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QRM – Workshop 5

Question 1: Quality Kitchens

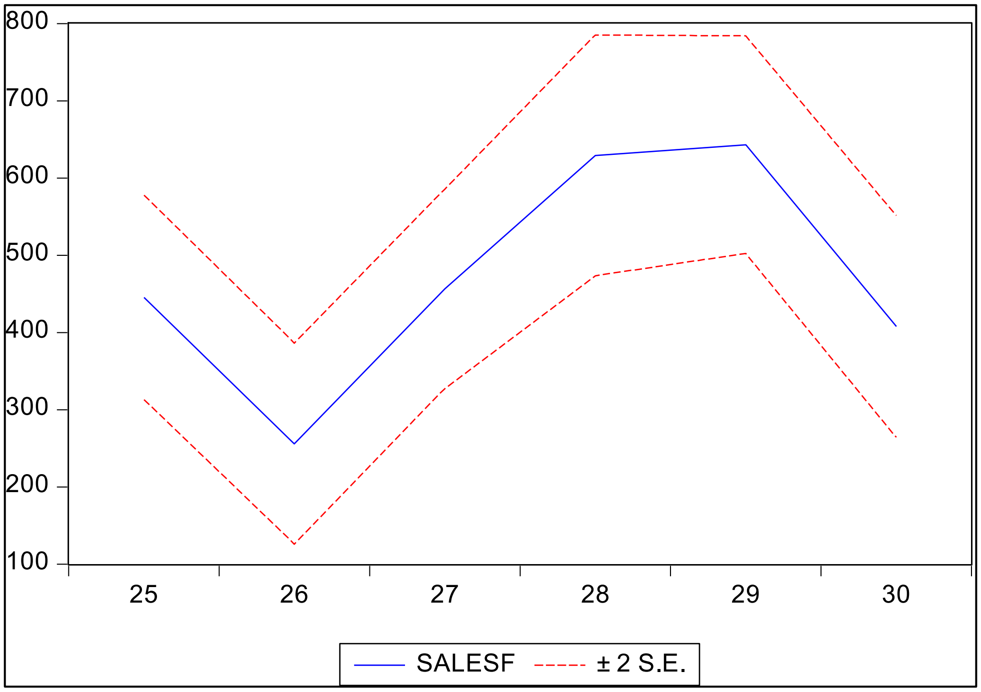
Equation estimation:

Dependent Variable: SALES
Method: Least Squares
Date: 02/15/19 Time: 12:16
Sample (adjusted): 2 20
Included observations: 19 after adjustments

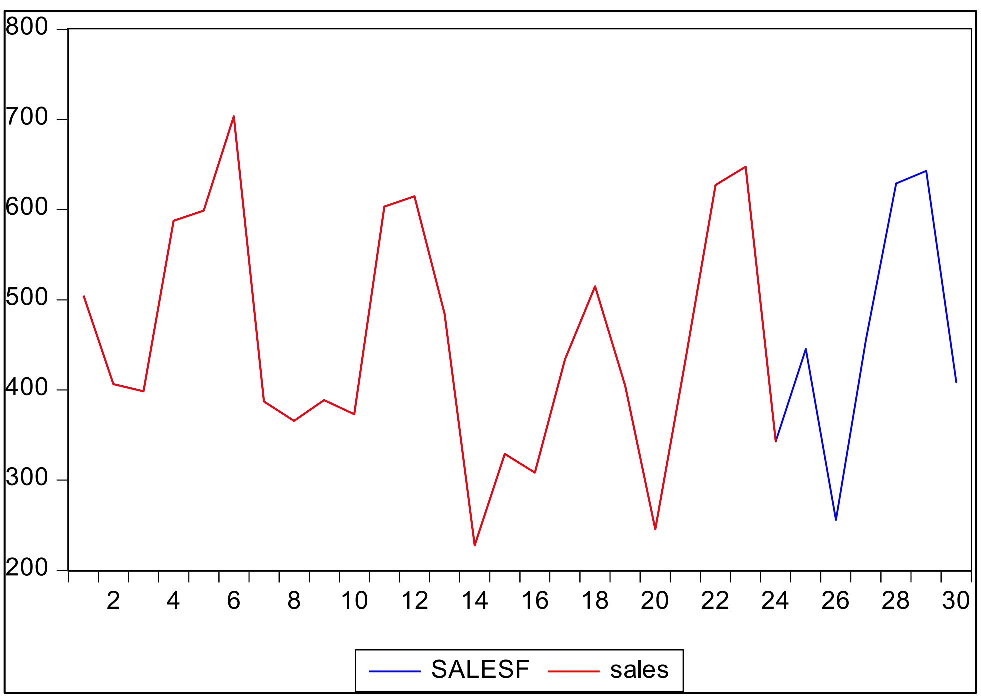
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	291.7436	32.83913	8.884023	0.0000
ADV	2.402544	0.857354	2.802279	0.0150
ADV(-1)	2.798535	0.885248	3.161301	0.0075
PROM	5.358379	1.006197	5.325379	0.0001
PROM(-1)	-3.194436	0.991057	-3.223262	0.0067
DLOG(INDEX)	-1477.015	605.3332	-2.440003	0.0298

