Quantitative Methods in Finance

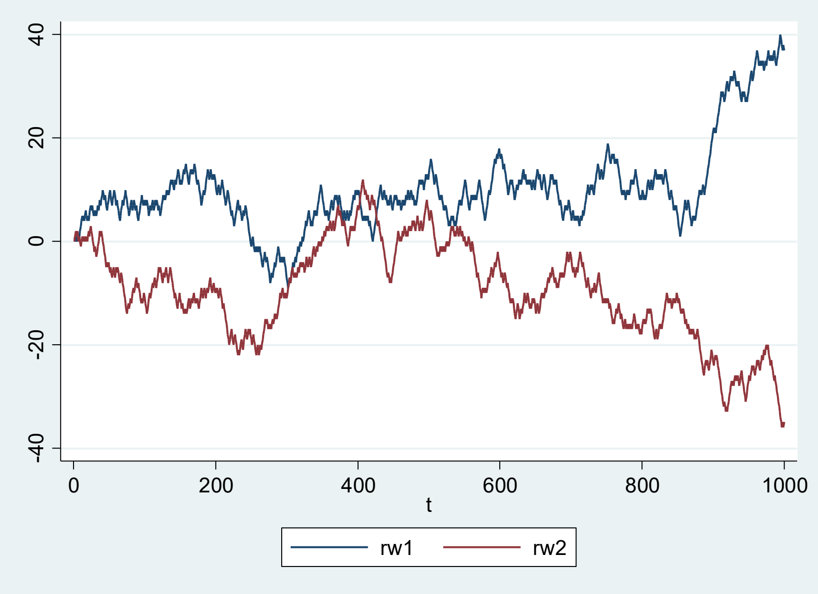
Tutorial, Part 11:
Stationarity of a time series. ARMA (Box-Jenkins) models.

Example 1: Generate two random walk series (e.g. with integer steps). See the code in the Stata do-file `randomwalk-commands.do`. Are such series always uncorrelated?

Computer printout of the results in Stata:

```
. set obs 1000
. set seed 100

. gen t=_n
. tsset t
        time variable:  t, 1 to 1000
                delta:  1 unit

. gen drift1=-1
. replace drift1=1 if runiform()>0.5
(519 real changes made)

. gen drift2=-1
. replace drift2=1 if runiform()>0.5
(482 real changes made)

. gen rw1=0
. gen rw2=0

. replace rw1=l.rw1+l.drift1 if t>1
(989 real changes made)

. replace rw2=l.rw2+l.drift2 if t>1
(968 real changes made)

. dfuller rw1

Dickey-Fuller test for unit root                   Number of obs   =       999

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -0.697            -3.430            -2.860            -2.570
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.8476

. dfuller rw2

Dickey-Fuller test for unit root                   Number of obs   =       999

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -0.742            -3.430            -2.860            -2.570
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.8356
```

```
. tsline rw1 rw2
```




```
. regress rw1 rw2

      Source |       SS           df       MS      Number of obs   =     1,000
-------------+----------------------------------   F(1, 998)       =    422.52
       Model |   22149.705         1   22149.705   Prob > F        =    0.0000
    Residual |   52318.131       998   52.422977   R-squared       =    0.2974
-------------+----------------------------------   Adj R-squared   =    0.2967
       Total |   74467.836       999  74.5423784   Root MSE        =    7.2404

------------------------------------------------------------------------------
         rw1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         rw2 |  -.5043769   .0245376   -20.56   0.000    -.5525281   -.4562257
       _cons |   5.357481   .3264995    16.41   0.000     4.716777    5.998185
------------------------------------------------------------------------------
```

■

Example 2: Let us define the difference operator $\Delta = (1-L)$, where L is the lag operator, such that $L^j Y_t = y_{t-j}$. In general, $\Delta_j^i = (1-L^j)^i$, where *i* and *j* are typically omitted when they take the value of 1. Show the expressions in Y only when applying the difference operator to the following expressions, and provide an interpretation for the resulting expression, assuming that you are working with quarterly data:

a) $\Delta_4 Y_t$;

b) $\Delta^2 Y_t$;

c) $\Delta_1 \Delta_4 Y_t$;

d) $\Delta_4^2 Y_t$.

■

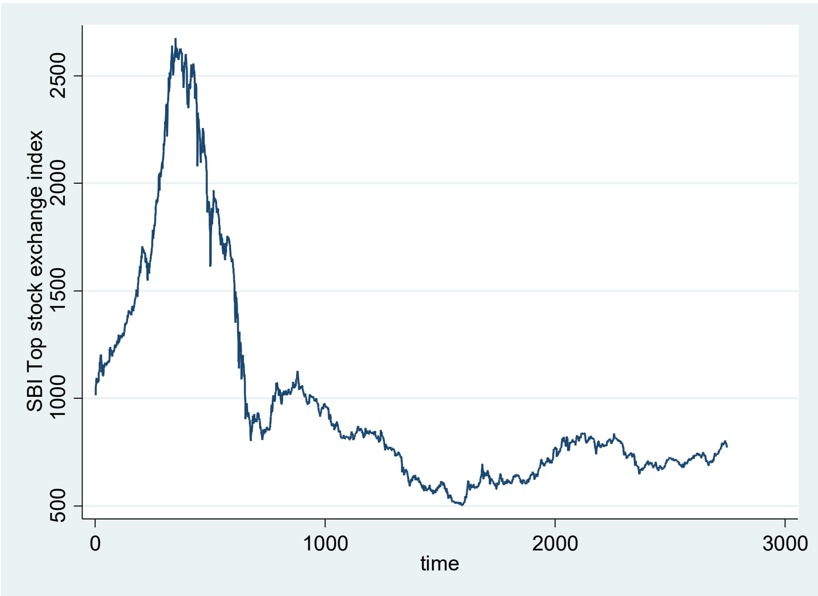
Example 3: The data set `SBItop.dta` contains information on the Slovenian (blue chip) stock exchange index SBI Top for the period from 3 April 2006 until 31 March 2017.

