}_{t-1} \\ \Delta \log US_{t-1}\end{bmatrix}$$

$$\begin{bmatrix} 0.143 & 0.0499 & 0.00662 \\ (0.0937) & (0.0875) & (0.0962) \\ -0.176 & -0.0823 & -0.07195 \\ (0.0930) & (0.0868) & (0.0955) \\ 0.277 & 0.0238 & -0.01181 \\ (0.0918) & (0.0857) & (0.0942) \end{bmatrix} \begin{bmatrix}\Delta \log \hat{UK}_{t-2} \\ \Delta \log \hat{CA}_{t-2} \\ \Delta \log US_{t-2}\end{bmatrix}$$