Autoregressive Integrated Moving Average (ARIMA) Models

Example

MA(1)

$$Y_{1t} = 0.1 + u_{1t} + 0.5\, u_{1t-1}$$

AR(1)

$$Y_{2t} = 0.1 + 0.5\, Y_{2t-1} + u_{2t}$$

ARMA(1,1)

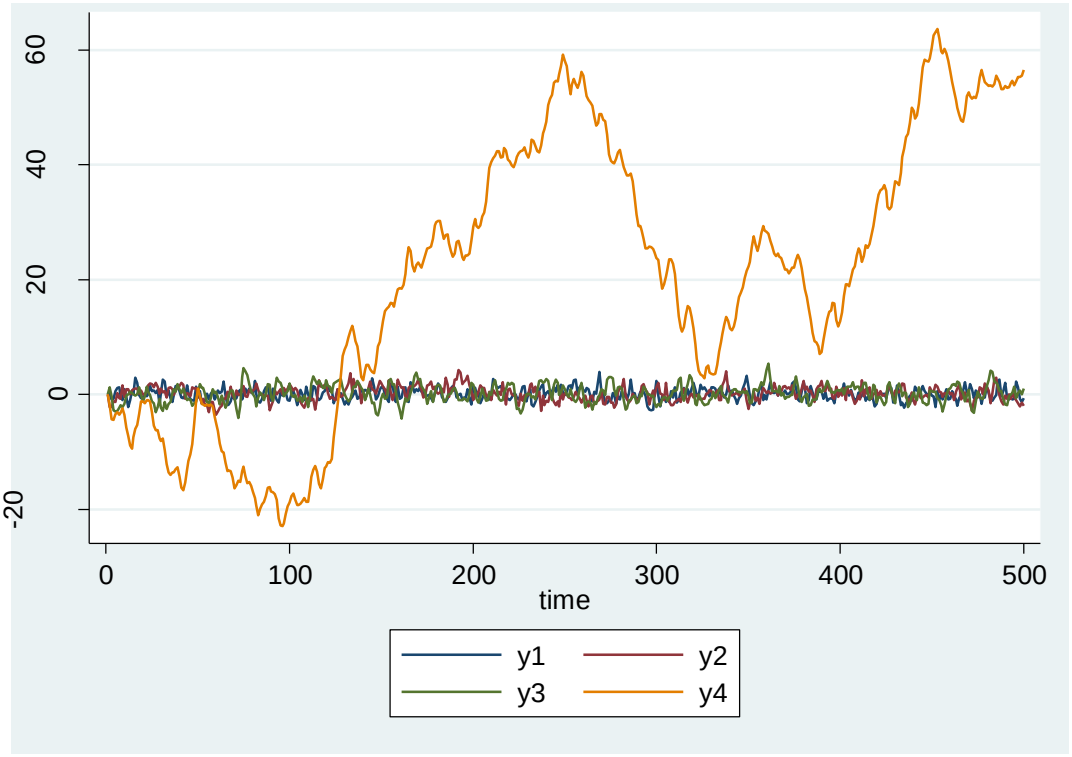
$$Y_{3t} = 0.1 + 0.5\, Y_{3t-1} + u_{3t} + 0.5\, u_{3t-1}$$

ARIMA(1,1,1)

$$\Delta Y_{4t} = 0.1 + 0.5\, \Delta Y_{4t-1} + u_{4t} + 0.5\, u_{4t-1}$$

```
. set obs 500
obs was 0, now 500

. g time=_n

. tsset time
        time variable:  time, 1 to 500
                delta:  1 unit

. set seed 5432

. g y1=0 in 1
(499 missing values generated)

. g y2=0 in 1
(499 missing values generated)

. g y3=0 in 1
(499 missing values generated)

. g y4=0 in 1
(499 missing values generated)

. g dy4 = 0 in 1
(499 missing values generated)

. g u1= rnormal(0,1)

. g u2= rnormal(0,1)

. g u3= rnormal(0,1)

. g u4= rnormal(0,1)

. replace y1=0.1+u1+0.5*l.u1 if time>1
(499 real changes made)

. replace y2=0.1+0.5*l.y2+u2 if time>1
(499 real changes made)

. replace y3=0.1+0.5*l.y3+u3+0.5*l.u3 if time>1
(499 real changes made)

. replace y4=0.1+l.y4+u4+0.5*l.u4 if time>1
(499 real changes made)

. replace dy4=d.y4 if time>1
(499 real changes made)

. replace y4=0.1+l.y4+0.5*l.dy4+u4+0.5*l.u4 if time>1
(498 real changes made)
```

```
. line y1 y2 y3 y4 time
```



Example: Finding ARIMA process ─ Box-Jenkins Methodology

Identification and Estimation: The first step is to identify the order of ARIMA(p,d,q). To find the value of p, d, and q, we should firstly identify value of d by performing unit root test to find which order the series is integrated.

