Example 1: We will analyse monthly UK house price series for the period from January 1991 to May 2013, already prepared in Stata data file `ukhp.dta`. The programming code is given in Stata Do file `ukhp-commands.do`.

First, we will inspect, test and ensure stationarity of our monthly UK house price series.

a) Inspect the UK house price (time series *HP*) visually. Does it look stationary? Perform the Augmented Dickey-Fuller (ADF) test on the time series. How many lags should you use? Should you include a trend into the DF regression? What do you find?
b) Also perform the Dickey-Fuller GLS test (DFGLS), which has in general more statistical power than the ADF test. What do you find? You can use information on the number of lags from the DFGLS test in the ADF test. Has the conclusion changed?
c) How can you make a time series stationary? Apply first differences on the time series *HP* and inspect the new time series visually. Does it look stationary? Repeat the ADF test on the new time series. What do you find?
d) Another way of making a time series stationary, often used in finance, is to generate continuously compounded percentage returns (percentage changes). Do this and inspect the new time series visually. Repeat the ADF test on this time series. What do you find?

Now, we will build an ARMA model for the house price changes. Recall that there are three stages involved: identification, estimation and diagnostic checking.

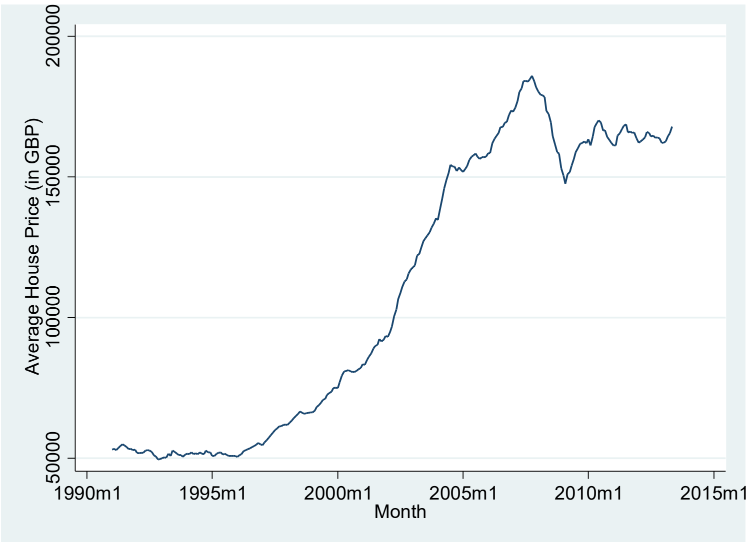
e) Identification is carried out by looking at the autocorrelation and partial autocorrelation coefficients to identify any structure in the data. Generate a table of autocorrelations, partial correlations and related test statistics. Draw the autocorrelation function (ACF) and the partial autocorrelation function (PACF). Does the time series appear to be an autoregressive (AR) process, a moving average (MA) process or a mixed ARMA process?
f) Use information criteria to decide on model orders p and q. Consider at least the first four lags. Which information criterion will you focus on? What do you find?
g) Estimate the model, proposed by the information criteria analysis, by employing the maximum likelihood estimator. Interpret the Stata output, but keep in mind that because the construction of these models is not based on economic or financial theory, it is often best not to interpret the individual parameter estimates, but rather to examine the plausibility of the model as a whole, and to determine whether it describes the data well and produces accurate forecasts. Also obtain the impulse responses (IRs).
h) Check for stability of the chosen model by examining inverse AR and MA roots of the characteristic equation. What do you find?
i) Now, suppose that the chosen time series model was estimated using observations from the period February 1991 – December 2010, leaving 29 remaining observations for constructing forecasts (for the period January 2011 – May 2013). Generate static and dynamic forecasts and present them graphically, together with the actual data, which are in fact available for the forecasting period. What do you find?

Static forecasts imply a sequence of one-step-ahead forecasts, rolling the sample forwards one observation after each forecast. Dynamic forecast calculates multi-step forecasts starting from the first period in the forecast sample. The dynamic forecasts quickly converge upon the long-term unconditional mean value as the horizon increases. This does not occur with the series of one-step-ahead forecasts, which seem to more closely resemble the actual series.

Computer printout of the results in Stata:

Data exploration

```
. tsset Month
        time variable:  Month, 1991m1 to 2013m5
                delta:  1 month

. twoway line HP Month
```



Performing the Dickey-Fuller tests

```
. dfuller HP, lags(12)

Augmented Dickey-Fuller test for unit root         Number of obs   =       256

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -0.960            -3.460            -2.880            -2.570
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.7676

. dfuller HP, regress lags(12)

Augmented Dickey-Fuller test for unit root         Number of obs   =       256

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -0.960            -3.460            -2.880            -2.570
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.7676

------------------------------------------------------------------------------
        D.HP |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          HP |
         L1. |  -.0014392   .0014994    -0.96   0.338    -.0043926    .0015143
         LD. |   .2859919   .0633351     4.52   0.000     .1612334    .4107504
```

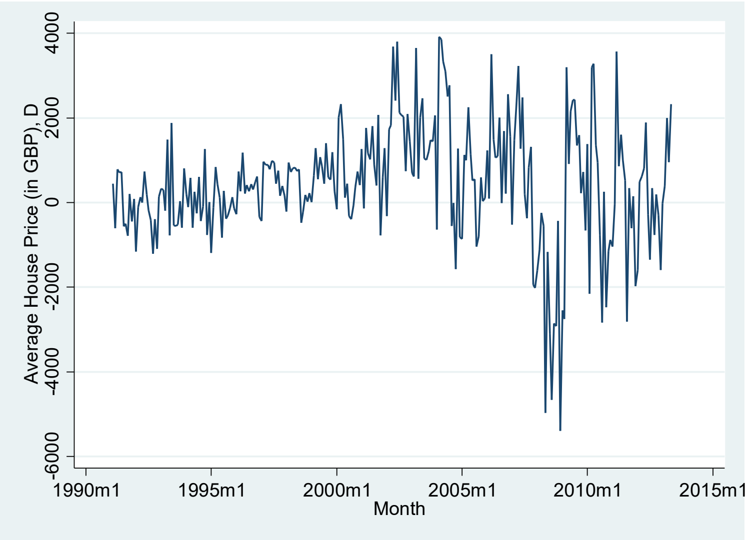
```
        L2D. |   .3226638   .0656779     4.91   0.000     .1932906    .4520371
        L3D. |   .0217977   .0687253     0.32   0.751    -.1135784    .1571738
        L4D. |   .0249136   .0685106     0.36   0.716    -.1100396    .1598668
        L5D. |  -.0288369   .0684909    -0.42   0.674    -.1637514    .1060775
        L6D. |   .0128432   .0683735     0.19   0.851    -.1218399    .1475263
        L7D. |  -.1132738   .0683326    -1.66   0.099    -.2478763    .0213288
        L8D. |   .0238635   .0687485     0.35   0.729    -.1115583    .1592852
        L9D. |   .0884816   .0686746     1.29   0.199    -.0467948     .223758
       L10D. |  -.1151423   .0689386    -1.67   0.096    -.2509386     .020654
       L11D. |   .0911545   .0662825     1.38   0.170    -.0394098    .2217187
       L12D. |   .1653165   .0640052     2.58   0.010      .039238    .2913949
             |
       _cons |   271.1407   183.6549     1.48   0.141    -90.62553    632.9069
------------------------------------------------------------------------------
```

```
. dfuller HP, trend lags(12)

Augmented Dickey-Fuller test for unit root         Number of obs   =       256

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -2.364            -3.990            -3.430            -3.130
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.3987

. dfuller HP, trend regress lags(12)

Augmented Dickey-Fuller test for unit root         Number of obs   =       256

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -2.364            -3.990            -3.430            -3.130
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.3987

------------------------------------------------------------------------------
D.HP         |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          HP |
         L1. |  -.0109715   .0046402    -2.36   0.019    -.0201121   -.0018309
         LD. |   .2790635   .0629371     4.43   0.000     .1550865    .4030405
        L2D. |   .3231062   .0651813     4.96   0.000     .1947084    .4515039
        L3D. |   .0278044   .0682616     0.41   0.684    -.1066611    .1622698
        L4D. |   .0331733   .0680988     0.49   0.627    -.1009716    .1673182
        L5D. |  -.0203513   .0680853    -0.30   0.765    -.1544694    .1137669
        L6D. |   .0162966   .0678748     0.24   0.810    -.1174071    .1500003
        L7D. |  -.1099157   .0678333    -1.62   0.106    -.2435375    .0237061
        L8D. |   .0258148   .0682343     0.38   0.706    -.1085969    .1602265
        L9D. |   .0919464   .0681738     1.35   0.179    -.0423462     .226239
       L10D. |  -.1083164   .0684894    -1.58   0.115    -.2432307    .0265979
       L11D. |   .0991286   .0658837     1.50   0.134    -.0306528      .22891
       L12D. |   .1798951   .0638756     2.82   0.005     .0540692    .3057209
      _trend |   6.705113   3.091602     2.17   0.031     .6151001    12.79512
       _cons |   369.3101   187.8018     1.97   0.050    -.6325458    739.2527
------------------------------------------------------------------------------
```

```
. dfgls HP, maxlag(12)

DF-GLS for HP                                          Number of obs =   256

               DF-GLS tau      1% Critical       5% Critical      10% Critical
  [lags]     Test Statistic        Value             Value             Value
------------------------------------------------------------------------------
    12           -2.019           -3.480            -2.836            -2.554
    11           -1.706           -3.480            -2.844            -2.561
    10           -1.478           -3.480            -2.851            -2.568
    9            -1.510           -3.480            -2.859            -2.575
    8            -1.317           -3.480            -2.866            -2.582
    7            -1.223           -3.480            -2.873            -2.589
    6            -1.296           -3.480            -2.880            -2.595
    5            -1.269           -3.480            -2.887            -2.601
    4            -1.344           -3.480            -2.893            -2.606
    3            -1.349           -3.480            -2.899            -2.612
    2            -1.310           -3.480            -2.905            -2.617
    1            -0.897           -3.480            -2.910            -2.622

Opt Lag (Ng-Perron seq t) = 12 with RMSE  1139.738
Min SC    =  14.22714 at lag  2 with RMSE  1189.249
Min MAIC =  14.19142 at lag  2 with RMSE  1189.249

. dfuller HP, trend lags(2)

Augmented Dickey-Fuller test for unit root         Number of obs   =       266

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.674            -3.989            -3.429            -3.130
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.7623
```

