Assignment 14
ARIMA & GARCH Models
Guideline Solution

From the data set `assign_timeseries.dta`:
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.

```
. *Define variable y
.   g y = spot

. *Specify order p d q
. forvalue d = 1(1)1 {
  2.   forvalue p = 1(1)4 {
  3.   forvalue q = 1(1)4 {
  4.           display "estimate arima`p'`d'`q'"
  5.           capture: quietly arima y, arima(`p',`d',`q') nolog
  6.           if _rc~=0 {
  7.           display "flatlog when pdq =" `p'`d'`q'
  8.           continue
  9.           }
 10.           estimates store arima`p'`d'`q'
 11.           display "arima`p'`d'`q' already estimated"
 12.   }
 13.   }
 14. estimates table arima1`d'1 arima1`d'2 arima1`d'3 arima1`d'4, star(0.1 0.05
0.01) stat(aic bic ll)
 15. estimates table arima2`d'1 arima2`d'2 arima2`d'3 arima2`d'4, star(0.1 0.05
0.01) stat(aic bic ll)
 16. estimates table arima3`d'1 arima3`d'2 arima3`d'3 arima3`d'4, star(0.1 0.05
0.01) stat(aic bic ll)
 17. estimates table arima4`d'1 arima4`d'2 arima4`d'3 arima4`d'4, star(0.1 0.05
0.01) stat(aic bic ll)
 18.   }
estimate arima111
arima111 already estimated
estimate arima112
arima112 already estimated
estimate arima113
arima113 already estimated
estimate arima114
arima114 already estimated
estimate arima211
arima211 already estimated
estimate arima212
arima212 already estimated
estimate arima213
arima213 already estimated
estimate arima214
arima214 already estimated
estimate arima311
arima311 already estimated
estimate arima312
arima312 already estimated
estimate arima313
arima313 already estimated
estimate arima314
arima314 already estimated
estimate arima411
arima411 already estimated
estimate arima412
arima412 already estimated
```

```
estimate arima413
arima413 already estimated
estimate arima414
arima414 already estimated
```

Variable	arima111	arima112	arima113	arima114
y				
_cons	-.10463992	-.10431285	-.10490685	-.10762587
ARMA				
ar				
L1.	.43560284*	.32893676	-.20984574	.59516858
ma				
L1.	-.35365432	-.25292378	.28723483	-.52234499
L2.		.02671647	.06246922	-.00145314
L3.			.0707883*	.03367041
L4.				-.07222272*
SIGMA2				
_cons	66.263079***	66.237621***	66.074703***	65.939507***
Statistics				
aic	5590.984	5592.6813	5592.7471	5593.1444
bic	5609.6924	5616.0667	5620.8096	5625.884
ll	-2791.492	-2791.3407	-2790.3735	-2789.5722

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

Variable	arima211	arima212	arima213	arima214
y				
_cons	-.10439333	-.10728774	-.10625673	-.10501072
ARMA				
ar				
L1.	.30245493	1.3262749***	.46564924***	1.3083589***
L2.	.02458526	-.92606036***	-.83902823***	-.94942893***
ma				
L1.	-.22523074	-1.3037166***	-.3925185***	-1.2435331***
L2.		.94997827***	.83168716***	.90763824***
L3.			.09629827***	.05103105
L4.				.0110425
SIGMA2				
_cons	66.242605***	65.241971***	65.856633***	65.065891***
Statistics				
aic	5592.7574	5582.6829	5592.1328	5584.5362
bic	5616.1428	5610.7454	5624.8724	5621.9528
ll	-2791.3787	-2785.3414	-2789.0664	-2784.2681

