Example
Time Series

ARIMA: From the data set example.dta:

Requirements:
1. Test whether the series spot and future are stationary series.
2. Determine order of integration of the series spot and future.
3. Generate series of the return of spot (*rspot*) and return of future (*rfuture*) and test whether they are stationary.
4. Estimate Autoregressive Integrated Moving Average (ARIMA(p,d,q)) model for spot return (*rspot*) and future return (*rfuture*) – determine the most appropriated order for p, d, and q using SBIC given the maximum lag equals 5.

---

1. Test whether the series spot and future are stationary series.

```
. tsset t
        time variable:  t, 1 to 7684
                delta:  1 unit

. dfuller spot, trend lag(1) regress

Augmented Dickey-Fuller test for unit root         Number of obs   =      7682

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -2.438            -3.960            -3.410            -3.120
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.3597

------------------------------------------------------------------------------
D.spot       |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        spot |
         L1. |   -.001489   .0006108    -2.44   0.015    -.0026862   -.0002917
         LD. |   .0440347   .0114011     3.86   0.000     .0216855    .0663839
      _trend |   .0000171   8.32e-06     2.05   0.040     7.62e-07    .0000334
       _cons |   .7447753    .302873     2.46   0.014     .1510615    1.338489
------------------------------------------------------------------------------

. dfuller future, trend lag(1) regress

Augmented Dickey-Fuller test for unit root         Number of obs   =      7682

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -2.563            -3.960            -3.410            -3.120
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.2971

------------------------------------------------------------------------------
D.future     |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      future |
         L1. |   -.001768   .0006898    -2.56   0.010    -.0031202   -.0004159
         LD. |  -.0275938   .0114077    -2.42   0.016    -.0499561   -.0052315
      _trend |   .0000222     .00001     2.22   0.026     2.62e-06    .0000418
       _cons |     .86276   .3338726     2.58   0.010     .2082785    1.517241
------------------------------------------------------------------------------
```

- ***spot and future are nonstationary.***

2. Determine order of integration of the series spot and future.

```
. dfuller d.spot, trend lag(1) regress

Augmented Dickey-Fuller test for unit root         Number of obs   =      7681

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)            -63.765            -3.960            -3.410            -3.120
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
D2.spot      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      D.spot |
         L1. |  -1.005364   .0157667   -63.77   0.000    -1.036271    -.974457
         LD. |   .0508571    .011398     4.46   0.000     .0285139    .0732003
      _trend |   7.82e-07   4.94e-06     0.16   0.874    -8.90e-06    .0000105
       _cons |   .0088178   .0219189     0.40   0.687    -.0341492    .0517848
------------------------------------------------------------------------------

. dfuller d.future , trend lag(1) regress

Augmented Dickey-Fuller test for unit root         Number of obs   =      7681

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)            -65.269            -3.960            -3.410            -3.120
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
D2.future    |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    D.future |
         L1. |  -1.067592   .0163567   -65.27   0.000    -1.099655   -1.035528
         LD. |    .038008   .0114045     3.33   0.001     .0156522    .0603639
      _trend |   1.01e-06   5.59e-06     0.18   0.856    -9.94e-06     .000012
       _cons |   .0096235   .0247823     0.39   0.698    -.0389566    .0582036
------------------------------------------------------------------------------
```

- ***spot and future are Integrated series of order 1 or I(1).***

3. Generate series of the return of spot (*rspot*) and return of future (*rfuture*) and test whether they are stationary.

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

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

. dfuller rspot, trend lag(1) regress

Augmented Dickey-Fuller test for unit root         Number of obs   =      7681

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)            -63.787            -3.960            -3.410            -3.120
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
D.rspot      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       rspot |
```

```
          L1. |  -1.005168   .0157581   -63.79   0.000    -1.036058   -.9742776
          LD. |   .0517018   .0113974     4.54   0.000     .0293598    .0740439
      _trend  |   9.56e-10   9.19e-09     0.10   0.917    -1.71e-08    1.90e-08
       _cons  |   .0000199   .0000408     0.49   0.626      -.00006    .0000998
------------------------------------------------------------------------------

. dfuller rspot, lag(1) regress

Augmented Dickey-Fuller test for unit root         Number of obs   =      7681

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)           -63.791            -3.430            -2.860            -2.570
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
     D.rspot |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       rspot |
          L1. |  -1.005165   .0157571   -63.79   0.000    -1.036053   -.9742771
          LD. |   .0517007   .0113967     4.54   0.000     .0293601    .0740413
              |
       _cons  |   .0000235   .0000204     1.15   0.248    -.0000164    .0000635
------------------------------------------------------------------------------

. dfuller rfuture, trend lag(1) regress

Augmented Dickey-Fuller test for unit root         Number of obs   =      7681

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)           -65.070            -3.960            -3.410            -3.120
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
D.rfuture    |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     rfuture |
          L1. |  -1.063572   .0163449   -65.07   0.000    -1.095612   -1.031531
          LD. |     .03575   .0114053     3.13   0.002     .0133924    .0581076
      _trend  |   1.17e-09   1.06e-08     0.11   0.912    -1.96e-08    2.19e-08
       _cons  |   .0000231    .000047     0.49   0.624    -.0000691    .0001152
------------------------------------------------------------------------------

. dfuller rfuture, lag(1) regress

Augmented Dickey-Fuller test for unit root         Number of obs   =      7681

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)           -65.074            -3.430            -2.860            -2.570
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
   D.rfuture |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     rfuture |
          L1. |  -1.063569   .0163439   -65.07   0.000    -1.095608   -1.031531
          LD. |   .0357488   .0114046     3.13   0.002     .0133927    .0581049
              |
       _cons  |   .0000276   .0000235     1.17   0.241    -.0000185    .0000736
------------------------------------------------------------------------------
```

- ***rspot and rfuture are stationary.***

4. Estimate Autoregressive Integrated Moving Average (ARIMA(p,d,q)) model for spot return (*rspot*) and future return (*rfuture*) – determine the most appropriated order for p, d, and q using SBIC given the maximum lag equals 5.

