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EE435: Assignment 9

1. Perform unit root test of series y and x.

```
. dfuller y, trend lag(1) regress

Augmented Dickey-Fuller test for unit root         Number of obs   =       498

                              ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)              1.000            -3.980            -3.420            -3.130
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 1.0000

------------------------------------------------------------------------------
D.y          |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           y |
         L1. |   .0001178   .0001179     1.00   0.318    -.0001137    .0003494
         LD. |   .6997015   .0248993    28.10   0.000     .6507799    .7486231
      _trend |   2.897751   1.159296     2.50   0.013      .619992    5.175511
       _cons |   1811.233   147.0426    12.32   0.000     1522.327    2100.139
------------------------------------------------------------------------------
```

To perform the unit root test, the hypothesis test is H_o $\beta 1 = 1$. The result shows that p-value=1 which is higher than o.o5. Then, the null hypothesis of unit root is accepted at 95% level of significance. Hence, the series of y are non-stationary at I(0).

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

Augmented Dickey-Fuller test for unit root         Number of obs   =       497

                              ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)            -10.554            -3.980            -3.420            -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. |  -.2787856   .0264156   -10.55   0.000    -.3306866   -.2268845
         LD. |    -.32127   .0373756    -8.60   0.000    -.3947051   -.2478349
      _trend |   3.631984   .3708318     9.79   0.000     2.903379     4.36059
       _cons |   1678.082   154.4788    10.86   0.000     1374.564      1981.6
------------------------------------------------------------------------------
```

Since the series of y is non-stationary, we need to further perform the test whether the variables are integrated at level 1, I(1) or not. H_o: H_o: $\gamma = 0$. The result shows that p-value=0 which is lower than o.o5. Then, the null hypothesis of unit root is rejected at 95% level of significance. Hence, the series of y are integrated at level 1.

```
. dfuller x, trend lag(1) regress

Augmented Dickey-Fuller test for unit root         Number of obs   =       498

                              ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)              0.601            -3.980            -3.420            -3.130
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.9970

------------------------------------------------------------------------------
D.x          |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           x |
         L1. |   .0001061   .0001764     0.60   0.548    -.0002405    .0004526
         LD. |     .46018   .0349881    13.15   0.000     .3914361    .5289239
      _trend |   4.166909    1.14105     3.65   0.000     1.924999    6.408818
       _cons |   2128.626   140.0551    15.20   0.000     1853.449    2403.803
------------------------------------------------------------------------------
```

To perform the unit root test, the hypothesis test is H_o $\beta 1 = 1$. The result shows that MacKinnon approximate p-value = 0.997 which is higher than o.o5. Then, the null hypothesis of unit root is accepted at 95% level of significance. Hence, the series of x are non-stationary at I(0).

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

Augmented Dickey-Fuller test for unit root         Number of obs   =       497

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)            -10.657            -3.980            -3.420            -3.130
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
D2.x         |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         D.x |
         L1. |  -.4007114   .0376021   -10.66   0.000    -.4745915   -.3268312
         LD. |   -.414172   .0358603   -11.55   0.000    -.4846298   -.3437141
      _trend |   3.508317   .3506567    10.00   0.000     2.819351    4.197283
       _cons |   1596.429   147.0971    10.85   0.000     1307.415    1885.444
------------------------------------------------------------------------------
```

Since the series of x is non-stationary, we need to further perform the test whether the variables are integrated at level 1, I(1) or not. H_o: $\gamma = 0$. The result shows that p-value=0 which is lower than o.o5. Then, the null hypothesis of unit root is rejected at 95% level of significance. Hence, the series of x are integrated at level 1.

2. Perform cointegration test of series *y* and *x* using set up of (i) linear trend; (ii) restricted trend; (iii) unrestricted constant; (iv) restricted constant; and (v) no trend, with one lag term.