Unit Root Test

Find integrated order of the series using unit root test.

```
. tsset time
        time variable:  time, 1 to 357
                delta:  1 unit

. dfuller y, trend lags(1) regress
Augmented Dickey-Fuller test for unit root         Number of obs   =       355

                              ---------- Interpolated Dickey-Fuller ---------
                 Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value            Value
------------------------------------------------------------------------------
 Z(t)            -2.152            -3.986            -3.426           -3.130
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.5167

------------------------------------------------------------------------------
D.y          |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           y |
         L1. |  -.0237778   .0110475    -2.15   0.032    -.0455054   -.0020502
         LD. |   .0625276   .0531988     1.18   0.241    -.0421009     .167156
      _trend |   .0143903   .0082343     1.75   0.081    -.0018044     .030585
       _cons |   23.00759   11.00167     2.09   0.037     1.370103    44.64508
------------------------------------------------------------------------------
```

```
. dfuller y, lags(1) regress

Augmented Dickey-Fuller test for unit root         Number of obs   =       355

                                 ---------- Interpolated Dickey-Fuller ---------
                 Test         1% Critical       5% Critical      10% Critical
               Statistic          Value             Value             Value
------------------------------------------------------------------------------
 Z(t)            -1.414           -3.452            -2.876            -2.570
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.5757

------------------------------------------------------------------------------
         D.y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           y |
         L1. |  -.0129893   .0091884    -1.41   0.158    -.0310604    .0050818
         LD. |    .059847   .0533316     1.12   0.263    -.0450416    .1647357
             |
       _cons |   14.12272   9.784939     1.44   0.150    -5.121575    33.36702
------------------------------------------------------------------------------

. dfuller d.y, trend lags(1) regress

Augmented Dickey-Fuller test for unit root         Number of obs   =       354

                                 ---------- Interpolated Dickey-Fuller ---------
                 Test         1% Critical       5% Critical      10% Critical
               Statistic          Value             Value             Value
------------------------------------------------------------------------------
 Z(t)           -12.054           -3.986            -3.426            -3.130
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
D2.y         |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         D.y |
         L1. |  -.8856237   .0734696   -12.05   0.000    -1.030121   -.7411262
         LD. |  -.0668939   .0533317    -1.25   0.211    -.1717849    .0379971
      _trend |   .0042522   .0069007     0.62   0.538    -.0093198    .0178243
       _cons |  -.4529247   1.418181    -0.32   0.750    -3.242154    2.336305
------------------------------------------------------------------------------

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

ARIMA regression

Sample:  2 - 357                                  Number of obs      =       356
                                                  Wald chi2(2)       =      3.13
Log likelihood = -1423.146                        Prob > chi2        =    0.2089

------------------------------------------------------------------------------
             |                 OPG
         D.y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
y            |
       _cons |   .3700177   .8218557     0.45   0.653     -1.24079    1.980825
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |   .2948697   .6818072     0.43   0.665    -1.041448    1.631187
             |
          ma |
         L1. |  -.2368839   .7055342    -0.34   0.737    -1.619705    1.145938
-------------+----------------------------------------------------------------
      /sigma |   13.17852   .3681099    35.80   0.000     12.45704         13.9
------------------------------------------------------------------------------

. 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(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(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

. est table arima11*, star(0.1 0.05 0.01) stat(N ll chi2 aic bic)

-------------------------------------------------------------
    Variable |   arima111        arima112        arima113
-------------+-----------------------------------------------
y            |
       _cons |  .37001774       .37418642        .3987889
-------------+-----------------------------------------------
ARMA         |
          ar |
         L1. |  .29486971      -.31289111       .97476406***
             |
          ma |
         L1. | -.23688394       .36887941      -.92682332
         L2. |                  .11337558**     .03029933
         L3. |                                 -.10347864
-------------+-----------------------------------------------
sigma        |
       _cons |  13.178521***    13.127234***    13.055651
-------------+-----------------------------------------------
Statistics   |
           N |        356             356             356
          ll | -1423.1463      -1421.7567      -1420.6373
        chi2 |  3.1319865       6.7574223       9222.4937
         aic |  2854.2926       2853.5135       2853.2745
         bic |  2869.7923       2872.8881       2876.5241
-------------------------------------------------------------
                          legend: * p<.1; ** p<.05; *** p<.01

. est table arima21*, star(0.1 0.05 0.01) stat(N ll chi2 aic bic)

-------------------------------------------------------------
    Variable |   arima211        arima212        arima213
-------------+-----------------------------------------------
y            |
       _cons |  .37274811       .37283121       .37413313
-------------+-----------------------------------------------
ARMA         |
          ar |
         L1. | -.28216023      -.66642562**     .80124027**
         L2. |  .09539459**    -.39627716      -.3650645
             |
          ma |
         L1. |  .33242601       .71235711***   -.75250981**
         L2. |                  .50413388       .39755506
         L3. |                                 -.10013858*
-------------+-----------------------------------------------
sigma        |
       _cons |  13.139922***    13.112555***    13.079159***
-------------+-----------------------------------------------
Statistics   |
```