Applying first differences and repeating the ADF test

```
. twoway line d.HP Month
```



. dfuller d.HP, lags(2)

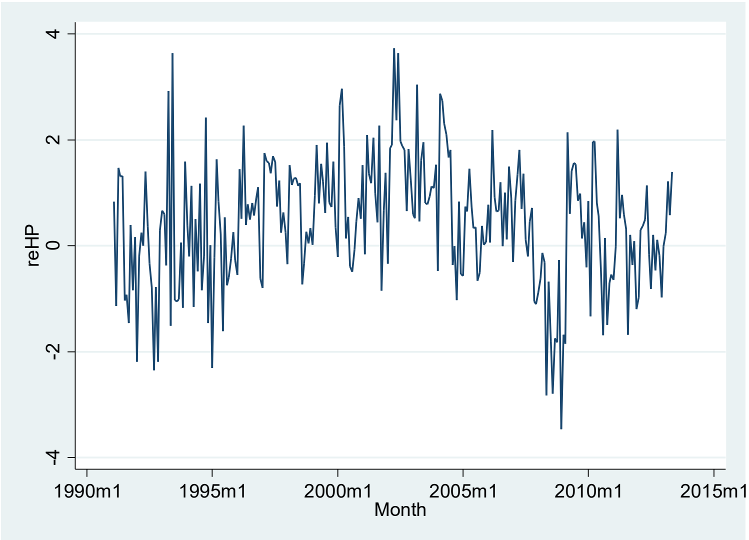
```
Augmented Dickey-Fuller test for unit root         Number of obs   =       265

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -5.344            -3.459            -2.879            -2.570
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000
```

Generating continuously compounded percentage returns (percentage changes) and repeating the ADF test

. generate reHP=100*(ln(HP/L.HP))

```
(1 missing value generated)
```

. twoway line reHP Month



. dfuller reHP, lags(2)

```
Augmented Dickey-Fuller test for unit root         Number of obs   =       265

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -5.771            -3.459            -2.879            -2.570
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000
```

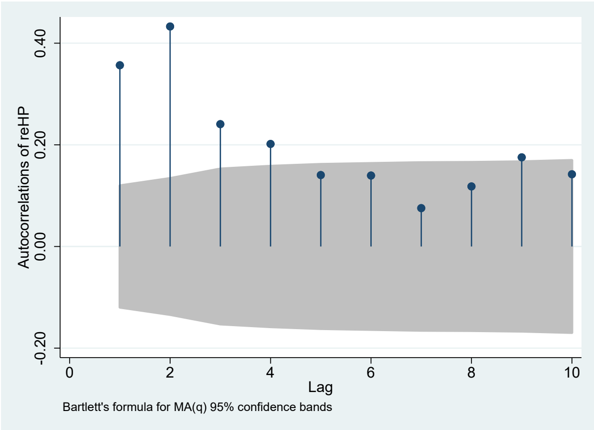
Constructing an ARMA model

. corrgram reHP, lags(10)

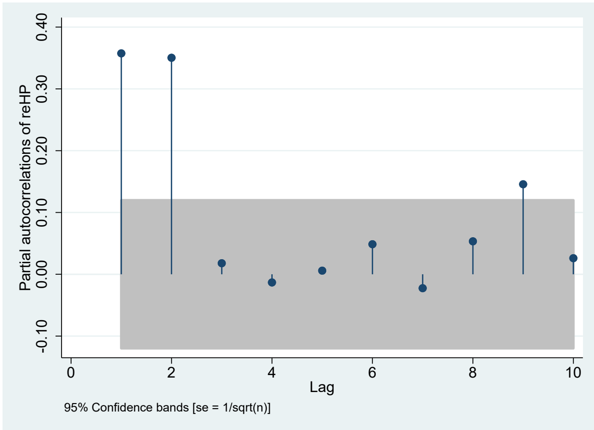
```
                                          -1       0       1 -1       0       1
 LAG       AC       PAC      Q     Prob>Q  [Autocorrelation]  [Partial Autocor]
-------------------------------------------------------------------------------
1        0.3566   0.3575   34.468  0.0000          |--                |--
2        0.4329   0.3504   85.444  0.0000          |---               |--
3        0.2407   0.0179   101.27  0.0000          |-                 |
```

```
4         0.2018   -0.0132   112.43   0.0000          |-                  |
5         0.1406    0.0058   117.86   0.0000          |-                  |
6         0.1396    0.0486   123.24   0.0000          |-                  |
7         0.0755   -0.0225   124.82   0.0000          |                   |
8         0.1182    0.0533   128.71   0.0000          |                   |
9         0.1754    0.1457   137.31   0.0000          |-                  |-
10        0.1421    0.0260   142.97   0.0000          |-                  |
```

. ac reHP, lags(10)



. pac reHP, lags(10)



. arima reHP, arima(0,0,0)

```
(setting optimization to BHHH)
Iteration 0:   log likelihood = -427.80328
Iteration 1:   log likelihood = -427.80328

ARIMA regression

Sample:  1991m2 - 2013m5                        Number of obs     =        268
                                                Wald chi2(.)      =          .
Log likelihood = -427.8033                      Prob > chi2       =          .

------------------------------------------------------------------------------
             |                 OPG
        reHP |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
reHP         |
       _cons |   .4299142   .0732932     5.87   0.000     .2862623    .5735662
-------------+----------------------------------------------------------------
      /sigma |    1.19404   .0484286    24.66   0.000     1.099122    1.288958
------------------------------------------------------------------------------
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
-------------+---------------------------------------------------------------
           . |        268         .  -427.8033       2    859.6066   866.7885
-----------------------------------------------------------------------------
               Note: N=Obs used in calculating BIC; see [R] BIC note.

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

```
. generate variable=reHP
(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) = 859.60656
AIC(0,1) = 840.82476
AIC(0,2) = 804.35416
AIC(0,3) = 801.8014
AIC(0,4) = 800.01893
AIC(1,0) = 825.17453
AIC(1,1) = 802.16762
AIC(1,2) = 795.50644
AIC(1,3) = 794.0435
AIC(1,4) = 795.2866
AIC(2,0) = 792.09006
AIC(2,1) = 794.01043
AIC(2,2) = 795.95615
AIC(2,3) = 794.75456
AIC(2,4) = 796.10834
AIC(3,0) = 794.00444
AIC(3,1) = 793.38271
AIC(3,2) = 797.94062
AIC(3,3) = 796.4548
AIC(3,4) = 795.86876
AIC(4,0) = 795.95778
AIC(4,1) = 795.26527
AIC(4,2) = 791.60913
AIC(4,3) = 791.43349
AIC(4,4) = 795.39434

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

SBIC(0,0) = 866.78854
SBIC(0,1) = 851.59773
SBIC(0,2) = 818.71811
SBIC(0,3) = 819.75633
SBIC(0,4) = 821.56485
SBIC(1,0) = 835.94749
SBIC(1,1) = 816.53157
SBIC(1,2) = 813.46137
SBIC(1,3) = 815.58942
SBIC(1,4) = 820.42351
SBIC(2,0) = 806.45401
SBIC(2,1) = 811.96537
SBIC(2,2) = 817.50207
```

```
SBIC(2,3) = 819.89146
SBIC(2,4) = 824.83624
SBIC(3,0) = 811.95937
SBIC(3,1) = 814.92863
SBIC(3,2) = 823.07753
SBIC(3,3) = 825.1827
SBIC(3,4) = 828.18765
SBIC(4,0) = 817.5037
SBIC(4,1) = 820.40218
SBIC(4,2) = 816.74604
SBIC(4,3) = 823.75237
SBIC(4,4) = 831.30421