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

Variable	arima311	arima312	arima313	arima314
y				
_cons	-.1048968	-.10616092	-.10736138	-.10698521
ARMA				
ar				
L1.	-.56022313	.56905277***	.66921804**	.5840905
L2.	.08578916*	-.9024755***	-.07185295	.02591186
L3.	.06384012**	.09786885***	-.59940023*	-.67572834
ma				
L1.	.63830067	-.49240481***	-.61205348*	-.51844022
L2.		.89237576***	.05741574	-.03456817
L3.			.6591812**	.72211506
L4.				.02393586
SIGMA2				

```
       _cons |  66.099007***    65.826877***    65.060223***    65.037574***
-------------+------------------------------------------------------------
Statistics   |
         aic |  5593.0503       5591.795       5584.4358       5586.1767
         bic |  5621.1128      5624.5346       5621.8525       5628.2704
          ll | -2790.5251     -2788.8975      -2784.2179      -2784.0883
------------------------------------------------------------------------------
                                        legend: * p<.1; ** p<.05; *** p<.01

------------------------------------------------------------------------------
    Variable |   arima411        arima412        arima413        arima414
-------------+----------------------------------------------------------------
y            |
       _cons | -.10700174      -.10498146      -.10675533      -.10499738
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |  .60248722*      1.3757104***    .61609693       3.0810002***
         L2. |  -.0019893      -1.0295517***    .00752272      -4.2436695***
         L3. |    .023634       .05265445      -.68004038       2.9454045***
         L4. | -.07473907**     .00828148       .02406626      -.92115224***
             |
          ma |
         L1. |  -.5260961      -1.3105504***    -.5496138      -3.0683139***
         L2. |                  .98439816***   -.01812692        4.242353***
         L3. |                                  .72581701      -2.9737384***
         L4. |                                                  .94241771***
-------------+----------------------------------------------------------------
SIGMA2       |
       _cons |  65.901721***     65.06169***    65.037661***    64.460186***
-------------+----------------------------------------------------------------
Statistics   |
         aic |  5592.6351       5584.5083       5586.1528       5581.1168
         bic |  5625.3746       5621.9249       5628.2466       5627.8877
          ll | -2789.3175      -2784.2541      -2784.0764      -2780.5584
------------------------------------------------------------------------------
                                        legend: * p<.1; ** p<.05; *** p<.01

. drop y

.
. *Define Variable y
.  g y = future

. *Specify order p d q
.  forvalue d = 1(1)1 {
  2.   forvalue p = 1(1)4 {
  3.   forvalue q = 1(1)4 {
  4.           display "estimate arima`p'`d'`q'"
  5.           capture: quietly arima y, arima(`p',`d',`q') nolog
  6.           if _rc~=0 {
  7.           display "flatlog when pdq =" `p'`d'`q'
  8.           continue
  9.           }
 10.           estimates store arima`p'`d'`q'
 11.           display "arima`p'`d'`q' already estimated"
 12.   }
 13.   }
 14. estimates table arima1`d'1 arima1`d'2 arima1`d'3 arima1`d'4, star(0.1 0.05
0.01) stat(aic bic ll)
 15. estimates table arima2`d'1 arima2`d'2 arima2`d'3 arima2`d'4, star(0.1 0.05
0.01) stat(aic bic ll)
 16. estimates table arima3`d'1 arima3`d'2 arima3`d'3 arima3`d'4, star(0.1 0.05
0.01) stat(aic bic ll)
 17. estimates table arima4`d'1 arima4`d'2 arima4`d'3 arima4`d'4, star(0.1 0.05
0.01) stat(aic bic ll)
 18.   }
estimate arima111
arima111 already estimated
estimate arima112
arima112 already estimated
estimate arima113
arima113 already estimated
estimate arima114
arima114 already estimated
estimate arima211
arima211 already estimated
```

```
estimate arima212
arima212 already estimated
estimate arima213
arima213 already estimated
estimate arima214
arima214 already estimated
estimate arima311
arima311 already estimated
estimate arima312
arima312 already estimated
estimate arima313
arima313 already estimated
estimate arima314
arima314 already estimated
estimate arima411
arima411 already estimated
estimate arima412
arima412 already estimated
estimate arima413
arima413 already estimated
estimate arima414
arima414 already estimated
```

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				
aic	5843.4479	5844.8473	5846.3321	5847.7535
bic	5862.1563	5868.2327	5874.3946	5880.493
ll	-2917.724	-2917.4236	-2917.166	-2916.8767