a) Inspect the time series visually. Does it look stationary? Support your decision by using a graphical representation and an analytical test.
b) How could the SBI Top time series be transformed to a stationary one? Apply the procedure(s) and check the stationarity of the transformed time series.
c) Identify the SBI Top time series with an appropriate ARMA model.
d) By using the identified ARMA model, provide an "in-sample" forecast for the last half a year (trading days, i.e. for the last 123 observations).

Computer printout of the results in Stata:

a) Checking for stationarity

```
. generate time=_n

. tsset time
        time variable:  time, 1 to 2749
                delta:  1 unit

. order time sbitop

. twoway line sbitop time
```




```
. dfuller sbitop

Dickey-Fuller test for unit root                   Number of obs   =      2748

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -0.681            -3.430            -2.860            -2.570
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.8515
```

. dfuller sbitop, regress

```
Dickey-Fuller test for unit root                   Number of obs   =      2748

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -0.681            -3.430            -2.860            -2.570
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.8515

------------------------------------------------------------------------------
    D.sbitop |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      sbitop |
         L1. |  -.0003697   .0005425    -0.68   0.496    -.0014334    .0006941
             |
       _cons |   .2813994   .6075337     0.46   0.643    -.9098699    1.472669
------------------------------------------------------------------------------
```

. dfgls sbitop

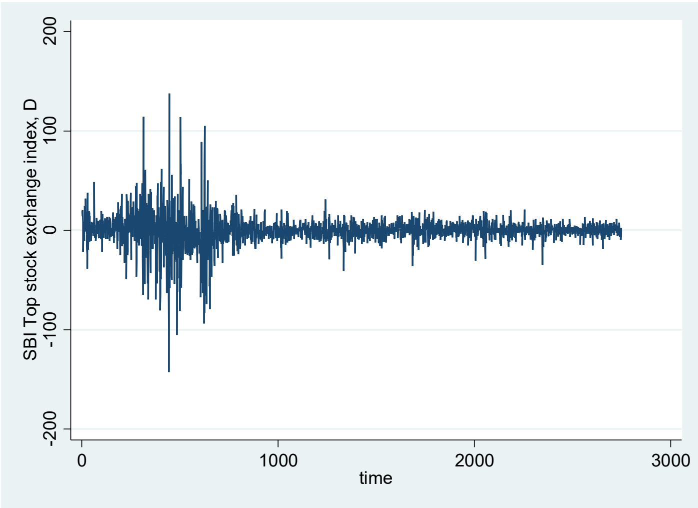
```
DF-GLS for sbitop                                        Number of obs =  2721
Maxlag = 27 chosen by Schwert criterion

               DF-GLS tau      1% Critical       5% Critical      10% Critical
  [lags]     Test Statistic        Value             Value             Value
------------------------------------------------------------------------------
    27           -1.314           -3.480            -2.832            -2.545
    26           -1.263           -3.480            -2.832            -2.546
    25           -1.308           -3.480            -2.833            -2.546
    24           -1.308           -3.480            -2.833            -2.547
    23           -1.372           -3.480            -2.834            -2.547
    22           -1.352           -3.480            -2.835            -2.548
    21           -1.291           -3.480            -2.835            -2.548
    20           -1.250           -3.480            -2.836            -2.549
    19           -1.214           -3.480            -2.836            -2.549
    18           -1.213           -3.480            -2.837            -2.549
    17           -1.216           -3.480            -2.837            -2.550
    16           -1.211           -3.480            -2.838            -2.550
    15           -1.172           -3.480            -2.838            -2.551
    14           -1.066           -3.480            -2.839            -2.551
    13           -1.006           -3.480            -2.839            -2.552
    12           -0.918           -3.480            -2.840            -2.552
    11           -0.945           -3.480            -2.840            -2.553
    10           -0.944           -3.480            -2.841            -2.553
    9            -0.881           -3.480            -2.841            -2.554
    8            -0.902           -3.480            -2.842            -2.554
    7            -0.856           -3.480            -2.842            -2.554
    6            -0.875           -3.480            -2.843            -2.555
    5            -0.867           -3.480            -2.843            -2.555
    4            -0.892           -3.480            -2.844            -2.556
    3            -0.864           -3.480            -2.844            -2.556
    2            -0.883           -3.480            -2.845            -2.557
    1            -1.013           -3.480            -2.845            -2.557

Opt Lag (Ng-Perron seq t) = 27 with RMSE  13.62633
Min SC   =  5.276277 at lag  2 with RMSE  13.92629
Min MAIC =  5.245152 at lag 27 with RMSE  13.62633
```

```
. dfuller sbitop, lags(2)

Augmented Dickey-Fuller test for unit root         Number of obs   =      2746

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -0.770            -3.430            -2.860            -2.570
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.8277

. dfuller sbitop, regress lags(2)

Augmented Dickey-Fuller test for unit root         Number of obs   =      2746

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -0.770            -3.430            -2.860            -2.570
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.8277

------------------------------------------------------------------------------
    D.sbitop |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      sbitop |
         L1. |  -.0004024   .0005223    -0.77   0.441    -.0014266    .0006218
         LD. |    .268612   .0189101    14.20   0.000     .2315326    .3056914
        L2D. |  -.1375565   .0189065    -7.28   0.000     -.174629    -.100484
             |
       _cons |   .3135708   .5849874     0.54   0.592    -.8334898    1.460631
------------------------------------------------------------------------------

. dfuller sbitop, trend lags(2)

Augmented Dickey-Fuller test for unit root         Number of obs   =      2746

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.372            -3.960            -3.410            -3.120
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.8689

. dfuller sbitop, trend regress lags(2)

Augmented Dickey-Fuller test for unit root         Number of obs   =      2746

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.372            -3.960            -3.410            -3.120
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.8689

------------------------------------------------------------------------------
D.sbitop     |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      sbitop |
         L1. |  -.0009808   .0007147    -1.37   0.170    -.0023823    .0004207
         LD. |   .2686385   .0189087    14.21   0.000     .2315618    .3057152
```