<u>Linear trend</u>

```
. vecrank y x, trend(t) lags(1) max

                       Johansen tests for cointegration
Trend: trend                                            Number of obs =     499
Sample:  2 - 500                                                 Lags =       1
-------------------------------------------------------------------------------
                                                         5%
maximum                                      trace    critical
  rank    parms       LL       eigenvalue  statistic    value
    0       4     -7387.4577           .    790.3357    18.17
    1       7     -6992.3441     0.79477      0.1085*    3.74
    2       8     -6992.2899     0.00022
-------------------------------------------------------------------------------
                                                         5%
maximum                                        max    critical
  rank    parms       LL       eigenvalue  statistic    value
    0       4     -7387.4577           .    790.2272    16.87
    1       7     -6992.3441     0.79477      0.1085     3.74
    2       8     -6992.2899     0.00022
-------------------------------------------------------------------------------
```

1. H_o: r = 0 Ha: r>=1
2. H_o : r = 1 Ha: r>=2

Since the trace statistic of rank 0 (790.3357) is higher than the critical value (18.17), the null hypothesis is rejected. Then, in rank1, the trace statistic (0.1085) is lower than the critical value (3.74). The null hypothesis is accepted at 95% level of significance. Rank is 1

<u>Restricted trend</u>

```
. vecrank y x, trend(rt) lag(1/1) max

                       Johansen tests for cointegration
Trend: rtrend                                           Number of obs =     499
Sample:  2 - 500                                                 Lags =       1
-------------------------------------------------------------------------------
                                                         5%
maximum                                      trace    critical
  rank    parms       LL       eigenvalue  statistic    value
    0       2     -8050.4781           .   2116.3764    25.32
    1       6     -7075.2453     0.97993    165.9107    12.25
    2       8     -6992.2899     0.28286
-------------------------------------------------------------------------------
                                                         5%
maximum                                        max    critical
  rank    parms       LL       eigenvalue  statistic    value
    0       2     -8050.4781           .   1950.4657    18.96
    1       6     -7075.2453     0.97993    165.9107    12.52
    2       8     -6992.2899     0.28286
-------------------------------------------------------------------------------
```

Since the trace statistic of rank 0 (2116.3764) is higher than the critical value (25.32), the null hypothesis is rejected. Then, in rank1, the trace statistic (165.9107) is higher than the critical value (12.25). The null hypothesis is rejected at 95% level of significance. Rank is 2

Unrestricted constant

```
. vecrank y x, trend(c) lags(1/1) max

                        Johansen tests for cointegration
Trend: constant                                        Number of obs =      499
Sample:  2 - 500                                                Lags =        1
-------------------------------------------------------------------------------
                                                               5%
maximum                                           trace     critical
  rank    parms       LL        eigenvalue   statistic     value
    0       2     -8050.4781            .     2086.8946     15.41
    1       5     -7083.8611      0.97923      153.6607      3.76
    2       6     -7007.0308      0.26504
-------------------------------------------------------------------------------
                                                               5%
maximum                                             max     critical
  rank    parms       LL        eigenvalue   statistic     value
    0       2     -8050.4781            .     1933.2339     14.07
    1       5     -7083.8611      0.97923      153.6607      3.76
    2       6     -7007.0308      0.26504
-------------------------------------------------------------------------------
```

Since the trace statistic of rank 0 (2086.8946) is higher than the critical value (15.41), the null hypothesis is rejected. Then, in rank1, the trace statistic (153.6607) is higher than the critical value (3.765). The null hypothesis is rejected at 95% level of significance. Rank is 2

Restricted constant

```
. vecrank y x, trend(rc) lags(1/1) max

                        Johansen tests for cointegration
Trend: rconstant                                       Number of obs =      499
Sample:  2 - 500                                                Lags =        1
-------------------------------------------------------------------------------
                                                               5%
maximum                                           trace     critical
  rank    parms       LL        eigenvalue   statistic     value
    0       0     -8811.3759            .     3607.1930     19.96
    1       4     -7092.1887      0.99898      168.8185      9.42
    2       6     -7007.7794      0.28703
-------------------------------------------------------------------------------
                                                               5%
maximum                                             max     critical
  rank    parms       LL        eigenvalue   statistic     value
    0       0     -8811.3759            .     3438.3745     15.67
    1       4     -7092.1887      0.99898      168.8185      9.24
    2       6     -7007.7794      0.28703
-------------------------------------------------------------------------------
```

