Part I

1. **Estimate Autoregressive Integrated Moving Average (ARIMA(p,d,q)) model for spot and future – determine the most appropriated order for p, d, and q using SBIC given the maximum lag equals 4.**

```
tsset t
        time variable:  time, 1 to 795
                delta:  1 unit

. g y = spot

. arima y, arima(1,1,1) nolog

ARIMA regression

Sample:  2 - 795                                Number of obs     =        794
                                                Wald chi2(2)      =      18.31
Log likelihood = -2791.496                      Prob > chi2       =     0.0001

------------------------------------------------------------------------------
             |                 OPG
         D.y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
y            |
       _cons |  -.1047174   .3525647    -0.30   0.766    -.7957316    .5862967
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |   .4353655   .2343856     1.86   0.063    -.0240219    .8947528
             |
          ma |
         L1. |  -.3535108    .242659    -1.46   0.145    -.8291138    .1220922
-------------+----------------------------------------------------------------
      /sigma |   8.139999   .1507405    54.00   0.000     7.844553    8.435444
------------------------------------------------------------------------------
Note: The test of the variance against zero is one sided, and the two-sided
      confidence interval is truncated at zero.

. est store arima111

. qui arima y, arima(1,1,2) nolog

. est store arima112

. qui arima y, arima(1,1,3) nolog

. est store arima113

. qui arima y, arima(1,1,4) nolog

. est store arima114

. qui arima y, arima(2,1,1) nolog

. est store arima211

. qui arima y, arima(2,1,2) nolog
```

```
. est store arima212

. qui arima y, arima(2,1,3) nolog

. est store arima213

. qui arima y, arima(2,1,4) nolog

. est store arima214

. qui arima y, arima(3,1,1) nolog

. est store arima311

. qui arima y, arima(3,1,2) nolog

. est store arima312

. qui arima y, arima(3,1,3) nolog

. est store arima313

. qui arima y, arima(3,1,4) nolog

. est store arima314

. est table arima1*, star(0.1 0.05 0.01) stat(N ll chi2 aic bic)

------------------------------------------------------------------------------
    Variable |   arima111         arima112         arima113         arima114
-------------+----------------------------------------------------------------
y            |
       _cons | -.10471744      -.10468155      -.10474014      -.10717398
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |  .43536547*      .32884791      -.21609401       .59490084
             |
          ma |
         L1. | -.35351081      -.25287121       .29330109      -.52209152
         L2. |                  .02661686       .06275321      -.00167449
         L3. |                                  .07084457**     .03360908
         L4. |                                                 -.07201064*
-------------+----------------------------------------------------------------
sigma        |
       _cons |  8.1399985***    8.1383248***    8.1283318***    8.1204174***
-------------+----------------------------------------------------------------
Statistics   |
           N |        794             794             794             794
          ll | -2791.4965      -2791.3458      -2790.3816      -2789.5823
        chi2 |  18.312657        16.97941       13.218602       28.319443
         aic |   5590.993       5592.6915       5592.7633       5593.1646
         bic |  5609.7013        5616.077       5620.8258       5625.9042
------------------------------------------------------------------------------
                                      legend: * p<.1; ** p<.05; *** p<.01

. est table arima2*, star(0.1 0.05 0.01) stat(N ll chi2 aic bic)
```

Variable	arima211	arima212	arima213	arima214
y				
_cons	-.10453586	-.10767543	-.10609456	-.10747347
ARMA				
ar				
L1.	.30210361	1.3247307***	.46523894***	1.3085163***
L2.	.02452891	-.92390999***	-.83397031***	-.92906275***
ma				
L1.	-.22494448	-1.3022249***	-.39216993***	-1.2433923***
L2.		.94779741***	.82697929***	.88679293***
L3.			.09595475***	.05677728
L4.				.00003472
sigma				
_cons	8.1387104***	8.077039***	8.1149358***	8.0663508***
Statistics				
N	794	794	794	794
ll	-2791.3835	-2785.5252	-2789.1057	-2784.5179
chi2	16.085901	3656.4673	241.72156	4791.7037
aic	5592.7671	5583.0504	5592.2113	5585.0358
bic	5616.1525	5611.1129	5624.9509	5622.4524

legend: * p<.1; ** p<.05; *** p<.01

```
. est table arima3*, star(0.1 0.05 0.01) stat(N ll chi2 aic bic)
```