```
. *Define variable y
.         g y = rspot
(1 missing value generated)

. *Specify order p d q
. forvalue d = 0(1)0 {
  2.  forvalue p = 1(1)5 {
  3.  forvalue q = 1(1)5 {
  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 arima1`d'5, 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 arima2`d'5, 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 arima3`d'5, 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 arima4`d'5, star(0.1 0.05
0.01) stat(aic bic ll)
 18.  estimates table arima5`d'1 arima5`d'2 arima5`d'3 arima5`d'4 arima5`d'5, star(0.1 0.05
0.01) stat(aic bic ll)
 19.  }
estimate arima101
arima101 already estimated
estimate arima102
arima102 already estimated
estimate arima103
arima103 already estimated
estimate arima104
arima104 already estimated
estimate arima105
arima105 already estimated
estimate arima201
arima201 already estimated
estimate arima202
arima202 already estimated
estimate arima203
arima203 already estimated
estimate arima204
arima204 already estimated
estimate arima205
arima205 already estimated
estimate arima301
arima301 already estimated
estimate arima302
arima302 already estimated
estimate arima303
arima303 already estimated
estimate arima304
arima304 already estimated
estimate arima305
arima305 already estimated
estimate arima401
arima401 already estimated
estimate arima402
arima402 already estimated
estimate arima403
arima403 already estimated
estimate arima404
arima404 already estimated
estimate arima405
arima405 already estimated
estimate arima501
arima501 already estimated
estimate arima502
```

```
arima502 already estimated
estimate arima503
arima503 already estimated
estimate arima504
arima504 already estimated
estimate arima505
arima505 already estimated

----------------------------------------------------------------------------------------
    Variable |   arima101        arima102        arima103        arima104        arima105
-------------+--------------------------------------------------------------------------
y            |
       _cons |  .00002358       .00002358       .00002358       .00002357        .0000236
-------------+--------------------------------------------------------------------------
ARMA         |
          ar |
         L1. | -.39222121***    .42866768***    .65121793**     -.4418708       .19422255
             |
          ma |
         L1. |  .44515732***   -.38284317***   -.60570251**      .48778125     -.14853288
         L2. |                 -.06805288***    -.0785457***   -.02952616       -.0578027**
         L3. |                                  .01541405      -.04117543      -.00879285
         L4. |                                                 -.00216733       .00427518
         L5. |                                                                 -.02212732*
-------------+--------------------------------------------------------------------------
sigma        |
       _cons |  .00178634***    .00178491***    .00178487***    .00178491***    .00178452***
-------------+--------------------------------------------------------------------------
Statistics   |
         aic | -75418.284      -75428.583      -75426.956      -75424.609      -75425.916
         bic | -75390.497       -75393.85      -75385.276      -75375.982      -75370.342
          ll |  37713.142       37719.292       37719.478       37719.305       37720.958
----------------------------------------------------------------------------------------
                                                       legend: * p<.1; ** p<.05; *** p<.01

----------------------------------------------------------------------------------------
    Variable |   arima201        arima202        arima203        arima204        arima205
-------------+--------------------------------------------------------------------------
y            |
       _cons |  .00002357       .00002358       .00002357       .00002358       .00002357
-------------+--------------------------------------------------------------------------
ARMA         |
          ar |
         L1. |  .38018903***     .4428634***   -.29668626       .20849565       .63263472***
         L2. | -.06525664***    .06485063       .18525538       .37776554      -.91731069***
             |
          ma |
         L1. | -.33467542**    -.39715673***     .3426502      -.16260084      -.58710754***
         L2. |                 -.13338401      -.22062902      -.43688009       .83965418***
         L3. |                                  -.0455461      -.02892354       .05476885***
         L4. |                                                  .02145155      -.03409321***
         L5. |                                                                 -.03012065***
-------------+--------------------------------------------------------------------------
sigma        |
       _cons |  .00178498***    .00178489***    .00178489***    .00178475***    .00178388***
-------------+--------------------------------------------------------------------------
Statistics   |
         aic | -75428.017      -75426.777      -75424.788      -75423.974      -75429.446
         bic | -75393.283      -75385.096      -75376.161        -75368.4      -75366.925
          ll |  37719.008       37719.388       37719.394       37719.987       37723.723
----------------------------------------------------------------------------------------
                                                       legend: * p<.1; ** p<.05; *** p<.01

----------------------------------------------------------------------------------------
    Variable |   arima301        arima302        arima303        arima304        arima305
-------------+--------------------------------------------------------------------------
y            |
       _cons |  .00002358       .00002358       .00002358       .00002358       .00002358
-------------+--------------------------------------------------------------------------
ARMA         |
          ar |
         L1. |  .77437319***    .75391093      -.00931271       .11659349       .17008802
         L2. | -.08500113***   -.07142142       .14076076      -.77533292***   -.75369599***
         L3. |  .02486609       .02349348       .27348399*      .50690923***    .56028712*
             |
          ma |
         L1. | -.72875825***   -.70829213       .05444554      -.07071828      -.12430409
```

L2.		-.0126675	-.19087608	.72187978***	.69757843***
L3.			-.29968133**	-.48363964***	-.53414149*
L4.				-.06737484***	-.06847599***
L5.					.00392386
sigma					
_cons	.00178484***	.00178484***	.00178455***	.00178409***	.00178409***
Statistics					
aic	-75427.175	-75425.178	-75425.675	-75427.585	-75425.609
bic	-75385.495	-75376.55	-75370.101	-75365.064	-75356.141
ll	37719.588	37719.589	37720.837	37722.792	37722.804

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

Variable	arima401	arima402	arima403	arima404	arima405
y					
_cons	.00002358	.00002358	.00002358	.00002358	.00002358
ARMA					
ar					
L1.	.7666053*	.19158964	.11479526	.11582617	-.55025558
L2.	-.0847024***	.40155116	-.84422456***	-.75582354***	-.78564519***
L3.	.02504525	-.03039789	.47666348***	.51458285***	-.04871012
L4.	-.00097078	.02217215	-.06669164***	.01927272	.25153939
ma					
L1.	-.72097599*	-.14607877	-.06913672	-.07000046	.59631735
L2.		-.45952184	.79177357***	.70233001***	.76311658***
L3.			-.45297968***	-.49146562***	.03723265
L4.				-.08652975	-.30357175
L5.					-.04488519
sigma					
_cons	.00178484***	.0017848***	.00178412***	.00178409***	.00178406***
Statistics					
aic	-75425.181	-75423.574	-75427.294	-75425.598	-75423.821
bic	-75376.553	-75368	-75364.773	-75356.13	-75347.407
ll	37719.59	37719.787	37722.647	37722.799	37722.91

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

Variable	arima501	arima502	arima503	arima504	arima505
y					
_cons	.00002358	.00002357	.00002357	.00002358	.00002357
ARMA					
ar					
L1.	.16545423	.27864543	.40337768	.45212007	.65262081
L2.	-.05696613**	-.38380203	-.81291959**	-.79726544***	-.84750045
L3.	-.00729372	.0132755	-.23210031	.79847234	.13436587
L4.	.00131373	-.01409715	-.01694377	-.14234401	-.03733553
L5.	-.02387488**	-.027723**	-.03800524	.02403092	.21196901
ma					
L1.	-.11967988	-.23291974	-.35773961	-.40627736	-.6073824
L2.		.32183897	.74635725**	.72752725***	.76923758
L3.			.27245433	-.75638633	-.08161162
L4.				.06670883	.00421319
L5.					-.24353795
sigma					
_cons	.0017845***	.00178443***	.00178393***	.00178407***	.00178371***
Statistics					
aic	-75426.156	-75424.789	-75426.981	-75423.79	-75424.907
bic	-75370.582	-75362.269	-75357.513	-75347.376	-75341.546
ll	37721.078	37721.395	37723.49	37722.895	37724.453

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