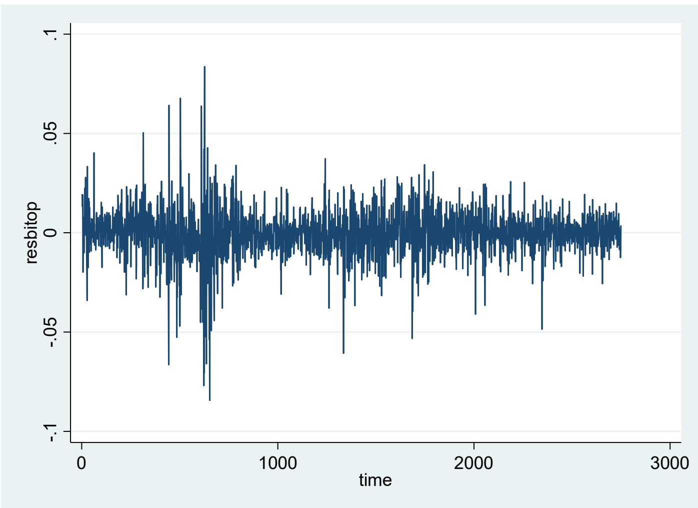
```
        L2D. |  -.1373757   .0189058    -7.27   0.000    -.1744467   -.1003048
      _trend |  -.0005445   .0004594    -1.19   0.236    -.0014453    .0003562
       _cons |   1.639399   1.262146     1.30   0.194    -.8354547    4.114254
------------------------------------------------------------------------------
```

b) Ensuring stationarity

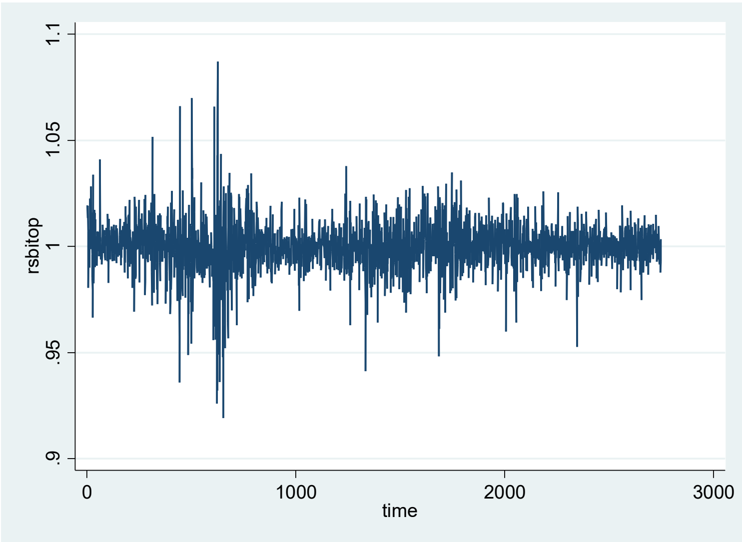
```
. twoway line d.sbitop time                 // First differences //
```




```
. dfuller d.sbitop, lags(2)

Augmented Dickey-Fuller test for unit root         Number of obs   =      2745

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)            -31.012            -3.430            -2.860            -2.570
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

. generate resbitop=ln(sbitop/L.sbitop)    // Continuously compounded returns //
(1 missing value generated)

. twoway line resbitop time
```



```
. dfuller resbitop, lags(2)

Augmented Dickey-Fuller test for unit root         Number of obs   =      2745

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)            -30.284            -3.430            -2.860            -2.570
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

. generate rsbitop=sbitop/l.sbitop        // Growth rates //
(1 missing value generated)

. twoway line rsbitop time
```

