Problem Set 4

Thao Duong

**Question 1:**

1. Basic OLS regression:

Source | SS df MS Number of obs = 30

-------------+---------------------------------- F(4, 25) = 91.54

Model | 5.42774163 4 1.35693541 Prob > F = 0.0000

Residual | .370572985 25 .014822919 R-squared = 0.9361

-------------+---------------------------------- Adj R-squared = 0.9259

Total | 5.79831462 29 .199941883 Root MSE = .12175

------------------------------------------------------------------------------

lnC | Coef. Std. Err. t P>|t| [95% Conf. Interval]

-------------+----------------------------------------------------------------

lnI | .4675086 .1659868 2.82 0.009 .1256524 .8093647

lnL | .2794423 .1147258 2.44 0.022 .0431602 .5157244

lnH | -.0051515 .142947 -0.04 0.972 -.2995564 .2892534

lnA | .4414491 .1065083 4.14 0.000 .222091 .6608071

\_cons | -1.500441 1.00302 -1.50 0.147 -3.5662 .5653184

-------------------------------------------------------------------------------

Interpretation: We estimate that

* 1% increase in the twelve-month average index of industrial production will lead to .468% increase in the average U.S. domestic price of copper, controlling for all other factors.
* 1% increase in the twelve-month average London metal exchange price of copper will lead to .279% increase in the average U.S. domestic price of copper, controlling for all other factors.
* 1% increase in the number of housing starts per year will lead to .005% decrease in the average U.S. domestic price of copper, controlling for all other factors.
* 1% increase in the twelve-month average price of aluminum will lead to .441% increase in the average U.S. domestic price of copper, controlling for all other factors.

1. Diagnose the presentation of autocorrelation (AR1)

* Calculate the correlation coefficient between the current and lagged residuals:

Source | SS df MS Number of obs = 29

-------------+---------------------------------- F(5, 23) = 1.91

Model | .108318574 5 .021663715 Prob > F = 0.1317

Residual | .260921678 23 .011344421 R-squared = 0.2934

-------------+---------------------------------- Adj R-squared = 0.1397

Total | .369240252 28 .013187152 Root MSE = .10651

------------------------------------------------------------------------------

ehat | Coef. Std. Err. t P>|t| [95% Conf. Interval]

-------------+----------------------------------------------------------------

lnI | -.0950496 .1570796 -0.61 0.551 -.4199936 .2298944

lnL | .0848892 .1067305 0.80 0.435 -.1358997 .3056782

lnH | .0419316 .127108 0.33 0.744 -.2210114 .3048746

lnA | -.0099235 .0932328 -0.11 0.916 -.2027902 .1829432

|

ehat |

L1. | .565019 .1830605 3.09 0.005 .1863294 .9437085

|

\_cons | -.360735 .8863072 -0.41 0.688 -2.194201 1.472731

------------------------------------------------------------------------------

* Construct the correlogram of the residuals:



There is sign of autocorrelation in the first lag.

Test for autocorrelation:

Ho: no autocorrelation;

Ha: there’s autocorrelation

* Manually conduct the Lagrange Multiplier test:

LM = T\*R2 = 8.507

p-value = 0.0353724 < 0.05 => there is enough evidence to reject the null hypothesis. We conclude that there is sign of auto correlation.

* Confirm with the automated Breusch-Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 8.841 1 0.0029

2 | 13.507 2 0.0012

3 | 13.707 3 0.0033

4 | 13.754 4 0.0081

5 | 14.273 5 0.0140

---------------------------------------------------------------------------

H0: no serial correlation

Breusch-Godfrey test also confirms that there is enough evidence to reject the null hypothesis. We conclude that there is sign of auto-correlation.

