Session 5
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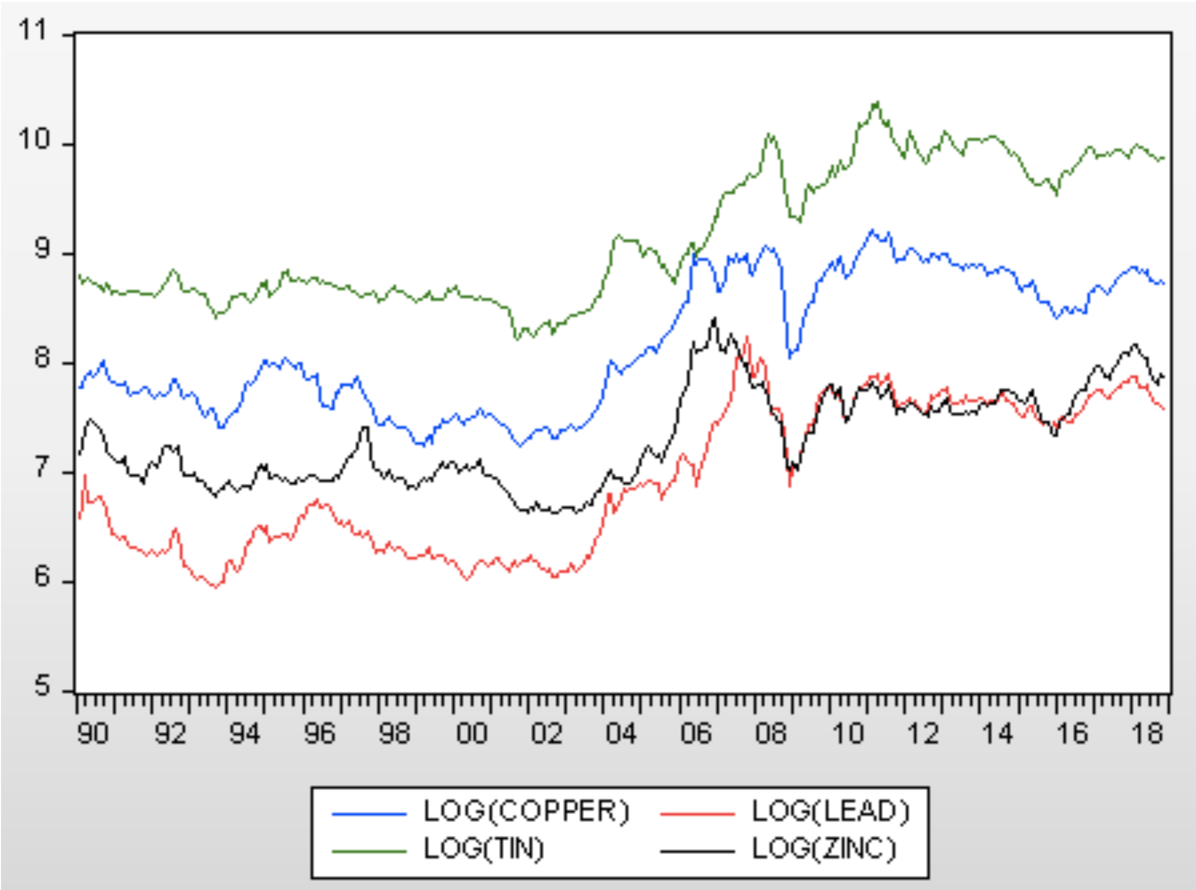
1. Took the log of the prices to reduce heteroscedasticity. Below is the graph:



2. Using Johnson-cointegration test, we can conclude that there is at least one cointegration equation. Below is the screenshot:

Date: 02/16/19 Time: 15:44
Sample (adjusted): 1990M03 2018M12
Included observations: 346 after adjustments
Trend assumption: No deterministic trend (restricted constant)
Series: LOG(COPPER) LOG(TIN) LOG(LEAD) 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

Building the VAR model with log(copper), log(zinc), log(tin), and log(lead), we got the below result:

Vector Error Correction Estimates
Date: 02/16/19 Time: 15:52
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]