Variable	arima311	arima312	arima313	arima314
y				
_cons	-.10486338	-.10606429	-.10806841	-.10765207
ARMA				
ar				
L1.	-.56058829	.56814277***	.66749387**	.58444954
L2.	.08569307*	-.89762851***	-.06995188	.02671133
L3.	.06374492**	.09752318***	-.59846871*	-.67269654
ma				
L1.	.63856195	-.49161072***	-.61040004*	-.51894361
L2.		.88783712***	.0556601	-.035013
L3.			.65798111**	.71899187
L4.				.02307553
sigma				
_cons	8.1302906***	8.1136284***	8.0655263***	8.0640794***
Statistics				
N	794	794	794	794
ll	-2790.5308	-2788.9397	-2784.4054	-2784.2793
chi2	21.334447	289.47777	1722.9017	1770.3818
aic	5593.0617	5591.8793	5584.8108	5586.5587
bic	5621.1242	5624.6189	5622.2274	5628.6524

```
--------------------------------------------------------------------------------
                                            legend: * p<.1; ** p<.05; *** p<.01

. qui arima y, arima(4,1,1) nolog

. est store arima411

. qui arima y, arima(4,1,2) nolog

. est store arima412

. qui arima y, arima(4,1,3) nolog

. est store arima413

. qui arima y, arima(4,1,4) nolog

. est store arima414

. est table arima4*, star(0.1 0.05 0.01) stat(N ll chi2 aic bic)

--------------------------------------------------------------------------------
    Variable |   arima411        arima412        arima413        arima414
-------------+------------------------------------------------------------------
y            |
       _cons | -.10781888      -.10736741      -.10798992      -.10783286
-------------+------------------------------------------------------------------
ARMA         |
          ar |
         L1. |   .6019371*      1.3677375***    .61532081        .8379873
         L2. | -.00196743      -1.0093777***    .00952804      -.12990838
         L3. |  .02357655       .05752757      -.6765738       -.67732522
         L4. |   -.074501**    -.00157964       .02303935        .1696285
             |
          ma |
         L1. | -.52565375      -1.3026568***   -.54893042      -.77060667
         L2. |                  .96445075***   -.01956286       .10759475
         L3. |                                  .72228244       .72452578
         L4. |                                                 -.15673595
-------------+------------------------------------------------------------------
sigma        |
       _cons |  8.1178063***    8.0663819***    8.0637584***    8.0632846***
-------------+------------------------------------------------------------------
Statistics   |
           N |        794             794             794             794
          ll | -2789.3297      -2784.5185      -2784.2686      -2784.2263
        chi2 |  30.742143       5309.2623       1879.1703       2712.7298
         aic |  5592.6594        5585.037       5586.5371       5588.4525
         bic |   5625.399       5622.4537       5628.6309       5635.2234
--------------------------------------------------------------------------------
                                            legend: * p<.1; ** p<.05; *** p<.01

. drop y

. g y = future

. arima y, arima(1,1,1) nolog
```

```
ARIMA regression

Sample:  2 - 795                                Number of obs     =        794
                                                Wald chi2(2)      =       3.33
Log likelihood = -2917.724                      Prob > chi2       =     0.1890

------------------------------------------------------------------------------
             |                 OPG
         D.y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
y            |
       _cons |  -.1142458   .3326737    -0.34   0.731    -.7662743    .5377828
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |   -.368505   .5847749    -0.63   0.529    -1.514643    .7776328
             |
          ma |
         L1. |   .3311954   .5949511     0.56   0.578    -.8348873    1.497278
-------------+----------------------------------------------------------------
      /sigma |    9.54277   .1687756    56.54   0.000     9.211975    9.873564
------------------------------------------------------------------------------
Note: The test of the variance against zero is one sided, and the two-sided
      confidence interval is truncated at zero.

.
. est store arima111

.
. qui arima y, arima(1,1,2) nolog

.
. est store arima112

.
. qui arima y, arima(1,1,3) nolog

.
. est store arima113

.
. qui arima y, arima(1,1,4) nolog

.
. est store arima114

.
. qui arima y, arima(2,1,1) nolog

.
. est store arima211

.
. qui arima y, arima(2,1,2) nolog

.
. est store arima212
```

```
.
. qui arima y, arima(2,1,3) nolog

.
. est store arima213

.
. qui arima y, arima(2,1,4) nolog

.
. est store arima214

.
. qui arima y, arima(3,1,1) nolog

.
. est store arima311

.
. qui arima y, arima(3,1,2) nolog

.
. est store arima312

.
. qui arima y, arima(3,1,3) nolog

.
. est store arima313

.
. qui arima y, arima(3,1,4) nolog

.
. est store arima314

.
. est table arima1*, star(0.1 0.05 0.01) stat(N ll chi2 aic bic)

------------------------------------------------------------------------------
    Variable |   arima111        arima112        arima113        arima114
-------------+----------------------------------------------------------------
y            |
       _cons | -.11424575      -.11408115       -.1139183      -.11370744
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. | -.36850497       .30224152       .07471074      -.26441554
             |
          ma |
         L1. |  .33119538      -.33885872      -.11128313       .23060131
