Cointegration between Energy Commodities and the South African Financial Market

Corlise L. Le Roux

Abstract The long-run relationship between three energy commodities, namely crude oil, jet kerosene and natural gas; and the FTSE/JSE Top 40 Index will be examined. A second relationship between the three commodities and the FTSE/JSE Top 40 Index against the South African Rand (versus the United States Dollar) will also be explored to determine the impact of the variables on the ZAR. The analysis of the variables will include correlation, regression, vector autoregression and the Johansen cointegration test to determine linear interdependencies among the variables. The results indicate that there is a cointegrating relationship between the both relationships investigated.

Keywords: Energy commodities; FTSE/JSE Top 40 Index; South African Rand; Cointegration

1. Introduction

Relationships are important in the financial market context as the relationships guide investment related decisions. These relationships cause investors to buy, sell or hold investments. The relationships can be linked to economic variables, financial statement variables or between other financial or real assets to name a few. By understanding relationships investments are better understood in how they react to outside factors. Understanding which factors affect the investment is very important in the investment process.

This paper explores the initial relationships between energy commodities, the FTSE/JSE Top 40 Index and the South African Rand (versus the United States Dollar), denoted as ZAR which will be used for a further study.

The historical time-series datasets examined in the study are three energy commodities, crude oil, jet kerosene and natural gas, the FTSE/JSE Top 40 Index and the ZAR. These commodities formed part of the study as they are part of the international benchmarks for energy commodities.

The objective of the study is to determine the following the significant relationships:

- Three energy commodities against the FTSE/JSE Top 40 Index
- Three energy commodities and the FTSE/JSE Top 40 Index against the ZAR

The empirical data analysis of the study will include correlation, single and multiple regressions, vector autoregression and the Johansen cointegration test to determine significant relationships that will be used for a study to identify causality in the five datasets included in this paper.

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The remainder of the paper is structured as follows; part 2 provides a brief review of current literature. Part 3 and 4 discussed the methodology and explanation of the data. Part 5 illustrates the results and interprets the findings. The final part, part 6, discusses the conclusion and implication of the study.

2. Review of the literature

Long run relationships between similar variables are not often studied. Prior studies which investigated the relationships that metal, agricultural and chemical commodities have with the FTSE/JSE Top 40 Index and ZAR have been explored by le Roux (2014, 2015a, 2015b). Each set of commodity data tested had a long run relationship.

The agricultural commodities explored to test for a long run relationship between the FTSE/JSE Top 40 Index and the ZAR, were cocoa, coffee, corn, cotton, soyabean, sugar and wheat. These commodities were compared firstly against the FTSE/JSE Top 40 Index and then the seven commodities and the FTSE/JSE Top 40 Index were compared against the ZAR, similar to methodology in this paper. Both datasets tested showed that a cointegrating relationship exists between the variables. Breaking the data down to investigate relationships between the variables showed that strong relationships exist between soyabean and cocoa, soyabean and corn, wheat and corn, and wheat and soyabean. The multiple regression included based on the methodology mentioned showed that cotton, as an independent variable caused the largest percentage change in the FTSE/JSE Top 40 Index and wheat, as an independent variable caused the largest percentage change in the ZAR (le Roux, 2015a).

The metal commodities, copper, palladium, platinum and silver were compared to the FTSE/JSE Top 40 Index and the ZAR in the same manner as the agricultural commodities. Both relationships investigated shows that a long run relationship existed, between the four commodities against FTSE/JSE Top 40 Index as well as between the four commodities and the FTSE/JSE Top 40 Index against the ZAR. The strongest relationships between the variables were between platinum and copper, silver and copper, FTSE/JSE Top 40 Index and copper, silver and platinum, FTSE/JSE Top 40 Index and platinum, and FTSE/JSE Top 40 Index and silver. From the multiple regression, platinum caused the largest percentage change in the FTSE/JSE Top 40 Index and the FTSE/JSE Top 40 Index caused the largest percentage change in the ZAR, with copper and silver close behind it with the largest negative coefficient affecting the ZAR (le Roux, 2014).

The chemical commodities were compared to the FTSE/JSE Top 40 Index and the ZAR following the same methodology. The chemical commodities included in the analysis were naphtha, paraffinic-xylene, poly vinyl chloride, polyethylene, styrene, terephthalic acid and vinyl chloride monomer. The empirical results showed that a cointegrating relationship exists between the seven commodities against FTSE/JSE Top 40 Index as well as between the seven commodities and the FTSE/JSE Top 40 Index and the ZAR. Naphtha and paraffinic-xylene, naphtha and polyethylene, naphtha and styrene, paraffinic-xylene and terephthalic acid, and polyethylene and styrene showed the strongest interrelationships. The multiple regression revealed that vinyl chloride monomer caused the largest percentage change in the FTSE/JSE Top 40 Index and the ZAR (le Roux, 2015b).

