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Predictive Relationships between Metal Commodities and the FTSE/JSE Top 40 Index

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ABSTRACT

The paper will investigate the possible predictive relationships between four commodities, namely copper, palladium, platinum and silver against the FTSE/JSE Top 40 Index. The impact of the relationship between the commodities and the FTSE/JSE Top 40 on the South African Rand (ZAR) will also be investigated. Single and multiple regressions will be used to explore any indication of a statistical significant relationship. Correlation will also be explored in the investigation process. Once the initial investigation is completed to ensure statistical significance, a VAR study will be undertaken to validate the linear interdependencies among multiple time series, followed by the Johansen Cointegration test. The results indicate that there is a cointegrating relationship between the datasets.

Keywords: Commodities, Copper, Palladium, Platinum and silver, FTSE/JSE top 40 index, significant relationships.
JEL Classification: G1, Q02.

1. Introduction

"A pessimist sees the difficulty in every opportunity; an optimist sees the opportunity in every difficulty" (Churchill, n.d.).

Opportunities in the investment environment are present in many different forms and manners and are limited only be the amount of knowledge an individual has about the asset classes and their related characteristics. The speed that market events affect investment opportunities has increased over the last number of years as a result of technology utilised in the financial markets. This speed factor reduces traditional investment opportunities available to investors. The need for alternative investment opportunities creates the need for alternative investments in order to search for alpha (Mulvey, 2012).

Alpha is the risk-adjusted return available to an investor. It is the return received by an investor over and above the return as a result of the risk free rate and the market risk premium. In alternative investment classes, the search for alpha is cast over a wider opportunity set as compared to traditional asset classes. The search for alpha is not just reliant of the investment class, but also on the strategy used within and between asset classes (Anson, Chambers, Black and Kazemi, 2012).

One type of investment related strategy in the financial industry is one of cross hedging. To hedge is a means of protection or defence against a financial loss (Merriam-Webster, n.d.). When taking an offsetting position in an alternative instrument or good with similar movements in price a cross hedge action is entered into. A cross hedge is necessary as there could be an instance where no direct alternative is available to hedge an instrument which leads to the concept of analysing other instruments to identify possible significant relationships (Powers, 1991).In order to investigate cross hedging relationships, the relationship between various instruments or goods needs to be explored in order to determine the nature of relationships that exist. The movement of instruments provide the opportunity for cross hedging if the correct combinations of instruments are chosen. The combination of instruments selected for this paper are four metal commodities namely, copper, palladium, platinum and silver; the FTSE/JSE Top 40 and the South African Rand (ZAR) against the United States Dollar. The four above-mentioned commodities were selected as they are produced in South Africa and exported internationally. The FTSE/JSE Top 40 Index and the ZAR were chosen as the comparative datasets as the FTSE/JSE Top 40 Index is representative of the majority of companies that trade of the JSE and the ZAR is included as the commodities are exported for use around the world.

The objective of the study is to investigate the significant relationships between four commodities against the FTSE/JSE Top 40 Index as well as between the ZAR, FTSE/JSE Top 40 Index and the four commodities. Once the initial relationships are determined between the six datasets by means of correlation and single regression, the impact of the relationships will be investigated using multiple regression. The use of single and multiple regressions are used to explore any indication of a statistical significant relationship.

Once the initial investigation is completed to ensure statistical significance, a VAR study will be undertaken to validate the linear interdependencies among multiple time series in order to determine significant relationships. The VAR will be followed by a Johansen Cointegration test.

The remainder of the paper is structured in the following format. Part 2 provides a review of the current literature available. Part 3 explains the methodology used in the study. Part 4 provides an explanation of the data. Part 5 explains and interprets the results and findings of the study. Lastly, part 6, provides the conclusions drawn from the results of the study.

2. Review of the Literature

The traditional investment strategy of buying and selling equities has become extremely difficult to consistently outperform the market specifically in the short-term, based on the efficient market hypothesis. The amount of information presented to the market and the speed of processing the information has increased substantially over the last two decades (Stout, 1997).

Traditional investment strategies are influenced by market efficiency behaviour which in turn influences the related return opportunities. With the growing size of the participants in the financial markets environment the opportunities for above-market return generation or alpha are diminished as supply of return is limited, but there is an always increasing demand (Anson, Fabozzi and Jones, 2011).

A method of creating an opportunity for alpha is by means of alternative assets and alternative investment strategies. Alternative investment opportunities are part of modern financial developments and extend beyond the range of traditional investment instruments and traditional investment strategies. Examples of alternative investment assets are hedge funds, commodities and structured products. Alternative investment strategies are the ways in which the investments in alternative asset instruments and traditional assets instruments are traded, such as event driven, emerging markets focused, or sector driven (Amenc, Martellini and Vaissie, 2003).

Commodities are separated into two main subclasses, namely hard and soft commodities. Hard commodities include metals such as gold, silver, and platinum; soft commodities include agricultural products such as maize and corn. Commodities can be traded by purchasing the commodity at a spot price via the actual commodity or via purchasing a commodity linked company share; or alternatively for a future date via a derivative contract such as a future or future contract (Le Roux and Els, 2013).

Various studies have been undertaken to investigate what type of relationship commodity prices have to prices of other instruments, such as exchange rates, stock prices and monetary policy instruments. Garcia-Herrero and Thornton (1997) did a comparison of world commodity prices to retail prices of products in the United Kingdom, as a forecasting tool. The study showed inconclusive results that commodity prices can be used to forecast changes in retail prices. The authors used Cointegration and Granger-causality techniques to identify any forecasting possibilities.

Saghaian (2010) investigated the possible relations and simultaneous causal structures between energy and commodity datasets. The study indicated that there is a strong correlation between oil and commodity prices, but the causal relation between oil and commodity prices showed mixed results. Cointegration and Granger-Causality was used to present the empirical results.

A study on stock prices and exchange rates in Australia with emphasis on commodity prices was done by Groenewold and Paterson (2013). The authors found that the short-run relationship indicated that the exchange rate had a significant effect on commodity prices and that the commodity prices influence stock prices. In the long-run however, the effect of commodity prices on stock prices is weak. A further study was done to explore the relationship between the exchange rate and commodity prices. The exchange rate had a strong effect on commodity prices, but commodity prices did not have a strong effect on the exchange rate. Cointegration, Vector Error Correction Model and Granger Causality was used in the study.