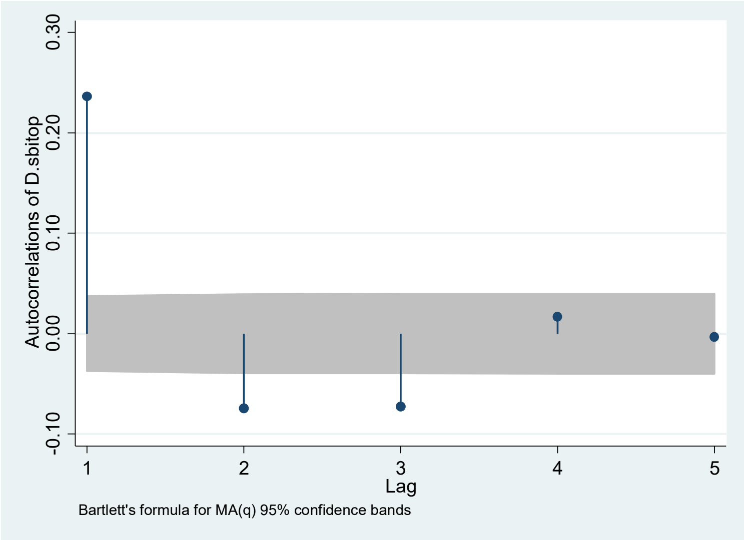



```
. dfuller rsbitop, lags(2)

Augmented Dickey-Fuller test for unit root         Number of obs   =      2745

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)            -30.363            -3.430            -2.860            -2.570
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000
```

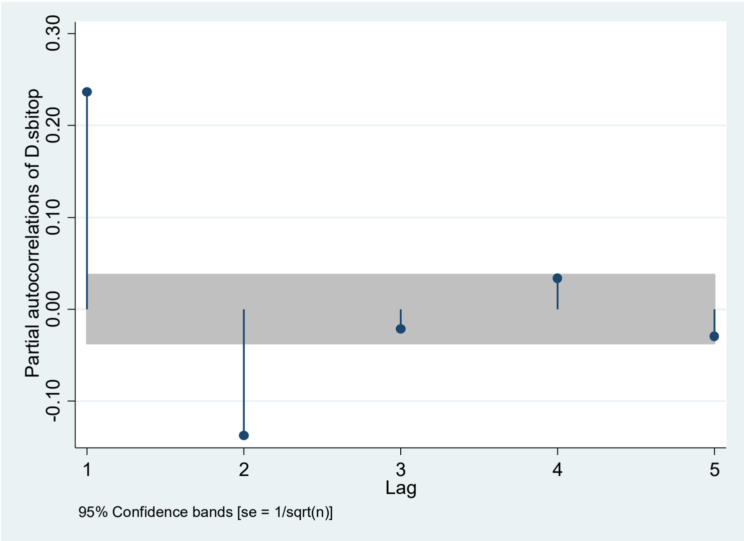
c) Identification of the ARMA model

```
. corrgram d.sbitop, lags(5)

                                          -1       0       1 -1       0       1
 LAG       AC       PAC      Q     Prob>Q  [Autocorrelation]  [Partial Autocor]
-------------------------------------------------------------------------------
1        0.2364   0.2364   153.69  0.0000          |-                 |-
2       -0.0744  -0.1378   168.91  0.0000          |                 -|
3       -0.0726  -0.0216   183.41  0.0000          |                  |
4        0.0168   0.0339   184.19  0.0000          |                  |
5       -0.0031  -0.0294   184.21  0.0000          |                  |
```

```
. ac d.sbitop, lags(5)
```




```
. pac d.sbitop, lags(5)
```




```
. arima d.sbitop, arima(0,0,0)

(setting optimization to BHHH)
Iteration 0:   log likelihood = -11244.623
Iteration 1:   log likelihood = -11244.623

ARIMA regression

Sample:  2 - 2749                               Number of obs      =      2748
                                                Wald chi2(.)       =         .
Log likelihood = -11244.62                      Prob > chi2        =         .

------------------------------------------------------------------------------
             |                 OPG
    D.sbitop |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
sbitop       |
       _cons |  -.0872525   .2774404    -0.31   0.753    -.6310257    .4565208
-------------+----------------------------------------------------------------
```

```
      /sigma |   14.48323   .0623727   232.20   0.000     14.36098    14.60548
------------------------------------------------------------------------------
Note: The test of the variance against zero is one sided, and the two-sided
      confidence interval is truncated at zero.

. estat ic

Akaike's information criterion and Bayesian information criterion

-----------------------------------------------------------------------------
       Model |    Obs    ll(null)   ll(model)     df          AIC         BIC
-------------+---------------------------------------------------------------
           . |   2748           .   -11244.62      2     22493.25    22505.08
-----------------------------------------------------------------------------
               Note:  N=Obs used in calculating BIC; see [R] BIC note

. display e(ll), e(rank)
-11244.623 2

// We continue to estimate all possible ARMA models manually
// Alternatively, we can use the following program:

. generate variable=d.sbitop
(1 missing value generated)

. scalar pset=4
. scalar qset=4

. forvalues p=0/`=pset' {
  2.          forvalues q=0/`=qset' {
  3.                  qui arima variable, arima(`p',0,`q')
  4.                  scalar aic_`p'_`q'=-2*e(ll)+2*e(rank)
  5.                  scalar bic_`p'_`q'=-2*e(ll)+e(rank)*ln(e(N))
  6.          }
  7. }

. forvalues p=0/`=pset' {
  2.          forvalues q=0/`=qset' {
  3.                  display "AIC(`p',`q') = "aic_`p'_`q'
  4.          }
  5. }

AIC(0,0) = 22493.246
AIC(0,1) = 22303.154
AIC(0,2) = 22302.321
AIC(0,3) = 22283.048
AIC(0,4) = 22284.417
AIC(1,0) = 22337.218
AIC(1,1) = 22303.481
AIC(1,2) = 22296.374
AIC(1,3) = 22280.056
AIC(1,4) = 22254.553
AIC(2,0) = 22286.494
AIC(2,1) = 22287.615
AIC(2,2) = 22285.706
AIC(2,3) = 22279.698
AIC(2,4) = 22254.738
AIC(3,0) = 22287.211
AIC(3,1) = 22279.644
AIC(3,2) = 22259.567
AIC(3,3) = 22281.604
AIC(3,4) = 22244.954
AIC(4,0) = 22286.043
AIC(4,1) = 22280.393
AIC(4,2) = 22253.788
```

```
AIC(4,3) = 22255.754
AIC(4,4) = 22246.645

. forvalues p=0(1)`=pset' {
  2.         forvalues q=0(1)`=qset' {
  3.                 display "SBIC(`p',`q') = "bic_`p'_`q'
  4.         }
  5. }

SBIC(0,0) = 22505.083
SBIC(0,1) = 22320.91
SBIC(0,2) = 22325.995
SBIC(0,3) = 22312.641
SBIC(0,4) = 22319.929
SBIC(1,0) = 22354.973
SBIC(1,1) = 22327.155
SBIC(1,2) = 22325.967
SBIC(1,3) = 22315.568
SBIC(1,4) = 22295.984
SBIC(2,0) = 22310.168
SBIC(2,1) = 22317.208
SBIC(2,2) = 22321.217
SBIC(2,3) = 22321.128
SBIC(2,4) = 22302.087
SBIC(3,0) = 22316.805
SBIC(3,1) = 22315.156
SBIC(3,2) = 22300.998
SBIC(3,3) = 22328.953
SBIC(3,4) = 22298.221
SBIC(4,0) = 22321.555
SBIC(4,1) = 22321.823
SBIC(4,2) = 22301.137
SBIC(4,3) = 22309.022
SBIC(4,4) = 22305.832

. arima d.sbitop, ar(1) ma(1/4)

(setting optimization to BHHH)
Iteration 0:   log likelihood = -11136.971
Iteration 1:   log likelihood = -11136.345
Iteration 2:   log likelihood = -11130.593
Iteration 3:   log likelihood = -11127.363
Iteration 4:   log likelihood = -11124.873
(switching optimization to BFGS)
Iteration 5:   log likelihood = -11123.942
Iteration 6:   log likelihood = -11121.744
Iteration 7:   log likelihood = -11120.387
Iteration 8:   log likelihood = -11120.335
Iteration 9:   log likelihood = -11120.305
Iteration 10:  log likelihood = -11120.288
Iteration 11:  log likelihood = -11120.284
Iteration 12:  log likelihood = -11120.278
Iteration 13:  log likelihood = -11120.277
Iteration 14:  log likelihood = -11120.277
(switching optimization to BHHH)
Iteration 15:  log likelihood = -11120.277
Iteration 16:  log likelihood = -11120.277
Iteration 17:  log likelihood = -11120.277
Iteration 18:  log likelihood = -11120.277
Iteration 19:  log likelihood = -11120.277
(switching optimization to BFGS)
Iteration 20:  log likelihood = -11120.277
Iteration 21:  log likelihood = -11120.277
Iteration 22:  log likelihood = -11120.277
Iteration 23:  log likelihood = -11120.277
```

```
ARIMA regression

Sample:  2 - 2749                               Number of obs     =       2748
                                                Wald chi2(5)      =  173101.70
Log likelihood = -11120.28                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
             |                 OPG
    D.sbitop |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
sbitop       |
       _cons |   .0239208   .9110657     0.03   0.979    -1.761735    1.809577
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |   .9919309   .0034908   284.15   0.000      .985089    .9987728
             |
          ma |
         L1. |  -.7376104   .0068678  -107.40   0.000     -.751071   -.7241497
         L2. |  -.3306478   .0088123   -37.52   0.000    -.3479196   -.3133759
         L3. |  -.0198507   .0097767    -2.03   0.042    -.0390127   -.0006887
         L4. |   .1121987   .0086706    12.94   0.000     .0952047    .1291927
-------------+----------------------------------------------------------------
      /sigma |    13.8415   .0581916   237.86   0.000     13.72744    13.95555
------------------------------------------------------------------------------
Note: The test of the variance against zero is one sided, and the two-sided
      confidence interval is truncated at zero.
```