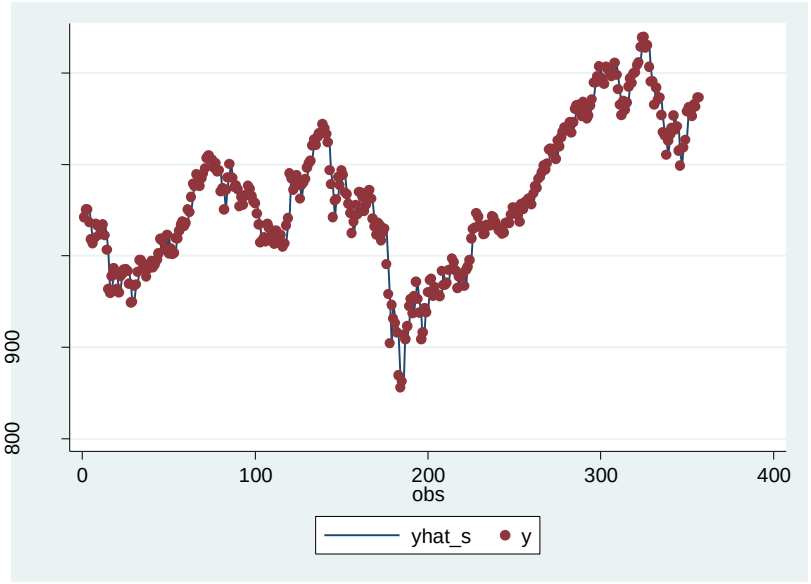
```
           N |         356             356             356
          ll | -1422.0873      -1421.3508       -1420.453
        chi2 |  4.7048993       17.316358       18.662816
         aic |  2854.1745       2854.7016       2854.9059
         bic |  2873.5492       2877.9512       2882.0304
------------------------------------------------------------
                          legend: * p<.1; ** p<.05; *** p<.01

. est table arima31*, star(0.1 0.05 0.01) stat(N ll chi2 aic bic)

------------------------------------------------------------
    Variable |   arima311        arima312        arima313
-------------+----------------------------------------------
y            |
       _cons |  .37269062        .3751536       .37488954
-------------+----------------------------------------------
ARMA         |
          ar |
         L1. |  .51072432       .67284808*      .63119128
         L2. |  .04992461      -.20028258      -.15281824
         L3. | -.12395064***   -.11233502**    -.16502621
             |
          ma |
         L1. | -.46077982      -.62568637*     -.58388774
         L2. |                   .2450268       .19971418
         L3. |                                  .05258667
-------------+----------------------------------------------
sigma        |
       _cons |  13.082025***    13.075786***    13.075313***
-------------+----------------------------------------------
Statistics   |
           N |         356             356             356
          ll | -1420.5393      -1420.3504      -1420.3353
        chi2 |  11.701303       16.675786       16.501777
         aic |  2853.0786       2854.7008       2856.6706
         bic |  2876.3282       2881.8253       2887.67
------------------------------------------------------------
                          legend: * p<.1; ** p<.05; *** p<.01
```

Forecast

Command: predict, xb

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

ARIMA regression

Sample:  2 - 357                                Number of obs      =       356
                                                Wald chi2(2)       =      3.13
Log likelihood = -1423.146                      Prob > chi2        =    0.2089

------------------------------------------------------------------------------
             |                 OPG
         D.y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
y            |
       _cons |   .3700177   .8218557     0.45   0.653     -1.24079    1.980825
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |   .2948697   .6818072     0.43   0.665    -1.041448    1.631187
             |
          ma |
         L1. |  -.2368839   .7055342    -0.34   0.737    -1.619705    1.145938
-------------+----------------------------------------------------------------
      /sigma |   13.17852   .3681099    35.80   0.000     12.45704        13.9
------------------------------------------------------------------------------
. predict dyhat, xb

