DSC5211C Quantitative Risk Management Workshop 5

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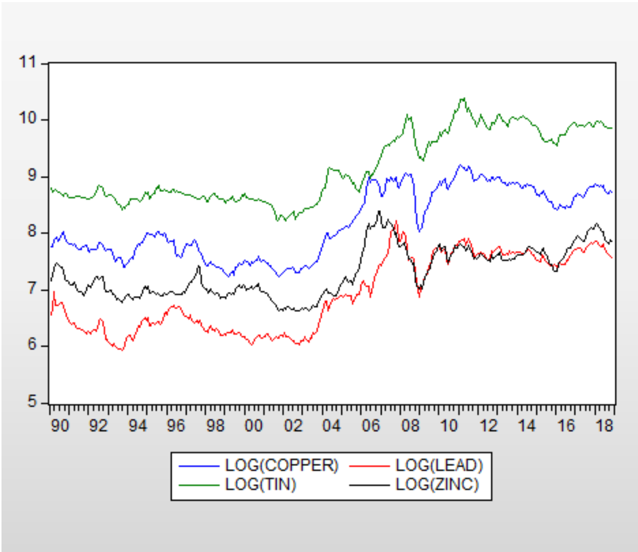
1. First, check they are non-stationary!



The prices are not stationary from the graph above. There is not a long-term mean and we see an obvious increase in 05.

2. Then, use the Johansen – Cointegration Test.

Johansen Cointegration Test

Date: 02/16/19 Time: 15:41
Sample (adjusted): 1990M03 2018M12
Included observations: 346 after adjustments
Trend assumption: No deterministic trend (restricted constant)
Series: LOG(COPPER) LOG(LEAD) LOG(TIN) LOG(ZINC)
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.078118	54.58767	54.07904	0.0450
At most 1	0.044796	26.44455	35.19275	0.3177
At most 2	0.026528	10.58727	20.26184	0.5822
At most 3	0.003706	1.284661	9.164546	0.9101

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.078118	28.14312	28.58808	0.0569
At most 1	0.044796	15.85728	22.29962	0.3085
At most 2	0.026528	9.302613	15.89210	0.4020
At most 3	0.003706	1.284661	9.164546	0.9101

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

LOG(COPPER)	LOG(LEAD)	LOG(TIN)	LOG(ZINC)	C
-2.664133	6.755345	-4.381520	-0.442444	18.44987
4.599743	-1.138564	-3.601509	0.888597	-3.114668
3.798540	1.556980	-2.014232	-5.279514	15.14970
-0.254843	0.728597	0.615509	0.310015	-11.42763

Unrestricted Adjustment Coefficients (alpha):

D(LOG(COPP...	0.006838	-0.004264	-0.001509	-0.002849
D(LOG(LEAD))	-0.004979	0.004102	-0.001740	-0.003780
D(LOG(TIN))	0.009695	0.006532	0.000283	-0.001506
D(LOG(ZINC))	0.001629	-0.000571	0.005745	-0.002782

1 Cointegrating Equation(s): Log likelihood 2192.584

Normalized cointegrating coefficients (standard error in parentheses)

LOG(COPPER)	LOG(LEAD)	LOG(TIN)	LOG(ZINC)	C
1.000000	-2.535663	1.644632	0.166074	-6.925281
	(0.45645)	(0.40814)	(0.34076)	(1.93706)

Adjustment coefficients (standard error in parentheses)

D(LOG(COPP...	-0.018218
	(0.00820)
D(LOG(LEAD))	0.013266
	(0.00982)
D(LOG(TIN))	-0.025830
	(0.00746)
D(LOG(ZINC))	-0.004341
	(0.00838)

2 Cointegrating Equation(s): Log likelihood 2200.512

Normalized cointegrating coefficients (standard error in parentheses)

LOG(COPPER)	LOG(LEAD)	LOG(TIN)	LOG(ZINC)	C
1.000000	0.000000	-1.045597	0.196117	-0.001223
		(0.17043)	(0.24422)	(1.03506)
0.000000	1.000000	-1.060957	0.011848	2.730669
		(0.10856)	(0.15556)	(0.65931)

Adjustment coefficients (standard error in parentheses)