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

Variable	arima211	arima212	arima213	arima214
y				
_cons	-.11399264	-.11468686	-.11518755	-.114745
ARMA				
ar				
L1.	.26006773	1.2835845***	.39680958***	.29779715***
L2.	.03927244	-.90741041***	-.83492246***	-.89274399***
ma				
L1.	-.29537225	-1.2846838***	-.43709178***	-.33588403***
L2.		.95026799***	.86844397***	.9442071***
L3.			.02125732	.00060118
L4.				.05136959*
sigma				
_cons	9.5398841***	9.4618855***	9.4808276***	9.473342***
Statistics				
aic	5844.9792	5834.3032	5839.2433	5840.0292
bic	5868.3646	5862.3657	5871.9829	5877.4458
ll	-2917.4896	-2911.1516	-2912.6217	-2912.0146

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

Variable	arima311	arima312	arima313	arima314
y				
_cons	-.11395314	-.11434855	-.11478801	-.11489771
ARMA				
ar				
L1.	.06416111	1.3204613***	-.56212344***	.01972589
L2.	.02920804	-.90163025***	-.42052406***	-.77499053***
L3.	.02294871	-.05791248**	-.83397003***	-.25249026
ma				
L1.	-.10003354	-1.3735497	.51812134	-.05826621
L2.		1.0000008	.40800786	.81652449***
L3.			.88988554	.26256084
L4.				.05469308*
sigma				
_cons	9.5380895***	9.4185571	9.4576111	9.4722994***
Statistics				
aic	5846.6836	5833.5271	5839.0595	5841.8806
bic	5874.7461	5866.2666	5876.4762	5883.9743
ll	-2917.3418	-2909.7635	-2911.5297	-2911.9403

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

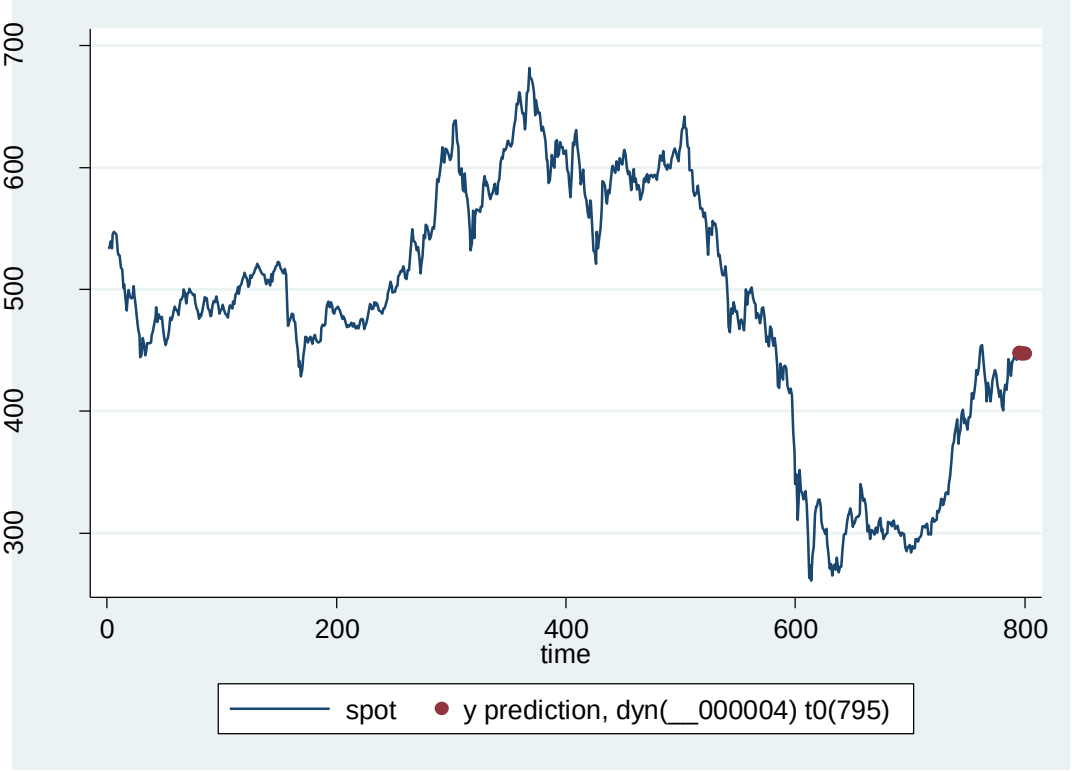
Variable	arima411	arima412	arima413	arima414
y				
_cons	-.11336618	-.11461152	-.11590868	-.11376705
ARMA				
ar				
L1.	-.26142231	.3181852***	1.7676399***	-.41944632***
L2.	.01694481	-.85050807***	-1.5054801*	.36718541***
L3.	.03124469	.00130972	.41843725	-.35522863***
L4.	.0307881	.04773204	.00058669	-.86090936***
ma				
L1.	.22521179	-.35750674***	-1.8167692***	.38743681***
L2.		.90090477***	1.6207449*	-.30501342***
L3.			-.4995255	.42560261***
L4.				.8658178***
sigma				
_cons	9.5350812***	9.4739792***	9.4436415***	9.4058783***
Statistics				
aic	5848.1853	5840.1622	5837.2193	5832.9696
bic	5880.9249	5877.5789	5879.313	5879.7404
ll	-2917.0927	-2912.0811	-2909.6096	-2906.4848