R-squared	0.856287	Mean dependent var	440.8705
Adjusted R-squared	0.801013	S.D. dependent var	131.9646
S.E. of regression	58.86679	Akaike info criterion	11.24052
Sum squared resid	45048.89	Schwarz criterion	11.53876
Log likelihood	-100.7849	Hannan-Quinn criter.	11.29100
F-statistic	15.49160	Durbin-Watson stat	1.310164
Prob(F-statistic)	0.000044		

Forecast generated (based on expected values in workshop file):



Plot SALES and SALESF in the same graph:



We are not able to compare the forecasts with any actual sales figures to determine how good is the fit. From the graph, the forecasts seem to follow the same seasonal trend as the historical figures.

Question 2: VAR & COINTEGRATION: Precious Metals

1. First you decided to take the log of the prices to reduce heteroscedasticity. You think that the prices are non-stationary and possibly cointegrated.
    a. 1. First, check they are non-stationary!

Unit Root test – log(copper): top left, log(tin): top right, log(lead): bottom left, log(zinc): bottom right

Null Hypothesis: LOG(COPPER) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=16)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.267586	0.4501
Test critical values:	1% level	-3.984804	
	5% level	-3.422865	
	10% level	-3.134337	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG(COPPER))
Method: Least Squares
Date: 02/15/19 Time: 14:47
Sample (adjusted): 1990M03 2018M12
Included observations: 346 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(COPPER(-1))	-0.017756	0.007830	-2.267586	0.0240
D(LOG(COPPER(-1)))	0.393459	0.049672	7.921135	0.0000
C	0.131705	0.057950	2.272715	0.0237
@TREND("1990M01")	8.62E-05	4.78E-05	1.805034	0.0719

R-squared	0.161078	Mean dependent var	0.002733
Adjusted R-squared	0.153719	S.D. dependent var	0.062258
S.E. of regression	0.057274	Akaike info criterion	-2.870458
Sum squared resid	1.121853	Schwarz criterion	-2.825991
Log likelihood	500.5893	Hannan-Quinn criter.	-2.852751
F-statistic	21.88860	Durbin-Watson stat	1.966386
Prob(F-statistic)	0.000000		

Null Hypothesis: LOG(TIN) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 2 (Automatic - based on SIC, maxlag=16)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.536736	0.3102
Test critical values:	1% level	-3.984882	
	5% level	-3.422903	
	10% level	-3.134360	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG(TIN))
Method: Least Squares
Date: 02/15/19 Time: 14:54
Sample (adjusted): 1990M04 2018M12
Included observations: 345 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(TIN(-1))	-0.021853	0.008615	-2.536736	0.0116
D(LOG(TIN(-1)))	0.235898	0.053277	4.427781	0.0000
D(LOG(TIN(-2)))	0.143100	0.053337	2.682950	0.0077
C	0.180375	0.071153	2.535008	0.0117
@TREND("1990M01")	0.000124	5.35E-05	2.325114	0.0207