Since the trace statistic of rank 0 (3607.1930) is higher than the critical value (19.96), the null hypothesis is rejected. Then, in rank1, the trace statistic (168.8185) is higher than the critical value (9.42). The null hypothesis is rejected at 95% level of significance. Rank is 2

No trend

```
. vecrank y x, trend(n) lags(1/1) max

                        Johansen tests for cointegration
Trend: none                                            Number of obs =      499
Sample:  2 - 500                                                Lags =        1
-------------------------------------------------------------------------------
                                                               5%
maximum                                           trace     critical
  rank    parms       LL        eigenvalue   statistic     value
    0       0     -8811.3759            .     3204.1194     12.53
    1       3     -7211.7592      0.99836        4.8860      3.84
    2       4     -7209.3162      0.00974
-------------------------------------------------------------------------------
                                                               5%
maximum                                             max     critical
  rank    parms       LL        eigenvalue   statistic     value
    0       0     -8811.3759            .     3199.2334     11.44
    1       3     -7211.7592      0.99836        4.8860      3.84
    2       4     -7209.3162      0.00974
-------------------------------------------------------------------------------
```

Since the trace statistic of rank 0 (3204.1194) is higher than the critical value (12.53), the null hypothesis is rejected. Then, in rank1, the trace statistic (4.886) is higher than the critical value (3.84). The null hypothesis is rejected at 95% level of significance. Rank is 2

3. Perform cointegration test of series y and x using set up of linear trend with (i) one lag term; (ii) two lag terms; and (iii) three lag terms.

Linear trend with 1 lag term

```
. vecrank y x, trend(t) lags(1) max

                      Johansen tests for cointegration
Trend: trend                                         Number of obs =     499
Sample:  2 - 500                                              Lags =       1
-------------------------------------------------------------------------------
                                                          5%
maximum                                      trace    critical
  rank    parms       LL       eigenvalue  statistic    value
    0      4     -7387.4577          .      790.3357    18.17
    1      7     -6992.3441     0.79477       0.1085*    3.74
    2      8     -6992.2899     0.00022
-------------------------------------------------------------------------------
                                                          5%
maximum                                       max     critical
  rank    parms       LL       eigenvalue  statistic    value
    0      4     -7387.4577          .      790.2272    16.87
    1      7     -6992.3441     0.79477       0.1085     3.74
    2      8     -6992.2899     0.00022
-------------------------------------------------------------------------------
```

Linear trend with 2 lag terms

```
. vecrank y x, trend(t) lags(2) max

                      Johansen tests for cointegration
Trend: trend                                         Number of obs =     498
Sample:  3 - 500                                              Lags =       2
-------------------------------------------------------------------------------
                                                          5%
maximum                                      trace    critical
  rank    parms       LL       eigenvalue  statistic    value
    0      8     -6795.5337          .      187.5771    18.17
    1     11     -6703.3826     0.30932       3.2749*    3.74
    2     12     -6701.7451     0.00655
-------------------------------------------------------------------------------
                                                          5%
maximum                                       max     critical
  rank    parms       LL       eigenvalue  statistic    value
    0      8     -6795.5337          .      184.3022    16.87
    1     11     -6703.3826     0.30932       3.2749     3.74
    2     12     -6701.7451     0.00655
-------------------------------------------------------------------------------
```

Linear trend with 3 lag terms

```
. vecrank y x, trend(t) lags(3) max

                      Johansen tests for cointegration
Trend: trend                                         Number of obs =     497
Sample:  4 - 500                                              Lags =       3
-------------------------------------------------------------------------------
                                                          5%
maximum                                      trace    critical
  rank    parms       LL       eigenvalue  statistic    value
    0     12      -6756.658          .      140.0434    18.17
    1     15      -6688.113     0.24106       2.9534*    3.74
    2     16     -6686.6363     0.00592
-------------------------------------------------------------------------------
                                                          5%
maximum                                       max     critical
  rank    parms       LL       eigenvalue  statistic    value
    0     12      -6756.658          .      137.0900    16.87
    1     15      -6688.113     0.24106       2.9534     3.74
    2     16     -6686.6363     0.00592
-------------------------------------------------------------------------------
```

4. From (2) & (3), determine the most appropriated set up and make the conclusion of the test whether *y* and *x* are cointegrated series? If yes, how many cointegrating Equations.