         L2. |                  .04456173        .0345267       .02935071
         L3. |                                  .03319847       .04074154
         L4. |                                                  .03843721
-------------+----------------------------------------------------------------
sigma        |
       _cons |  9.5427695***    9.5390832***    9.5360585***     9.532552***
-------------+----------------------------------------------------------------
```

```
Statistics   |
           N |       794            794            794            794
          ll | -2917.724      -2917.4236      -2917.166      -2916.8767
        chi2 | 3.3320137       3.4714053      5.5726249      7.6343946
         aic | 5843.4479       5844.8473      5846.3321      5847.7535
         bic | 5862.1563       5868.2327      5874.3946       5880.493
------------------------------------------------------------------------------
                                          legend: * p<.1; ** p<.05; *** p<.01

.
. est table arima2*, star(0.1 0.05 0.01) stat(N ll chi2 aic bic)

------------------------------------------------------------------------------
    Variable |   arima211       arima212       arima213       arima214
-------------+----------------------------------------------------------------
y            |
       _cons | -.11399264     -.11488781     -.11518755       -.114745
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |  .26006773      1.2835738***   .39680958***   .29779715***
         L2. |  .03927244     -.90739116***  -.83492246***  -.89274399***
             |
          ma |
         L1. | -.29537225     -1.2846762***  -.43709178***  -.33588403***
         L2. |                 .95025686***   .86844397***     .9442071***
         L3. |                                .02125732      .00060118
         L4. |                                               .05136959*
-------------+----------------------------------------------------------------
sigma        |
       _cons |  9.5398841***   9.4620541***   9.4808276***    9.473342***
-------------+----------------------------------------------------------------
Statistics   |
           N |       794            794            794            794
          ll | -2917.4896     -2911.1516     -2912.6217     -2912.0146
        chi2 |  2.8388146      3447.4967      566.77521      690.44183
         aic |  5844.9792      5834.3032      5839.2433      5840.0292
         bic |  5868.3646      5862.3657      5871.9829      5877.4458
------------------------------------------------------------------------------
                                          legend: * p<.1; ** p<.05; *** p<.01

.
. est table arima3*, star(0.1 0.05 0.01) stat(N ll chi2 aic bic)

------------------------------------------------------------------------------
    Variable |   arima311       arima312       arima313       arima314
-------------+----------------------------------------------------------------
y            |
       _cons | -.11395314     -.11434855     -.11487997     -.11489771
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |  .06416111      1.3204613***  -.56194538***   .01972589
         L2. |  .02920804     -.90163025***  -.42027467***  -.77499053***
         L3. |  .02294871     -.05791248**   -.83389917***  -.25249026
             |
          ma |
         L1. | -.10003354     -1.3735497      .51794954     -.05826621
```

```
         L2. |                   1.0000008       .40778767       .81652449***
         L3. |                                   .88983994       .26256083
         L4. |                                                   .05469308*
-------------+----------------------------------------------------------------
sigma        |
       _cons |  9.5380895***    9.4185571       9.4578166       9.4722994***
-------------+----------------------------------------------------------------
Statistics   |
           N |        794             794             794             794
          ll | -2917.3418      -2909.7635      -2911.5297      -2911.9403
        chi2 |  3.8262796        32923.58       7410.3936       480.87615
         aic |  5846.6836       5833.5271       5839.0595       5841.8806
         bic |  5874.7461       5866.2666       5876.4761       5883.9743
------------------------------------------------------------------------------
                                           legend: * p<.1; ** p<.05; *** p<.01

.
. qui arima y, arima(4,1,1) nolog

.
. est store arima411

.
. qui arima y, arima(4,1,2) nolog

.
. est store arima412

.
. qui arima y, arima(4,1,3) nolog

.
. est store arima413

.
. qui arima y, arima(4,1,4) nolog

.
. est store arima414

.
. est table arima4*, star(0.1 0.05 0.01) stat(N ll chi2 aic bic)

------------------------------------------------------------------------------
    Variable |   arima411        arima412        arima413        arima414
-------------+----------------------------------------------------------------
y            |
       _cons | -.11336618      -.11461152      -.11590868      -.11376705
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. | -.26142231        .3181852***    1.7676398***   -.41944632***
         L2. |  .01694481      -.85050807***     -1.50548*       .36718541***
         L3. |  .03124469       .00130972       .41843717      -.35522863***
         L4. |   .0307881       .04773204       .00058669      -.86090936***
             |
          ma |
         L1. |  .22521179      -.35750674***   -1.8167691***    .38743681***
```