R-squared	0.103639	Mean dependent var	0.003253
Adjusted R-squared	0.093094	S.D. dependent var	0.055073
S.E. of regression	0.052446	Akaike info criterion	-3.043662
Sum squared resid	0.935214	Schwarz criterion	-2.987958
Log likelihood	530.0317	Hannan-Quinn criter.	-3.021478
F-statistic	9.827899	Durbin-Watson stat	1.990740
Prob(F-statistic)	0.000000		

Null Hypothesis: LOG(LEAD) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=16)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.595238	0.2828
Test critical values:	1% level	-3.984804	
	5% level	-3.422865	
	10% level	-3.134337	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG(LEAD))
Method: Least Squares
Date: 02/15/19 Time: 15:13
Sample (adjusted): 1990M03 2018M12
Included observations: 346 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(LEAD(-1))	-0.026045	0.010036	-2.595238	0.0099
D(LOG(LEAD(-1)))	0.225874	0.052324	4.316864	0.0000
C	0.154243	0.060236	2.560641	0.0109
@TREND("1990M01")	0.000161	6.65E-05	2.416013	0.0162

R-squared	0.065584	Mean dependent var	0.002682
Adjusted R-squared	0.057387	S.D. dependent var	0.070456
S.E. of regression	0.068404	Akaike info criterion	-2.515269
Sum squared resid	1.600268	Schwarz criterion	-2.470801
Log likelihood	439.1415	Hannan-Quinn criter.	-2.497562
F-statistic	8.001345	Durbin-Watson stat	1.987390
Prob(F-statistic)	0.000036		

Null Hypothesis: LOG(ZINC) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=16)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.803237	0.1971
Test critical values:	1% level	-3.984804	
	5% level	-3.422865	
	10% level	-3.134337	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG(ZINC))
Method: Least Squares
Date: 02/15/19 Time: 15:16
Sample (adjusted): 1990M03 2018M12
Included observations: 346 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(ZINC(-1))	-0.028339	0.010109	-2.803237	0.0053
D(LOG(ZINC(-1)))	0.322091	0.050919	6.325595	0.0000
C	0.190087	0.068837	2.761382	0.0061
@TREND("1990M01")	0.000104	4.39E-05	2.357597	0.0190

R-squared	0.117896	Mean dependent var	0.001814
Adjusted R-squared	0.110159	S.D. dependent var	0.062555
S.E. of regression	0.059009	Akaike info criterion	-2.810746
Sum squared resid	1.190882	Schwarz criterion	-2.766279
Log likelihood	490.2591	Hannan-Quinn criter.	-2.793039
F-statistic	15.23652	Durbin-Watson stat	2.018432
Prob(F-statistic)	0.000000		

All tests indicate that the ADF t-statistic for the log of each metal price is greater than the critical values, so we do not reject the null hypothesis that each of these prices has a unit root and is non-stationary.

2. Then, use the Johansen – Cointegration Test.

Date: 02/15/19 Time: 15:22
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(COP...	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(COP...	-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(COP...	-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(COP...	-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?

The trace rank test suggest that there is only 1 co-integration equation at 5% level as the hypothesis that there is at most 1 cointeegration equations cannot be rejected.

The Maximum Eigenvalue trank test suggest that there is no cointegration at the 5% level as the hypothesis of there is none cointegration cannot be rejected.