   1. H_o: r = 0 Ha: r>=1

   2. H_o : r = 1 Ha: r>=2

   With one lag term, since the trace statistic of rank 0 (790.3357) is higher than the critical value (18.17), the null hypothesis is rejected. Then, in rank1, the trace statistic (0.1085) is lower than the critical value (3.74). The null hypothesis is accepted at 95% level of significance. The rank is 1 with 1 lag term. Thus, all variables are stationary. There is no cointegrating equation because of the integrating VAR at 0.

   With two lag terms, since the trace statistic of rank 0 (187.5771) is higher than the critical value (18.17), the null hypothesis is rejected. Then, in rank1, the trace statistic (3.2749) is lower than the critical value (3.74). The null hypothesis is accepted at 95% level of significance. The rank is 1 with 2 lags term. Thus, the cointegrating equation exists and at most 1.

   With three lag terms, since the trace statistic of rank 0 (140.0434) is higher than the critical value (18.17), the null hypothesis is rejected. Then, in rank1, the trace statistic (2.9534) is lower than the critical value (3.74). The null hypothesis is accepted at 95% level of significance. The rank is 1 with 3 lags term. Thus, the cointegrating equation exists and at most 1.

5. Estimated VECM models of *y* and *x* using (i) one lag term; (ii) two lag terms; and (iii) three lag terms. Determine the optimal lags. Specify cointegrating equation and speed of adjustment parameters.

   From the data, the overall test for cointegrated equations is significant at 95% level since all P>chi2 values (0.00) is less than 0.05, indicating the cointegrated relationship.

   To determine the optimal lag, we need to consider the SBIC value. The optimal lag is 3 since it has the lowest SBIC of 27.23459.

   Cointegrating equation: $y_t = \beta 0 + \beta_1 x1$. From, $y_t - 1.50049x_t - 92.13439 = 0$

   Then, $y_t = 92.13439 + 1.50049x_t$ is the cointegrating equation for for lag-3 model

   The speed of adjustment parameters of y is -0.3193909 and x is 0.4434064 in the 3-lag model.

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One lag term

```
. vec y x, lags(1)

Vector error-correction model

Sample:  2 - 500                                Number of obs     =        499
                                                AIC               =   28.41227
Log likelihood = -7083.861                      HQIC              =   28.42883
Det(Sigma_ml)  =  7.34e+09                      SBIC              =   28.45448

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
D_y                  2     331.479   0.9988   399343.6   0.0000
D_x                  2     430.726   0.9953   105050.2   0.0000
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
D_y          |
        _ce1 |
         L1. |  -1.303404   .0095397  -136.63   0.000    -1.322102   -1.284707
             |
       _cons |   -107.843   69.40373    -1.55   0.120    -243.8718    28.18583
-------------+----------------------------------------------------------------
D_x          |
        _ce1 |
         L1. |  -.8364345   .0123959   -67.48   0.000    -.8607301    -.812139
             |
       _cons |   168.0502    90.1839     1.86   0.062    -8.706965    344.8074
------------------------------------------------------------------------------
```

```
Cointegrating equations

Equation           Parms    chi2     P>chi2
-------------------------------------------
_ce1                 1   1.71e+10   0.0000
-------------------------------------------

Identification:  beta is exactly identified

                 Johansen normalization restriction imposed
------------------------------------------------------------------------------
        beta |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
_ce1         |
           y |          1          .        .       .            .           .
           x |  -1.500508   .0000115 -1.3e+05   0.000    -1.500531   -1.500486
       _cons |  -1678.204          .        .       .            .           .
------------------------------------------------------------------------------
```