. g yhat_s=l.y+dyhat if time>1
(3 missing values generated)
```

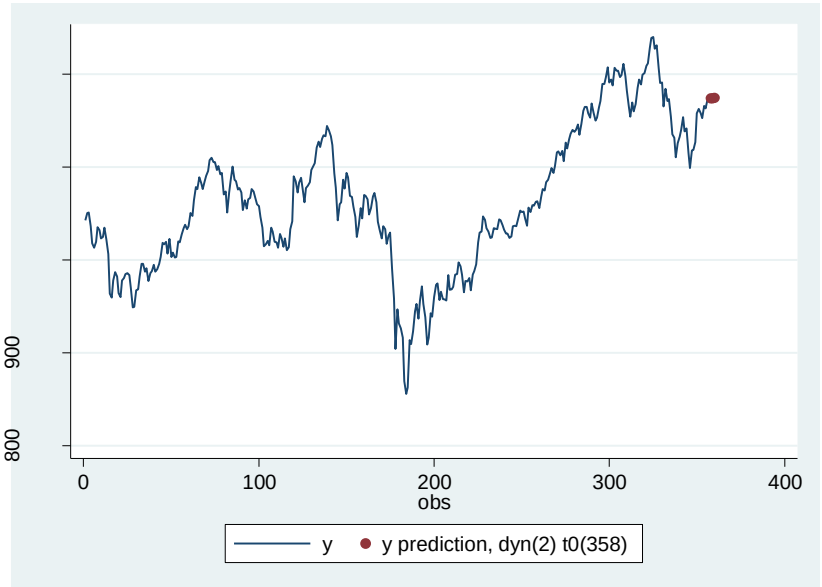
```
. twoway (line yhat_s time, sort) (scatter y time, sort)
```



Command: predict, y

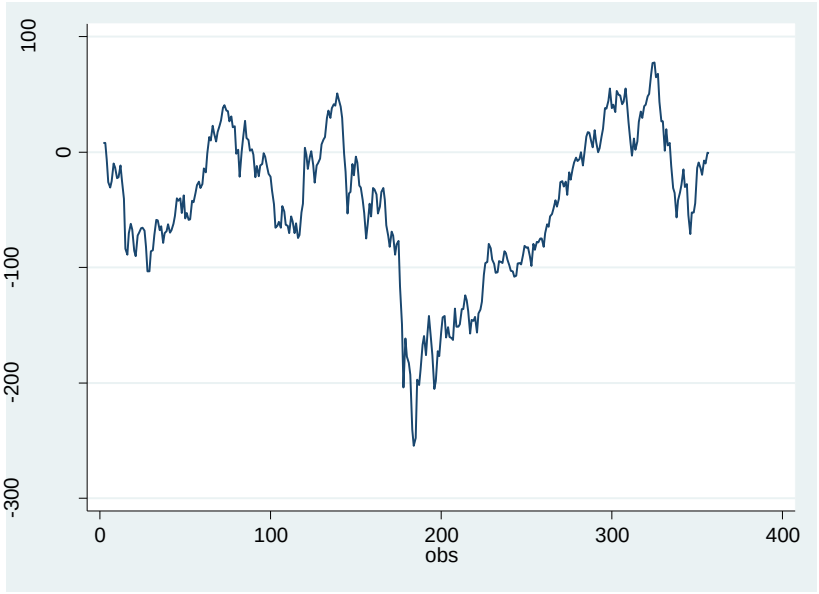
Dynamic Forecast

```
. predict yhat, y dynamic(.) t0(357)
Note: beginning dynamic predictions in period 2
(356 missing values generated)

. predict yhat2, y dynamic(.) t0(358)
Note: beginning dynamic predictions in period 2
(357 missing values generated)

. twoway (line y time, sort) (scatter yhat2 time, sort)
```



Forecasting Error

```
. predict yhat_d, y dynamic(.)
Note: beginning dynamic predictions in period 2
(1 missing value generated)

. g ferror=y-yhat_d if time<358
(4 missing values generated)

. twoway (line ferror time, sort)
```



SARIMA

```
. arima y, arima(1,1,1) sarima(1,1,1,13) nolog

ARIMA regression

Sample:  15 - 357                               Number of obs      =       343
                                                Wald chi2(4)       =    190.55
Log likelihood = -1390.897                      Prob > chi2        =    0.0000

------------------------------------------------------------------------------
             |                 OPG
      DS13.y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
y            |
       _cons |    .055653   .0949183     0.59   0.558    -.1303835    .2416896
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |  -.6610302   1.885136    -0.35   0.726    -4.355829    3.033769
             |
          ma |
         L1. |   .6497243   1.909893     0.34   0.734    -3.093598    4.393047
-------------+----------------------------------------------------------------
ARMA13       |
          ar |
         L1. |  -.0235579    .057453    -0.41   0.682    -.1361638     .089048
             |
          ma |
         L1. |  -.9555681   .0798977   -11.96   0.000    -1.112165   -.7989715
-------------+----------------------------------------------------------------
      /sigma |   13.33896   .5078398    26.27   0.000     12.34361    14.33431
------------------------------------------------------------------------------
Note: The test of the variance against zero is one sided, and the two-sided
confidence interval is truncated at zero.
```

ARMAX

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

ARIMA regression

Sample:  3 - 357                                Number of obs      =       355
                                                Wald chi2(3)       =     41.61
Log likelihood = -1405.373                      Prob > chi2        =    0.0000

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