// SBIC is consistent, but requires a large sample, which we seem to have (T = 268) //
```

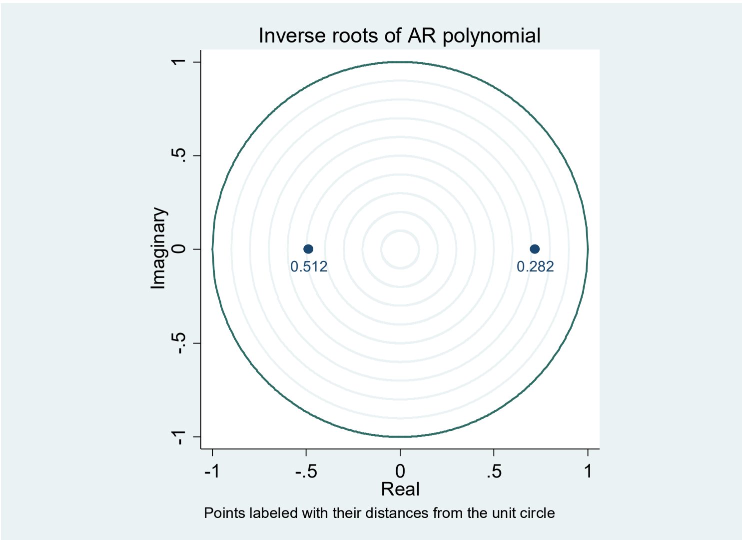
. arima reHP, ar(1/2)

```
(setting optimization to BHHH)
Iteration 0:   log likelihood = -392.04832
Iteration 1:   log likelihood = -392.04526
Iteration 2:   log likelihood = -392.04505
Iteration 3:   log likelihood = -392.04503

ARIMA regression

Sample:  1991m2 - 2013m5                        Number of obs     =        268
                                                Wald chi2(2)      =      79.64
Log likelihood =  -392.045                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
             |                 OPG
        reHP |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
reHP         |
       _cons |   .4324219   .1542394     2.80   0.005     .1301183    .7347255
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |   .2299696   .0508839     4.52   0.000      .130239    .3297002
         L2. |   .3508321   .0488959     7.18   0.000     .2549978    .4466663
-------------+----------------------------------------------------------------
      /sigma |   1.044089   .0415722    25.12   0.000     .9626087    1.125569
------------------------------------------------------------------------------
Note: The test of the variance against zero is one sided, and the two-sided
      confidence interval is truncated at zero.
```

. arima reHP, arima(2,0,0)

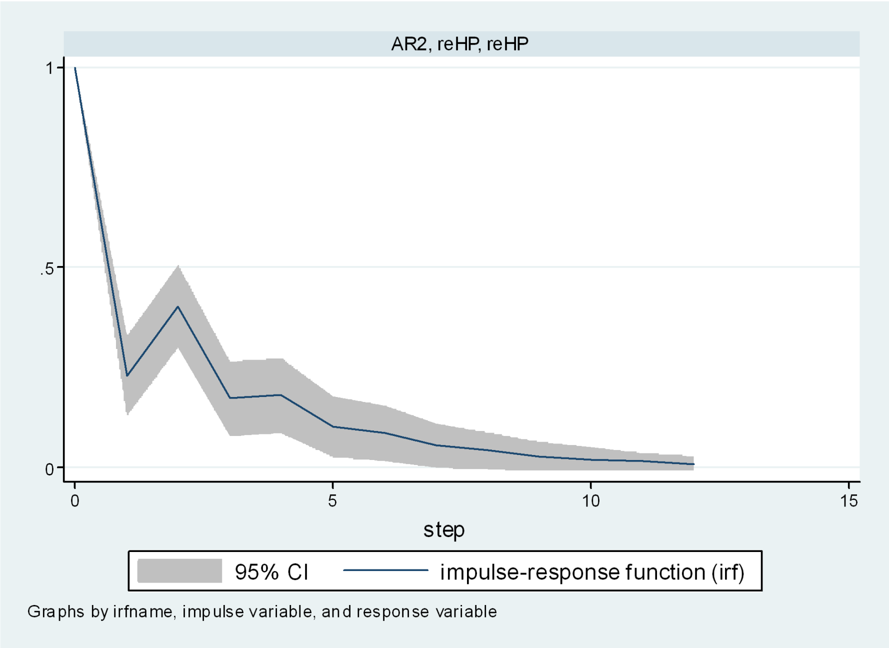
```
(setting optimization to BHHH)
Iteration 0:   log likelihood = -392.04832
Iteration 1:   log likelihood = -392.04526
Iteration 2:   log likelihood = -392.04505
Iteration 3:   log likelihood = -392.04503

ARIMA regression

Sample:  1991m2 - 2013m5                        Number of obs     =        268
                                                Wald chi2(2)      =      79.64
Log likelihood =  -392.045                      Prob > chi2       =     0.0000
```

```
------------------------------------------------------------------------------
             |                 OPG
        reHP |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
reHP         |
       _cons |   .4324219   .1542394     2.80   0.005     .1301183    .7347255
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |   .2299696   .0508839     4.52   0.000      .130239    .3297002
         L2. |   .3508321   .0488959     7.18   0.000     .2549978    .4466663
-------------+----------------------------------------------------------------
      /sigma |   1.044089   .0415722    25.12   0.000     .9626087    1.125569
------------------------------------------------------------------------------
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    |
  |--------------------------+------------|
  |   .7183533                 |   .718353    |
  |  -.4883837                 |   .488384    |
  +----------------------------------------+
   All the eigenvalues lie inside the unit circle.
   AR parameters satisfy stability condition.
```




```
. irf create AR2, set(myirf, replace) step(12)
(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 (*)
---------------+------------------------------------------------------------
           AR2 | arima    reHP
----------------------------------------------------------------------------
  (*) order is relevant only when model is var
```

```
. irf graph irf
```




```
. irf table irf
```

Results from AR2

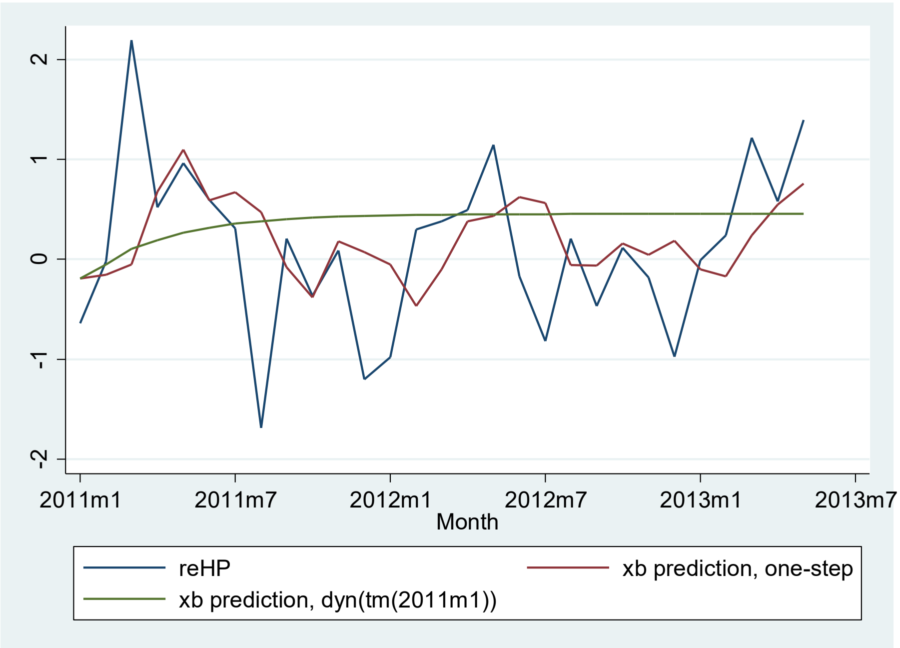
step	(1) irf	(1) Lower	(1) Upper
0	1	1	1
1	.22997	.130239	.3297
2	.403718	.301934	.505502
3	.173524	.081296	.265751
4	.181542	.088293	.274792
5	.102627	.027752	.177502
6	.087292	.018908	.155676
7	.056079	.002009	.11015
8	.043521	-.002335	.089378
9	.029683	-.006318	.065684
10	.022095	-.007103	.051293
11	.015495	-.007249	.038239
12	.011315	-.00664	.02927

95% lower and upper bounds reported
(1) irfname = AR2, impulse = reHP, and response = reHP

Forecasting using an ARMA model

```
. arima reHP if Month<=tm(2010m12), arima(2,0,0)

(setting optimization to BHHH)
Iteration 0:   log likelihood = -355.03462
Iteration 1:   log likelihood = -355.02874
Iteration 2:   log likelihood = -355.02815
Iteration 3:   log likelihood = -355.02809
Iteration 4:   log likelihood = -355.02808
```

```
ARIMA regression

Sample:  1991m2 - 2010m12                      Number of obs      =        239
                                               Wald chi2(2)       =      73.84
Log likelihood = -355.0281                     Prob > chi2        =     0.0000

------------------------------------------------------------------------------
             |                 OPG
        reHP |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
reHP         |
       _cons |   .4540309   .1702274     2.67   0.008     .1203913    .7876704
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |   .2255672   .0535307     4.21   0.000      .120649    .3304854
         L2. |   .3631374   .0516035     7.04   0.000     .2619963    .4642784
-------------+----------------------------------------------------------------
      /sigma |    1.06785   .0460784    23.17   0.000     .9775385    1.158163
------------------------------------------------------------------------------
Note: The test of the variance against zero is one sided, and the two-sided
      confidence interval is truncated at zero.