Vector Error Correction Estimates
Date: 02/15/19 Time: 15:30
Sample (adjusted): 1990M03 2018M12
Included observations: 346 after adjustments
Standard errors in ( ) & t-statistics in [ ]

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

Error Correction:	D(LOG(CO...	D(LOG(TIN))	D(LOG(LE...	D(LOG(ZINC))
CointEq1	-0.018218	-0.025830	0.013266	-0.004341
	(0.00820)	(0.00746)	(0.00982)	(0.00838)
	[-2.22041]	[-3.46049]	[1.35031]	[-0.51821]
D(LOG(COPPER(-1)))	0.420624	0.091521	0.089441	0.191225
	(0.06844)	(0.06226)	(0.08195)	(0.06987)
	[6.14621]	[1.46997]	[1.09147]	[2.73686]
D(LOG(TIN(-1)))	-0.021968	0.200727	-0.153571	-0.221108
	(0.06506)	(0.05919)	(0.07791)	(0.06643)
	[-0.33765]	[3.39117]	[-1.97125]	[-3.32867]
D(LOG(LEAD(-1)))	-0.089978	0.016599	0.227445	-0.052085
	(0.05860)	(0.05331)	(0.07017)	(0.05983)
	[-1.53538]	[0.31135]	[3.24128]	[-0.87054]
D(LOG(ZINC(-1)))	0.032673	-0.016137	0.024900	0.303236
	(0.06797)	(0.06184)	(0.08139)	(0.06939)
	[0.48070]	[-0.26096]	[0.30595]	[4.36983]
R-squared	0.163207	0.112511	0.063175	0.136039
Adj. R-squared	0.153391	0.102100	0.052186	0.125904
Sum sq. resids	1.119006	0.926161	1.604394	1.166389
S.E. equation	0.057285	0.052115	0.068593	0.058485
F-statistic	16.62706	10.80750	5.748865	13.42340
Log likelihood	501.0290	533.7515	438.6961	493.8543
Akaike AIC	-2.867220	-3.056367	-2.506914	-2.825747
Schwarz SC	-2.811635	-3.000782	-2.451330	-2.770163
Mean dependent	0.002733	0.003296	0.002682	0.001814
S.D. dependent	0.062258	0.054999	0.070456	0.062555

Determinant resid covariance (dof adj.)	3.90E-11
Determinant resid covariance	3.68E-11
Log likelihood	2192.584
Akaike information criterion	-12.52939
Schwarz criterion	-12.25146
Number of coefficients	25

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

Interpret the equation.

Log(Copper) = -1.64 Log(tin) + 2.54Log(lead) + 6.93

The system of equations estimated is as follows. Interpret the result.

Which prices are the main drivers?

Previous month's Copper price affects itself and Zinc prices.

Previous month's Tin price affects itself and Zinc prices.

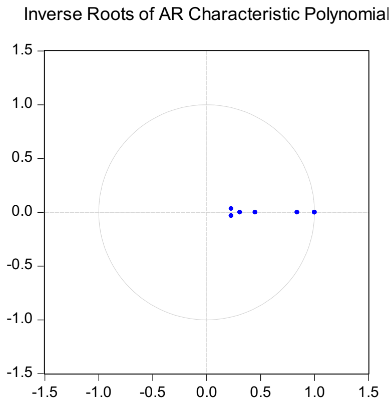
Previous month's Lead price affects only itself.

Previous month's Zinc price affects only itself.

How can you improve the model?