Two lag terms

```
. vec y x, lags(2)

Vector error-correction model

Sample:  3 - 500                                Number of obs     =        498
                                                AIC               =   27.18032
Log likelihood = -6758.899                      HQIC              =   27.21018
Det(Sigma_ml)  =  2.11e+09                      SBIC              =   27.25641

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
D_y                  4     213.415   0.9995   964110.3   0.0000
D_x                  4     263.876   0.9982   280728.2   0.0000
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
D_y          |
        _ce1 |
         L1. |   -.427199   .0483639    -8.83   0.000    -.5219905   -.3324075
             |
           y |
         LD. |   .4022605   .0224005    17.96   0.000     .3583563    .4461646
             |
           x |
         LD. |   .4814843   .0598769     8.04   0.000     .3641276    .5988409
             |
       _cons |   171.4547   44.03061     3.89   0.000     85.15624    257.7531
-------------+----------------------------------------------------------------
D_x          |
        _ce1 |
         L1. |   .2903827   .0597995     4.86   0.000     .1731779    .4075875
             |
           y |
         LD. |   .5734396   .0276971    20.70   0.000     .5191544    .6277249
             |
           x |
         LD. |   .3676105   .0740347     4.97   0.000     .2225051    .5127159
             |
       _cons |    252.237   54.44157     4.63   0.000     145.5335    358.9405
------------------------------------------------------------------------------
```

```
Cointegrating equations

Equation           Parms    chi2     P>chi2
-------------------------------------------
_ce1                 1   8.09e+08   0.0000
-------------------------------------------

Identification:  beta is exactly identified

                 Johansen normalization restriction imposed
------------------------------------------------------------------------------
        beta |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
_ce1         |
           y |          1          .        .       .            .           .
           x |  -1.500176   .0000527 -2.8e+04   0.000     -1.50028   -1.500073
       _cons |  -577.9622          .        .       .            .           .
------------------------------------------------------------------------------
```

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Three lag terms

```
. vec y x, lags(3)

Vector error-correction model

Sample:  4 - 500                                Number of obs     =        497
                                                AIC               =    27.1245
Log likelihood = -6727.439                      HQIC              =   27.16771
Det(Sigma_ml)  =  1.96e+09                      SBIC              =   27.23459

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
D_y                  6     211.673   0.9995   980003.4   0.0000
D_x                  6     253.098   0.9984   305162.2   0.0000
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
D_y          |
         _ce1 |
          L1. |  -.3193909    .058155    -5.49   0.000    -.4333726   -.2054092
             |
            y |
          LD. |   .3553209   .0559202     6.35   0.000     .2457194    .4649225
         L2D. |   .0174858   .0312998     0.56   0.576    -.0438607    .0788323
             |
            x |
          LD. |   .6042668   .0763396     7.92   0.000     .4546439    .7538896
         L2D. |   .0521968   .0634683     0.82   0.411    -.0721988    .1765925
             |
        _cons |   181.5838   45.38519     4.00   0.000     92.63049    270.5372
-------------+----------------------------------------------------------------
D_x          |
         _ce1 |
          L1. |   .4434064   .0695359     6.38   0.000     .3071185    .5796943
             |
            y |
          LD. |   .4713427   .0668638     7.05   0.000     .3402922    .6023932
         L2D. |    .012763   .0374252     0.34   0.733     -.060589    .0861151
             |
            x |
          LD. |   .5220109   .0912792     5.72   0.000     .3431069     .700915
         L2D. |   .0911602   .0758891     1.20   0.230    -.0575797    .2399001
             |
        _cons |    130.797   54.26707     2.41   0.016     24.43548    237.1585
------------------------------------------------------------------------------

Cointegrating equations

Equation           Parms    chi2     P>chi2
-------------------------------------------
_ce1                 1   6.64e+08   0.0000
-------------------------------------------

Identification:  beta is exactly identified

                 Johansen normalization restriction imposed
------------------------------------------------------------------------------
        beta |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
_ce1         |
           y |          1          .        .       .            .           .
           x |  -1.500049   .0000582 -2.6e+04   0.000    -1.500163   -1.499935
       _cons |  -92.13439          .        .       .            .           .
------------------------------------------------------------------------------
```