```
y               |
          usd   |
           D2.  |  -25.89824   4.143719    -6.25   0.000    -34.01978    -17.7767
                |
        _cons   |   .3479213   .8288965     0.42   0.675    -1.276686    1.972529
----------------+------------------------------------------------------------------
ARMA            |
           ar   |
           L1.  |   .2162354   .3554955     0.61   0.543    -.4805229    .9129937
                |
           ma   |
           L1.  |  -.0959384   .3756771    -0.26   0.798    -.8322521    .6403752
----------------+------------------------------------------------------------------
       /sigma   |   12.67782   .3774993    33.58   0.000     11.93794    13.41771
------------------------------------------------------------------------------
Note: The test of the variance against zero is one sided, and the two-sided
confidence interval is truncated at zero.
```

Generalized Autoregressive Conditional Heteroscedastic (GARCH) Models

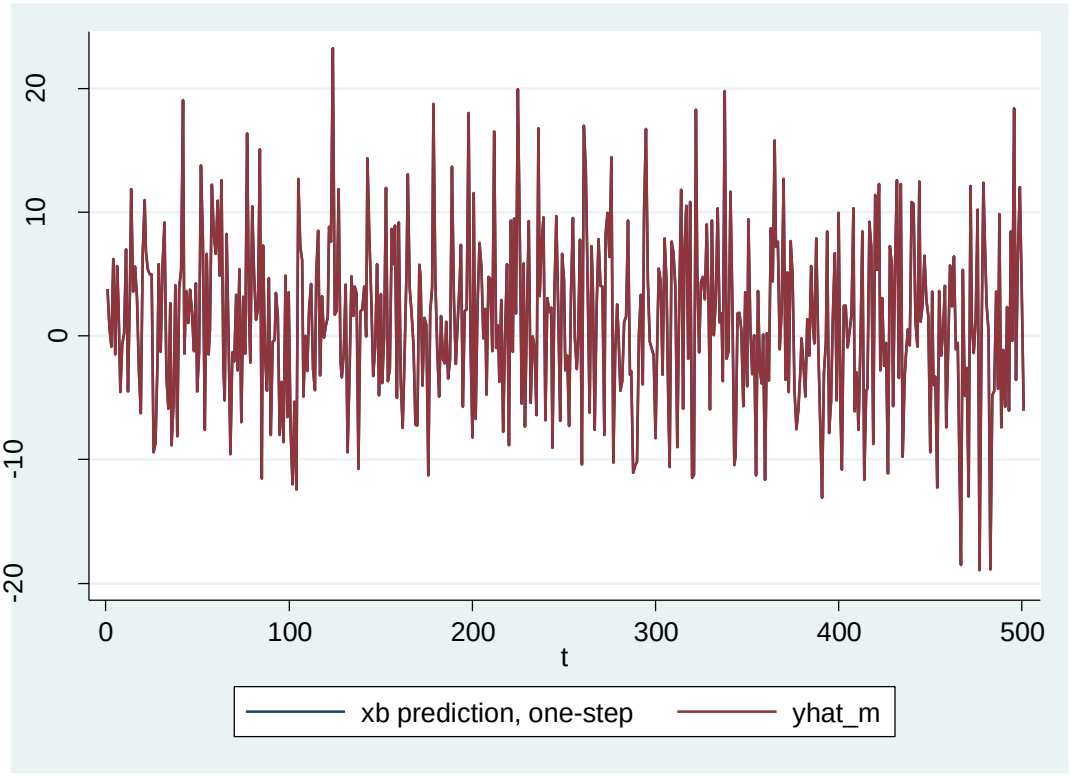
Example Simulated Data

```
set obs 501
g t=_n
tsset t
g s2=1 in 1
g u=rnormal(0,s2) in 1
g u2=u^2 in 1
forvalue i=2(1)501 {
  replace s2=0.3+0.3*l.u2+0.3*l.s2 in `i'
  replace u=rnormal(0,s2) in `i'
  replace u2=u^2 in `i'
}
g x=rnormal(1,10)
g y=0.5+0.7*x+u
reg y x if t>1
estat archlm
arch y x  if t>1, arch(1) garch(1) nolog
predict s2hat, v
twoway (line s2hat t) (scatter s2 t)
```

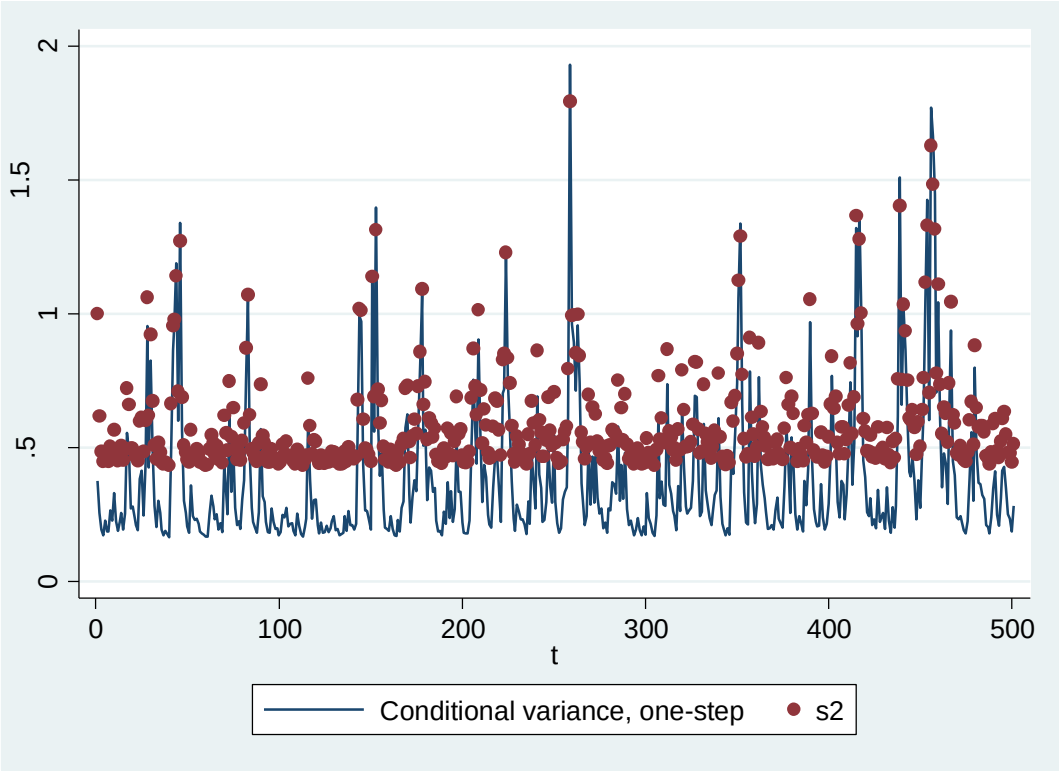
```
. set obs 501
number of observations (_N) was 0, now 501