```
. drop y
```

```
. *Define Variable y
.    g y = rfuture
(1 missing value generated)

. *Specify order p d q
. forvalue d = 0(1)0 {
  2.  forvalue p = 1(1)3 {
  3.  forvalue q = 1(1)3 {
  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 arima1`d'5, 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 arima2`d'5, 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 arima3`d'5, 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 arima4`d'5, star(0.1 0.05
0.01) stat(aic bic ll)
 18.  estimates table arima5`d'1 arima5`d'2 arima5`d'3 arima5`d'4 arima5`d'5, star(0.1 0.05
0.01) stat(aic bic ll)
 19.  }
estimate arima101
arima101 already estimated
estimate arima102
arima102 already estimated
estimate arima103
arima103 already estimated
estimate arima201
arima201 already estimated
estimate arima202
arima202 already estimated
estimate arima203
arima203 already estimated
estimate arima301
arima301 already estimated
estimate arima302
arima302 already estimated
estimate arima303
arima303 already estimated

------------------------------------------------------------------------------------------
    Variable |   arima101        arima102        arima103        arima104        arima105    
-------------+----------------------------------------------------------------------------
y            |
       _cons |  .00002616       .00002615       .00002616       .00002357        .0000236    
-------------+----------------------------------------------------------------------------
ARMA         |
          ar |
         L1. |  .57862596***     .1646139      -.99197304***    -.4418708       .19422255    
             |
          ma |
         L1. | -.61250239***   -.19269514       .96410702***    .48778125     -.14853288    
         L2. |                 -.03060977**    -.06339899***   -.02952616      -.0578027**   
         L3. |                                 -.03780979***   -.04117543     -.00879285    
         L4. |                                                 -.00216733      .00427518    
         L5. |                                                                -.02212732*   
-------------+----------------------------------------------------------------------------
sigma        |
       _cons |  .00205937***    .00205903***    .00205869***    .00178491***    .00178452***
-------------+----------------------------------------------------------------------------
Statistics   |
         aic | -73232.774      -73233.366      -73233.777      -75424.609      -75425.916    
         bic | -73204.987      -73198.632      -73192.096      -75375.982      -75370.342    
          ll |  36620.387       36621.683       36622.888       37719.305       37720.958    
------------------------------------------------------------------------------------------
                                                      legend: * p<.1; ** p<.05; *** p<.01

------------------------------------------------------------------------------------------
```

Variable	arima201	arima202	arima203	arima204	arima205
y					
_cons	.00002615	.00002616	.00002616	.00002358	.00002357
ARMA					
ar					
L1.	.1969293	.15226369	-.89430512***	.20849565	.63263472***
L2.	-.02961053**	.01296948	.09704817	.37776554	-.91731069***
ma					
L1.	-.22502128	-.18034762	.8665611***	-.16260084	-.58710754***
L2.		-.0439096	-.15750986	-.43688009	.83965418***
L3.			-.03516485***	-.02892354	.05476885***
L4.				.02145155	-.03409321***
L5.					-.03012065***
sigma					
_cons	.00205903***	.00205902***	.00205869***	.00178475***	.00178388***
Statistics					
aic	-73233.346	-73231.368	-73231.866	-75423.974	-75429.446
bic	-73198.612	-73189.687	-73183.239	-75368.4	-75366.925
ll	36621.673	36621.684	36622.933	37719.987	37723.723

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

Variable	arima301	arima302	arima303	arima304	arima305
y					
_cons	.00002616	.00002616	.00002618	.00002358	.00002358
ARMA					
ar					
L1.	.43745093	-.8588441***	-.52730643***	.11659349	.17008802
L2.	-.02300296	.09802834	-.40394239**	-.77533292***	-.75369599***
L3.	.00950901	-.03401356**	.5172721***	.50690923***	.56028712*
ma					
L1.	-.46553637	.83106571***	.49689489***	-.07071828	-.12430409
L2.		-.15724365	.3607837**	.72187978***	.69757843***
L3.			-.55348204***	-.48363964***	-.53414149*
L4.				-.06737484***	-.06847599***
L5.					.00392386
sigma					
_cons	.00205902***	.00205869***	.0020583***	.00178409***	.00178409***
Statistics					
aic	-73231.387	-73231.797	-73232.791	-75427.585	-75425.609
bic	-73189.706	-73183.17	-73177.217	-75365.064	-75356.141
ll	36621.693	36622.898	36624.395	37722.792	37722.804

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

Variable	arima401	arima402	arima403	arima404	arima405
y					
_cons	.00002358	.00002358	.00002358	.00002358	.00002358
ARMA					
ar					
L1.	.7666053*	.19158964	.11479526	.11582617	-.55025558
L2.	-.0847024***	.40155116	-.84422456***	-.75582354***	-.78564519***
L3.	.02504525	-.03039789	.47666348***	.51458285***	-.04871012
L4.	-.00097078	.02217215	-.06669164***	.01927272	.25153939
ma					
L1.	-.72097599*	-.14607877	-.06913672	-.07000046	.59631735
L2.		-.45952184	.79177357***	.70233001***	.76311658***
L3.			-.45297968***	-.49146562***	.03723265
L4.				-.08652975	-.30357175
L5.					-.04488519
sigma					

_cons	.00178484***	.0017848***	.00178412***	.00178409***	.00178406***
Statistics					
aic	-75425.181	-75423.574	-75427.294	-75425.598	-75423.821
bic	-75376.553	-75368	-75364.773	-75356.13	-75347.407
ll	37719.59	37719.787	37722.647	37722.799	37722.91

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

Variable	arima501	arima502	arima503	arima504	arima505
y					
_cons	.00002358	.00002357	.00002357	.00002358	.00002357
ARMA					
ar					
L1.	.16545423	.27864543	.40337768	.45212007	.65262081
L2.	-.05696613**	-.38380203	-.81291959**	-.79726544***	-.84750045
L3.	-.00729372	.0132755	-.23210031	.79847234	.13436587
L4.	.00131373	-.01409715	-.01694377	-.14234401	-.03733553
L5.	-.02387488**	-.027723**	-.03800524	.02403092	.21196901
ma					
L1.	-.11967988	-.23291974	-.35773961	-.40627736	-.6073824
L2.		.32183897	.74635725**	.72752725***	.76923758
L3.			.27245433	-.75638633	-.08161162
L4.				.06670883	.00421319
L5.					-.24353795
sigma					
_cons	.0017845***	.00178443***	.00178393***	.00178407***	.00178371***
Statistics					
aic	-75426.156	-75424.789	-75426.981	-75423.79	-75424.907
bic	-75370.582	-75362.269	-75357.513	-75347.376	-75341.546
ll	37721.078	37721.395	37723.49	37722.895	37724.453

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

.
end of do-file

- ***The most appropriated order for rspot is ARIMA(1,0,2).***
- ***The most appropriated order for rfuture is ARIMA(1,0,1).***

<u>GARCH</u>:

The following GARCH model:

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

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

From the data set example.dta:

<u>Requirements</u>:

1. Test whether there exists significant ARCH effects.
2. Estimate GARCH(p,q) for spot return (*rspot*) using future return (*rfuture*) as explanatory variable for mean equation – determine the most appropriated order p and q for variance equation using SBIC given the maximum lag equals to 2.
3. From (2), predict the variance of future return (*rfuture*).

---

1. Test whether there exists significant ARCH effects.