1. Estimate the model using HAC (Newey-West) standard errors.

Lag = 3

Regression with Newey-West standard errors Number of obs = 30

maximum lag: 3 F( 4, 25) = 147.59

Prob > F = 0.0000

------------------------------------------------------------------------------

| Newey-West

lnC | Coef. Std. Err. t P>|t| [95% Conf. Interval]

-------------+----------------------------------------------------------------

lnI | .4675086 .1741095 2.69 0.013 .1089233 .8260938

lnL | .2794423 .0983982 2.84 0.009 .0767874 .4820972

lnH | -.0051515 .1828855 -0.03 0.978 -.3818113 .3715083

lnA | .4414491 .1419226 3.11 0.005 .149154 .7337442

\_cons | -1.500441 1.341943 -1.12 0.274 -4.264224 1.263343

------------------------------------------------------------------------------

This model has the same estimators with the OLS model; lnL become more significant, while lnI, lnH and lnA become less significant. P-value is slightly different because of changes in standard errors.

1. Estimate using a Cochrane-Orcutt version of this model:

Iteration 0: rho = 0.0000

Iteration 1: rho = 0.5208

Iteration 2: rho = 0.5498

Iteration 3: rho = 0.5516

Iteration 4: rho = 0.5517

Iteration 5: rho = 0.5517

Iteration 6: rho = 0.5517

Cochrane-Orcutt AR(1) regression -- iterated estimates

Source | SS df MS Number of obs = 29

-------------+---------------------------------- F(4, 24) = 28.91

Model | 1.2664022 4 .31660055 Prob > F = 0.0000

Residual | .262807364 24 .010950307 R-squared = 0.8281

-------------+---------------------------------- Adj R-squared = 0.7995

Total | 1.52920957 28 .054614627 Root MSE = .10464

------------------------------------------------------------------------------

lnC | Coef. Std. Err. t P>|t| [95% Conf. Interval]

-------------+----------------------------------------------------------------

lnI | .391466 .2345944 1.67 0.108 -.0927131 .875645

lnL | .3424147 .1135776 3.01 0.006 .108002 .5768273

lnH | -.0518594 .1428745 -0.36 0.720 -.3467379 .2430192

lnA | .4562252 .1562551 2.92 0.008 .1337305 .77872

\_cons | -1.249471 1.095323 -1.14 0.265 -3.510107 1.011164

-------------+----------------------------------------------------------------

rho | .5517068

------------------------------------------------------------------------------

Durbin-Watson statistic (original) 0.954940

Durbin-Watson statistic (transformed) 1.477441

Estimate using a Prais-Winsten version of this model:

Iteration 0: rho = 0.0000

Iteration 1: rho = 0.5208

Iteration 2: rho = 0.5524

Iteration 3: rho = 0.5544

Iteration 4: rho = 0.5546

Iteration 5: rho = 0.5546

Iteration 6: rho = 0.5546

Prais-Winsten AR(1) regression -- iterated estimates

Source | SS df MS Number of obs = 30

-------------+---------------------------------- F(4, 25) = 47.20

Model | 1.98794605 4 .496986512 Prob > F = 0.0000

Residual | .263228321 25 .010529133 R-squared = 0.8831

-------------+---------------------------------- Adj R-squared = 0.8644

Total | 2.25117437 29 .077626702 Root MSE = .10261

------------------------------------------------------------------------------

lnC | Coef. Std. Err. t P>|t| [95% Conf. Interval]

-------------+----------------------------------------------------------------

lnI | .3688932 .2030577 1.82 0.081 -.049312 .7870984

lnL | .3477807 .1084652 3.21 0.004 .1243923 .571169

lnH | -.0480582 .1387265 -0.35 0.732 -.3337708 .2376544

lnA | .4580408 .1534998 2.98 0.006 .141902 .7741796

\_cons | -1.211574 1.059562 -1.14 0.264 -3.393784 .9706356

-------------+----------------------------------------------------------------

rho | .5545602

------------------------------------------------------------------------------

Durbin-Watson statistic (original) 0.954940

Durbin-Watson statistic (transformed) 1.517088

The Cochrane-Orcutt and Prais-Winsten versions have different coefficients than the OLS model. At 0.10 level of significance, the OLS have lnI, lnL, and lnA statistically significant; the Cochrane-Orcutt version has only lnL and lnA statistically significant; and the Prais-Winsten version has lnI, lnL, and lnA statistically significant. Cochrane-Orcutt get rid of the first observation => lose 1 observersation. Prais-Winsten transforms the first observation => do not lose any.