. g t=_n

. tsset t
        time variable:  t, 1 to 501
                delta:  1 unit

. g s2=1 in 1
(500 missing values generated)

. g u=rnormal(0,s2) in 1
(500 missing values generated)

. g u2=u^2 in 1
(500 missing values generated)

. forvalue i=2(1)501 {
  2.   replace s2=0.3+0.3*l.u2+0.3*l.s2 in `i'
  3.   replace u=rnormal(0,s2) in `i'
  4.   replace u2=u^2 in `i'
  5. }

. g x=rnormal(1,10)

. g y=0.5+0.7*x+u

. reg y x if t>1
      Source |       SS           df       MS      Number of obs   =       500
-------------+----------------------------------   F(1, 498)       =  63539.73
       Model |  23398.9523         1  23398.9523   Prob > F        =    0.0000
    Residual |  183.391992       498  .368257012   R-squared       =    0.9922
-------------+----------------------------------   Adj R-squared   =    0.9922
       Total |  23582.3443       499   47.259207   Root MSE        =    .60684

------------------------------------------------------------------------------
           y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           x |   .7013338   .0027823   252.07   0.000     .6958673    .7068002
       _cons |   .4743123   .0273053    17.37   0.000     .4206645    .5279601
------------------------------------------------------------------------------
```

```
. estat archlm
LM test for autoregressive conditional heteroskedasticity (ARCH)
-------------------------------------------------------------------------------
    lags(p)  |          chi2               df                 Prob > chi2
-------------+-----------------------------------------------------------------
       1     |         35.821               1                   0.0000
-------------------------------------------------------------------------------
         H0: no ARCH effects      vs.  H1: ARCH(p) disturbance

. arch y x  if t>1, arch(1) garch(1) nolog

ARCH family regression

Sample: 2 - 501                                   Number of obs   =        500
Distribution: Gaussian                            Wald chi2(1)    =   84227.65
Log likelihood =  -426.751                        Prob > chi2     =     0.0000

------------------------------------------------------------------------------
             |                 OPG
           y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
y            |
           x |   .7028459   .0024218   290.22   0.000     .6980993    .7075925
       _cons |   .4758044    .023265    20.45   0.000     .4302058    .5214029
-------------+----------------------------------------------------------------
ARCH         |
        arch |
         L1. |   .3970325    .093721     4.24   0.000     .2133428    .5807223
             |
       garch |
         L1. |   .3355659    .112419     2.98   0.003     .1152287    .5559032
             |
       _cons |    .105968   .0289994     3.65   0.000     .0491302    .1628059
------------------------------------------------------------------------------

. predict s2hat, v

. predict yhat, xb

. mat beta=e(b)

. mat list beta

beta[1,5]
            y:          y:      ARCH:      ARCH:      ARCH:
                                   L.         L.
            x       _cons       arch      garch       _cons
y1  .70284588  .47580435  .39703251  .33556595  .10596802

. sca b0=el(beta,1,2)

. sca b1=el(beta,1,1)

. sca a0=el(beta,1,5)

. sca d1=el(beta,1,4)

. sca a1=el(beta,1,3)

. g yhat_m=b0+b1*x

. g ehat_m=y-yhat_m

. predict uhat, r

. g uhat2=uhat^2

. g s2hat_m=a0+d1*l.uhat2+a1*l.uhat2 in 2
```

```
(500 missing values generated)

. replace s2hat_m=a0+d1*l.s2hat_m+a1*l.uhat2 if t>2
(499 real changes made)

. line yhat yhat_m t
```




```
. twoway (line s2hat t) (scatter s2 t)
```



Example

$$SET_t = \beta_0 + \beta_1 IBR + \beta_2 GOLD + \beta_3 USD + \varepsilon_t$$

where: SET_t = Return on Stock Exchange of Thailand (SET).

IBR_t = Inter-bank rate.

$GOLD_t$ = Gold price.

USD_t = Exchange rate ($US/฿Baht).

ε_t = Residual which has GARCH(p,q) process:

$$\sigma_t^2 = \alpha_0 + \delta_1\sigma_{t-1}^2 + \delta_2\sigma_{t-2}^2 + \cdots + \delta_p\sigma_{t-p}^2 + \alpha_1\varepsilon_{t-1}^2 + \alpha_2\varepsilon_{t-2}^2 + \cdots + \alpha_q\varepsilon_{t-q}^2$$

Testing GARCH Effect

Firstly, estimate the model using OLS without ARCH(p) process.