```
. reg rfuture rspot

      Source |       SS           df       MS      Number of obs   =     7,683
-------------+----------------------------------   F(1, 7681)      =   6787.70
       Model |  .01531231         1  .01531231     Prob > F        =    0.0000
    Residual | .017327485     7,681  2.2559e-06    R-squared       =    0.4691
-------------+----------------------------------   Adj R-squared   =    0.4691
       Total | .032639795     7,682  4.2489e-06    Root MSE        =     .0015

------------------------------------------------------------------------------
     rfuture |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       rspot |   .7889924   .0095766    82.39   0.000     .7702196    .8077651
       _cons |   7.58e-06   .0000171     0.44   0.658     -.000026    .0000412
------------------------------------------------------------------------------

. estat archlm
LM test for autoregressive conditional heteroskedasticity (ARCH)
---------------------------------------------------------------------------
    lags(p)  |          chi2               df                 Prob > chi2
-------------+-------------------------------------------------------------
       1     |          6.951               1                   0.0084
---------------------------------------------------------------------------
         H0: no ARCH effects      vs.  H1: ARCH(p) disturbance
```

- ***According to ARCH-effect test, there exists significant ARCH effect.***

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

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

ARCH family regression

Sample: 2 - 7684                                Number of obs     =      7,683
Distribution: Gaussian                          Wald chi2(1)      =  110866.60
Log likelihood =  39218.14                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
             |                 OPG
     rfuture |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
```