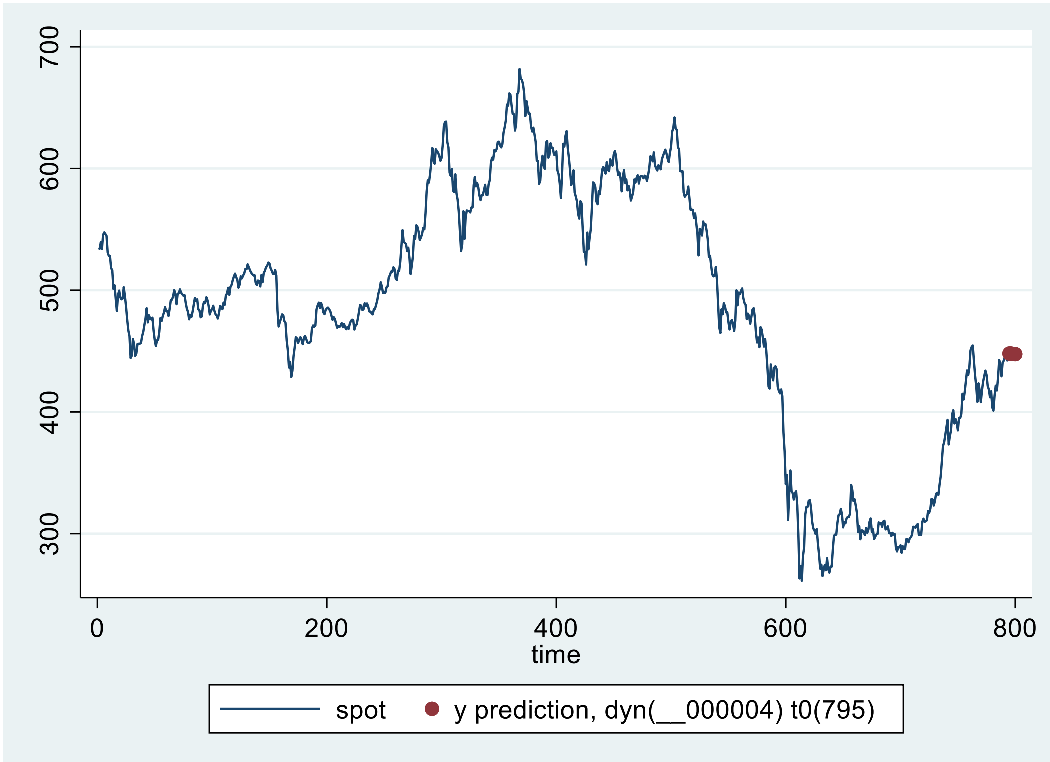
```
        L2. |                 .90090477***    1.6207448*     -.30501342***
        L3. |                                 -.49952541       .42560261***
        L4. |                                                  .8658178***
-------------+----------------------------------------------------------------
sigma        |
       _cons |  9.5350812***    9.4739792***    9.4436415***    9.4058783***
-------------+----------------------------------------------------------------
Statistics   |
           N |       794             794             794             794
          ll | -2917.0927      -2912.0811      -2909.6096      -2906.4848
        chi2 |  5.4882963       661.06102       4207.3323       932.73412
         aic |  5848.1853       5840.1622       5837.2193       5832.9696
         bic |  5880.9249       5877.5789        5879.313       5879.7404
------------------------------------------------------------------------------
                                        legend: * p<.1; ** p<.05; *** p<.01
```