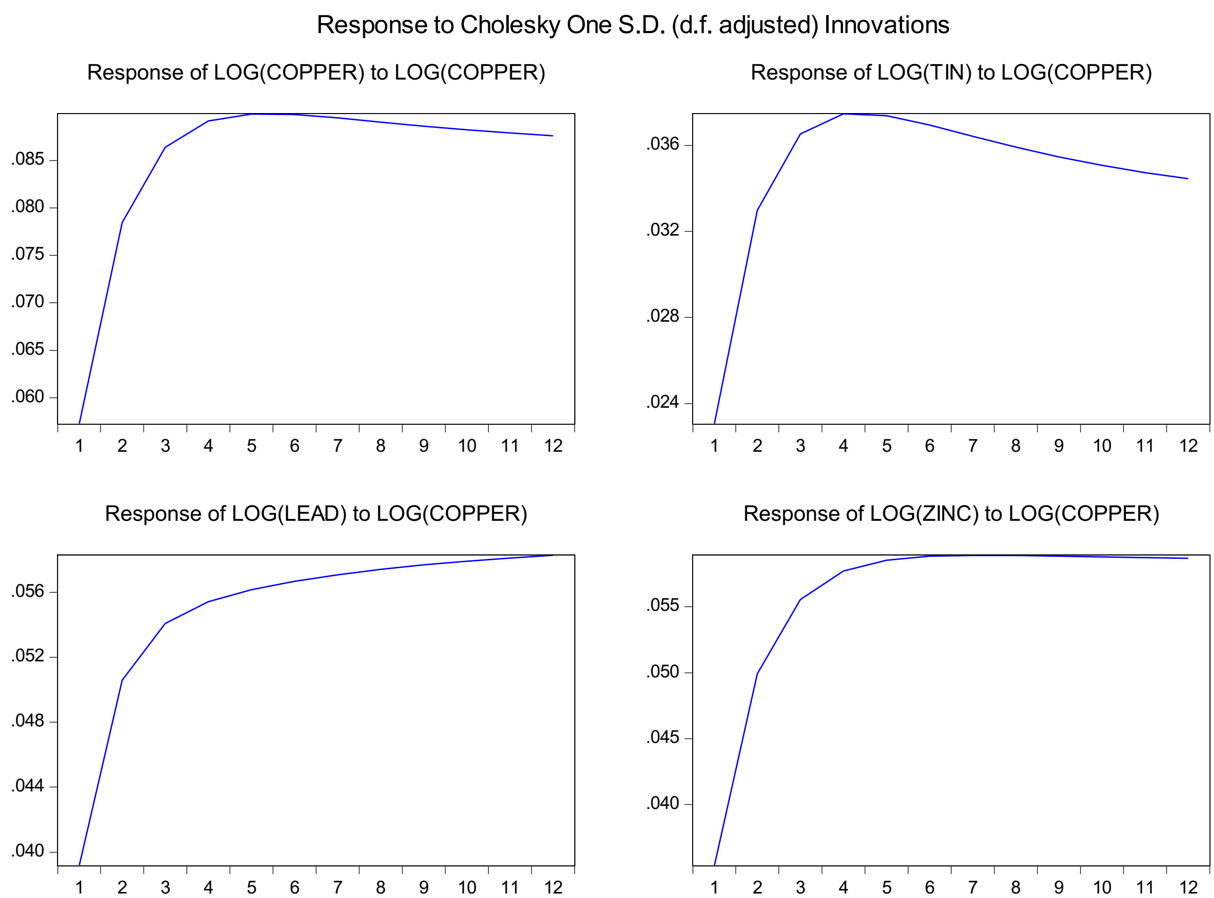
We should remove zinc from the model and model zinc independently.

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



Given that the inverse roots are within the circle, we can conclude that the series are stationary.

For example. This is the impulse response for an innovation on the copper price. Interpret the result.



When there is a positive shock (exogenous) on copper price, the other metals' prices (tin, lead, and zinc) also exhibited a positive response. In terms of degree of response, copper itself responded the most significantly, followed by lead, zinc and tin.

For copper itself, the shock peaked at about 5 months and start to decay.

For tin, the response peaked at about 4 months and started to decay at a faster rate than the other metals.

For lead, the response continues to exhibit an upward trend within the 12 months time period, and suggests a more long term impact to its prices.

For zinc, the response peaked at about 5 months and plateau thereafter.

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?

This is the revised model excluding zinc and including gold and nickel:

Vector Error Correction Estimates
Date: 02/16/19 Time: 16:50
Sample (adjusted): 1990M03 2018M12
Included observations: 346 after adjustments
Standard errors in ( ) & t-statistics in [ ]