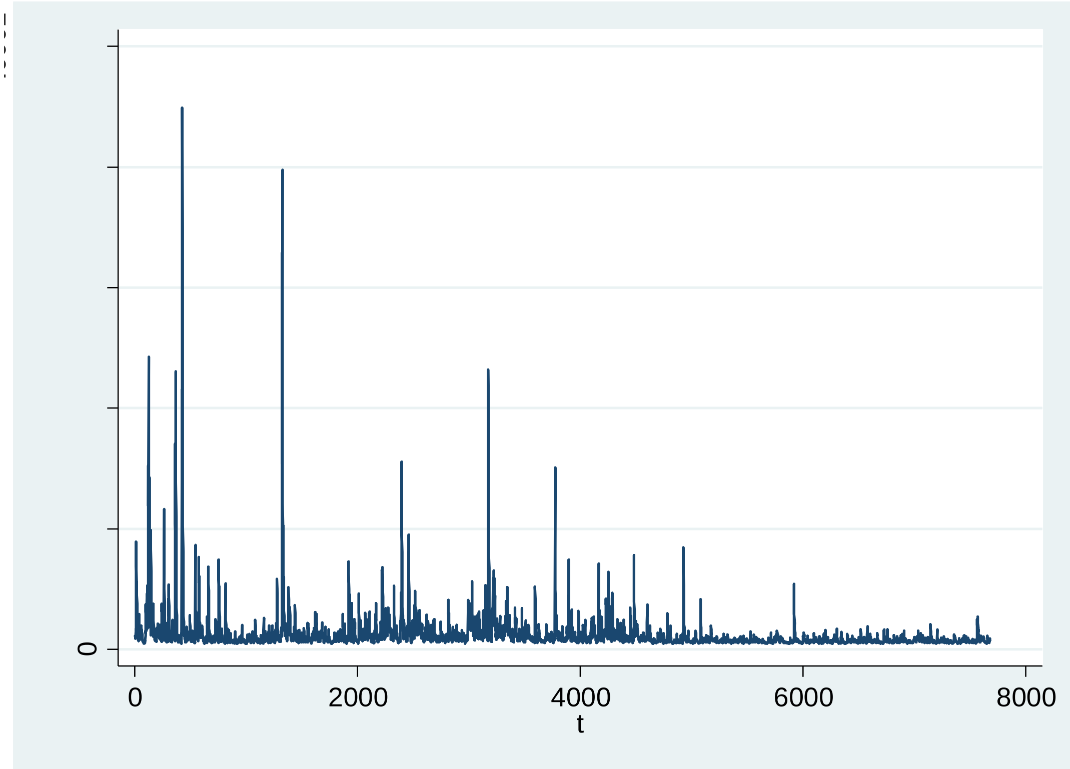
```
-------------+----------------------------------------------------------------
rfuture      |
       rspot |   .8122738   .0024395   332.97   0.000     .8074924    .8170551
       _cons |  -1.78e-06   .0000129    -0.14   0.890     -.000027    .0000234
-------------+----------------------------------------------------------------
ARCH         |
        arch |
         L1. |   .2336873   .0081368    28.72   0.000     .2177393    .2496352
             |
       _cons |   1.84e-06   8.36e-09   219.94   0.000     1.82e-06    1.86e-06
------------------------------------------------------------------------------

. estat ic

Akaike's information criterion and Bayesian information criterion

-----------------------------------------------------------------------------
       Model |        Obs  ll(null)  ll(model)      df         AIC        BIC
-------------+---------------------------------------------------------------
           . |      7,683         .   39218.14       4   -78428.29   -78400.5
-----------------------------------------------------------------------------
               Note: N=Obs used in calculating BIC; see [R] BIC note.

. arch rfuture rspot, arch(1/2) nolog

ARCH family regression

Sample: 2 - 7684                                Number of obs     =      7,683
Distribution: Gaussian                          Wald chi2(1)      =  108336.82
Log likelihood =  39351.85                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
             |                 OPG
     rfuture |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
rfuture      |
       rspot |   .8356596   .0025389   329.15   0.000     .8306835    .8406357
       _cons |  -.0000147   9.46e-06    -1.55   0.121    -.0000332    3.89e-06
-------------+----------------------------------------------------------------
ARCH         |
        arch |
         L1. |   .2467993   .0079396    31.08   0.000     .2312379    .2623607
         L2. |   .1915003   .0060913    31.44   0.000     .1795616     .203439
             |
       _cons |   1.50e-06   1.03e-08   145.53   0.000     1.48e-06    1.52e-06
------------------------------------------------------------------------------

. estat ic

Akaike's information criterion and Bayesian information criterion

-----------------------------------------------------------------------------
       Model |        Obs  ll(null)  ll(model)      df         AIC        BIC
-------------+---------------------------------------------------------------
           . |      7,683         .   39351.85       5   -78693.69  -78658.96
-----------------------------------------------------------------------------
               Note: N=Obs used in calculating BIC; see [R] BIC note.

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

ARCH family regression

Sample: 2 - 7684                                Number of obs     =      7,683
Distribution: Gaussian                          Wald chi2(1)      =  144307.98
Log likelihood =  39695.02                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
             |                 OPG
     rfuture |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
rfuture      |
       rspot |   .8163588    .002149   379.88   0.000     .8121468    .8205708
       _cons |   9.03e-06   .0000117     0.77   0.441     -.000014     .000032
-------------+----------------------------------------------------------------
ARCH         |
        arch |
         L1. |   .1583928   .0035413    44.73   0.000     .1514519    .1653336
```

```
             |
       garch |
         L1. |   .7734065   .0038485   200.96   0.000     .7658637    .7809494
             |
       _cons |   1.95e-07   5.80e-09    33.59   0.000     1.84e-07    2.06e-07
------------------------------------------------------------------------------

. estat ic

Akaike's information criterion and Bayesian information criterion

-----------------------------------------------------------------------------
       Model |        Obs  ll(null)  ll(model)      df         AIC        BIC
-------------+---------------------------------------------------------------
           . |      7,683         .   39695.02       5   -79380.04   -79345.3
-----------------------------------------------------------------------------
               Note: N=Obs used in calculating BIC; see [R] BIC note.

. arch rfuture rspot, arch(1/1) garch(1/2) nolog

ARCH family regression

Sample: 2 - 7684                                Number of obs     =      7,683
Distribution: Gaussian                          Wald chi2(1)      =  118871.71
Log likelihood =  39697.75                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
             |                 OPG
     rfuture |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
rfuture      |
       rspot |   .8153033   .0023647   344.78   0.000     .8106685     .819938
       _cons |   8.43e-06   .0000118     0.71   0.476    -.0000148    .0000316
-------------+----------------------------------------------------------------
ARCH         |
        arch |
         L1. |   .1729364   .0061173    28.27   0.000     .1609467    .1849261
             |
       garch |
         L1. |   .6135491   .0310685    19.75   0.000     .5526559    .6744422
         L2. |   .1402425   .0250312     5.60   0.000     .0911823    .1893027
             |
       _cons |   2.09e-07   8.64e-09    24.17   0.000     1.92e-07    2.26e-07
------------------------------------------------------------------------------

. estat ic

Akaike's information criterion and Bayesian information criterion

-----------------------------------------------------------------------------
       Model |        Obs  ll(null)  ll(model)      df         AIC        BIC
-------------+---------------------------------------------------------------
           . |      7,683         .   39697.75       6    -79383.5  -79341.82
-----------------------------------------------------------------------------
               Note: N=Obs used in calculating BIC; see [R] BIC note.

. arch rfuture rspot, arch(1/2) garch(1/1) nolog
flat log likelihood encountered, cannot find uphill direction
r(430);

. arch rfuture rspot, arch(1/2) garch(1/2) nolog
flat log likelihood encountered, cannot find uphill direction
r(430);
```

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

3. From (2), predict the variance of future return (*rfuture*).

```
. predict sigmahat, v
. line sigmahat t
```



VAR:

The following VARs models:

$$Y_t = A_0 + A_1 Y_{t-1} + \in_t$$

where: $Y_t = \begin{pmatrix} rspot_t \\ rfuture_t \end{pmatrix}$, $A_0 = \begin{pmatrix} a_{10} \\ a_{20} \end{pmatrix}$, $A_1 = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}$, $\in_t = \begin{pmatrix} e_{1t} \\ e_{2t} \end{pmatrix}$

From the data set example.dta:

Requirements:

1. Estimate VARs models using spot return (*rspot*) and future return (*rfuture*) as endogenous variables and determine the most appropriated lags models using SBIC.
2. Perform stability test and Granger exogeneity test.
3. Perform Impulse response analysis and determine which variable has more impact.
4. Perform Forecast error variance decomposition and determine variable that has more impact on each endogenous variable.

---

1. Estimate VARs models using spot return (*rspot*) and future return (*rfuture*) as endogenous variables and determine the most appropriated lags models using SBIC.