. arima d.sbitop, arima(1,0,4)

```
(setting optimization to BHHH)
Iteration 0:   log likelihood = -11136.971
Iteration 1:   log likelihood = -11136.345
Iteration 2:   log likelihood = -11130.593
Iteration 3:   log likelihood = -11127.363
Iteration 4:   log likelihood = -11124.873
(switching optimization to BFGS)
Iteration 5:   log likelihood = -11123.942
Iteration 6:   log likelihood = -11121.744
Iteration 7:   log likelihood = -11120.387
Iteration 8:   log likelihood = -11120.335
Iteration 9:   log likelihood = -11120.305
Iteration 10:  log likelihood = -11120.288
Iteration 11:  log likelihood = -11120.284
Iteration 12:  log likelihood = -11120.278
Iteration 13:  log likelihood = -11120.277
Iteration 14:  log likelihood = -11120.277
(switching optimization to BHHH)
Iteration 15:  log likelihood = -11120.277
Iteration 16:  log likelihood = -11120.277
Iteration 17:  log likelihood = -11120.277
Iteration 18:  log likelihood = -11120.277
Iteration 19:  log likelihood = -11120.277
(switching optimization to BFGS)
Iteration 20:  log likelihood = -11120.277
Iteration 21:  log likelihood = -11120.277
Iteration 22:  log likelihood = -11120.277
Iteration 23:  log likelihood = -11120.277

ARIMA regression

Sample:  2 - 2749                               Number of obs     =       2748
                                                Wald chi2(5)      =  173101.70
Log likelihood = -11120.28                      Prob > chi2       =     0.0000
```

```
------------------------------------------------------------------------------
             |                 OPG
    D.sbitop |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
sbitop       |
       _cons |   .0239208   .9110657     0.03   0.979    -1.761735    1.809577
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |   .9919309   .0034908   284.15   0.000      .985089    .9987728
             |
          ma |
         L1. |  -.7376104   .0068678  -107.40   0.000     -.751071   -.7241497
         L2. |  -.3306478   .0088123   -37.52   0.000    -.3479196   -.3133759
         L3. |  -.0198507   .0097767    -2.03   0.042    -.0390127   -.0006887
         L4. |   .1121987   .0086706    12.94   0.000     .0952047    .1291927
-------------+----------------------------------------------------------------
      /sigma |    13.8415   .0581916   237.86   0.000     13.72744    13.95555
------------------------------------------------------------------------------
Note: The test of the variance against zero is one sided, and the two-sided
      confidence interval is truncated at zero.
```