. predict reHP_fstatic, xb
. predict reHP_fdynamic, xb dynamic(tm(2011m1))

. twoway (tsline reHP) (tsline reHP_fstatic) (tsline reHP_fdynamic) if
  Month>tm(2010m12)
```



■

Example 2: We will examine whether there are lead-lag relationships between the returns to three exchange rates against the US dollar: the euro, the British pound and the Japanese yen. The data are daily and run from 7 July 2002 to 6 June 2013, giving a total of 3,988 observations. The data are contained in Stata data file `currencies.dta`. The programming code is given in Stata Do file `currencies-commands-l18.do`.

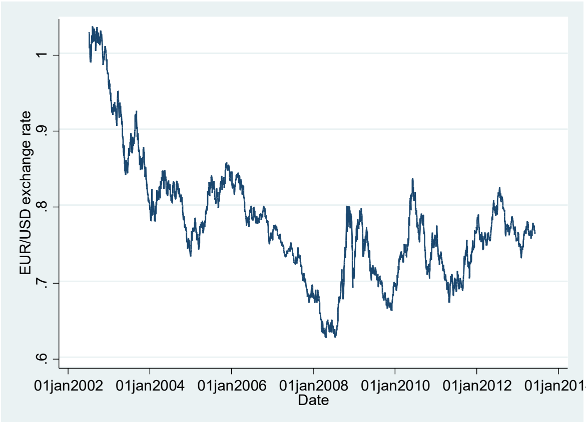
a) Inspect the three time series visually. Do they look stationary? Perform the Dickey-Fuller GLS test (DFGLS) on each of the three time series. What do you find?
b) Construct a set of continuously compounded percentage returns (percentage changes). Check for stationarity of the newly generated time series. What do you find?
c) Now, we will focus on a vector autoregressive (VAR) model based on the returns to three exchange rates. Choose the optimal lag length based on multivariate information criteria and estimate the suggested VAR model. Interpret the Stata output, but keep in mind that because the construction of these models is usually not based on economic or financial theory, it is often best not to interpret the individual parameter estimates, but rather to examine the plausibility of the model as a whole, and to determine whether it describes the data well and produces accurate forecasts.
d) After fitting a VAR model, one hypothesis of interest is that all the variables at a given lag are jointly zero. In order to test this hypothesis, perform the Wald lag-exclusion tests for different lag orders. What do you find?
e) Check for stability of the chosen model by examining roots of the companion matrix (whether the eigenvalues lie inside the unit circle). What do you find?
f) Check for residual autocorrelation of at least the first two lag orders with an appropriate Lagrange-multiplier (LM) test. What do you find?
g) Run Granger causality Wald tests and figure out whether the "excluded" variable Granger-causes the "equation" variable. Do you find evidence of lead-lag interactions between the series? Which exchange rate reacts the fastest to market information?
h) Obtain the impulse responses (IRs), orthogonalised impulse responses (OIRs) and forecast-error variance decompositions (FEVDs) for the estimated model. Interpret the results. Could these results have been expected based on previous results?
i) Remember that the ordering of variables has an effect on the impulse responses and variance decompositions, and when, as in this case, theory does not suggest an obvious ordering of the series, sensitivity analysis should be undertaken. Reverse the ordering of variables and compare the new results with the initial ones. What do you find?
j) Finally, employ the estimated VAR model in order to compute dynamic forecasts of the returns to three exchange rates for the following 20 days. Present the forecasts graphically, together with 95% confidence intervals.

Computer printout of the results in Stata:

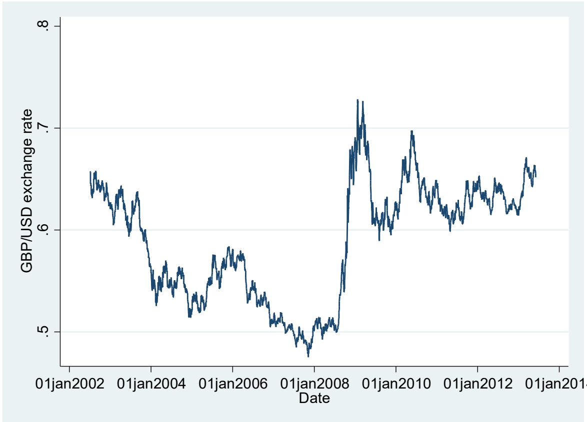
Data exploration

```
. tsset Date
        time variable:  Date, 07jul2002 to 06jun2013
                delta:  1 day
```

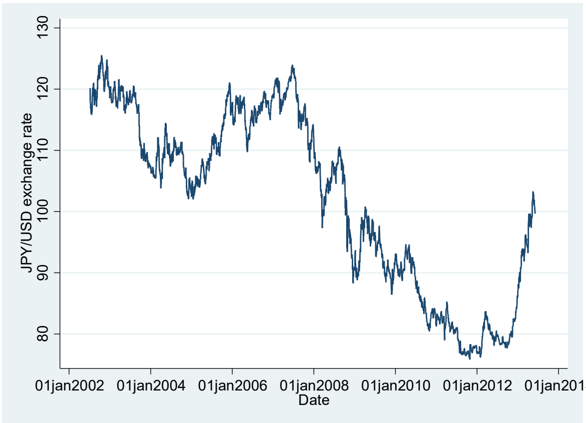
```
. twoway line EUR Date
```




```
. twoway line GBP Date
```




```
. twoway line JPY Date
```



Performing the Dickey-Fuller GLS test

```
. dfgls EUR, maxlag(5)

DF-GLS for EUR                                          Number of obs =   3982

               DF-GLS tau      1% Critical        5% Critical        10% Critical
  [lags]     Test Statistic        Value              Value              Value
------------------------------------------------------------------------------
    5           -0.985            -3.480             -2.841             -2.554
    4           -0.960            -3.480             -2.842             -2.554
    3           -1.000            -3.480             -2.842             -2.554
    2           -1.016            -3.480             -2.842             -2.554
    1           -1.026            -3.480             -2.843             -2.555

Opt Lag (Ng-Perron seq t) =  1 with RMSE  .0037332
Min SC   = -11.17684 at lag  1 with RMSE  .0037332
Min MAIC = -11.17997 at lag  1 with RMSE  .0037332

. dfgls GBP, maxlag(5)

DF-GLS for GBP                                          Number of obs =   3982

               DF-GLS tau      1% Critical        5% Critical        10% Critical
  [lags]     Test Statistic        Value              Value              Value
------------------------------------------------------------------------------
    5           -1.185            -3.480             -2.841             -2.554
    4           -1.204            -3.480             -2.842             -2.554
```

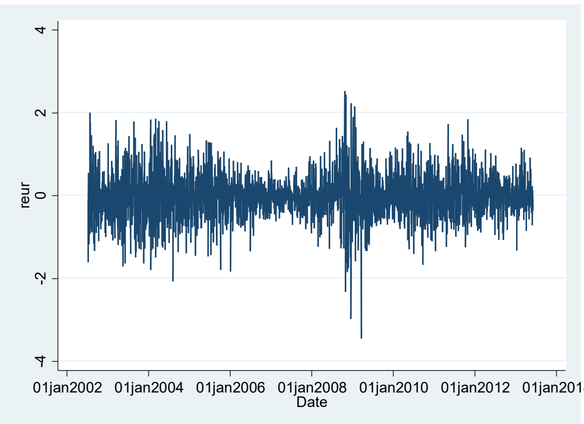
```
     3             -1.237           -3.480            -2.842            -2.554
     2             -1.223           -3.480            -2.842            -2.554
     1             -1.306           -3.480            -2.843            -2.555

Opt Lag (Ng-Perron seq t) =  2 with RMSE   .002617
Min SC   = -11.88519 at lag  2 with RMSE   .002617
Min MAIC = -11.88968 at lag  2 with RMSE   .002617
```

```
. dfgls JPY, maxlag(5)

DF-GLS for JPY                                        Number of obs =   3982

               DF-GLS tau      1% Critical       5% Critical      10% Critical
  [lags]     Test Statistic        Value             Value             Value
------------------------------------------------------------------------------
     5             -1.625           -3.480            -2.841            -2.554
     4             -1.644           -3.480            -2.842            -2.554
     3             -1.771           -3.480            -2.842            -2.554
     2             -1.788           -3.480            -2.842            -2.554
     1             -1.764           -3.480            -2.843            -2.555