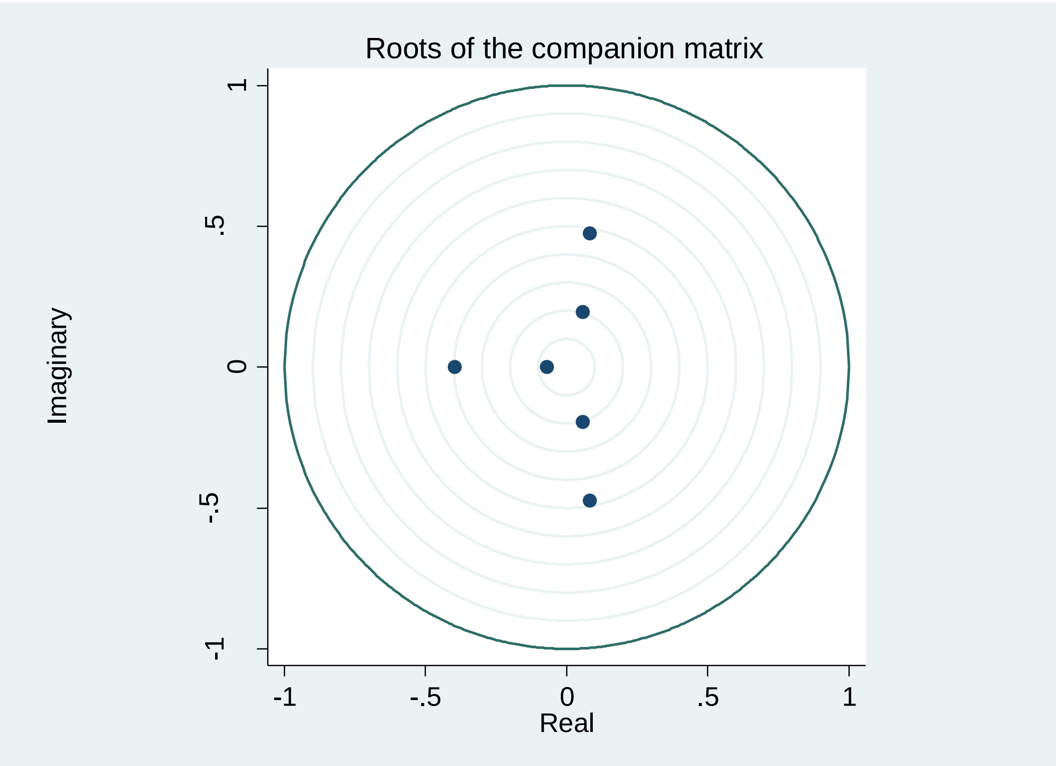
```
. varsoc rspot rfuture

   Selection-order criteria
   Sample:  6 - 7684                            Number of obs      =      7679
  +---------------------------------------------------------------------------+
  |lag |    LL      LR      df    p      FPE       AIC      HQIC      SBIC    |
  |----+----------------------------------------------------------------------|
  |  0 |  76705.7                       7.2e-12  -19.9775  -19.9769  -19.9757  |
  |  1 |  76876.4  341.45    4  0.000  6.9e-12  -20.0209  -20.0191  -20.0155  |
  |  2 |  76966.2  179.52    4  0.000  6.8e-12  -20.0433  -20.0402  -20.0342  |
  |  3 |  76999.2   66.06    4  0.000  6.7e-12  -20.0508  -20.0465  -20.0382* |
  |  4 |  77015.7  32.907*   4  0.000  6.7e-12* -20.0541* -20.0485* -20.0378  |
  +---------------------------------------------------------------------------+
   Endogenous:  rspot rfuture
    Exogenous:  _cons
```

- ***According to SBIC, the most appropriated lag order is 3.***

2. Perform stability test and Granger exogeneity test.

```
. var rspot rfuture, lag(1/3)

Vector autoregression

Sample:  5 - 7684                                  No. of obs      =      7680
Log likelihood =  77010.15                         AIC             = -20.05108
FPE            =  6.71e-12                         HQIC            = -20.04674
Det(Sigma_ml)  =  6.69e-12                         SBIC            = -20.03842

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
rspot                 7     .001779   0.0122   95.07421   0.0000
rfuture               7     .002044   0.0181   141.3296   0.0000
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
rspot        |
```

```
       rspot |
         L1. |  -.0323987   .0159661    -2.03   0.042    -.0636918   -.0011057
         L2. |  -.1099664   .0160841    -6.84   0.000    -.1414905   -.0784422
         L3. |  -.0418984   .0159205    -2.63   0.008    -.0731019   -.0106949
             |
     rfuture |
         L1. |   .0933035   .0138966     6.71   0.000     .0660668    .1205403
         L2. |   .0688434   .0141336     4.87   0.000     .0411421    .0965447
         L3. |   .0317131   .0139194     2.28   0.023     .0044315    .0589946
             |
       _cons |   .0000231   .0000203     1.14   0.256    -.0000167    .0000629
-------------+----------------------------------------------------------------
rfuture      |
       rspot |
         L1. |   .2004382   .0183405    10.93   0.000     .1644915    .2363849
         L2. |   .0600679    .018476     3.25   0.001     .0238557    .0962801
         L3. |   .0609707    .018288     3.33   0.001     .0251268    .0968146
             |
     rfuture |
         L1. |  -.1528221   .0159632    -9.57   0.000    -.1841093   -.1215349
         L2. |  -.0926647   .0162354    -5.71   0.000    -.1244855   -.0608439
         L3. |  -.0524571   .0159894    -3.28   0.001    -.0837958   -.0211184
             |
       _cons |   .0000262   .0000233     1.12   0.262    -.0000195    .0000719
------------------------------------------------------------------------------

. varstable, graph

   Eigenvalue stability condition
  +----------------------------------------+
  |        Eigenvalue         |   Modulus  |
  |---------------------------+------------|
  |    .0829301 +  .4737693i  |   .480973  |
  |    .0829301 -  .4737693i  |   .480973  |
  |   -.3959128               |   .395913  |
  |    .0571976 +  .1954789i  |   .203675  |
  |    .0571976 -  .1954789i  |   .203675  |
  |  -.06956342               |   .069563  |
  +----------------------------------------+
   All the eigenvalues lie inside the unit circle.
   VAR satisfies stability condition.
```



```
. vargranger
```