**Question 2**

1. Drop the first observation and run the 4 models:

**OLS**

Source | SS df MS Number of obs = 29

-------------+---------------------------------- F(4, 24) = 81.50

Model | 5.01203897 4 1.25300974 Prob > F = 0.0000

Residual | .368995122 24 .015374797 R-squared = 0.9314

-------------+---------------------------------- Adj R-squared = 0.9200

Total | 5.38103409 28 .192179789 Root MSE = .124

------------------------------------------------------------------------------

lnC | Coef. Std. Err. t P>|t| [95% Conf. Interval]

-------------+----------------------------------------------------------------

lnI | .4852123 .1778522 2.73 0.012 .1181434 .8522813

lnL | .2718042 .1192498 2.28 0.032 .0256846 .5179237

lnH | -.011334 .1468573 -0.08 0.939 -.3144327 .2917646

lnA | .4411242 .1084777 4.07 0.000 .2172372 .6650111

\_cons | -1.488594 1.022191 -1.46 0.158 -3.598292 .6211037

------------------------------------------------------------------------------

Breusch-Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 8.857 1 0.0029

2 | 12.851 2 0.0016

3 | 12.962 3 0.0047

4 | 12.994 4 0.0113

5 | 13.530 5 0.0189

---------------------------------------------------------------------------

H0: no serial correlation

p-value < 0.05 => reject the Null hypothesis. There is sign of autocorrelation.

**ARDL(0,1)**

Source | SS df MS Number of obs = 29

-------------+---------------------------------- F(5, 23) = 64.90

Model | 5.02489636 5 1.00497927 Prob > F = 0.0000

Residual | .356137728 23 .015484249 R-squared = 0.9338

-------------+---------------------------------- Adj R-squared = 0.9194

Total | 5.38103409 28 .192179789 Root MSE = .12444

------------------------------------------------------------------------------

lnC | Coef. Std. Err. t P>|t| [95% Conf. Interval]

-------------+----------------------------------------------------------------

lnI | .588025 .2111555 2.78 0.011 .1512165 1.024833

lnL | .1797669 .1565991 1.15 0.263 -.144183 .5037168

lnH | .0452779 .1599384 0.28 0.780 -.28558 .3761358

|

lnA |

--. | .848855 .4605003 1.84 0.078 -.1037624 1.801472

L1. | -.4545938 .4988754 -0.91 0.372 -1.486596 .5774087

|

\_cons | -1.671594 1.045296 -1.60 0.123 -3.833953 .4907649

------------------------------------------------------------------------------

Breusch-Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 9.177 1 0.0025

2 | 13.105 2 0.0014

3 | 13.341 3 0.0040

4 | 13.532 4 0.0089

5 | 14.032 5 0.0154

---------------------------------------------------------------------------

p-value < 0.05 => reject the Null hypothesis. There is sign of autocorrelation.

**ARDL(1,0)**

Source | SS df MS Number of obs = 29

-------------+---------------------------------- F(5, 23) = 87.94

Model | 5.11356119 5 1.02271224 Prob > F = 0.0000

Residual | .267472902 23 .011629257 R-squared = 0.9503

-------------+---------------------------------- Adj R-squared = 0.9395

Total | 5.38103409 28 .192179789 Root MSE = .10784

------------------------------------------------------------------------------

lnC | Coef. Std. Err. t P>|t| [95% Conf. Interval]

-------------+----------------------------------------------------------------

lnC |

L1. | .4783737 .1619059 2.95 0.007 .1434458 .8133016

|

lnI | .0239165 .2197744 0.11 0.914 -.4307215 .4785546

lnL | .3543548 .1074094 3.30 0.003 .1321614 .5765481

lnH | .0877586 .1320522 0.66 0.513 -.1854123 .3609295

lnA | .1937267 .1261416 1.54 0.138 -.067217 .4546705

\_cons | -1.570403 .8894341 -1.77 0.091 -3.410338 .2695316

------------------------------------------------------------------------------

Breusch-Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 3.454 1 0.0631

2 | 5.589 2 0.0611

3 | 5.977 3 0.1127

4 | 6.223 4 0.1831

5 | 6.536 5 0.2575

---------------------------------------------------------------------------

H0: no serial correlation

p-value > 0.05 => there’s not enough evidence to reject the Null hypothesis. There is no sign of autocorrelation.