Kurihara and Fukushima (2014) did a study in the exchange rates, stock prices and commodity prices in Japan and the Euro area. The study showed that there was a weak relationship between stock prices and the exchange rate. In Japan, there was a significant effect on the commodity prices from the exchange rate, but the same was not found in the Euro area. The commodity prices of both Japan and the Euro area did not impact stock prices. The authors used Vector Autoregression, Cointegration and Pairwise Granger Causality tests as part of the empirical analysis.

Commodity prices have also been compared to monetary policy. Vala (2013) explored the link between commodity prices and monetary policy in India. The results showed that commodity price indices are able to predict GDP and inflation. Time-series econometric models were used in this study. The models and tests used were Johansen Cointegration, Vector Error Correction Model and Granger Causality.

The main focus of this paper will be on commodities and the significant relationships that are present which can lead to further research on whether these commodities can be used as a cross hedging instrument for both traditional and alternative investment asset classes and using this to identify any relationships which can be utilised for investment purposes.

3. Methodology

The research strategy implemented for this study is of a quantitative nature based on historic time-series data. The research objective of this study is to explore the relationships present between the six datasets included in the study. In order to explore the relationships a number of econometric tests need to be applied to the data.

The initial relationships that will be investigated by means of correlation and single regression are:

1. Movements in the copper price against movements in the FTSE/JSE Top 40 Index and vice-versa;
2. Movements in the palladium price against movements in the FTSE/JSE Top 40 Index and vice-versa;
3. Movements in the platinum price against movements in the FTSE/JSE Top 40 Index and vice-versa;
4. Movements in the silver price against movements in the FTSE/JSE Top 40 Index and vice-versa;
5. Movements in the copper price against movements in the ZAR and vice-versa;
6. Movements in the palladium price against movements in the ZAR and vice-versa;
7. Movements in the platinum price against movements in the ZAR and vice-versa;
8. Movements in the silver price against movements in the ZAR and vice-versa; and
9. Movements in the FTSE/JSE Top 40 Index against movements in the ZAR and vice-versa.

Further relationships will be investigated which will include a combination of the 6 datasets by means of multiple regression in order to identify any statistical significant relationships between a number of datasets. The multiple regressions will be followed by the use of a Vector Autoregressive (VAR) model which is a model used to capture the dynamics of time series data. The VAR model will be followed by Johansen Cointegration (Luetkepohl, 2011; Watson, 1994; Asteriou and Hall, 2011).

The combination of the above mentioned econometric tests are required to identify any relationships that are of interest in order to locate interdependencies between the datasets which can form the basis for cross hedging in the South African financial market.

4. Data

A selection of four metal commodities was chosen to use in this paper. The four metal commodities are namely copper, palladium, platinum and silver. The daily spot prices of these four commodities will be compared to the daily spot price of the FTSE/JSE Top 40 Index. The spot price of the ZAR against the United States Dollar will also be utilised in this paper to investigate any relationship between the ZAR and the FTSE/JSE Top 40 Index and the four commodities.

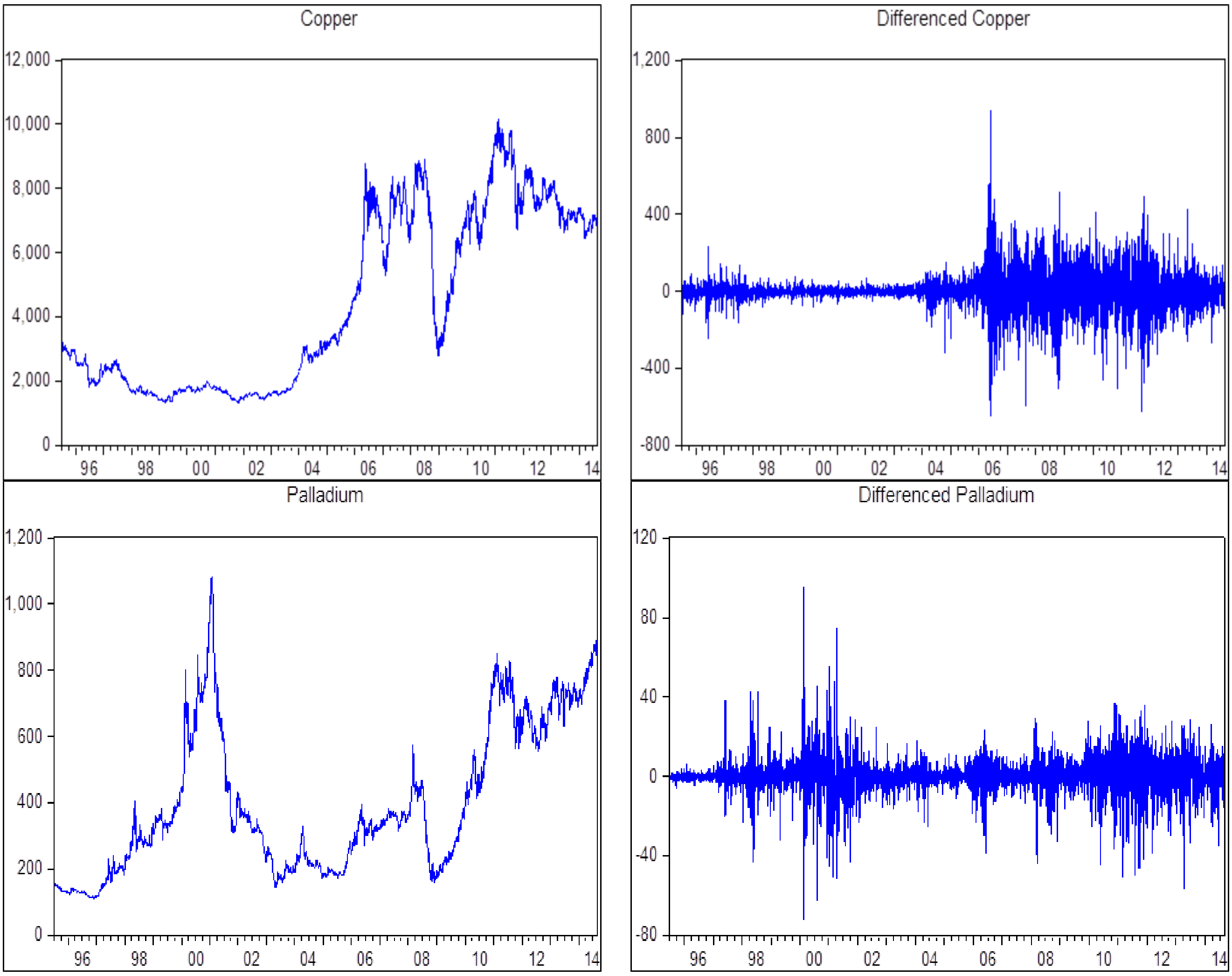
The daily prices were obtained from the Thomson Reuters Datastream database. The sample selected to be used in this paper is from 3 July 1995 to 29 August 2014 as each dataset has a different initial date. These dates were chosen as each dataset was active at this time. A total of 4990 data points were included in the study. The data points were cleaned by removing any date that had no value in any of the datasets from all datasets. The data was analysed using Eviews.