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

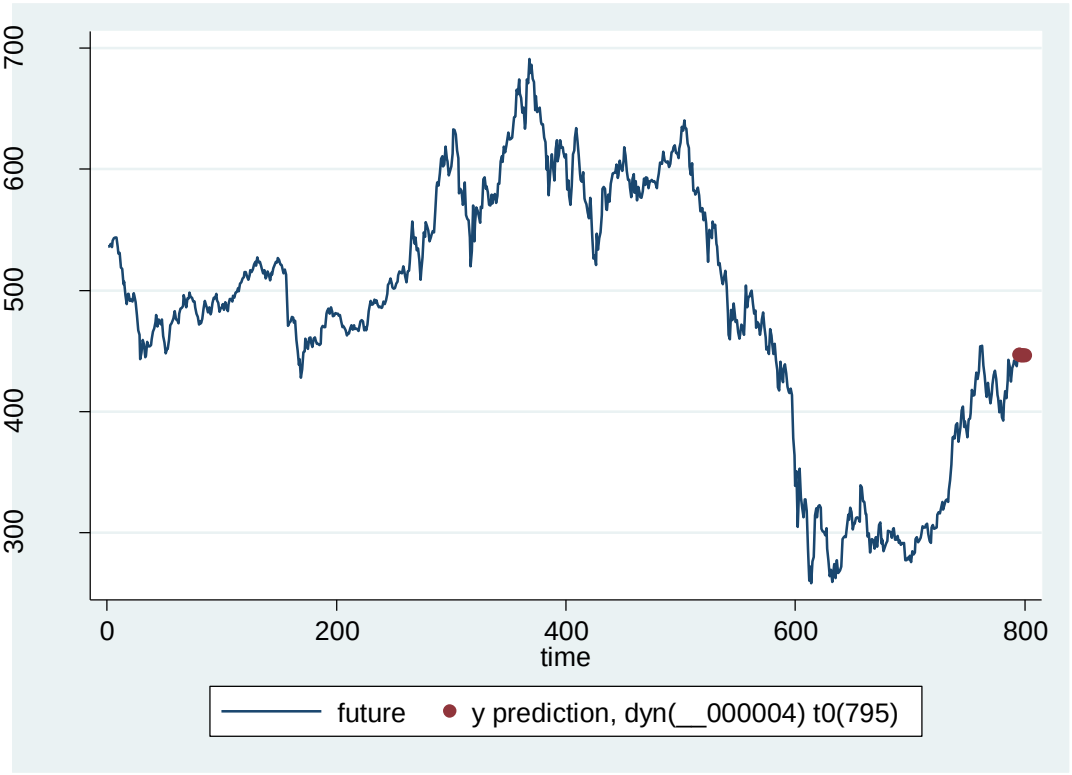
- ***The most appropriated order for rspot is ARIMA(1,1,1).***
- ***The most appropriated order for rfuture is ARIMA(1,1,1).***