Opt Lag (Ng-Perron seq t) =  4 with RMSE  .4787147
Min SC   =  -1.46636 at lag  1 with RMSE    .47938
Min MAIC = -1.469925 at lag  4 with RMSE  .4787147
```

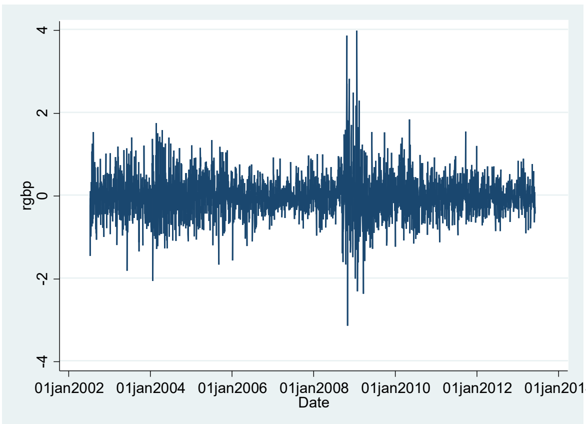
Generating continuously compounded percentage returns (percentage changes) and repeating the Dickey-Fuller GLS test

```
. generate reur=100*(ln(EUR/L.EUR))
(1 missing value generated)

. generate rgbp=100*(ln(GBP/L.GBP))
(1 missing value generated)

. generate rjpy=100*(ln(JPY/L.JPY))
(1 missing value generated)
```

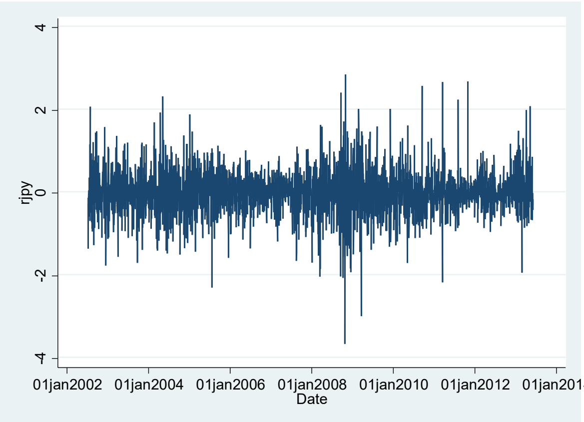
. twoway line reur Date



. twoway line rgbp Date



```
. twoway line rjpy Date
```




```
. dfgls reur, maxlag(5)

DF-GLS for reur                                          Number of obs =   3981

               DF-GLS tau      1% Critical       5% Critical      10% Critical
  [lags]     Test Statistic        Value             Value             Value
------------------------------------------------------------------------------
    5           -24.487           -3.480            -2.841            -2.554
    4           -26.944           -3.480            -2.842            -2.554
    3           -30.815           -3.480            -2.842            -2.554
    2           -34.634           -3.480            -2.842            -2.554
    1           -41.158           -3.480            -2.843            -2.555

Opt Lag (Ng-Perron seq t) =  4 with RMSE  .4722431
Min SC   = -1.495368 at lag  1 with RMSE  .4724769
Min MAIC = -.0863627 at lag  5 with RMSE  .4722112

. dfgls rgbp, maxlag(5)

DF-GLS for rgbp                                          Number of obs =   3981

               DF-GLS tau      1% Critical       5% Critical      10% Critical
  [lags]     Test Statistic        Value             Value             Value
------------------------------------------------------------------------------
    5           -25.393           -3.480            -2.841            -2.554
    4           -27.246           -3.480            -2.842            -2.554
    3           -30.256           -3.480            -2.842            -2.554
    2           -33.928           -3.480            -2.842            -2.554
    1           -40.914           -3.480            -2.843            -2.555

Opt Lag (Ng-Perron seq t) =  1 with RMSE  .4333588
Min SC   = -1.668214 at lag  1 with RMSE  .4333588
Min MAIC = -.3197095 at lag  2 with RMSE  .4333307

. dfgls rjpy, maxlag(5)

DF-GLS for rjpy                                          Number of obs =   3981

               DF-GLS tau      1% Critical       5% Critical      10% Critical
  [lags]     Test Statistic        Value             Value             Value
------------------------------------------------------------------------------
    5           -24.263           -3.480            -2.841            -2.554
    4           -27.220           -3.480            -2.842            -2.554
    3           -30.605           -3.480            -2.842            -2.554
    2           -33.610           -3.480            -2.842            -2.554
    1           -40.031           -3.480            -2.843            -2.555
```

```
Opt Lag (Ng-Perron seq t) =  5 with RMSE  .4701428
Min SC   = -1.503243 at lag  1 with RMSE  .4706203
Min MAIC = -.1675009 at lag  5 with RMSE  .4701428
```

Estimating a VAR model

. varsoc reur rgbp rjpy, maxlag(10)

```
   Selection-order criteria
   Sample:  18jul2002 - 06jun2013               Number of obs      =      3977
  +---------------------------------------------------------------------------+
  |lag |    LL      LR      df    p      FPE       AIC      HQIC      SBIC    |
  |----+----------------------------------------------------------------------|
  |  0 | -6324.33                      .004836   3.18196   3.18364   3.18671  |
  |  1 | -6060.26  528.13    9  0.000  .004254   3.05369   3.06042   3.07266* |
  |  2 | -6034.87  50.784    9  0.000  .004219*  3.04545*  3.05722*  3.07865  |
  |  3 | -6030.96  7.8286    9  0.552   .00423     3.048   3.06482   3.09544  |
  |  4 | -6022.94   16.04    9  0.066  .004232    3.0485   3.07036   3.11016  |
  |  5 | -6015.11  15.655    9  0.074  .004234   3.04909     3.076   3.12498  |
  |  6 | -6009.17  11.881    9  0.220  .004241   3.05063   3.08258   3.14075  |
  |  7 | -6000.17  17.998*   9  0.035  .004241   3.05063   3.08763   3.15498  |
  |  8 | -5992.97  14.408    9  0.109  .004245   3.05153   3.09358   3.17012  |
  |  9 | -5988.13  9.6673    9  0.378  .004254   3.05362   3.10072   3.18644  |
  | 10 | -5984.25  7.7658    9  0.558  .004264    3.0562   3.10834   3.20325  |
  +---------------------------------------------------------------------------+
   Endogenous:  reur rgbp rjpy
    Exogenous:  _cons
```

. var reur rgbp rjpy, lags(1/2)

```
Vector autoregression

Sample:  10jul2002 - 06jun2013                      Number of obs     =      3,985
Log likelihood =   -6043.54                         AIC               =   3.043684
FPE            =   .0042115                         HQIC              =   3.055437
Det(Sigma_ml)  =   .0041673                         SBIC              =   3.076832

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
reur                  7     .470301   0.0255   104.1884   0.0000
rgbp                  7     .430566   0.0522   219.6704   0.0000
rjpy                  7     .466151   0.0243   99.23658   0.0000
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
reur         |
        reur |
         L1. |   .2001552   .0226876     8.82   0.000     .1556883    .2446221
         L2. |  -.0334134   .0225992    -1.48   0.139     -.077707    .0108802
             |
        rgbp |
         L1. |  -.0615658   .0240862    -2.56   0.011    -.1087738   -.0143578
         L2. |    .024656   .0240581     1.02   0.305    -.0224971    .0718091
             |
        rjpy |
         L1. |  -.0201509   .0166431    -1.21   0.226    -.0527707    .0124689
         L2. |    .002628   .0166676     0.16   0.875    -.0300398    .0352958
             |
       _cons |  -.0058355   .0074464    -0.78   0.433    -.0204301    .0087591
-------------+----------------------------------------------------------------
```