The alternative hypotheses for the sets of data are:

1. H_a: There is a movement relationship between the commodity price and the FTSE/JSE Top 40 Index;
2. H_a: There is a movement relationship between the commodity price and the ZAR;
3. H_a: There is a movement relationship between the FTSE/JSE Top 40 Index and the ZAR;
4. H_a: There is a movement relationship between a combination of the 6 datasets by means of single and multiple regressions;
5. H_a: There is a movement relationship between a combination of the 6 datasets by means of VAR and Johansen Cointegration.

5. Empirical Results

An initial evaluation of the data by means of a graphical representation illustrated in Figure 1 shows movements between the datasets, from a daily price on the line graph as well as on the differenced graphs. The global financial crisis of 2008 did have a strong impact on the copper, platinum, and the FTSE/JSE Top 40 Index. The ZAR was affected by the global financial crisis for a short period before the volatility in the ZAR stabilised within a tighter range.



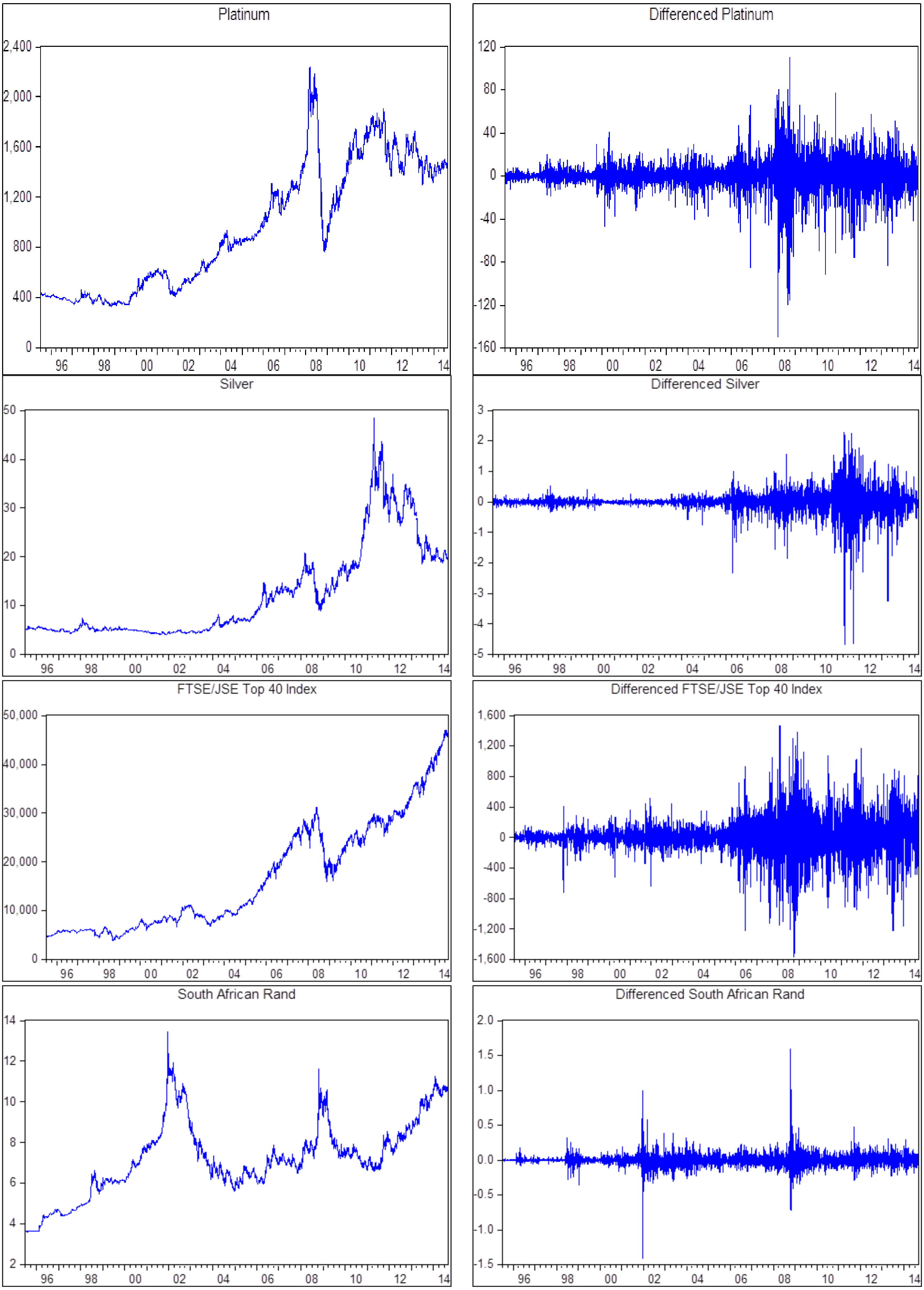


Figure-1. Graphical representation of movement in the six datasets

Source: Thomson Reuters Datastream and Eviews

The correlation matrix in Table 1 shows that there is a strong positive correlation between the following dataset combinations:

1. Silver and platinum
2. FTSE/JSE Top 40 and platinum
3. Copper and platinum
4. FTSE/JSE Top 40 and silver
5. Copper and silver
6. Copper and FTSE/JSE Top 40

Table-1. Correlation Matrix

	ZAR	Platinum	Palladium	Silver	JSE Top 40	Copper
ZAR	1	0.399	0.494	0.319	0.560	0.269
Platinum	0.399	1	0.538	0.865	0.896	0.950
Palladium	0.494	0.538	1	0.636	0.631	0.502
Silver	0.319	0.865	0.636	1	0.830	0.877
JSE Top 40	0.560	0.896	0.631	0.830	1	0.888
Copper	0.269	0.950	0.502	0.877	0.888	1

Source: Thomson Reuters Datastream and Eviews

Table 2 shows the descriptive statistics of the six datasets. 4990 observations are included for all 6 variables.

Table-2. Descriptive Statistics (3 July 1995 to 29 August 2014)

	Copper	JSE Top 40	Silver	Palladium	Platinum	ZAR
Mean	4429.042	16953.496	12.242	400.860	956.100	7.229
Median	3185.250	11521.740	7.050	337.000	860.500	7.110
Maximum	10179.500	47080.380	48.410	1085.000	2240.000	13.450
Minimum	1318.250	3903.020	4.050	114.000	333.000	3.605
Std. Dev.	2727.757	11248.232	9.490	221.072	499.487	1.821
Skewness	0.371	0.705	1.274	0.697	0.357	0.248
Kurtosis	1.492	2.377	3.688	2.312	1.781	2.797
Jarque-Bera	587.274	493.720	1447.338	501.831	414.871	59.615
Probability	0.000	0.000	0.000	0.000	0.000	0.000
Sum	22100919.93	84597943.28	61088.79	2000290.3	4770936.9	36072.285
Sum Sq. Dev.	37121433694	631221912477	449320.7	243826071	1244693602	16549.224
Observations	4990	4990	4990	4990	4990	4990

Source: Thomson Reuters Datastream and Eviews

When exploring the relationship between time series data a risk that is present is that the data is not stationary. The unit root tests, namely the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) are test runs to determine if the time series is stationary or not. The null hypotheses of the two unit root tests are:

- ADF test: variable has a unit root
- PP test: variable has a unit root

The two tests mentioned above were used to test for unit roots and the results are shown in Table 3. The order of the tests started by testing for stationarity at level, followed by first difference of the trend and intercept, intercept only, and no intercept of trend for the ADF and PP test respectively.

Table-3. Unit Roots Test using the Augmented Dickey-Fuller method

Variable	ADF (Trend & Intercept)			ADF (Intercept only)			ADF (None)		
	t-stat	Prob	Unit root	t-stat	Prob	Unit root	t-stat	Prob	Unit root
Copper (1st diff)	-12.272*	0.000	No	-12.270*	0.000	No	-12.258*	0.000	No
Palladium (1st diff)	-12.016*	0.000	No	-12.004*	0.000	No	-11.963*	0.000	No
Platinum (1st diff)	-15.155*	0.000	No	-15.156*	0.000	No	-15.140*	0.000	No
									Continue

Silver (1st diff)	-14.243*	0.000	No	-14.245*	0.000	No	-14.230*	0.000	No
JSE Top 40 (1st diff)	-14.006*	0.000	No	-13.848*	0.000	No	-13.541*	0.000	No
ZAR (1st diff)	-15.342*	0.000	No	-15.344*	0.000	No	-15.294*	0.000	No
	PP (Trend & Intercept)			PP (Intercept Only)			PP (None)		
Variable	t-stat	Prob	Unit root	t-stat	Prob	Unit root	t-stat	Prob	Unit root
Copper (1st diff)	-78.841*	0.000	No	-74.847*	0.000	No	-47.848*	0.000	No
Palladium (1st diff)	-64.564*	0.000	No	-64.567*	0.000	No	-64.564*	0.000	No
Platinum (1st diff)	-64.285*	0.000	No	-64.291*	0.000	No	-64.294*	0.000	No
Silver (1st diff)	-68.100*	0.000	No	-68.107*	0.000	No	-68.111*	0.000	No
JSE Top 40 (1st diff)	-70.677*	0.000	No	-70.551*	0.000	No	-70.374*	0.000	No
ZAR (1st diff)	-75.908*	0.000	No	-5.916*	0.000	No	-75.892*	0.000	No

Source: Thomson Reuters Datastream and Eviews

An Asterisk (*) indicates that the null hypothesis of a unit root is rejected (at a 1% significance level).

The unit root tests indicate that all the variables are stationary at first difference at a 1% significance level. This specifies that the single and multiple regressions need to be run using data that is logged. The single regression outputs are summarised in the following tables.

Table-4. Summary of Single Regression outputs

Independent/Dependent Variable	Independent/Dependent Variable	R-Squared
Palladium	Copper	0.184
Platinum	Copper	0.847
Silver	Copper	0.864
JSE Top 40	Copper	0.822
ZAR	Copper	0.069
Platinum	Palladium	0.289
Silver	Palladium	0.339
JSE Top 40	Palladium	0.358
ZAR	Palladium	0.356
Silver	Platinum	0.810
JSE Top 40	Platinum	0.906
ZAR	Platinum	0.263
JSE Top 40	Silver	0.827
ZAR	Silver	0.148
ZAR	JSE Top 40	0.379

Source: Thomson Reuters Datastream and Eviews

The following relationships show very high R-Squared results displayed in Table 4 which is in line with the 6 relationships which showed a high correlation discussed above:

1. Platinum and copper
2. Silver and copper
3. FTSE/JSE Top 40 Index and copper
4. Silver and platinum
5. FTSE/JSE Top 40 Index and platinum
6. FTSE/JSE Top 40 Index and silver

The R-Squared in regression results indicate the percentage of total variation in the dependent variable explained by variation in the independent variable (Cameron and Windmeijer, 1995).