**ARDL(1,1)**

Source | SS df MS Number of obs = 29

-------------+---------------------------------- F(6, 22) = 70.59

Model | 5.11533075 6 .852555124 Prob > F = 0.0000

Residual | .265703342 22 .012077425 R-squared = 0.9506

-------------+---------------------------------- Adj R-squared = 0.9372

Total | 5.38103409 28 .192179789 Root MSE = .1099

------------------------------------------------------------------------------

lnC | Coef. Std. Err. t P>|t| [95% Conf. Interval]

-------------+----------------------------------------------------------------

lnC |

L1. | .4636319 .1694313 2.74 0.012 .1122529 .815011

|

lnI | .0772992 .2638404 0.29 0.772 -.4698724 .6244708

lnL | .3167486 .1470837 2.15 0.042 .0117158 .6217815

lnH | .1062716 .143 0.74 0.465 -.1902922 .4028354

|

lnA |

--. | .3566786 .4446952 0.80 0.431 -.5655628 1.27892

L1. | -.1731807 .4524327 -0.38 0.706 -1.111469 .7651074

|

\_cons | -1.637597 .9232528 -1.77 0.090 -3.552306 .2771121

------------------------------------------------------------------------------

Breusch-Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 4.028 1 0.0447

2 | 6.434 2 0.0401

3 | 6.624 3 0.0849

4 | 7.156 4 0.1279

5 | 7.638 5 0.1774

---------------------------------------------------------------------------

H0: no serial correlation

p-value < 0.05 => reject the Null hypothesis. There is sign of autocorrelation.

1. Compare the 4 models

--------------------------------------------------------------

Variable | OLS ARDL01 ARDL10 ARDL11

-------------+------------------------------------------------

lnI | 0.485 0.588 0.024 0.077

| 0.178 0.211 0.220 0.264

lnL | 0.272 0.180 0.354 0.317

| 0.119 0.157 0.107 0.147

lnH | -0.011 0.045 0.088 0.106

| 0.147 0.160 0.132 0.143

|

lnA |

--. | 0.441 0.849 0.194 0.357

| 0.108 0.461 0.126 0.445

L1. | -0.455 -0.173

| 0.499 0.452

|

lnC |

L1. | 0.478 0.464

| 0.162 0.169

|

\_cons | -1.489 -1.672 -1.570 -1.638

| 1.022 1.045 0.889 0.923

-------------+------------------------------------------------

N | 29 29 29 29

aic | -34.265 -33.294 **-41.597** -39.789

bic | -27.429 -25.090 **-33.393** -30.218

--------------------------------------------------------------

legend: b/se

ARDL(1,0) is the clear winner with smallest AIC and BIC/SC when compared AIC, BIC, we need to have the same number of observation.

1. There is enough evidence to suggest that OLS, ARDL(0,1) and ARDL(1,1) still have autocorrelation. Only ARDL(1,0) does not have autocorrelation.
2. Because we have to take the first lag for all the ARDL models and the first lag of the first observation is NULL, we need to drop the first observation for the original model so we can compare 4 models in similar condition.

**Question 3**

Source | SS df MS Number of obs = 28

-------------+---------------------------------- F(2, 25) = 237.60

Model | 2.74985996 2 1.37492998 Prob > F = 0.0000

Residual | .144671243 25 .00578685 R-squared = 0.9500

-------------+---------------------------------- Adj R-squared = 0.9460

Total | 2.8945312 27 .107204859 Root MSE = .07607

------------------------------------------------------------------------------

lnA | Coef. Std. Err. t P>|t| [95% Conf. Interval]