```
rgbp         |
        reur |
         L1. |  -.0427769   .0207708    -2.06   0.039    -.0834868   -.0020669
         L2. |   .0567707   .0206898     2.74   0.006     .0162194     .097322
             |
        rgbp |
         L1. |   .2616429   .0220512    11.87   0.000     .2184234    .3048623
         L2. |  -.0920986   .0220255    -4.18   0.000    -.1352678   -.0489294
             |
        rjpy |
         L1. |  -.0566386   .0152369    -3.72   0.000    -.0865024   -.0267747
         L2. |   .0029643   .0152593     0.19   0.846    -.0269435    .0328721
             |
       _cons |   .0000454   .0068172     0.01   0.995    -.0133161    .0134069
-------------+----------------------------------------------------------------
rjpy         |
        reur |
         L1. |   .0241862   .0224874     1.08   0.282    -.0198883    .0682607
         L2. |  -.0313338   .0223997    -1.40   0.162    -.0752365    .0125689
             |
        rgbp |
         L1. |  -.0679786   .0238736    -2.85   0.004    -.1147701   -.0211872
         L2. |   .0324034   .0238458     1.36   0.174    -.0143336    .0791404
             |
        rjpy |
         L1. |   .1508446   .0164962     9.14   0.000     .1185127    .1831766
         L2. |   .0007184   .0165205     0.04   0.965    -.0316611    .0330979
             |
       _cons |  -.0036822   .0073807    -0.50   0.618    -.0181481    .0107836
------------------------------------------------------------------------------
```

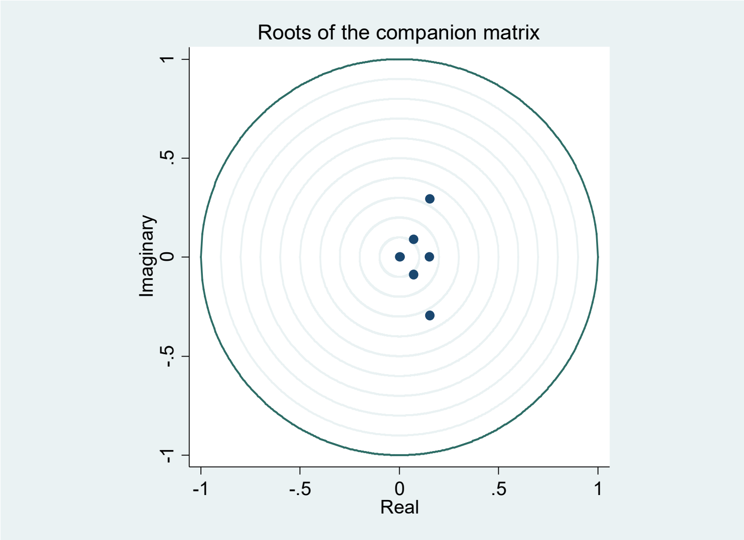
VAR model diagnostics

. varwle

```
   Equation: reur
  +--------------------------------------+
  | lag |    chi2      df   Prob > chi2  |
  |-----+--------------------------------|
  |   1 |  104.0216     3     0.000      |
  |   2 |  2.222079     3     0.528      |
  +--------------------------------------+

   Equation: rgbp
  +--------------------------------------+
  | lag |    chi2      df   Prob > chi2  |
  |-----+--------------------------------|
  |   1 |   214.893     3     0.000      |
  |   2 |  17.60756     3     0.001      |
  +--------------------------------------+

   Equation: rjpy
  +--------------------------------------+
  | lag |    chi2      df   Prob > chi2  |
  |-----+--------------------------------|
  |   1 |  95.98737     3     0.000      |
  |   2 |  2.298777     3     0.513      |
  +--------------------------------------+

   Equation: All
  +--------------------------------------+
  | lag |    chi2      df   Prob > chi2  |
  |-----+--------------------------------|
  |   1 |  592.6466     9     0.000      |
```

```
|   2 |   51.14752      9      0.000     |
+----------------------------------------+
```

```
. varstable, graph

   Eigenvalue stability condition
  +----------------------------------------+
  |        Eigenvalue         |   Modulus   |
  |---------------------------+-------------|
  |   .1556644 +   .2942196i  |   .332861   |
  |   .1556644 -   .2942196i  |   .332861   |
  |   .1531685                |   .153168   |
  |  .07266967 + .08855483i   |   .114555   |
  |  .07266967 - .08855483i   |   .114555   |
  |  .00280605                |   .002806   |
  +----------------------------------------+
   All the eigenvalues lie inside the unit circle.
   VAR satisfies stability condition.
```




```
. varlmar

   Lagrange-multiplier test
  +--------------------------------------+
  | lag  |      chi2    df   Prob > chi2 |
  |------+-------------------------------|
  |   1  |    6.8459     9      0.65316  |
  |   2  |    9.7778     9      0.36877  |
  +--------------------------------------+
   H0: no autocorrelation at lag order
```

Performing Granger causality tests

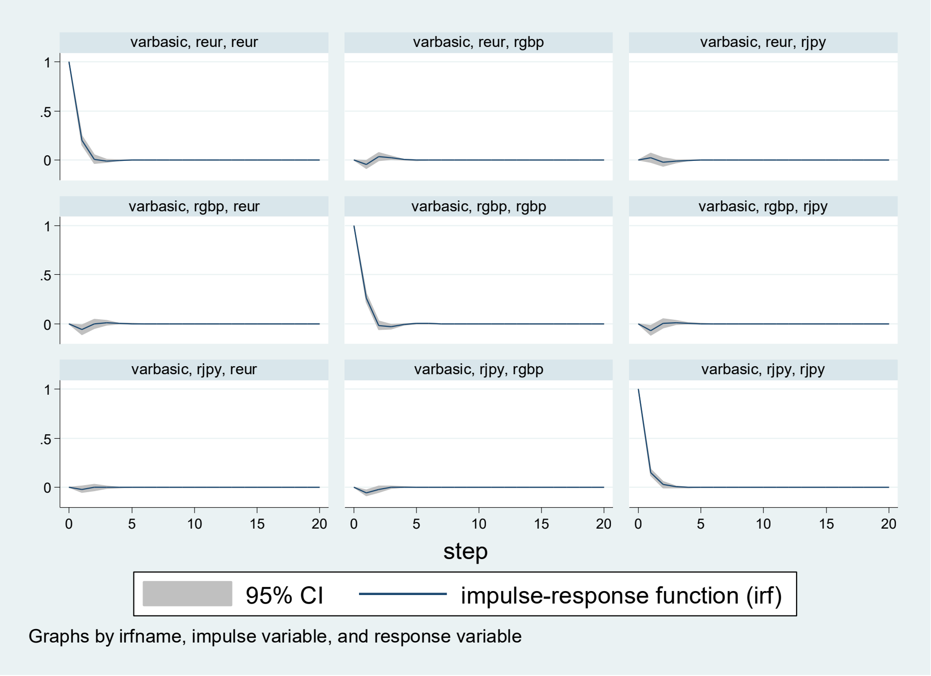
```
. vargranger

   Granger causality Wald tests
  +------------------------------------------------------------------+
  |          Equation           Excluded |   chi2     df Prob > chi2 |
  |--------------------------------------+---------------------------|
  |              reur               rgbp |  6.6529     2    0.036    |
  |              reur               rjpy |  1.4668     2    0.480    |
  |              reur                ALL |  7.9253     4    0.094    |
  |--------------------------------------+---------------------------|
  |              rgbp               reur |  9.8352     2    0.007    |
```

```
  |           rgbp              rjpy |  13.963     2    0.001    |
  |           rgbp               ALL |  28.095     4    0.000    |
  |----------------------------------+--------------------------|
  |           rjpy              reur |  2.5974     2    0.273    |
  |           rjpy              rgbp |  8.4808     2    0.014    |
  |           rjpy               ALL |  10.905     4    0.028    |
  +-------------------------------------------------------------+
```

Impulse responses and variance decompositions for 20 time periods (days)

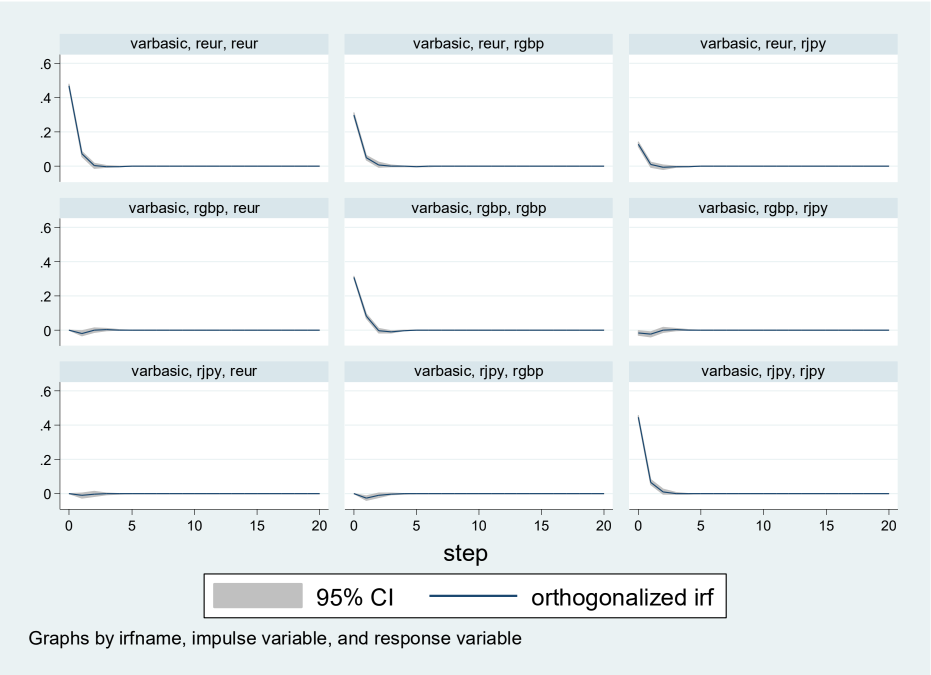
```
. varbasic reur rgbp rjpy, lags(1/2) step(20) irf
  // Impulse response functions, IRFs //