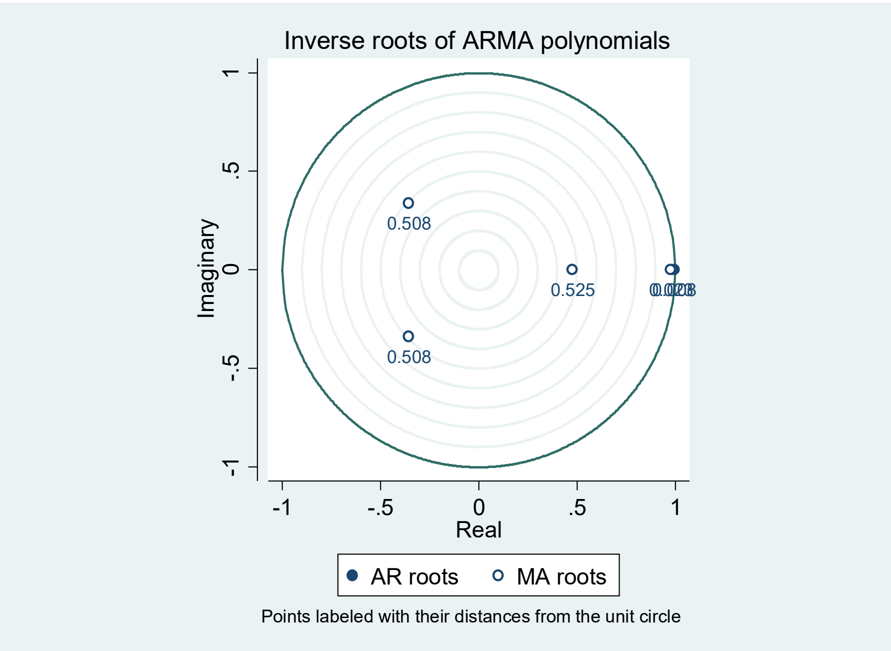
. arima sbitop, arima(1,1,4)

```
(setting optimization to BHHH)
Iteration 0:   log likelihood = -11136.971
Iteration 1:   log likelihood = -11136.345
Iteration 2:   log likelihood = -11130.593
Iteration 3:   log likelihood = -11127.363
Iteration 4:   log likelihood = -11124.873
(switching optimization to BFGS)
Iteration 5:   log likelihood = -11123.942
Iteration 6:   log likelihood = -11121.744
Iteration 7:   log likelihood = -11120.387
Iteration 8:   log likelihood = -11120.335
Iteration 9:   log likelihood = -11120.305
Iteration 10:  log likelihood = -11120.288
Iteration 11:  log likelihood = -11120.284
Iteration 12:  log likelihood = -11120.278
Iteration 13:  log likelihood = -11120.277
Iteration 14:  log likelihood = -11120.277
(switching optimization to BHHH)
Iteration 15:  log likelihood = -11120.277
Iteration 16:  log likelihood = -11120.277
Iteration 17:  log likelihood = -11120.277
Iteration 18:  log likelihood = -11120.277
Iteration 19:  log likelihood = -11120.277
(switching optimization to BFGS)
Iteration 20:  log likelihood = -11120.277
Iteration 21:  log likelihood = -11120.277
Iteration 22:  log likelihood = -11120.277
Iteration 23:  log likelihood = -11120.277

ARIMA regression

Sample:  2 - 2749                               Number of obs      =      2748
                                                Wald chi2(5)       =  173101.70
Log likelihood = -11120.28                      Prob > chi2        =    0.0000

------------------------------------------------------------------------------
             |                 OPG
    D.sbitop |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
sbitop       |
       _cons |   .0239208   .9110657     0.03   0.979    -1.761735    1.809577
```