Table 1 indicates that copper and platinum are highly correlated, with a correlation of 0.95. The high value indicates the possible existence of near multicollinearity. Multicollinearity violates one of the assumptions of the classical linear regression model. Brooks (2014) states that if a model is otherwise adequate having statistically significant coefficients with an appropriate sign, near multicollinearity can be ignored.

Since there are certain relationships between the 6 datasets as shown by the single regression, an investigation of the relationships between combinations of datasets is shown in the tables below. Table 5 shows that there is a statistical significant relationship between both relationships investigated.

Table-5. Multiple Regression outputs

Indep Variable	Dependent Variable	AdjustedR-Squared	F-Stat	Intercept	Intercept t-stat	Ind Coeff	Ind t-stat
Copper Palladium Platinum Silver	FTSE/JSE Top 40 Index	0.929	16219.89*	1.789	20.347*	0.124 0.148 0.765 0.175	10.059* 22.878* 58.208* 12.381*
Copper Palladium Platinum Silver FTSE/JSE Top 40 Index	ZAR	0.880	7348.956*	-0.524	-11.729*	-0.646 0.039 0.129 -0.646 0.708	-6.058* 11.958* 15.559* -91.976* 102.410*

Source: Thomson Reuters Datastream and Eviews
Note: All variables were logged
* Statistically significant at 99%

The Adjusted R-squared takes into account the loss of degrees of freedom. Adjusted R-squared is an indication of the total variation in the dependent variable explained by the model. In Table 5 the Adjusted R-squared indicate that the model explains a very large portion of the total variation in the dependent variable.

An attractive characteristic of the estimated models, using double log, is that the coefficients of the independent variables are interpreted as percentage changes, or elasticity (Gujarati and Porter, 2009). In the first multiple regression with the FTSE/JSE Top 40 Index as the dependent variable, platinum causes the largest percentage change in the dependent variable. The model with the ZAR as the dependent variable, copper, silver and the FTSE/JSE Top 40 Index have the largest coefficients which mean that the these three independent variables cause the largest percentage change in the dependent variable.

The investigation of the relationships between the datasets leads to the determination of whether the six datasets are cointegrated. In order to identify if the datasets are cointegrated a VAR model needs to be estimated, followed by the Johansen Cointegration test.

The results for the relationship between the FTSE/JSE Top 40 Index and the four commodities will be shown and discussed first, followed by the results for the relationship between the ZAR and the FTSE/JSE Top 40 Index and four commodities.

The VAR model requires the optimal lag length to be determined. The optimal lag length is four lags using the Final prediction error and the Akaike information criterion. The VAR model will therefore be estimated using four lags.

Table-6. VAR FTSE/JSE Top 40 Index and four commodities

	LJSE40	LCOPPER	LSILVER	LPALLAD	LPLAT
LJSE40(-1)	1.019604535	-0.02726852	0.059440171	-0.001515354	0.024167147
	0.01518991	0.01933913	0.021136929	0.024679261	0.015734511
	[67.1238]	[-1.41002]	[2.81215]	[-0.06140]	[1.53593]
LJSE40(-2)	-0.003636827	0.042270311	-0.063658351	0.051377235	-0.002538346
	0.021711597	0.027642258	0.030211929	0.035275138	0.022490019
	[-0.16751]	[1.52919]	[-2.10706]	[1.45647]	[-0.11287]
LJSE40(-3)	-0.083345689	-0.028081162	0.018010552	-0.013586832	-0.03361883
	0.021699036	0.027626266	0.030194452	0.035254731	0.022477008
	[-3.84099]	[-1.01647]	[0.59649]	[-0.38539]	[-1.49570]
LJSE40(-4)	0.066467771	0.013505924	-0.012436367	-0.033672992	0.014786002
	0.015151147	0.01928978	0.021082991	0.024616283	0.015694359
	[4.38698]	[0.70016]	[-0.58988]	[-1.36792]	[0.94212]
LCOPPER(-1)	0.033030773	0.954035221	-0.017657707	0.0329507	0.014856275
	0.012536606	0.01596106	0.017444828	0.020368402	0.012986079
	[2.63475]	[59.7727]	[-1.01220]	[1.61774]	[1.14402]
LCOPPER(-2)	-0.055595405	-0.003540597	0.020876245	-0.046139029	-0.011933838
	0.017254691	0.021967919	0.024010095	0.02803394	0.01787332
	[-3.22205]	[-0.16117]	[0.86948]	[-1.64583]	[-0.66769]
					Continue