Vector autoregression

Sample:  10jul2002 - 06jun2013                  Number of obs     =      3,985
Log likelihood =   -6043.54                     AIC               =   3.043684
FPE            =   .0042115                     HQIC              =   3.055437
Det(Sigma_ml)  =   .0041673                     SBIC              =   3.076832

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
reur                  7     .470301   0.0255   104.1884   0.0000
rgbp                  7     .430566   0.0522   219.6704   0.0000
rjpy                  7     .466151   0.0243   99.23658   0.0000
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
reur         |
        reur |
         L1. |   .2001552   .0226876     8.82   0.000     .1556883    .2446221
         L2. |  -.0334134   .0225992    -1.48   0.139     -.077707    .0108802
             |
        rgbp |
         L1. |  -.0615658   .0240862    -2.56   0.011    -.1087738   -.0143578
         L2. |    .024656   .0240581     1.02   0.305    -.0224971    .0718091
             |
        rjpy |
         L1. |  -.0201509   .0166431    -1.21   0.226    -.0527707    .0124689
         L2. |    .002628   .0166676     0.16   0.875    -.0300398    .0352958
             |
       _cons |  -.0058355   .0074464    -0.78   0.433    -.0204301    .0087591
-------------+----------------------------------------------------------------
rgbp         |
        reur |
         L1. |  -.0427769   .0207708    -2.06   0.039    -.0834868   -.0020669
         L2. |   .0567707   .0206898     2.74   0.006     .0162194     .097322
             |
        rgbp |
         L1. |   .2616429   .0220512    11.87   0.000     .2184234    .3048623
         L2. |  -.0920986   .0220255    -4.18   0.000    -.1352678   -.0489294
             |
        rjpy |
         L1. |  -.0566386   .0152369    -3.72   0.000    -.0865024   -.0267747
         L2. |   .0029643   .0152593     0.19   0.846    -.0269435    .0328721
             |
       _cons |   .0000454   .0068172     0.01   0.995    -.0133161    .0134069
-------------+----------------------------------------------------------------
rjpy         |
        reur |
         L1. |   .0241862   .0224874     1.08   0.282    -.0198883    .0682607
         L2. |  -.0313338   .0223997    -1.40   0.162    -.0752365    .0125689
```

```
             |
        rgbp |
         L1. |  -.0679786   .0238736    -2.85   0.004    -.1147701   -.0211872
         L2. |   .0324034   .0238458     1.36   0.174    -.0143336    .0791404
             |
        rjpy |
         L1. |   .1508446   .0164962     9.14   0.000     .1185127    .1831766
         L2. |   .0007184   .0165205     0.04   0.965    -.0316611    .0330979
             |
       _cons |  -.0036822   .0073807    -0.50   0.618    -.0181481    .0107836
------------------------------------------------------------------------------
```

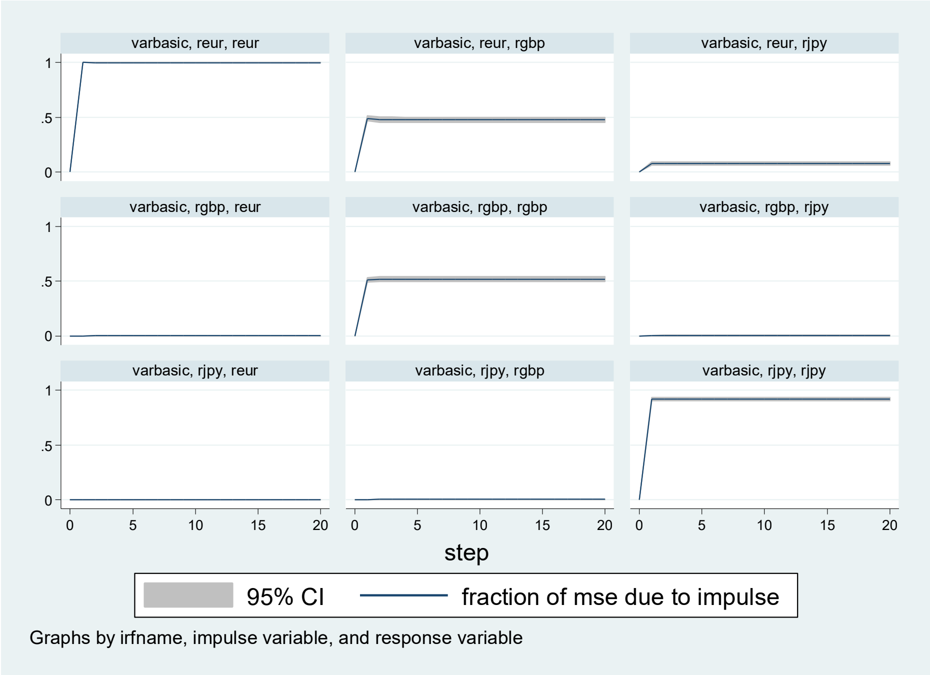



```
. varbasic reur rgbp rjpy, lags(1/2) step(20)
  // Orthogonalised impulse response functions, OIRFs //

Vector autoregression

Sample:  10jul2002 - 06jun2013                  Number of obs     =      3,985
Log likelihood =  -6043.54                      AIC               =   3.043684
FPE            =  .0042115                      HQIC              =   3.055437
Det(Sigma_ml)  =  .0041673                      SBIC              =   3.076832

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
reur                  7     .470301   0.0255   104.1884   0.0000
rgbp                  7     .430566   0.0522   219.6704   0.0000
rjpy                  7     .466151   0.0243   99.23658   0.0000
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
reur         |
        reur |
         L1. |   .2001552   .0226876     8.82   0.000     .1556883    .2446221
         L2. |  -.0334134   .0225992    -1.48   0.139     -.077707    .0108802
             |
        rgbp |
         L1. |  -.0615658   .0240862    -2.56   0.011    -.1087738   -.0143578
         L2. |    .024656   .0240581     1.02   0.305    -.0224971    .0718091
```

rjpy						
L1.	-.0201509	.0166431	-1.21	0.226	-.0527707	.0124689
L2.	.002628	.0166676	0.16	0.875	-.0300398	.0352958
_cons	-.0058355	.0074464	-0.78	0.433	-.0204301	.0087591
rgbp						
reur						
L1.	-.0427769	.0207708	-2.06	0.039	-.0834868	-.0020669
L2.	.0567707	.0206898	2.74	0.006	.0162194	.097322
rgbp						
L1.	.2616429	.0220512	11.87	0.000	.2184234	.3048623
L2.	-.0920986	.0220255	-4.18	0.000	-.1352678	-.0489294
rjpy						
L1.	-.0566386	.0152369	-3.72	0.000	-.0865024	-.0267747
L2.	.0029643	.0152593	0.19	0.846	-.0269435	.0328721
_cons	.0000454	.0068172	0.01	0.995	-.0133161	.0134069
rjpy						
reur						
L1.	.0241862	.0224874	1.08	0.282	-.0198883	.0682607
L2.	-.0313338	.0223997	-1.40	0.162	-.0752365	.0125689
rgbp						
L1.	-.0679786	.0238736	-2.85	0.004	-.1147701	-.0211872
L2.	.0324034	.0238458	1.36	0.174	-.0143336	.0791404
rjpy						
L1.	.1508446	.0164962	9.14	0.000	.1185127	.1831766
L2.	.0007184	.0165205	0.04	0.965	-.0316611	.0330979
_cons	-.0036822	.0073807	-0.50	0.618	-.0181481	.0107836

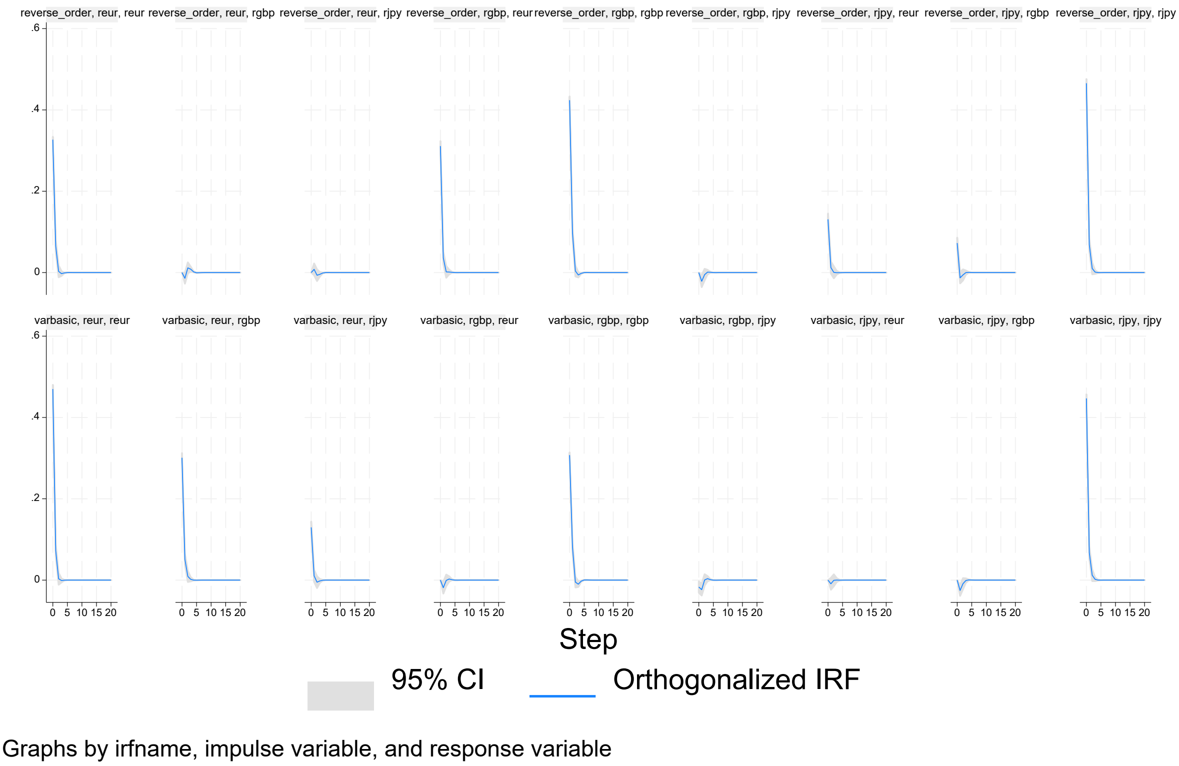