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

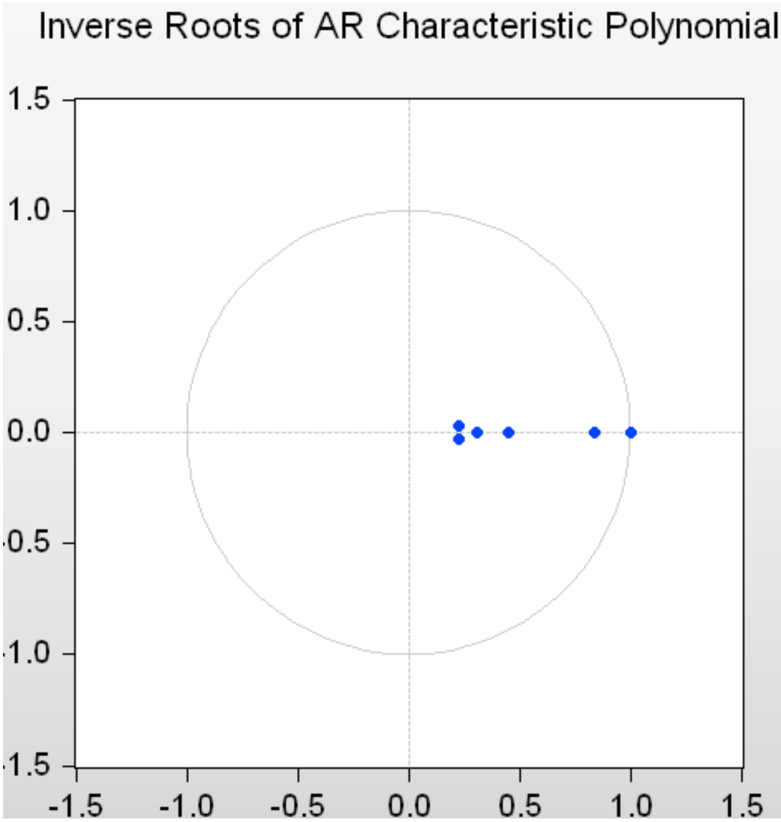
Determinant resid covariance (dof adj.)	3.90E-11
Determinant resid covariance	3.68E-11
Log likelihood	2192.584
Akaike information criterion	-12.52939
Schwarz criterion	-12.25146
Number of coefficients	25

3. We got the following cointegration equation (as zinc is not significant):

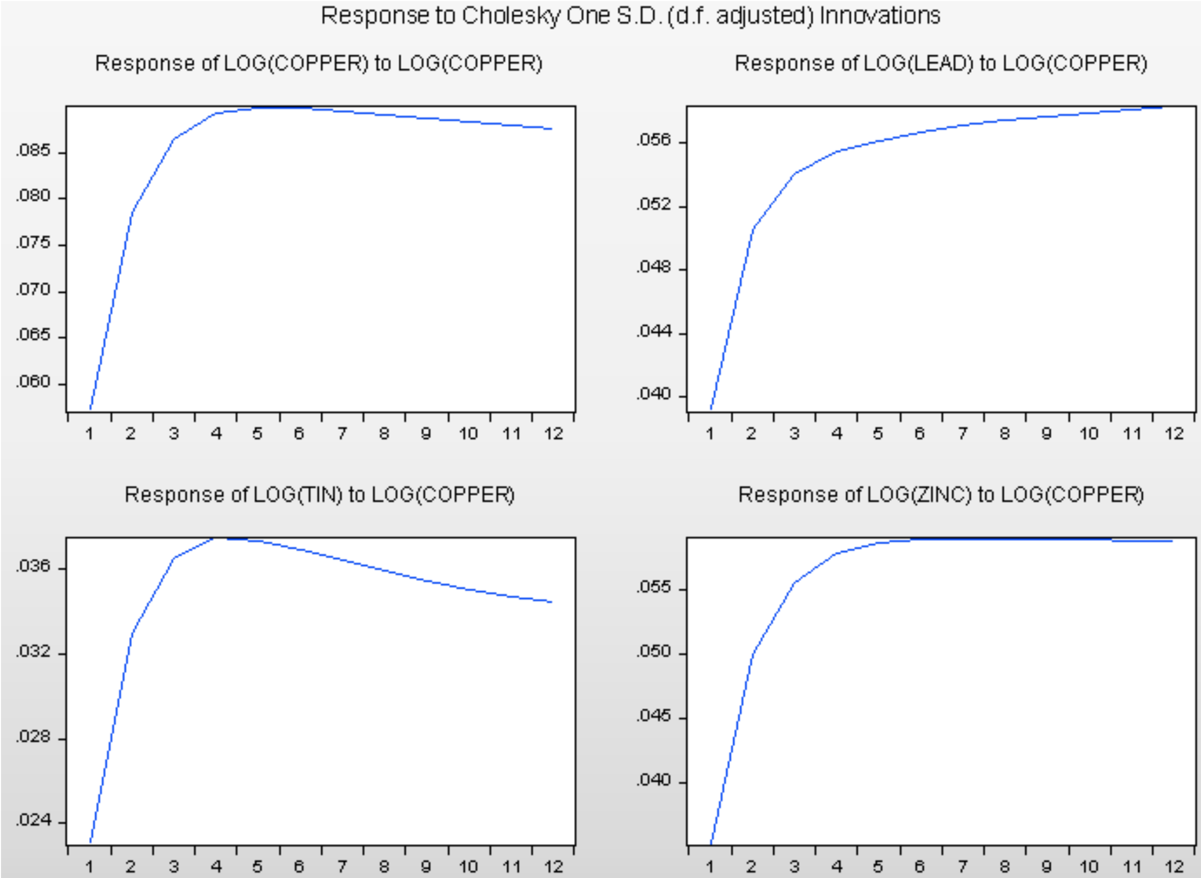
$$\log\big(copper(-1)\big) = 2.53\log\,(lead(-1)) - 1.64\log\,(tin(-1)) + 6.92$$