D(LOG(COPP...	-0.037830	0.051048
	(0.01632)	(0.02104)
D(LOG(LEAD))	0.032134	-0.038308
	(0.01957)	(0.02522)
D(LOG(TIN))	0.004214	0.058059
	(0.01477)	(0.01904)
D(LOG(ZINC))	-0.006969	0.011657
	(0.01671)	(0.02154)

3 Cointegrating Equation(s): Log likelihood 2205.164

Normalized cointegrating coefficients (standard error in parentheses)

LOG(COPPER)	LOG(LEAD)	LOG(TIN)	LOG(ZINC)	C
1.000000	0.000000	0.000000	-1.554440	3.157166
			(0.22633)	(1.65523)
0.000000	1.000000	0.000000	-1.764425	5.935456
			(0.25745)	(1.88281)
0.000000	0.000000	1.000000	-1.674218	3.020657
			(0.27570)	(2.01632)

Adjustment coefficients (standard error in parentheses)

D(LOG(COPP...	-0.043561	0.048699	-0.011566
	(0.02006)	(0.02157)	(0.01848)
D(LOG(LEAD))	0.025526	-0.041016	0.010547
	(0.02404)	(0.02585)	(0.02215)
D(LOG(TIN))	0.005290	0.058500	-0.066575
	(0.01816)	(0.01953)	(0.01673)
D(LOG(ZINC))	0.014855	0.020603	-0.016654
	(0.02044)	(0.02198)	(0.01883)

What is the conclusion?

From the result, there is not cointegration equation. Because in the first row, p=0.045 is lower than the significance level so we reject the null hypothesis.

3. You decided to proceed and estimate a cointegration model with 1 cointegration equation.

Vector Error Correction Estimates

Vector Error Correction Estimates
Date: 02/16/19 Time: 15:46
Sample (adjusted): 1990M03 2018M12
Included observations: 346 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
LOG(COPPER(-1))	1.000000
LOG(LEAD(-1))	-2.535663 (0.45645) [-5.55520]
LOG(TIN(-1))	1.644632 (0.40814) [4.02953]
LOG(ZINC(-1))	0.166074 (0.34076) [0.48736]
C	-6.925281 (1.93706) [-3.57515]

From the result, we can see that LOG(ZINC(-1)) is not significant for the long-term relationship so we exclude it from our equation. The equation is shown below:

$$\text{LOG(COPPER(-1))} = 2.54 \cdot \text{LOG(LEAD(-1))} - 1.64 \cdot \text{LOG(TIN(-1))} + 6.93$$

However, the sum of coefficients is not 1.

The system of equations estimated is as follows. Interpret the result. Which prices are the main drivers? How can you improve the model?