LCOPPER(-3)	0.050252466	0.026816946	0.01378229	0.030229811	0.025888589
	0.017258	0.021972133	0.024014701	0.028039318	0.017876749
	[2.91184]	[1.22050]	[0.57391]	[1.07812]	[1.44817]
LCOPPER(-4)	-0.027786347	0.01810701	-0.016090522	-0.017291768	-0.030024102
	0.012505563	0.015921537	0.017401631	0.020317965	0.012953923
	[-2.22192]	[1.13727]	[-0.92466]	[-0.85106]	[-2.31776]
LSILVER(-1)	0.028446709	-0.009191652	0.982525664	0.006157148	0.027073115
	0.012386149	0.015769505	0.017235465	0.020123952	0.012830228
	[2.29665]	[-0.58288]	[57.0060]	[0.30596]	[2.11010]
LSILVER(-2)	-0.011731595	0.01595488	0.026483797	-0.005217765	-0.041820781
	0.017252638	0.021965306	0.024007239	0.028030605	0.017871194
	[-0.67999]	[0.72637]	[1.10316]	[-0.18615]	[-2.34012]
LSILVER(-3)	-0.030810072	-0.031854674	-0.001451589	-0.016629562	0.00159112
	0.017234638	0.021942389	0.023982192	0.02800136	0.017852549
	[-1.78768]	[-1.45174]	[-0.06053]	[-0.59388]	[0.08913]
LSILVER(-4)	0.014544909	0.02627797	-0.009752587	0.017424927	0.013300939
	0.012375514	0.015755965	0.017220667	0.020106673	0.012819212
	[1.17530]	[1.66781]	[-0.56633]	[0.86662]	[1.03758]
LPALLAD(-1)	0.020854363	0.001618511	0.009404442	1.067461395	0.040005418
	0.010832791	0.013791837	0.01507395	0.017600189	0.011221177
	[1.92511]	[0.11735]	[0.62389]	[60.6506]	[3.56517]
LPALLAD(-2)	-0.018941878	0.00493137	0.000365548	-0.098246538	-0.051479481
	0.015612568	0.019877241	0.021725064	0.025365961	0.016172323
	[-1.21325]	[0.24809]	[0.01683]	[-3.87316]	[-3.18318]
LPALLAD(-3)	-0.003353727	-0.00241443	-0.019721742	-0.011604541	0.013540088
	0.015614191	0.019879307	0.021727322	0.025368597	0.016174004
	[-0.21479]	[-0.12145]	[-0.90769]	[-0.45744]	[0.83715]
LPALLAD(-4)	0.001304736	-0.005606186	0.009271581	0.040905044	-0.002914956
	0.010840759	0.013801982	0.015085038	0.017613135	0.011229431
	[0.12035]	[-0.40619]	[0.61462]	[2.32242]	[-0.25958]
LPLAT(-1)	0.007039937	0.044083237	-0.003319815	0.016718579	0.984918451
	0.018059767	0.022992908	0.025130368	0.02934196	0.018707261
	[0.38981]	[1.91725]	[-0.13210]	[0.56978]	[52.6490]
LPLAT(-2)	2.02E-05	-0.029943878	-0.03080063	-0.041974744	-0.007713551
	0.025274879	0.032178874	0.035170277	0.041064454	0.026181055
	[0.00080]	[-0.93054]	[-0.87576]	[-1.02217]	[-0.29462]
LPLAT(-3)	-0.009299839	-0.014890798	0.017321656	-0.001108213	-0.006952963
	0.025212482	0.032099433	0.035083451	0.040963077	0.026116421
	[-0.36886]	[-0.46390]	[0.49373]	[-0.02705]	[-0.26623]
LPLAT(-4)	0.002928744	0.005091529	0.016997639	0.022273153	0.027719933
	0.018033218	0.022959106	0.025093424	0.029298824	0.01867976
	[0.16241]	[0.22177]	[0.67737]	[0.76021]	[1.48396]
C	0.005067552	0.01041731	-0.012530657	0.009869005	0.00181868
	0.006570922	0.008365811	0.009143511	0.010675869	0.006806508
	[0.77121]	[1.24522]	[-1.37044]	[0.92442]	[0.26720]
R-squared	0.999635414	0.999358079	0.999301682	0.99853616	0.999405349
Adj. R-squared	0.999633946	0.999355493	0.999298869	0.998530264	0.999402954

Source: Thomson Reuters Datastream and Eviews
Note: Standard errors in ( ) and t-statistics in [ ]

As illustrated in Table 6 there are 20 significant relationships. For the FTSE/JSE Top 40 Index, the FTSE/JSE Top 40 Index in the previous period as well as the third and fourth lag period of the FTSE/JSE Top 40 Index is significant. Copper is a significant explanatory variable in all four periods of the optimal lag length. Silver at the first lag is the only other significant explanatory variable.

For the dependent copper variable, only the first lag of copper is significant. Silver as the dependent variable, only has the FTSE/JSE Top 40 Index at the second lag period as well as the copper at the first lag period as significant independent variables.

If palladium is the dependent variable, the statistically significant variables are, palladium at the first and second lag period only. If platinum is the dependent variable, the statistically significant variables are copper at the fourth lag, silver at the first and second lag, palladium at the first and second lag, and finally the platinum at the first lag period.

Table-7. Summary of all assumptions of the Johansen Cointegration test

Data Trend:	**None**	**None**	**Linear**	**Linear**	**Quadratic**
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	0	0	0	0	0
Max-Eig	0	0	0	1	1

Source: Thomson Reuters Datastream and Eviews
Selected (0.05 level*) Number of Cointegrating Relations by Model
*Critical values based on MacKinnon-Haug-Michelis (1999)

The Johansen Cointegration test shown in Table 7 indicates that there is a cointegrating relationship when the data is linear, testing intercept and trend as well as at when the data is quadratic, testing intercept and trend. The remainder of the empirical analysis will focus on the linear relationship with an intercept and trend.

Table-8. Maximum Eigenvalue Statistics and Trace Statistics

Hypothesized number of Cointegrating Equations	**Eigen-value**	**Trace Statistic**	**5% Critical Value**	**Prob**
None	0.007930	76.26564	88.8038	0.2835
At most 1	0.003412	36.57469	63.8761	0.9360
At most 2	0.001909	19.53544	42.91525	0.9683
At most 3	0.001278	10.011	25.87211	0.9245
At most 4	0.000729	3.637322	12.51798	0.7937
Hypothesized number of Cointegrating Equations	Eigen-value	Max-Eig Statistic	5% Critical Value	Prob
None*	0.007930	39.69095	38.33101	0.0347
At most 1	0.003412	17.03924	32.11832	0.8594
At most 2	0.001909	9.524441	25.82321	0.9749
At most 3	0.001278	6.373681	19.38704	0.9383
At most 4	0.000729	3.637322	12.51798	0.7937

Source: Thomson Reuters Datastream and Eviews
* Statistically significant at a 5% level of significance

Table 8 reports the maximum Eigenvalue statistics and Trace statistics as allowance for an intercept and a trend in the data was made. The table illustrates that only the null hypothesis based on the maximum eigenvalue of no cointegrating equations can be rejected.

The results for the relationship between the ZAR and the FTSE/JSE Top 40 Index and four commodities are shown below. The optimal lag length is four lags using the Final prediction error and the Akaike information criterion. The VAR model will therefore be estimated using four lags.