It seems that TIN price is the main driver. We can improve the model by removing zinc from the cointegration equation as well as VAR model. We can form another model for zinc using the other metals log price changes.

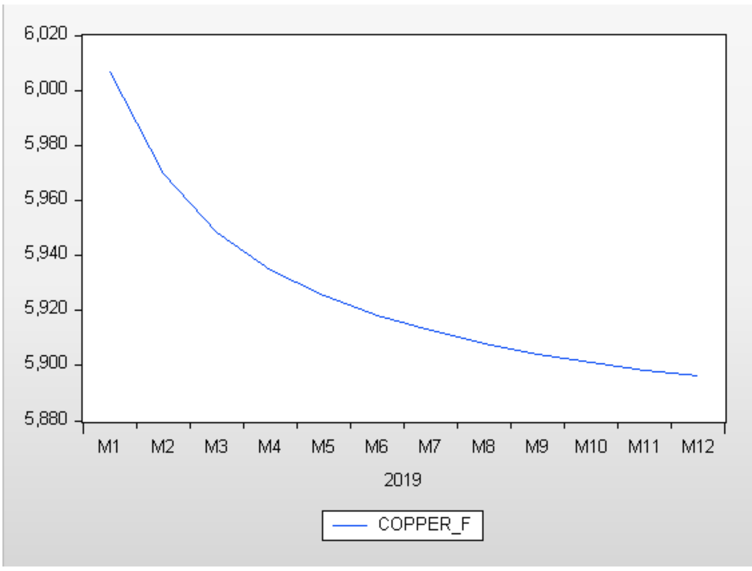
Analysing the stability conditions to test if any of the parameters or relationship between them is explosive, we found that all of the parameters fall within the unit root circle. Below is the screenshot:

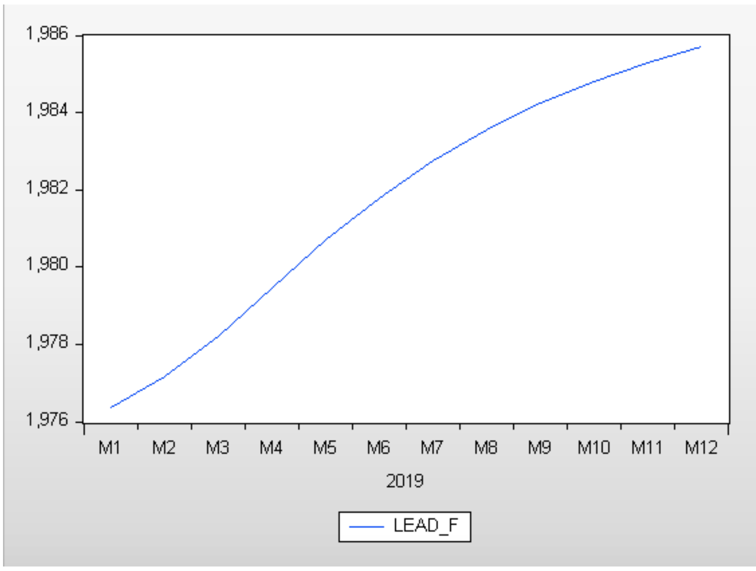


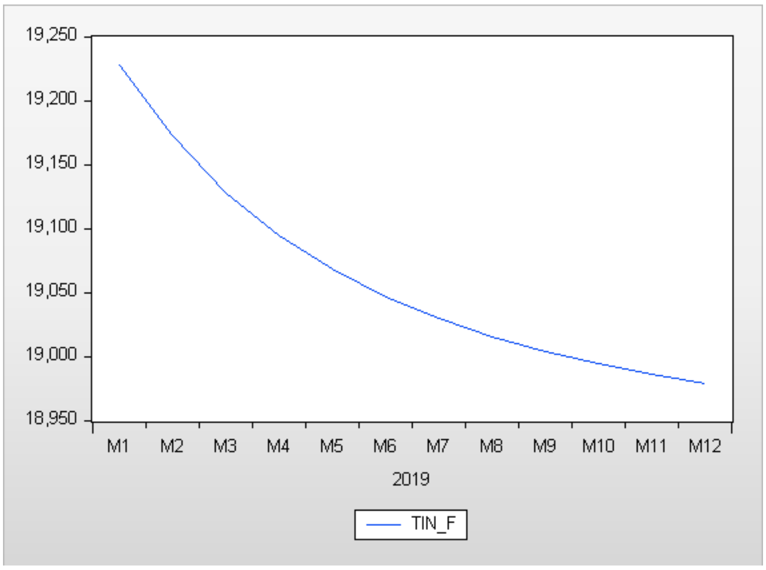
While given an impulse to copper, all the prices go up in the short period but after around 4 periods, copper and tin prices go down while lead price goes up and zinc price stays the same. Below is the screenshot:

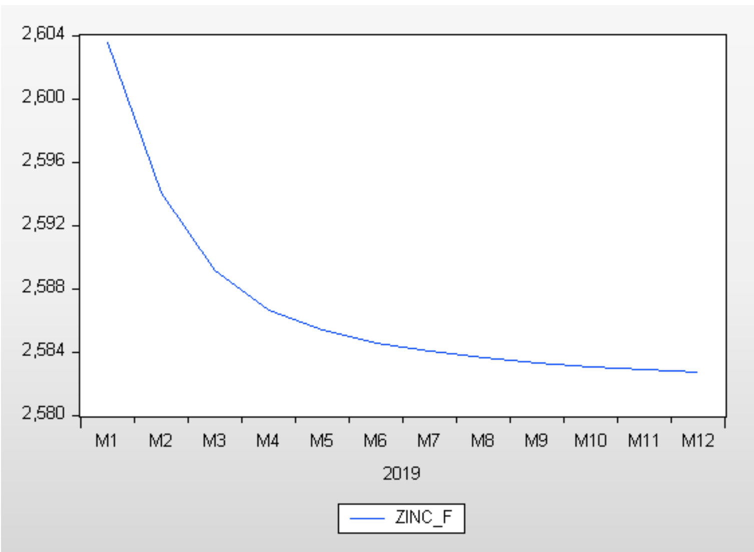


For the out-of-sample forecasting, we can see that the price of lead goes up, but the rest prices go down. Below is the screenshot:




1,986
1,984
1,982
1,980
1,978
1,976
M1 M2 M3 M4 M5 M6 M7 M8 M9 M10 M11 M12
2019
LEAD_F


19,250
19,200
19,150
19,100
19,050
19,000
18,950
M1 M2 M3 M4 M5 M6 M7 M8 M9 M10 M11 M12
2019
TIN_F


2,604
2,600
2,596
2,592
2,588
2,584
2,580
M1 M2 M3 M4 M5 M6 M7 M8 M9 M10 M11 M12
2019
ZINC_F