From estimated result, ARIMA(1,1,1) is the most appropriated for both cases.

2. Make dynamic forecast for period time = 796 to 800.

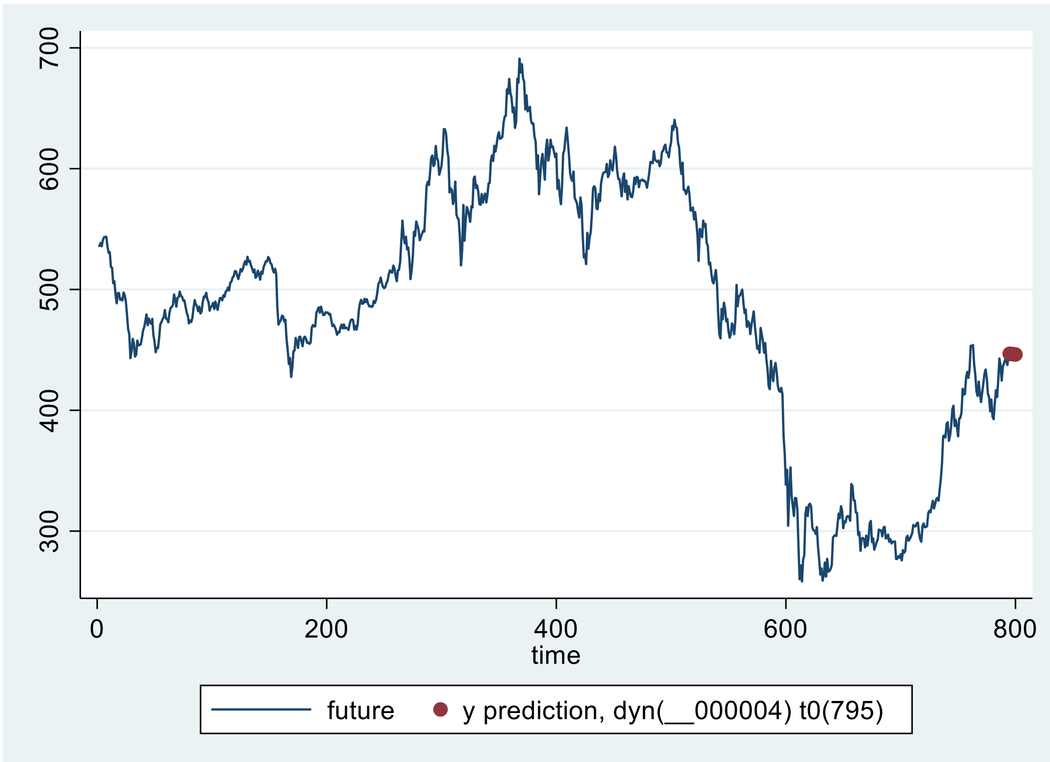
```
. arima spot, arima(1,1,1) nolog

ARIMA regression

Sample:  2 - 795                                Number of obs     =        794
                                                Wald chi2(2)      =      18.31
Log likelihood = -2791.496                      Prob > chi2       =     0.0001

------------------------------------------------------------------------------
             |                 OPG
      D.spot |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
spot         |
       _cons |  -.1047174   .3525647    -0.30   0.766    -.7957316    .5862967
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |   .4353655   .2343856     1.86   0.063    -.0240219    .8947528
             |
          ma |
         L1. |  -.3535108    .242659    -1.46   0.145    -.8291138    .1220922
-------------+----------------------------------------------------------------
      /sigma |   8.139999   .1507405    54.00   0.000     7.844553    8.435444
------------------------------------------------------------------------------
Note: The test of the variance against zero is one sided, and the two-sided
      confidence interval is truncated at zero.

. set obs 800
number of observations (_N) was 795, now 800

. replace time =_n
(5 real changes made)

. predict yhat, y dynamic(.) t0(795)
Note: beginning dynamic predictions in period       4.
(794 missing values generated)
```

```
. twoway (line spot time) (scatter yhat time, sort)
```




```
arima future, arima(1,1,1) nolog

ARIMA regression

Sample:  2 - 795                                Number of obs      =       794
                                                Wald chi2(2)       =      3.33
Log likelihood = -2917.724                      Prob > chi2        =    0.1890

------------------------------------------------------------------------------
             |                 OPG
    D.future |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
future       |
       _cons |  -.1142458   .3326737    -0.34   0.731    -.7662743    .5377828
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |   -.368505   .5847749    -0.63   0.529    -1.514643    .7776328
             |
          ma |
         L1. |   .3311954   .5949511     0.56   0.578    -.8348873    1.497278
-------------+----------------------------------------------------------------
      /sigma |    9.54277   .1687756    56.54   0.000     9.211975    9.873564
------------------------------------------------------------------------------
Note: The test of the variance against zero is one sided, and the two-sided
      confidence interval is truncated at zero.

. predict yhat2, y dynamic(.) t0(795)
```

```
Note: beginning dynamic predictions in period        4.
(794 missing values generated)

. twoway (line future time, sort) (scatter yhat2 time, sort)

.
```