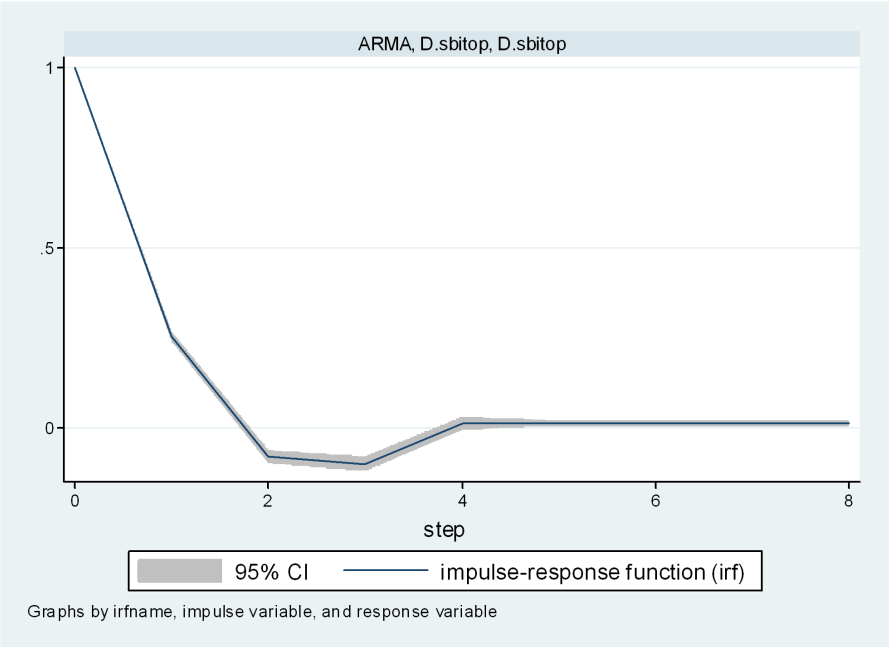
```
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |   .9919309   .0034908   284.15   0.000      .985089    .9987728
             |
          ma |
         L1. |  -.7376104   .0068678  -107.40   0.000     -.751071   -.7241497
         L2. |  -.3306478   .0088123   -37.52   0.000    -.3479196   -.3133759
         L3. |  -.0198507   .0097767    -2.03   0.042    -.0390127   -.0006887
         L4. |   .1121987   .0086706    12.94   0.000     .0952047    .1291927
-------------+----------------------------------------------------------------
      /sigma |    13.8415   .0581916   237.86   0.000     13.72744    13.95555
------------------------------------------------------------------------------
Note: The test of the variance against zero is one sided, and the two-sided
      confidence interval is truncated at zero.
```

. estat aroots, dlabel

```
   Eigenvalue stability condition
  +----------------------------------------+
  |         Eigenvalue         |  Modulus  |
  |----------------------------+-----------|
  |   .9919309                 |  .991931  |
  +----------------------------------------+
   All the eigenvalues lie inside the unit circle.
   AR parameters satisfy stability condition.

   Eigenvalue stability condition
  +----------------------------------------+
  |         Eigenvalue         |  Modulus  |
  |----------------------------+-----------|
  |   .9765367                 |  .976537  |
  |  -.3569913 +   .338248i    |  .491787  |
  |  -.3569913 -   .338248i    |  .491787  |
  |   .4750564                 |  .475056  |
  +----------------------------------------+
   All the eigenvalues lie inside the unit circle.
   MA parameters satisfy invertibility condition.
```



```
. irf create ARMA, set(myirf, replace)
(file myirf.irf created)
(file myirf.irf now active)
(file myirf.irf updated)

. irf describe
Contains irf results from myirf.irf

       irfname | model    endogenous variables and order (*)
---------------+-----------------------------------------------------------------
          ARMA | arima    D.sbitop
---------------------------------------------------------------------------------
  (*) order is relevant only when model is var

. irf graph irf
```

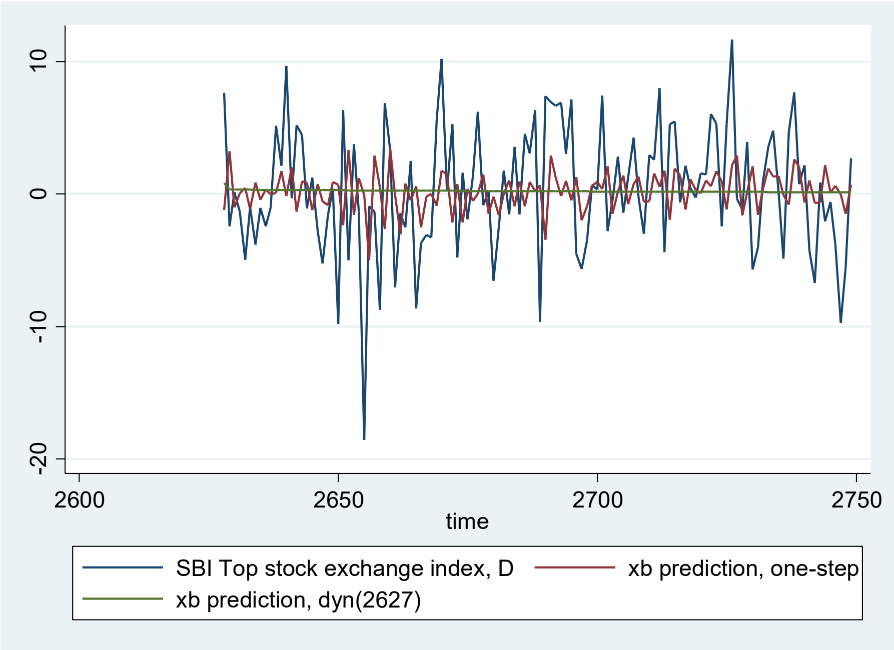



```
. irf table irf

             Results from ARMA

+----------------------------------------------+
|         |    (1)          (1)          (1)    |
|  step   |   irf         Lower        Upper    |
|---------+------------------------------------|
|0        | 1           1            1          |
|1        | .254321     .241383      .267258    |
|2        | -.078379    -.095964     -.060794   |
|3        | -.097598    -.118049     -.077146   |
|4        | .015389     -.002311     .033088    |
|5        | .015264     .008027      .022502    |
|6        | .015141     .007858      .022425    |
|7        | .015019     .007691      .022347    |
|8        | .014898     .007526      .02227     |
+----------------------------------------------+
95% lower and upper bounds reported
(1) irfname = ARMA, impulse = D.sbitop, and response = D.sbitop
```