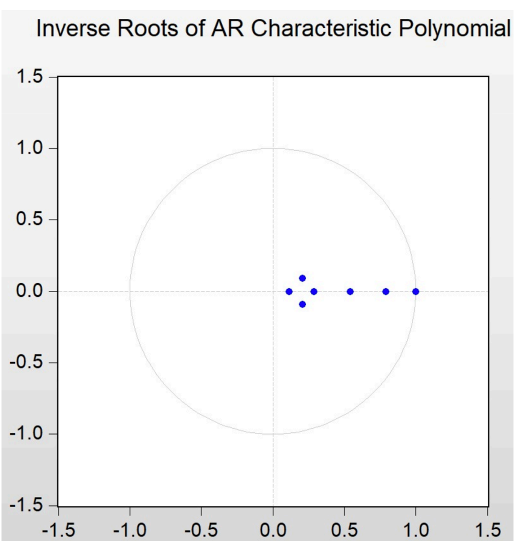
Cointegrating Eq:	CointEq1
LOG(COPPER(-1))	1.000000
LOG(LEAD(-1))	-0.843470 (0.18835) [-4.47825]
LOG(TIN(-1))	1.178727 (0.23784) [4.95587]
LOG(NICKEL(-1))	-0.475489 (0.09990) [-4.75979]
LOG(GOLD(-1))	-0.928613 (0.18767) [-4.94810]
C	-2.824662 (0.86964) [-3.24808]