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 800, 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, sort) (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

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.

```
. 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
```

- ***There exist significant ARCH effects since p-value of the ARCHLM-test is less than 0.05.***

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.

```
. qui arch rfuture rspot, garch(1/1) arch(1/1) nolog

. qui estat ic

. qui mat ic=r(S)

. qui scalar sic0=el(ic,1,6)

. local opt_lag_p=1

. local opt_lag_q=1

. forvalue p=1(1)2 {
  2.   forvalue q=1(1)2 {
  3.      display "estimate garch`p'`q'"
  4.      capture: qui arch rfuture rspot, garch(1/`p') arch(1/`q') nolog
  5.      if _rc~=0 {
  6.      display "flatlog when pq = "`p'`q'
  7.      continue
  8.      }
  9.   qui estimates store garch`p'`q'
 10.   qui estat ic
 11.   qui mat ic=r(S)
 12.   qui scalar sic1=el(ic,1,6)
 13.   *Check SIC
.   if sic1<sic0 {
 14.   local opt_lag_p=`p'
 15.   local opt_lag_q=`q'
 16.   }
 17.   display "garch`p'`q' already estimated"
 18.   }
```

```
 19. }
estimate garch11
garch11 already estimated
estimate garch12
garch12 already estimated
estimate garch21
garch21 already estimated
estimate garch22
garch22 already estimated

.
. estimates table garch11 garch12 garch21 garch22, star(0.1 0.05 0.01) stat(aic bic
ll)

-------------------------------------------------------------------------------
    Variable |    garch11         garch12         garch21         garch22
-------------+-----------------------------------------------------------------
rfuture      |
       rspot |   1.066779***    1.0686232***    1.0662306***    1.0681952***
       _cons |  .00003063       .00002254       .00002879       .00002246
-------------+-----------------------------------------------------------------
ARCH         |
        arch |
         L1. |  .08462311***    .21216575***    .11369072***    .21614044***
         L2. |                 -.14954552***                   -.17303698***
             |
       garch |
         L1. |  .89700599***    .92239363***    .54514867       1.1227148***
         L2. |                                  .31487288      -.17547369
             |
       _cons |  9.850e-07***    7.744e-07***    1.380e-06**     5.016e-07**
-------------+-----------------------------------------------------------------
Statistics   |
         aic | -5702.2841      -5708.9307       -5702.54       -5707.938
         bic | -5678.8987      -5680.8682      -5674.4775      -5675.1984
          ll |  2856.1421       2860.4654         2857.27        2860.969
-------------------------------------------------------------------------------
                                        legend: * p<.1; ** p<.05; *** p<.01

. display "Optimal order for GARCH = "`opt_lag_p'`opt_lag_q'
Optimal order for GARCH = 12

. arch rfuture rspot, garch(1/`opt_lag_p') arch(1/`opt_lag_q') nolog

ARCH family regression

Sample: 2 - 795                                 Number of obs   =        794
Distribution: Gaussian                          Wald chi2(1)    =   10668.22
Log likelihood =  2860.465                      Prob > chi2     =     0.0000

------------------------------------------------------------------------------
             |                 OPG
     rfuture |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
rfuture      |
       rspot |   1.068623   .0103461   103.29   0.000     1.048345    1.088901
       _cons |   .0000225   .0001926     0.12   0.907    -.0003549    .0003999
-------------+----------------------------------------------------------------
ARCH         |
        arch |
         L1. |   .2121657   .0566827     3.74   0.000     .1010698    .3232617
         L2. |  -.1495455   .0568688    -2.63   0.009    -.2610062   -.0380848
             |
       garch |
         L1. |   .9223936   .0146026    63.17   0.000      .893773    .9510143
             |
       _cons |   7.74e-07   2.42e-07     3.20   0.001     3.00e-07    1.25e-06
------------------------------------------------------------------------------
```

- ***According BIC, the most appropriated lags order in this case is GARCH(1,2)***

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

```
. predict sigmahat, v
. line sigmahat time
```