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
rspot	rfuture	58.069	3	0.000
rspot	ALL	58.069	3	0.000
rfuture	rspot	125.3	3	0.000
rfuture	ALL	125.3	3	0.000

- ***According to stability test, the system is stable since all the eigenvalues lie inside the unit circle.***
- ***According to Granger exogeneity, both rspot and rfuture are all endogenous variables since all the tests are significant.***

3. Perform Impulse response analysis and determine which variable has more impact.

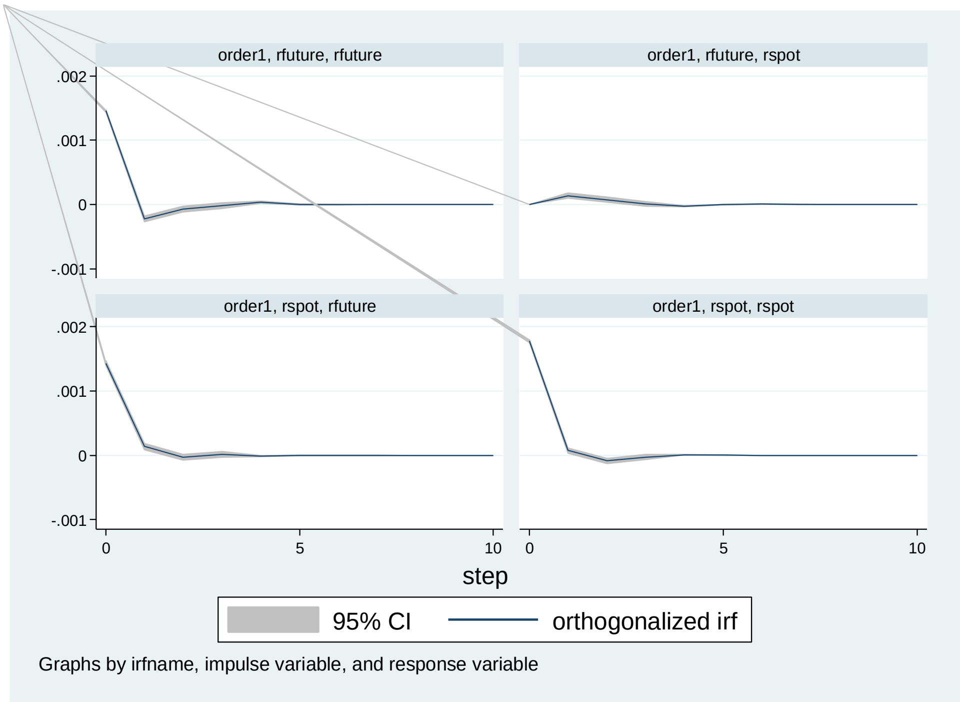
```
. irf create order1, o(rspot rfuture) step(10) set(irf01)
(file irf01.irf created)
(file irf01.irf now active)
(file irf01.irf updated)

. irf table oirf, impulse(rspot rfuture) response(rspot rfuture)
```

Results from order1

step	(1) oirf	(1) Lower	(1) Upper	(2) oirf	(2) Lower	(2) Upper	(3) oirf	(3) Lower	(3) Upper
0	.001778	.00175	.001806	.001434	.001395	.001474	0	0	0
1	.000076	.000036	.000116	.000137	.000091	.000183	.000136	.000096	.000175
2	-.000086	-.000126	-.000047	-.000032	-.000078	.000014	.000075	.000036	.000114
3	-.000028	-.000068	.000012	.000013	-.000033	.000058	6.6e-06	-.000032	.000045
4	.000011	3.5e-06	.000018	-.000012	-.00002	-4.5e-06	-.000028	-.00004	-.000016
5	5.1e-06	3.5e-07	9.8e-06	-2.5e-06	-7.0e-06	2.1e-06	-3.4e-06	-.00001	3.3e-06
6	-8.3e-07	-2.8e-06	1.1e-06	8.0e-07	-1.0e-06	2.6e-06	4.7e-06	2.1e-06	7.3e-06
7	-1.5e-06	-2.7e-06	-2.5e-07	1.5e-06	1.3e-07	2.9e-06	2.1e-06	-3.3e-07	4.6e-06
8	4.6e-08	-4.1e-07	5.0e-07	-2.1e-07	-5.6e-07	1.3e-07	-9.4e-07	-1.5e-06	-3.4e-07
9	3.1e-07	6.8e-08	5.4e-07	-2.8e-07	-5.2e-07	-3.8e-08	-5.7e-07	-1.1e-06	-4.2e-08
10	5.4e-08	-1.0e-07	2.1e-07	-4.3e-08	-1.9e-07	1.0e-07	9.1e-08	-1.3e-07	3.1e-07

step	(4) oirf	(4) Lower	(4) Upper
0	.001454	.001431	.001477
1	-.000222	-.000268	-.000177
2	-.000074	-.000119	-.000028
3	-.000021	-.000066	.000024
4	.000036	.00002	.000052
5	-3.4e-07	-6.6e-06	5.9e-06
6	-4.1e-06	-6.9e-06	-1.4e-06
7	-2.2e-06	-4.9e-06	5.1e-07
8	1.2e-06	5.8e-07	1.9e-06
9	4.6e-07	-5.3e-08	9.7e-07
10	-1.1e-07	-3.1e-07	8.6e-08

```
95% lower and upper bounds reported
(1) irfname = order1, impulse = rspot, and response = rspot
(2) irfname = order1, impulse = rspot, and response = rfuture
(3) irfname = order1, impulse = rfuture, and response = rspot
(4) irfname = order1, impulse = rfuture, and response = rfuture

. irf graph oirf, impulse(rspot rfuture) response(rspot rfuture)
```




```
. irf table coirf, impulse(rspot rfuture) response(rspot rfuture)
```