Table-9. VAR ZAR, FTSE/JSE Top 40 Index and four commodities

	LZAR	**LJSE40**	**LCOPPER**	**LSILVER**	**LPALLAD**	**LPLAT**
LZAR(-1)	0.95746	-0.06979	-0.06867	-0.09521	-0.10761	-0.07386
	-0.01498	-0.01884	-0.02396	-0.02621	-0.03061	-0.01952
	[63.8966]	[-3.70481]	[-2.86564]	[-3.63194]	[-3.51550]	[-3.78459]
LZAR(-2)	0.014994	0.032694	0.009741	0.03084	0.069831	0.040424
	-0.02055	-0.02584	-0.03287	-0.03596	-0.04199	-0.02677
						Continue

	[0.72952]	[1.26543]	[0.29636]	[0.85771]	[1.66319]	[1.51020]
LZAR(-3)	-0.01466	0.034581	0.062529	0.072889	0.068479	0.039432
	-0.02055	-0.02583	-0.03286	-0.03595	-0.04198	-0.02676
	[-0.71343]	[1.33866]	[1.90263]	[2.02741]	[1.63118]	[1.47330]
LZAR(-4)	0.037865	0.005586	-0.01422	-0.00957	-0.0368	-0.00894
	-0.01497	-0.01882	-0.02394	-0.02619	-0.03058	-0.0195
	[2.52940]	[0.29687]	[-0.59393]	[-0.36534]	[-1.20330]	[-0.45851]
LJSE40(-1)	0.013529	1.017171	-0.02539	0.057731	-0.00031	0.024109
	-0.01209	-0.0152	-0.01933	-0.02115	-0.02469	-0.01574
	[1.11920]	[66.9384]	[-1.31348]	[2.72988]	[-0.01273]	[1.53138]
LJSE40(-2)	0.025892	-0.00106	0.044911	-0.05978	0.054746	-0.00017
	-0.01725	-0.02169	-0.02759	-0.03019	-0.03525	-0.02247
	[1.50059]	[-0.04868]	[1.62758]	[-1.98035]	[1.55313]	[-0.00758]
LJSE40(-3)	-0.0322	-0.0807	-0.02613	0.02114	-0.01177	-0.03163
	-0.01725	-0.02168	-0.02759	-0.03018	-0.03524	-0.02247
	[-1.86677]	[-3.72160]	[-0.94708]	[0.70054]	[-0.33401]	[-1.40772]
LJSE40(-4)	-0.00478	0.06145	0.014562	-0.01703	-0.03575	0.012547
	-0.01208	-0.01518	-0.01931	-0.02113	-0.02467	-0.01573
	[-0.39588]	[4.04810]	[0.75405]	[-0.80617]	[-1.44922]	[0.79777]
LCOPPER(-1)	0.012823	0.026401	0.942473	-0.02855	0.019144	0.005659
	-0.01012	-0.01272	-0.01618	-0.0177	-0.02067	-0.01318
	[1.26721]	[2.07550]	[58.2393]	[-1.61283]	[0.92608]	[0.42943]
LCOPPER(-2)	-0.02532	-0.0507	-0.00168	0.02581	-0.03724	-0.00646
	-0.01391	-0.01748	-0.02224	-0.02433	-0.02841	-0.01811
	[-1.82083]	[-2.90005]	[-0.07560]	[1.06087]	[-1.31092]	[-0.35642]
LCOPPER(-3)	0.00089	0.052521	0.032523	0.019865	0.035219	0.028579
	-0.01391	-0.01749	-0.02225	-0.02434	-0.02842	-0.01812
	[0.06397]	[3.00349]	[1.46194]	[0.81630]	[1.23932]	[1.57746]
LCOPPER(-4)	0.010635	-0.02618	0.015338	-0.01671	-0.0212	-0.03079
	-0.01008	-0.01267	-0.01612	-0.01764	-0.02059	-0.01313
	[1.05506]	[-2.06619]	[0.95142]	[-0.94744]	[-1.02937]	[-2.34492]
LSILVER(-1)	-0.00577	0.020976	-0.01518	0.972911	-0.00353	0.020026
	-0.00995	-0.0125	-0.01591	-0.0174	-0.02032	-0.01296
	[-0.58022]	[1.67753]	[-0.95451]	[55.9071]	[-0.17390]	[1.54580]
LSILVER(-2)	0.005046	-0.00838	0.01708	0.02978	0.001335	-0.03792
	-0.01382	-0.01738	-0.0221	-0.02418	-0.02824	-0.018
	[0.36509]	[-0.48214]	[0.77269]	[1.23152]	[0.04729]	[-2.10617]
LSILVER(-3)	-0.03001	-0.02697	-0.0257	0.005993	-0.00973	0.005757
	-0.01381	-0.01736	-0.02209	-0.02416	-0.02821	-0.01799
	[-2.17269]	[-1.55372]	[-1.16352]	[0.24803]	[-0.34468]	[0.32005]
LSILVER(-4)	0.030371	0.014907	0.024585	-0.01095	0.013415	0.012148
	-0.00993	-0.01249	-0.01589	-0.01738	-0.02029	-0.01294
	[3.05755]	[1.19384]	[1.54766]	[-0.63022]	[0.66109]	[0.93905]
LPALLAD(-1)	0.001116	0.019132	-0.0012	0.006565	1.064168	0.037795
	-0.00861	-0.01083	-0.01377	-0.01507	-0.0176	-0.01122
	[0.12953]	[1.76706]	[-0.08683]	[0.43571]	[60.4796]	[3.36924]
LPALLAD(-2)	-0.00612	-0.01743	0.00622	0.002382	-0.0953	-0.04971
	-0.01241	-0.0156	-0.01985	-0.02171	-0.02535	-0.01616
	[-0.49294]	[-1.11732]	[0.31344]	[0.10973]	[-3.75913]	[-3.07544]
LPALLAD(-3)	0.013035	-0.00292	-0.00162	-0.01875	-0.01129	0.013809
	-0.01241	-0.0156	-0.01984	-0.02171	-0.02535	-0.01616
	[1.05048]	[-0.18742]	[-0.08169]	[-0.86379]	[-0.44554]	[0.85448]
LPALLAD(-4)	-0.00697	0.001028	-0.0044	0.009249	0.041241	-0.00258
	-0.00862	-0.01083	-0.01378	-0.01508	-0.01761	-0.01122
						Continue