-------------+----------------------------------------------------------------

lnA |

L1. | 1.41272 .1896943 7.45 0.000 1.022038 1.803403

L2. | -.3684702 .2122495 -1.74 0.095 -.8056062 .0686659

|

\_cons | -.1174315 .1917944 -0.61 0.546 -.5124394 .2775764

------------------------------------------------------------------------------

1. Forecast lnA for three periods beyond the last period in the data:

lnAhat1 = 4.3871597

lnAhat2 = 4.5104038

lnAhat3 = 4.6379708

1. Construct the 95% interval estimates for each forecast in (a)

Standard errors:

se1 = .07607135

se2 = .13166671

se3 = .18072211

Interval estimates

lnA1L = 4.2304878; lnA1U = 4.5438316

lnA2L = 4.2392311; lnA2U = 4.7815765

lnA3L = 4.2657667; lnA3U = 5.010175

**Question 4**

1. Report the alpha using STATA

**exponential coefficient = 0.9998**

sum-of-squared residuals = .29408

root mean squared error = .099009

Forecast lnA: 4.260817



1. Forecast lnA: 4.172943



**Question 5**

1. Estimate the model: lnC = beta1 + beta2\*lnI + v

Source | SS df MS Number of obs = 30

-------------+---------------------------------- F(1, 28) = 175.94

Model | 5.002249 1 5.002249 Prob > F = 0.0000

Residual | .79606562 28 .028430915 R-squared = 0.8627

-------------+---------------------------------- Adj R-squared = 0.8578

Total | 5.79831462 29 .199941883 Root MSE = .16861

------------------------------------------------------------------------------

lnC | Coef. Std. Err. t P>|t| [95% Conf. Interval]

-------------+----------------------------------------------------------------

lnI | 1.108845 .0835956 13.26 0.000 .937607 1.280083

\_cons | -1.234715 .3748875 -3.29 0.003 -2.002637 -.4667924

------------------------------------------------------------------------------

Use LM test to test for serial correlation: Ho = no autocorrelation

LM = T\*R2 = 10.665546

p-value = .0010915 < 0.05 => there is enough evidence to reject the null hypothesis. We can conclude that there is presence of serial correlation.

1. Create graphs



lnC appears non-stationary, because their means seem to fluctuate around a linear trend. Random walk with drift (more drift than trend)

D.lnC appears non-stationary because their variance seem not to be constant over time. More likely to be stationary around the mean = 0



lnI appears non-stationary, because their means seem to fluctuate around a linear trend. Random walk with trend (smooth line)

D.lnI appears non-stationary because their variance seem not to be constant over time. More likely to be stationary around the mean = 0

c. D.lnC and D.lnI appears to have non-constant variance, which suggest that there’s presence of autocorrelation in lnI and lnC, which was proved in part a.

d. The graphs seem to match the random walk with drift – wandering and trending => we’ll use the second Dickey-Fuller test with a constant:

D.lnC = alpha + gamma\*L.lnC + v

Ho: gamma = 0 – non-stationary; H1: gamma <0 – stationary

Source | SS df MS Number of obs = 29

-------------+---------------------------------- F(1, 27) = 0.09

Model | .002179195 1 .002179195 Prob > F = 0.7609

Residual | .622637254 27 .023060639 R-squared = 0.0035

-------------+---------------------------------- Adj R-squared = -0.0334

Total | .624816449 28 .022314873 Root MSE = .15186

------------------------------------------------------------------------------

D.lnC | Coef. Std. Err. t P>|t| [95% Conf. Interval]

-------------+----------------------------------------------------------------

lnC |

L1. | -.0209518 .0681568 -0.31 0.761 -.1607981 .1188945

|

\_cons | .1301796 .253087 0.51 0.611 -.3891121 .6494712

------------------------------------------------------------------------------

Breusch-Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.018 1 0.8927

---------------------------------------------------------------------------

H0: no serial correlation

0.8927 > 0.05 =>There is no sign of autocorrelation (Breusch – Godfrey LM test)

The 5% critical value for tau is -2.86. Since -0.31 > -2.86 => we do not reject the null hypothesis. We can’t conclude that the series is stationary.