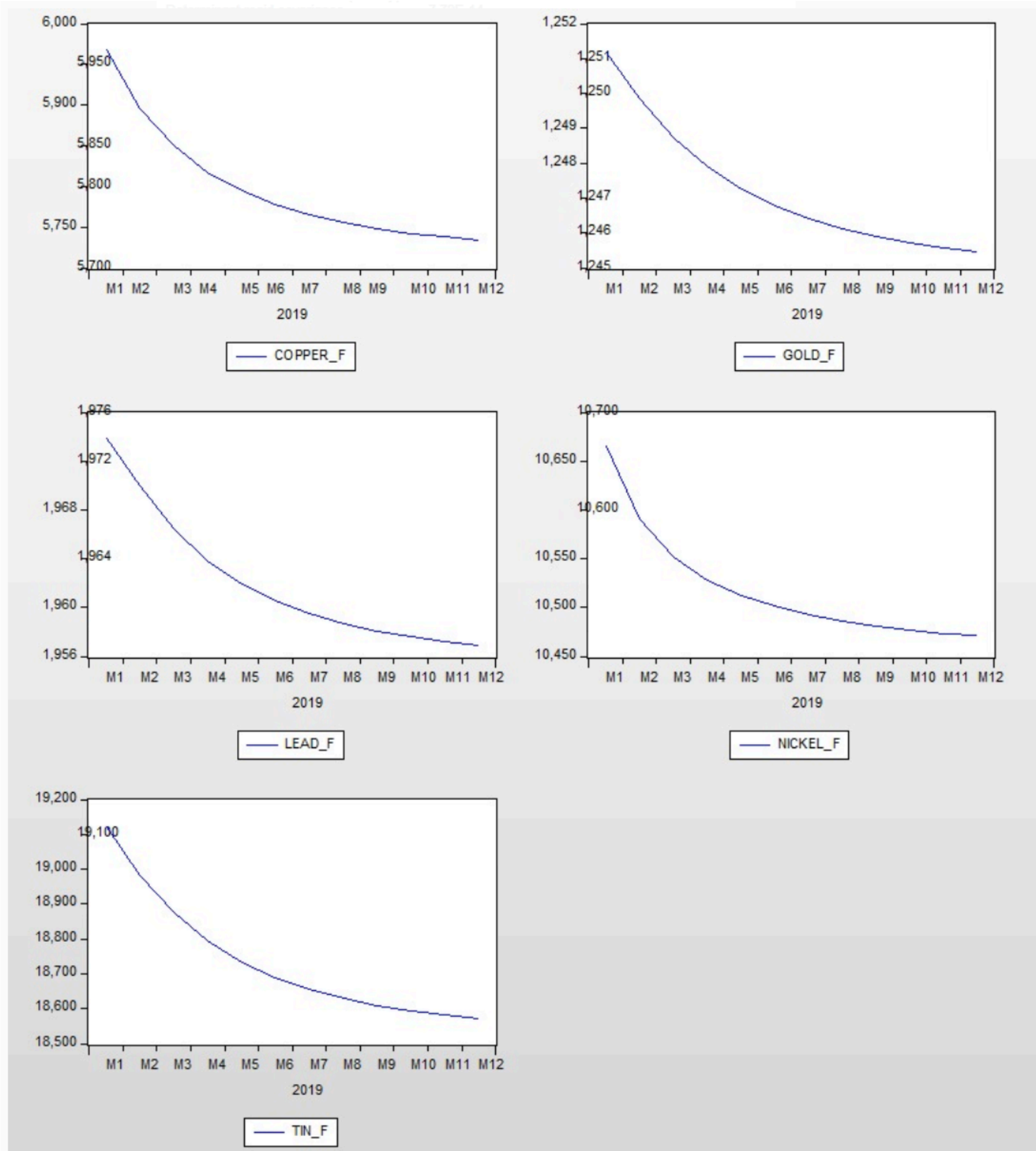
Error Correction:	D(LOG(CO...	D(LOG(LE...	D(LOG(TIN))	D(LOG(NIC...	D(LOG(GO...
CointEq1	-0.072064	-0.029519	-0.074224	-0.038637	-0.019545
	(0.01486)	(0.01821)	(0.01354)	(0.02049)	(0.00930)
	[-4.84927]	[-1.62072]	[-5.48264]	[-1.88519]	[-2.10096]
D(LOG(COPPER(-1)))	0.444604	0.113461	0.108138	0.025248	-0.026041
	(0.06582)	(0.08066)	(0.05996)	(0.09077)	(0.04120)
	[6.75518]	[1.40658]	[1.80355]	[0.27816]	[-0.63202]
D(LOG(LEAD(-1)))	-0.107225	0.195110	-0.000636	-0.017376	-0.010057
	(0.05371)	(0.06583)	(0.04893)	(0.07407)	(0.03362)
	[-1.99641]	[2.96405]	[-0.01301]	[-0.23458]	[-0.29911]
D(LOG(TIN(-1)))	-0.010849	-0.145339	0.218001	-0.035272	0.017720
	(0.06563)	(0.08043)	(0.05978)	(0.09051)	(0.04108)
	[-0.16532]	[-1.80699]	[3.64643]	[-0.38972]	[0.43134]
D(LOG(NICKEL(-1)))	-0.006380	-0.032981	-0.029926	0.288671	0.021620
	(0.04784)	(0.05864)	(0.04358)	(0.06598)	(0.02995)
	[-0.13335]	[-0.56248]	[-0.68663]	[4.37507]	[0.72186]
D(LOG(GOLD(-1)))	-0.073099	0.084277	-0.107265	-0.045638	0.100304
	(0.09137)	(0.11199)	(0.08324)	(0.12601)	(0.05720)
	[-0.80001]	[0.75256]	[-1.28863]	[-0.36216]	[1.75356]
R-squared	0.206056	0.068795	0.155678	0.096989	0.025850
Adj. R-squared	0.194380	0.055100	0.143262	0.083709	0.011524
Sum sq. resids	1.061706	1.594770	0.881113	2.019331	0.416067
S.E. equation	0.055881	0.068487	0.050907	0.077066	0.034982
F-statistic	17.64836	5.023629	12.53801	7.303628	1.804431
Log likelihood	510.1225	439.7369	542.3777	398.9026	672.1866
Akaike AIC	-2.914003	-2.507150	-3.100449	-2.271113	-3.850790
Schwarz SC	-2.847302	-2.440449	-3.033748	-2.204412	-3.784088
Mean dependent	0.002733	0.002682	0.003296	0.001272	0.003175
S.D. dependent	0.062258	0.070456	0.054999	0.080510	0.035185

Determinant resid covariance (dof adj.)	8.43E-14
Determinant resid covariance	7.72E-14
Log likelihood	2768.507
Akaike information criterion	-15.79484
Schwarz criterion	-15.39463
Number of coefficients	36

This model have a better Schwarz criterion with a value of -15.39.

We have also checked that the unit root by running the AR root graph to check that the series is stationary:





Above is the out of sample forecast for the metal prices. They exhibits similar trends over the 12 months period.