```
. varbasic reur rgbp rjpy, lags(1/2) step(20) fevd
  // Forecast-error variance decompositions, FEVDs //

Vector autoregression

Sample:  10jul2002 - 06jun2013                  Number of obs     =      3,985
Log likelihood =   -6043.54                     AIC               =   3.043684
FPE            =   .0042115                     HQIC              =   3.055437
Det(Sigma_ml)  =   .0041673                     SBIC              =   3.076832

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
reur                 7     .470301   0.0255   104.1884   0.0000
rgbp                 7     .430566   0.0522   219.6704   0.0000
rjpy                 7     .466151   0.0243   99.23658   0.0000
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
reur         |
        reur |
         L1. |   .2001552   .0226876     8.82   0.000     .1556883    .2446221
         L2. |  -.0334134   .0225992    -1.48   0.139     -.077707    .0108802
             |
        rgbp |
         L1. |  -.0615658   .0240862    -2.56   0.011    -.1087738   -.0143578
         L2. |    .024656   .0240581     1.02   0.305    -.0224971    .0718091
             |
        rjpy |
         L1. |  -.0201509   .0166431    -1.21   0.226    -.0527707    .0124689
         L2. |    .002628   .0166676     0.16   0.875    -.0300398    .0352958
             |
       _cons |  -.0058355   .0074464    -0.78   0.433    -.0204301    .0087591
-------------+----------------------------------------------------------------
rgbp         |
        reur |
         L1. |  -.0427769   .0207708    -2.06   0.039    -.0834868   -.0020669
         L2. |   .0567707   .0206898     2.74   0.006     .0162194     .097322
             |
        rgbp |
         L1. |   .2616429   .0220512    11.87   0.000     .2184234    .3048623
         L2. |  -.0920986   .0220255    -4.18   0.000    -.1352678   -.0489294
             |
        rjpy |
         L1. |  -.0566386   .0152369    -3.72   0.000    -.0865024   -.0267747
         L2. |   .0029643   .0152593     0.19   0.846    -.0269435    .0328721
             |
       _cons |   .0000454   .0068172     0.01   0.995    -.0133161    .0134069
-------------+----------------------------------------------------------------
rjpy         |
        reur |
         L1. |   .0241862   .0224874     1.08   0.282    -.0198883    .0682607
         L2. |  -.0313338   .0223997    -1.40   0.162    -.0752365    .0125689
             |
        rgbp |
         L1. |  -.0679786   .0238736    -2.85   0.004    -.1147701   -.0211872
         L2. |   .0324034   .0238458     1.36   0.174    -.0143336    .0791404
             |
        rjpy |
         L1. |   .1508446   .0164962     9.14   0.000     .1185127    .1831766
         L2. |   .0007184   .0165205     0.04   0.965    -.0316611    .0330979
             |
       _cons |  -.0036822   .0073807    -0.50   0.618    -.0181481    .0107836
------------------------------------------------------------------------------
```

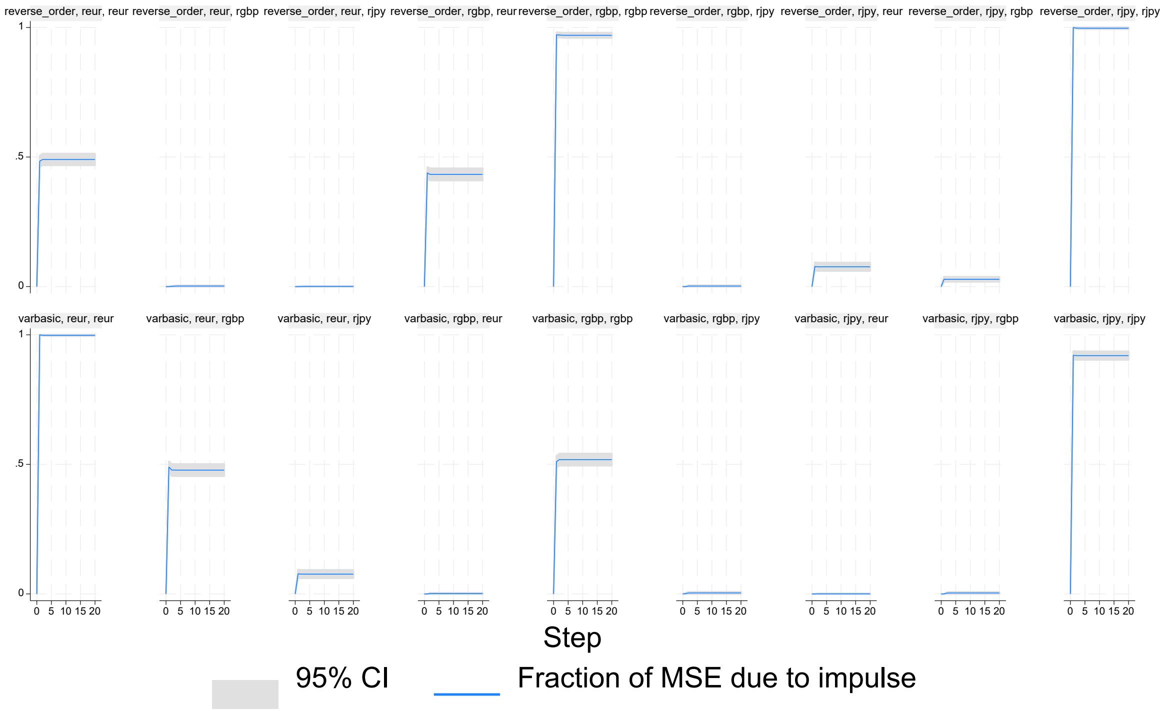


Changing the ordering of variables

```
. irf create reverse_order, replace step(20) order(rjpy rgbp reur)
irfname reverse_order not found in _varbasic.irf
(file _varbasic.irf updated)

. irf graph oirf, byopts(c(9))
```



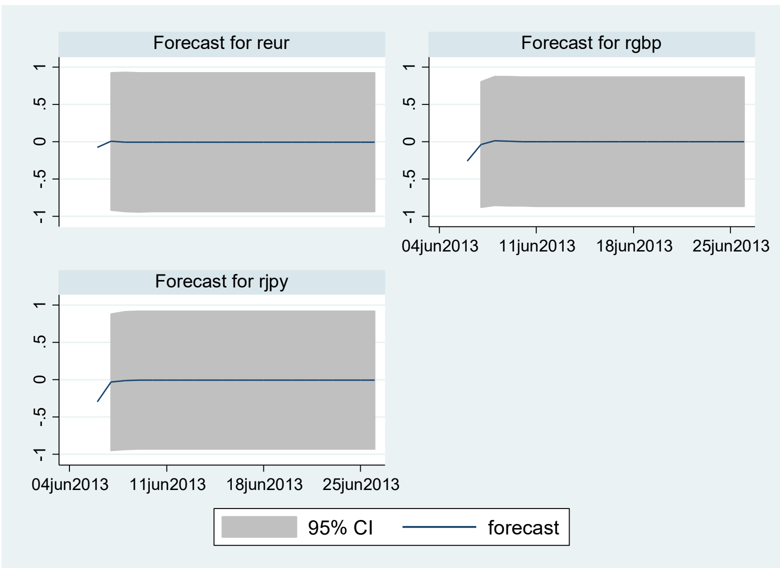
```
. irf graph fevd, byopts(c(9))
```



Graphs by irfname, impulse variable, and response variable

Forecasting based on VAR(2) for the following 20 time periods (days)

```
. qui var reur rgbp rjpy, lags(1/2)

. fcast compute fc_, step(20)
  // generates level, lower bound, upper bound, and std error //

. fcast graph fc_reur fc_rgbp fc_rjpy
```



■