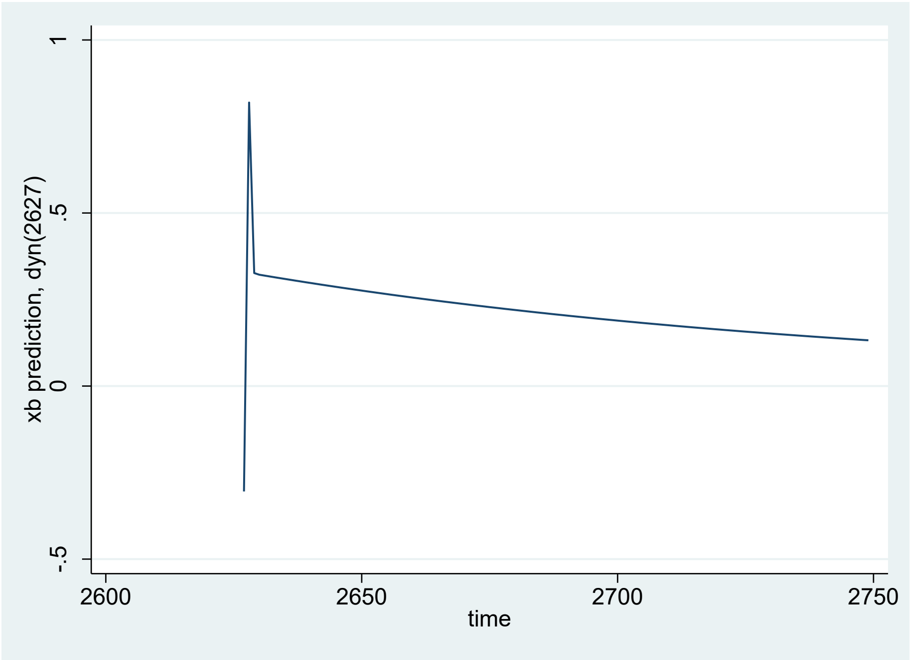
d) Forecasting using the ARMA model

```
. arima d.sbitop if time <= 2626, arima(1,0,4)

(setting optimization to BHHH)
Iteration 0:   log likelihood =  -10690.67
Iteration 1:   log likelihood = -10690.058
Iteration 2:   log likelihood = -10684.201
Iteration 3:   log likelihood = -10681.319
Iteration 4:   log likelihood = -10678.887
(switching optimization to BFGS)
Iteration 5:   log likelihood = -10678.421
Iteration 6:   log likelihood = -10676.075
Iteration 7:   log likelihood = -10674.765
Iteration 8:   log likelihood = -10674.635
Iteration 9:   log likelihood = -10674.593
Iteration 10:  log likelihood = -10674.582
Iteration 11:  log likelihood = -10674.572
Iteration 12:  log likelihood = -10674.569
Iteration 13:  log likelihood = -10674.565
Iteration 14:  log likelihood = -10674.564
(switching optimization to BHHH)
Iteration 15:  log likelihood = -10674.564
Iteration 16:  log likelihood = -10674.563
Iteration 17:  log likelihood = -10674.563
Iteration 18:  log likelihood = -10674.563
Iteration 19:  log likelihood = -10674.563
(switching optimization to BFGS)
Iteration 20:  log likelihood = -10674.563
Iteration 21:  log likelihood = -10674.563
Iteration 22:  log likelihood = -10674.563
Iteration 23:  log likelihood = -10674.563
Iteration 24:  log likelihood = -10674.563
Iteration 25:  log likelihood = -10674.563
Iteration 26:  log likelihood = -10674.563
Iteration 27:  log likelihood = -10674.563

ARIMA regression

Sample:  2 - 2626                               Number of obs      =      2625
                                                Wald chi2(5)       =  160118.49
Log likelihood = -10674.56                      Prob > chi2        =    0.0000

------------------------------------------------------------------------------
             |                 OPG
    D.sbitop |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
sbitop       |
       _cons |    .015196   .9543819     0.02   0.987    -1.855358     1.88575
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |   .9919454   .0036254   273.61   0.000     .9848398     .999051
             |
          ma |
         L1. |  -.7364219   .0071441  -103.08   0.000    -.7504241   -.7224196
         L2. |  -.3325661   .0091552   -36.33   0.000      -.35051   -.3146222
         L3. |   -.020701   .0101662    -2.04   0.042    -.0406264   -.0007755
         L4. |   .1138036   .0090247    12.61   0.000     .0961156    .1314916
-------------+----------------------------------------------------------------
      /sigma |   14.11854   .0618202   228.38   0.000     13.99737     14.2397
------------------------------------------------------------------------------
Note: The test of the variance against zero is one sided, and the two-sided
      confidence interval is truncated at zero.
```

```
. predict sbitop_fstatic, xb
. predict sbitop_fdynamic, xb dynamic(2627)

. twoway (tsline d.sbitop) (tsline sbitop_fstatic) (tsline sbitop_fdynamic) if time>2627
```




```
. twoway (tsline sbitop_fdynamic) if time>2626
```



■