Source | SS df MS Number of obs = 29

-------------+---------------------------------- F(1, 27) = 1.47

Model | .004096528 1 .004096528 Prob > F = 0.2359

Residual | .075272112 27 .002787856 R-squared = 0.0516

-------------+---------------------------------- Adj R-squared = 0.0165

Total | .07936864 28 .002834594 Root MSE = .0528

------------------------------------------------------------------------------

D.lnI | Coef. Std. Err. t P>|t| [95% Conf. Interval]

-------------+----------------------------------------------------------------

lnI |

L1. | -.0328905 .027133 -1.21 0.236 -.0885628 .0227818

|

\_cons | .1871754 .1211771 1.54 0.134 -.0614596 .4358103

------------------------------------------------------------------------------

. estat bgodfrey

Breusch-Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.130 1 0.7181

---------------------------------------------------------------------------

H0: no serial correlation

0.7181 > 0.05 =>There is no sign of autocorrelation (Breusch – Godfrey LM test)

The 5% critical value for tau is -2.86. Since -1.21 > -2.86 => we do not reject the null hypothesis. We can’t conclude that the series is stationary.

e. ADF test with no lags: We use no constant because the means of D.lnI and D.lnC seem to fluctuate around 0.

For D.lnC:

Dickey-Fuller test for unit root Number of obs = 28

---------- Interpolated Dickey-Fuller ---------

Test 1% Critical 5% Critical 10% Critical

Statistic Value Value Value

------------------------------------------------------------------------------

Z(t) -4.598 -2.655 -1.950 -1.601

-4.598 < -1.950 => we reject the null hypothesis. We can conclude that the series is stationary.

For D.lnI:

Dickey-Fuller test for unit root Number of obs = 28

---------- Interpolated Dickey-Fuller ---------

Test 1% Critical 5% Critical 10% Critical

Statistic Value Value Value

------------------------------------------------------------------------------

Z(t) -3.979 -2.655 -1.950 -1.601

-3.979 < -1.950 => we reject the null hypothesis. We can conclude that the series is stationary.

1. Test for cointegration:

With no L.D.ehat

Source | SS df MS Number of obs = 29

-------------+---------------------------------- F(1, 28) = 5.16

Model | .093736931 1 .093736931 Prob > F = 0.0310

Residual | .508951866 28 .018176852 R-squared = 0.1555

-------------+---------------------------------- Adj R-squared = 0.1254

Total | .602688797 29 .020782372 Root MSE = .13482

------------------------------------------------------------------------------

D.ehat | Coef. Std. Err. t P>|t| [95% Conf. Interval]

-------------+----------------------------------------------------------------

ehat |

L1. | -.3675054 .1618332 -2.27 0.031 -.6990058 -.0360051

------------------------------------------------------------------------------

. estat bgodfrey

Breusch-Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 5.368 1 0.0205

---------------------------------------------------------------------------

H0: no serial correlation

0.0205 < 0.10 => reject the Null hypothesis. There is presence of autocorrelation.

Run the test with L.D.ehat

Source | SS df MS Number of obs = 28

-------------+---------------------------------- F(2, 26) = 5.52

Model | .175692904 2 .087846452 Prob > F = 0.0100

Residual | .413530493 26 .015905019 R-squared = 0.2982

-------------+---------------------------------- Adj R-squared = 0.2442

Total | .589223396 28 .021043693 Root MSE = .12612

------------------------------------------------------------------------------

D.ehat | Coef. Std. Err. t P>|t| [95% Conf. Interval]

-------------+----------------------------------------------------------------

ehat |

L1. | -.5686146 .1769605 -3.21 0.003 -.9323622 -.204867

LD. | .4477287 .1893935 2.36 0.026 .0584248 .8370327

------------------------------------------------------------------------------

. estat bgodfrey

Breusch-Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 3.190 1 0.0741

---------------------------------------------------------------------------

H0: no serial correlation

0.0741 < 0.10 => reject the Null hypothesis. There is presence of autocorrelation.

Critical value at 0.10 level of significance is -1.950.

Tau = -3.21 < - 1.950 => reject the null hypothesis. We have enough evidence to conclude that the series are cointegrated.