	[-0.80908]	[0.09489]	[-0.31916]	[0.61343]	[2.34235]	[-0.22965]
LPLAT(-1)	0.019911	0.005323	0.041529	-0.00606	0.014068	0.982986
	-0.01435	-0.01804	-0.02295	-0.0251	-0.02931	-0.01869
	[1.38759]	[0.29513]	[1.80977]	[-0.24122]	[0.47992]	[52.6008]
LPLAT(-2)	0.000983	0.00293	-0.02668	-0.02655	-0.03669	-0.00435
	-0.02009	-0.02525	-0.03212	-0.03514	-0.04103	-0.02616
	[0.04895]	[0.11603]	[-0.83062]	[-0.75546]	[-0.89418]	[-0.16612]
LPLAT(-3)	0.007248	-0.00822	-0.01338	0.019189	-0.00079	-0.00633
	-0.02004	-0.02519	-0.03204	-0.03505	-0.04093	-0.02609
	[0.36176]	[-0.32621]	[-0.41751]	[0.54744]	[-0.01936]	[-0.24254]
LPLAT(-4)	-0.02916	0.000126	0.004125	0.013579	0.019994	0.025933
	-0.01434	-0.01802	-0.02293	-0.02508	-0.02929	-0.01867
	[-2.03388]	[0.00702]	[0.17992]	[0.54143]	[0.68273]	[1.38900]
C	-0.00515	0.006376	0.004624	-0.01346	0.006424	4.16E-05
	-0.00529	-0.00665	-0.00846	-0.00926	-0.01081	-0.00689
	[-0.97240]	[0.95862]	[0.54651]	[-1.45353]	[0.59434]	[0.00603]
R-squared	0.998384	0.999637	0.999362	0.999304	0.998541	0.999407
Adj. R-squared	0.998377	0.999635	0.999359	0.999301	0.998534	0.999405

Source: Thomson Reuters Datastream and Eviews
Note: Standard errors in ( ) and t-statistics in [ ]

As illustrated in Table 9 there are 29 significant relationships. For the ZAR as the dependent variable, the following are statistically significant independent variables:

- ZAR at the first and fourth lag period
- Silver at the third and fourth lag period
- Platinum at the fourth lag period

For the FTSE/JSE Top 40 Index as the dependent variable, the following independent variables are statistically significant:

- ZAR at the first lag period
- FTSE/JSE Top 40 Index at the first, third and fourth lag period
- Copper at the first, second, third and fourth lag period

Copper as the dependent variable, only the first lag of ZAR and the first lag of copper are significant.

Silver as the dependent variable, the following are statistically significant independent variables:

- ZAR at the first and third lag period
- FTSE/JSE Top 40 Index at the first lag period
- Silver at the first lag period

Palladium as the dependent variable, only the first lag of ZAR and the first, second and fourth lag of palladium as statistically significant.

If platinum is the dependent variable, the statistically significant variables are:

- ZAR at the first lag period
- Copper at the fourth lag period
- Silver at the second lag period
- Palladium at the first and second lag period
- Platinum at the first lag period

Table-10. Summary of all assumptions of the Johansen Cointegration test

Data Trend:	**None**	**None**	**Linear**	**Linear**	**Quadratic**
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	1	0	0	0	1
Max-Eig	1	1	1	1	1

Source: Thomson Reuters Datastream and Eviews
Selected (0.05 level*) Number of Cointegrating Relations by Model
*Critical values based on MacKinnon-Haug-Michelis (1999)

The Johansen Cointegration test in Table 10 shows there is a cointegrating relationship at the following sets:

- No trend in the data, not testing intercept and trend
- No trend in the data, testing intercept and not trend
- Data is linear, testing intercept and not trend
- Data is linear, testing intercept and trend
- Data is quadratic, testing intercept and trend

Table-11. Maximum Eigenvalue Statistics and Trace Statistics

Hypothesized number of Cointegrating Equations	**Eigen-value**	**Trace Statistic**	**5% Critical Value**	**Prob**
None	0.010231	111.6639	117.7082	0.1134
At most 1	0.004825	60.40069	88.8038	0.8453
At most 2	0.003019	36.29077	63.8761	0.9411
At most 3	0.002154	21.21595	42.91525	0.9342
At most 4	0.001423	10.46518	25.87211	0.9036
At most 5	0.000675	3.365868	12.51798	0.8305
Hypothesized number of Cointegrating Equations	Eigen-value	Maximum Eigenvalue Statistic	5% Critical Value	Prob
None*	0.010231	51.2632	44.4972	0.0080
At most 1	0.004825	24.10991	38.33101	0.7334
At most 2	0.003019	15.07482	32.11832	0.9457
At most 3	0.002154	10.75077	25.82321	0.9370
At most 4	0.001423	7.099314	19.38704	0.8939
At most 5	0.000675	3.365868	12.51798	0.8305

Source: Thomson Reuters Datastream and Eviews

Table 11 reports the maximum Eigenvalue statistics and Trace statistics as allowance for an intercept and a trend in the data was made. The table shows that only the null hypothesis based on the maximum eigenvalue of no cointegrating equations can be rejected.

6. Conclusion

Overall, the empirical results show that there are significant relationships in the long run and short run of the included datasets. The first four alternative hypotheses addressing a movement relationship between the datasets indicate that the following datasets move together, based on the correlation results and single regression results:

1. Platinum and copper
2. Silver and copper
3. FTSE/JSE Top 40 Index and copper
4. Silver and platinum
5. FTSE/JSE Top 40 Index and platinum
6. FTSE/JSE Top 40 Index and silver

The multiple regression analysis shows that platinum causes the largest percentage change in the FTSE/JSE Top 40 Index of the included independent variables. Copper, silver and the FTSE/JSE Top 40 Index causes the largest percentage change in the ZAR.

The remainder of the analysis focusing on VAR and Johansen Cointegration indicate that there are numerous significant relationships between the six datasets and that there is a cointegrating relationship between the FTSE/JSE Top 40 Index and the four commodities as well as between the ZAR, FTSE/JSE Top 40 Index and four commodities.

The empirical results indicate that there is opportunity for further study in metal commodities. In addition further studies can be undertaken in soft commodities, as well as in energy commodities. At this point, no distinct cross-hedging relationships have been identified, but this can be explored further between other commodities.

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