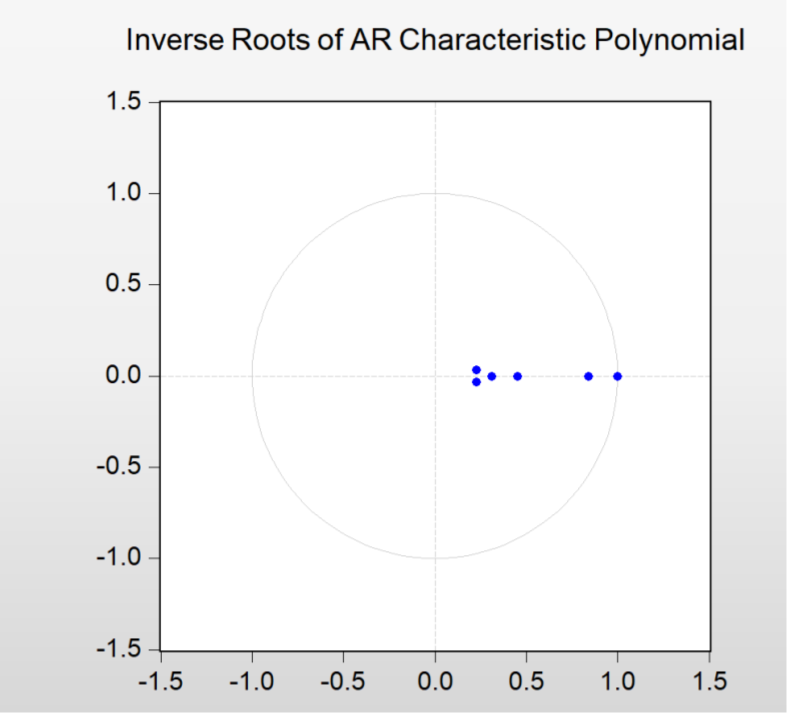
Error Correction:	D(LOG(COP...	D(LOG(LEAD))	D(LOG(TIN))	D(LOG(ZINC))
CointEq1	-0.018218 (0.00820) [-2.22041]	0.013266 (0.00982) [1.35031]	-0.025830 (0.00746) [-3.46049]	-0.004341 (0.00838) [-0.51821]
D(LOG(COPPER(-1)))	0.420624 (0.06844) [6.14621]	0.089441 (0.08195) [1.09147]	0.091521 (0.06226) [1.46997]	0.191225 (0.06987) [2.73686]
D(LOG(LEAD(-1)))	-0.089978 (0.05860) [-1.53538]	0.227445 (0.07017) [3.24128]	0.016599 (0.05331) [0.31135]	-0.052085 (0.05983) [-0.87054]
D(LOG(TIN(-1)))	-0.021968 (0.06506) [-0.33765]	-0.153571 (0.07791) [-1.97125]	0.200727 (0.05919) [3.39117]	-0.221108 (0.06643) [-3.32867]
D(LOG(ZINC(-1)))	0.032673 (0.06797) [0.48070]	0.024900 (0.08139) [0.30595]	-0.016137 (0.06184) [-0.26096]	0.303236 (0.06939) [4.36983]

From the result above, we think the variables D(LOG(TIN(-1))) and D(LOG(COPPER(-1))) are more important. Both the prices of TIN and COPPER influence the price of ZINC. Since the ZINC will not influence and will not be influenced by the long-term relationship so we will exclude ZINC from our model. We need to include the other two variables.

Error Correction:	D(LOG(COP...	D(LOG(LEAD))	D(LOG(TIN))	D(LOG(ZINC))
CointEq1	-0.022916	0.020034	-0.025251	-0.004988
	(0.01031)	(0.01214)	(0.00947)	(0.01062)
	[-2.22252]	[1.65062]	[-2.66535]	[-0.46962]
D(LOG(COPPER(-1)))	0.448480	0.106298	0.073327	0.177540
	(0.07206)	(0.08482)	(0.06621)	(0.07423)
	[6.22411]	[1.25327]	[1.10754]	[2.39167]
D(LOG(COPPER(-2)))	-0.143017	-0.111641	-0.003787	0.001596
	(0.07228)	(0.08509)	(0.06642)	(0.07447)
	[-1.97855]	[-1.31210]	[-0.05701]	[0.02143]
D(LOG(LEAD(-1)))	-0.097823	0.219139	0.026915	-0.054667
	(0.05929)	(0.06979)	(0.05448)	(0.06108)
	[-1.64992]	[3.13996]	[0.49406]	[-0.89499]
D(LOG(LEAD(-2)))	0.008355	-0.008847	0.047613	0.011454
	(0.06056)	(0.07128)	(0.05564)	(0.06239)
	[0.13797]	[-0.12412]	[0.85571]	[0.18359]
D(LOG(TIN(-1)))	-0.059336	-0.174132	0.165232	-0.248940
	(0.06734)	(0.07927)	(0.06188)	(0.06938)
	[-0.88113]	[-2.19676]	[2.67041]	[-3.58829]
D(LOG(TIN(-2)))	0.191401	0.200644	0.095623	0.135224
	(0.06828)	(0.08037)	(0.06273)	(0.07034)
	[2.80331]	[2.49652]	[1.52424]	[1.92244]
D(LOG(ZINC(-1)))	0.061559	0.029801	-0.014521	0.335260
	(0.07163)	(0.08432)	(0.06582)	(0.07380)
	[0.85937]	[0.35343]	[-0.22062]	[4.54301]
D(LOG(ZINC(-2)))	0.014934	0.037207	0.041792	-0.061302
	(0.07033)	(0.08279)	(0.06463)	(0.07246)
	[0.21232]	[0.44941]	[0.64667]	[-0.84601]
C	0.001272	0.001077	0.001946	0.000945
	(0.00306)	(0.00360)	(0.00281)	(0.00315)
	[0.41617]	[0.29930]	[0.69297]	[0.30017]

In the new model, TIN affects the prices of COPPER and LEAD. So TIN is the most important driver among the four prices.