```
. reg rset ibr rgold rusd

      Source |       SS       df       MS              Number of obs =     356
-------------+------------------------------           F(  3,   352) =   34.95
       Model |  .013629179     3   .00454306           Prob > F      =  0.0000
    Residual |  .045752082   352  .000129978           R-squared     =  0.2295
-------------+------------------------------           Adj R-squared =  0.2230
       Total |  .059381261   355  .000167271           Root MSE      =   .0114

------------------------------------------------------------------------------
        rset |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         ibr |  -.0148909   .0208497    -0.71   0.476    -.0558966    .0261148
       rgold |  -.0855076   .0551807    -1.55   0.122     -.194033    .0230178
        rusd |  -2.060204    .214308    -9.61   0.000    -2.481689   -1.638718
       _cons |   .0012448   .0009258     1.34   0.180    -.0005761    .0030656
------------------------------------------------------------------------------

. est store ols

. estat archlm
LM test for autoregressive conditional heteroskedasticity (ARCH)
-----------------------------------------------------------------------------
    lags(p)  |          chi2               df                 Prob > chi2
-------------+---------------------------------------------------------------
       1     |          8.225               1                   0.0041
-----------------------------------------------------------------------------
         H0: no ARCH effects      vs.  H1: ARCH(p) disturbance
```

In this case, since p-value of the ARCH effect test (F-statistic or Chi-Square (Obs*R-squared = 8.225) the p-value is less than level of significance 0.05, thus, null hypothesis that there is no ARCH effect is rejected, thus, there exists significant ARCH effect in this model with 0.05 significant level.

Identify Order (p,q) and Estimation

The next step is to identify order of GARCH(p,q) by estimating GARCH models in several orders and choose the model with the lowest AIC or SIC.

Estimate ARCH(q) using MLE

```
. arch rset ibr rgold rusd, arch(1) nolog

ARCH family regression

Sample: 2 - 357                                 Number of obs   =       356
Distribution: Gaussian                          Wald chi2(3)    =    114.64
Log likelihood =   1094.88                      Prob > chi2     =    0.0000

------------------------------------------------------------------------------
             |                 OPG
        rset |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
rset         |
         ibr |  -.0224536   .0227516    -0.99   0.324    -.0670459    .0221386
       rgold |  -.1352603   .0481352    -2.81   0.005    -.2296037    -.040917
        rusd |  -1.990394   .1956511   -10.17   0.000    -2.373863   -1.606925
       _cons |   .0019338   .0009473     2.04   0.041     .0000772    .0037904
-------------+----------------------------------------------------------------
ARCH         |
        arch |
         L1. |   .1410099   .0526486     2.68   0.007     .0378206    .2441992
             |
       _cons |   .0001097   7.65e-06    14.34   0.000     .0000947    .0001246
------------------------------------------------------------------------------

. est store arch1

. qui arch rset ibr rgold rusd, arch(1/2) nolog

. est store arch2

. qui arch rset ibr rgold rusd, arch(1/3) nolog

. est store arch3

. qui arch rset ibr rgold rusd, arch(1/4) nolog

. est store arch4

. est table ols arch*, star(0.1 0.05 0.01) stat(N rss ll F chi2 aic bic)