Part II

The following GARCH model:

Mean Equation: $$rfuture_t = \alpha + \beta rspot_t + \varepsilon_t \quad (1)$$

Variance Equation: $$\sigma_t^2 = \alpha_0 + \sum_{j=1}^{p} \delta_j \sigma_{t-j}^2 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 \quad (2)$$

3. Estimate model (1) using OLS by employing future return (rfuture) as dependent variable and spot return (rspot) as explanatory variable, and determine whether ARCH-effect significantly occurs.

```
g rspot = (spot/l.spot)-1
(6 missing values generated)

. g rfuture = (future/l.future)-1
(6 missing values generated)

. reg rfuture rspot
```

```
      Source |       SS           df       MS      Number of obs   =       794
-------------+----------------------------------   F(1, 792)       =   6189.46
       Model |  .338771077         1  .338771077   Prob > F        =    0.0000
    Residual |  .043348982       792  .000054734   R-squared       =    0.8866
-------------+----------------------------------   Adj R-squared   =    0.8864
       Total |  .382120059       793  .000481866   Root MSE        =     .0074

------------------------------------------------------------------------------
     rfuture |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       rspot |   1.108778   .0140935    78.67   0.000     1.081113    1.136443
       _cons |   .0000525   .0002626     0.20   0.841    -.0004629    .0005679
------------------------------------------------------------------------------

. estat archlm
LM test for autoregressive conditional heteroskedasticity (ARCH)
---------------------------------------------------------------------------
    lags(p)  |          chi2               df                 Prob > chi2
-------------+-------------------------------------------------------------
       1     |         43.545               1                   0.0000
---------------------------------------------------------------------------
         H0: no ARCH effects      vs.  H1: ARCH(p) disturbance

.
      From tested result, there exists ARCH-effect.
```

4. Estimate GARCH(p,q) for future return (rfuture) using spot return (rspot) as explanatory variable for mean equation (model (1) and (2)) – determine the most appropriated order p and q for variance equation using SBIC given the maximum lag equals to 2.

5. From (6), predict the variance of future return (rfuture).