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

```
. dfuller y, trend lags(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
------------------------------------------------------------------------------

. dfuller x, trend lags(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
------------------------------------------------------------------------------
. dfuller d.y, trend lags(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
------------------------------------------------------------------------------

. dfuller d.x, trend lags(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
```

From the Dickey-fuller unit root test, both x and y are non-stationary and the series are stationary at first difference I~(1) because the p-value of the tests is 0.00 which less than 0.05.

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

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

. vecrank y x, trend(rt) lags(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
-------------------------------------------------------------------------------

. 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
-------------------------------------------------------------------------------

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

                       Johansen tests for cointegration
Trend: rconstant                                        Number of obs =     499
Sample:  2 - 500                                                 Lags =       1
-------------------------------------------------------------------------------
```

Chitphatsorn Sitthisomprasong
6104641011

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

. 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           .   3204.1193    12.53
    1       3     -7211.7592     0.99836      4.8860     3.84
    2       4     -7209.3163     0.00974
-------------------------------------------------------------------------------
                                                       5%
maximum                                     max     critical
  rank    parms       LL       eigenvalue  statistic    value
    0       0     -8811.3759           .   3199.2333    11.44
    1       3     -7211.7592     0.99836      4.8860     3.84
    2       4     -7209.3163     0.00974
-------------------------------------------------------------------------------
```

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.

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

```
. 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
-------------------------------------------------------------------------------

. 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
-------------------------------------------------------------------------------
```

For the linear trend model with one lag term, we rejected model with rank 0 ($H_0: r = 0$) because the critical value is higher than statistic test (790.3357 > 18.17), hence we continue to rank one test ($H_0: r = 1$). We failed to reject the model with rank1 with a critical value equal to 0.185 (< 3.74), therefore there is one cointegration equation.

From the linear trend model with two lag terms, we rejected model with rank 0 ($H_0: r = 1$) because the critical value is higher (187.5771 > 18.17), so we continue to rank one test ($H_0: r = 1$). We failed to reject the model with rank1 with a critical value equal to 3.2749 (< 3.74), hence there is one cointegration equation.

Chitphatsorn Sitthisomprasong
6104641011

For the linear trend model with three lag terms, we rejected model with rank 0 ($H_0: r = 0$)since the critical value is higher (140.0434 > 18.17), so we continue to rank one test ($H_1: r = 0$). We failed to reject the model with rank1 with a critical value equal to 2.9534 (< 3.74), therefore there is one cointegration equation.

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.**

From (2) & (3), y and x are cointegrated series since the rank of the matrix is not 0, and there is 1 cointegrating equation from the maximum rank equal to 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.**

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

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    -8.706964    344.8074
------------------------------------------------------------------------------

Cointegrating equations

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

Chitphatsorn Sitthisomprasong
6104641011

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

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          .        .       .            .           .
------------------------------------------------------------------------------

. 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 |   171.4546   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
```

Chitphatsorn Sitthisomprasong
6104641011

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

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          .        .       .            .           .
------------------------------------------------------------------------------

. 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 |
```

Chitphatsorn Sitthisomprasong
6104641011

```
         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          .        .       .            .           .
------------------------------------------------------------------------------
```

Because the model with the number of lag equal to 3 has the lowest SBIC, the most appropriated model is model with 3 lag term. The cointegrating equation is $y = 1.500049x + 92.13439$, and the speed of adjustment parameter: $\delta_1 = -.3193909\ and\ \delta_2 = .4434064$