-------------------------------------------------------------------------------------------------
    Variable |      ols            arch1           arch2           arch3           arch4
-------------+-----------------------------------------------------------------------------------
             |
_            |
         ibr | -.01489091
       rgold | -.08550759
        rusd | -2.0602036***
       _cons |  .00124476
-------------+-----------------------------------------------------------------------------------
rset         |
         ibr |                -.02245364      -.03228511      -.02934212      -.02443571
       rgold |                -.13526031***   -.15316854***   -.14704494***   -.12657214**
        rusd |                 -1.990394***   -1.8927342***   -1.8023097***   -1.7960216***
       _cons |                 .00193379**     .00262446***    .00210875**     .00172192**
-------------+-----------------------------------------------------------------------------------
ARCH         |
        arch |
         L1. |                 .14100992***    .15429368**     .13569541**     .11527677*
         L2. |                                 .22850896***    .14715617*      .15313291*
         L3. |                                                 .17200035**     .16646817**
         L4. |                                                                 .12103532***
             |
       _cons |                 .00010965***     .0000819***    .00007027***    .00005809***
-------------+-----------------------------------------------------------------------------------
Statistics   |
           N |         356             356             356             356             356
         rss |  .04575208
          ll |  1089.6398       1094.8804       1101.4192       1107.1823       1111.1621
           F |  34.952661
        chi2 |                  114.64432       113.73733       111.95123       108.03864
         aic | -2171.2795      -2177.7608      -2188.8384      -2198.3645      -2204.3242
         bic | -2155.7798      -2154.5112      -2161.7138      -2167.3651      -2169.4499
-------------------------------------------------------------------------------------------------
                                                        legend: * p<.1; ** p<.05; *** p<.01
```

Estimate GARCH(p,q) using MLE

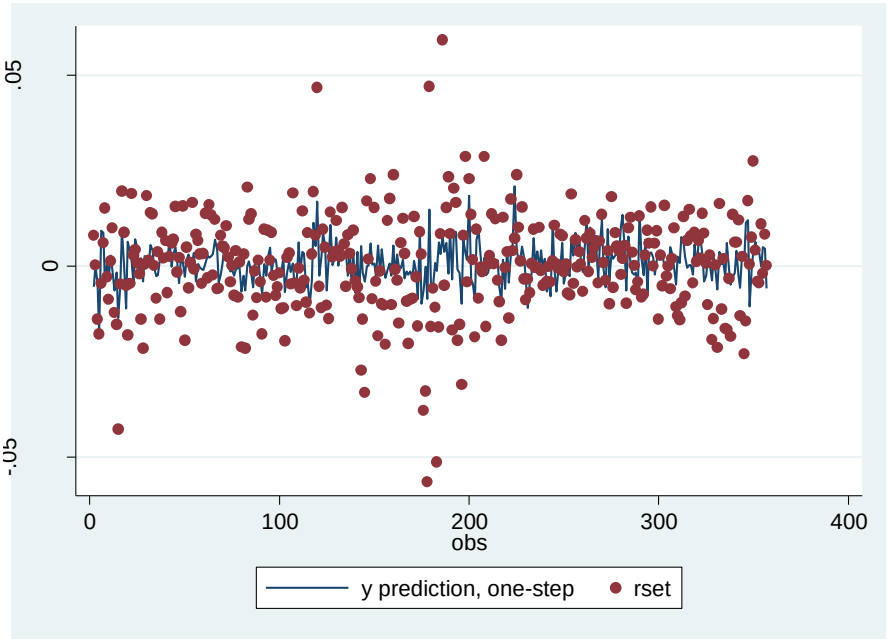
```
. qui arch rset ibr rgold rusd, arch(1) garch(1) nolog

. est store garch11

. qui arch rset ibr rgold rusd, arch(1) garch(1/2) nolog

. est store garch12

. qui arch rset ibr rgold rusd, arch(1/2) garch(1) nolog

. est store garch21

. qui arch rset ibr rgold rusd, arch(1/2) garch(1/2) nolog

. est store garch22

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

Variable	garch11	garch12	garch21	garch22
rset				
ibr	-.02671053	-.02670456	-.02669459	-.02681346
rgold	-.12290548***	-.12283479**	-.12267326**	-.09998894**
rusd	-1.7803476***	-1.7804212***	-1.7802643***	-1.7176602***
_cons	.00205671***	.00205576***	.00205456***	.00201858***
ARCH				
arch				
L1.	.12274144***	.12226525**	.12140524**	.14859642***
L2.			.00283013	.07798055*
garch				
L1.	.82872934***	.8361347	.82647574***	-.09243062
L2.		-.00680923		.79361191***
_cons	6.190e-06*	6.175e-06	6.290e-06*	9.638e-06
Statistics				
N	356	356	356	356
ll	1116.3772	1116.3774	1116.3778	1117.2825
chi2	132.26126	131.01417	130.93732	135.01264
aic	-2218.7545	-2216.7548	-2216.7555	-2216.565
bic	-2191.6299	-2185.7554	-2185.7561	-2181.6906

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

Forecast using ARCH(1)

```
. arch rset ibr rgold rusd, arch(1/2) garch(1/2) nolog

ARCH family regression

Sample: 2 - 357                                 Number of obs   =       356
Distribution: Gaussian                          Wald chi2(3)    =    135.01
Log likelihood =  1117.283                      Prob > chi2     =    0.0000

------------------------------------------------------------------------------
             |                 OPG
        rset |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
rset         |
         ibr |  -.0268135   .0163996    -1.64   0.102    -.0589561    .0053292
       rgold |  -.0999889    .047902    -2.09   0.037     -.193875   -.0061028
        rusd |   -1.71766    .164051   -10.47   0.000    -2.039194   -1.396126
       _cons |   .0020186    .000773     2.61   0.009     .0005035    .0035337
-------------+----------------------------------------------------------------
ARCH         |
        arch |
         L1. |   .1485964   .0449342     3.31   0.001     .0605269    .2366659
         L2. |   .0779806   .0458139     1.70   0.089    -.0118131    .1677742
             |
       garch |
         L1. |  -.0924306   .0664156    -1.39   0.164    -.2226027    .0377415
         L2. |   .7936119   .0744962    10.65   0.000      .647602    .9396218
             |
       _cons |   9.64e-06   5.99e-06     1.61   0.107    -2.09e-06    .0000214
------------------------------------------------------------------------------

. predict rsetf, y
(4 missing values generated)

. twoway (line rsetf time) (scatter rset time)
```



Estimate Variance (Volatility) of Dependent Variable from Estimated Model

Variance or volatility of dependent variable (in this case, return on SET) can be estimated from the estimated result.

```
. predict sigma2, variance
(11 missing values generated)
```

The estimated variance series is then estimated and keep as sigma2.

```
. line sigma2 t
```