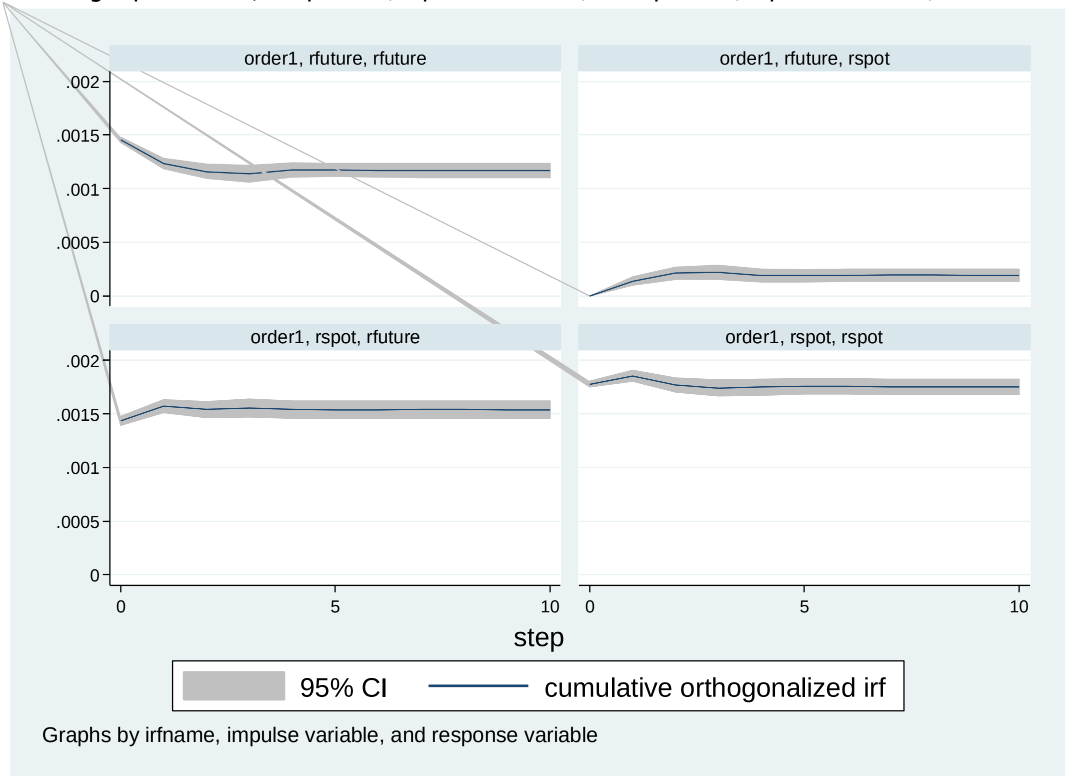
Results from order1

step	(1) coirf	(1) Lower	(1) Upper	(2) coirf	(2) Lower	(2) Upper	(3) coirf	(3) Lower	(3) Upper
0	.001778	.00175	.001806	.001434	.001395	.001474	0	0	0
1	.001855	.001805	.001904	.001572	.001513	.00163	.000136	.000096	.000175
2	.001768	.001704	.001832	.00154	.001467	.001613	.000211	.000154	.000268
3	.00174	.001665	.001815	.001552	.001468	.001637	.000217	.00015	.000285
4	.00175	.001676	.001825	.00154	.001457	.001623	.000189	.000132	.000247
5	.001756	.001684	.001827	.001538	.001457	.001618	.000186	.000132	.00024
6	.001755	.001683	.001826	.001538	.001458	.001619	.00019	.000135	.000245
7	.001753	.001681	.001825	.00154	.001459	.001621	.000192	.000136	.000249
8	.001753	.001681	.001825	.00154	.001459	.001621	.000192	.000135	.000248
9	.001754	.001682	.001826	.001539	.001459	.00162	.000191	.000135	.000247
10	.001754	.001682	.001826	.001539	.001459	.00162	.000191	.000135	.000247

step	(4) coirf	(4) Lower	(4) Upper
0	.001454	.001431	.001477
1	.001232	.001183	.001282
2	.001159	.001093	.001224
3	.001137	.001061	.001214
4	.001173	.001109	.001238
5	.001173	.001111	.001235
6	.001169	.001105	.001232
7	.001166	.001102	.001231
8	.001168	.001104	.001232
9	.001168	.001104	.001232
10	.001168	.001104	.001232

95% lower and upper bounds reported
(1) irfname = order1, impulse = rspot, and response = rspot
(2) irfname = order1, impulse = rspot, and response = rfuture
(3) irfname = order1, impulse = rfuture, and response = rspot
(4) irfname = order1, impulse = rfuture, and response = rfuture

```
. irf graph coirf, impulse(rspot rfuture) response(rspot rfuture)
```



- ***According to IRF analysis, rspot has more impact on rfuture.***

4. Perform Forecast error variance decomposition and determine variable that has more impact on each endogenous variable.

```
. irf table fevd, impulse(rspot rfuture) response(rspot rfuture)
```

Results from order1

step	(1) fevd	(1) Lower	(1) Upper	(2) fevd	(2) Lower	(2) Upper	(3) fevd	(3) Lower	(3) Upper
0	0	0	0	0	0	0	0	0	0
1	1	1	1	.493053	.47713	.508975	0	0	0
2	.994221	.990856	.997585	.48956	.473586	.505534	.005779	.002415	.009144
3	.992487	.988616	.996357	.489057	.473061	.505053	.007513	.003643	.011384
4	.992475	.988611	.996339	.489024	.47303	.505018	.007525	.003661	.011389
5	.992228	.988242	.996214	.488895	.472897	.504893	.007772	.003786	.011758
6	.992224	.988237	.996212	.488895	.472897	.504893	.007776	.003788	.011763
7	.992218	.988226	.996209	.488894	.472895	.504892	.007782	.003791	.011774
8	.992216	.988224	.996208	.488893	.472895	.504891	.007784	.003792	.011776
9	.992216	.988224	.996208	.488893	.472895	.504891	.007784	.003792	.011776
10	.992216	.988223	.996208	.488893	.472895	.504891	.007784	.003792	.011777

step	(4) fevd	(4) Lower	(4) Upper
0	0	0	0
1	.506947	.491025	.52287
2	.51044	.494466	.526414
3	.510943	.494947	.526939
4	.510976	.494982	.52697
5	.511105	.495107	.527103
6	.511105	.495107	.527103
7	.511106	.495108	.527105
8	.511107	.495109	.527105
9	.511107	.495109	.527105
10	.511107	.495109	.527105

```
95% lower and upper bounds reported
(1) irfname = order1, impulse = rspot, and response = rspot
(2) irfname = order1, impulse = rspot, and response = rfuture
```

```
(3) irfname = order1, impulse = rfuture, and response = rspot
(4) irfname = order1, impulse = rfuture, and response = rfuture
```

- ***According to Forecast error variance decomposition, rspot has more impact on rfuture.***