You finally need to analyze the stability conditions to test if any of the parameters or relationship between them is explosive.

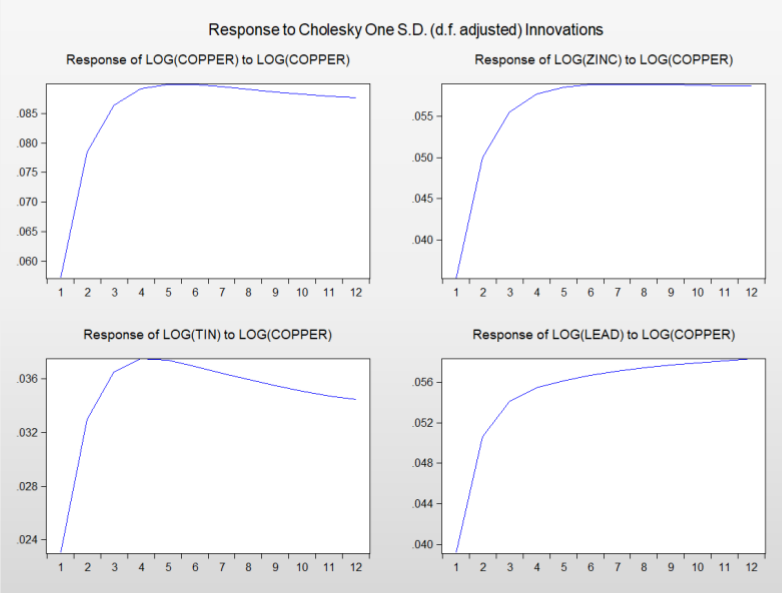


As shown in the graph above, the inverse unit roots of Z lie inside the unit circle, which means the value of Z is higher than 1. Therefore the time series does converge.

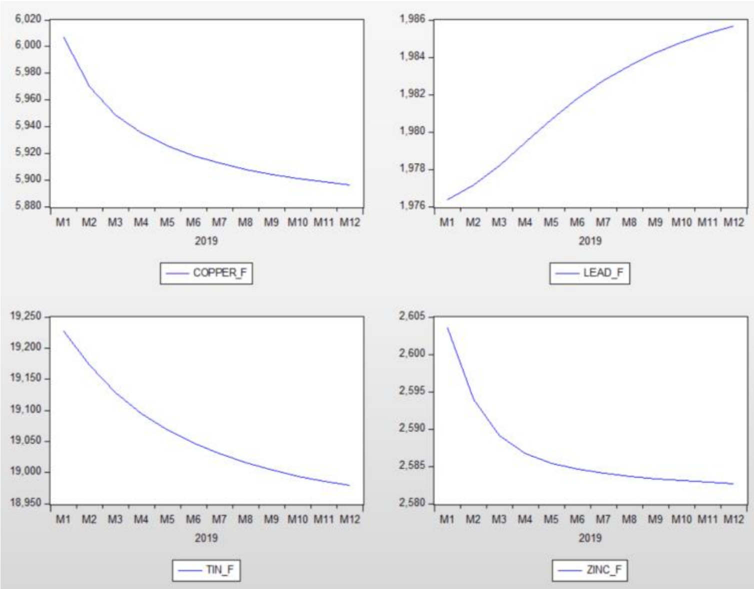
You can test the impact of an "innovation" or "shock" in one of the prices on the long-term impact of the other prices.

The vertical axis is expressed in units of the *LOG(COPPER)* variable. The solid line is a point estimate for the amount *LOG(COPPER)* is expected to change following a unit impulse after the number of periods on the horizontal axis.

For example, in the lower left graph, a one-unit price of TIN is expected to lead to a change in the price of COPPER after 5 periods.



Finally, you can test the model's forecasts. In the next figure you find the out-of-sample forecasts for 2019. What can you conclude?



From the long run, the price of COPPER, ZINC and TIN will decrease in 2019. The price of LEAD will increase.