Nazlioglu and Soytas (2011) applied panel cointegration and Granger causality to investigate the dynamic relationship presented between variables. The variables being, the world oil price and twenty four world agricultural commodity prices, some being maize, coffee, sugar, and rice. The prices of oil and the agricultural commodities took into account the changes in the relative strength of the United States Dollar. The study showed that oil prices have a strong effect on the agricultural commodity prices.

The relationship between the United Kingdom wholesale gas price and the Brent oil price was explored by Panagiotidis and Rutledge (2004). Empirical analysis included Johansen integration, Breitung nonparametric procedure, vector error correction models (VECM), McLeod-Li, Engle test for (G)ARCH effects and the BDS test statistic; with data from 1996 to 2003. The results indicated that a long run relationship exists through the period included.

Relationships between the energy commodities, the FTSE/JSE Top 40 Index and the ZAR have not yet been investigated and will be explored in the remainder of this paper.

3. Methodology

The data methodology applied in this study is based on historical time-series data which is used to explore the relationships that exist between the five datasets included. The presence of relationships between the datasets will be examined using econometric tests applied to the data, namely correlation, regression, vector autoregression and Johansen cointegration.

The initial movements between the datasets will be examined by the means of correlation and single regression. The relationships to be investigated are:

- Movements in each commodity price against movements in the FTSE/JSE Top 40 Index and vice-versa
- Movements in each commodity price against movements in the ZAR and vice-versa
- Movements in the FTSE/JSE Top 40 Index against movements in the ZAR and vice-versa

Once the initial movement are examined, the relationships will be further investigated by the use of multiple regressions. The multiple regressions will be followed by the vector autoregression model and Johansen cointegration test. These tests are applied to determine if any long-run relationships exist (Asteriou and Hall, 2011; Johansen, 1991; Luetkepohl, 2011; Watson, 1994). The analysis of this paper will be further applied in a paper which will follow that will investigate causality.

4. Data

There are three energy commodities included in the paper, namely crude oil, jet kerosene and natural gas. These commodities will be examined against the FTSE/JSE Top 40 Index initially, followed by the comparison of the three commodities and the FTSE/JSE Top 40 Index against the ZAR. The prices of the datasets are daily spot prices available from the commodity benchmarks from the Thomson Reuters Datastream database. The sample period runs from 7 January 2005 to 31 December 2014, which amounts to 2604 data points. The sample period was chosen as not all datasets had data available before 7 January 2005. The five datasets included in the paper was analysed using EViews.

The alternative hypotheses for the datasets are:

- Ha: There is a movement relationship between the commodity price and the FTSE/JSE Top 40 Index
- Ha: There is a movement relationship between the commodity price and the ZAR
- Ha: There is a movement relationship between the FTSE/JSE Top 40 Index and the ZAR
- Ha: There is a movement relationship between a combination of the 9 datasets by means of single and multiple regressions
- Ha: There is a movement relationship between a combination of the 9 datasets by means of VAR and Johansen cointegration test

The empirical results are referenced as follows (first code represents the daily spot price and the second code represented the log differenced data):

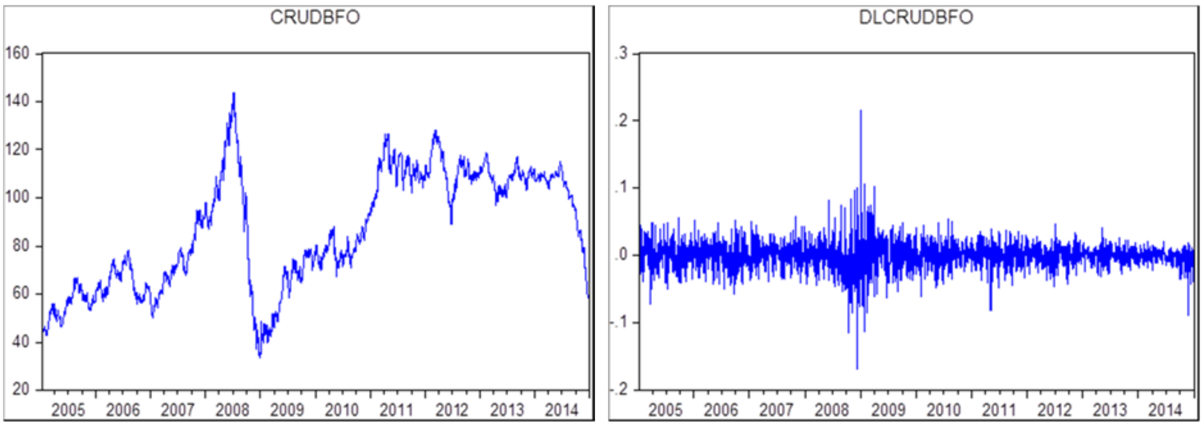
- Crude oil: CRUDBFO and LCRUDBFO
- Jet kerosene: JETFSIN and LJETFSIN
- Natural gas: NATGHEN and LNATGHEN
- FTSE/JSE Top 40 Index: JSE40 and LJSE40
- South African Rand: COMRAN and LCOMRAN

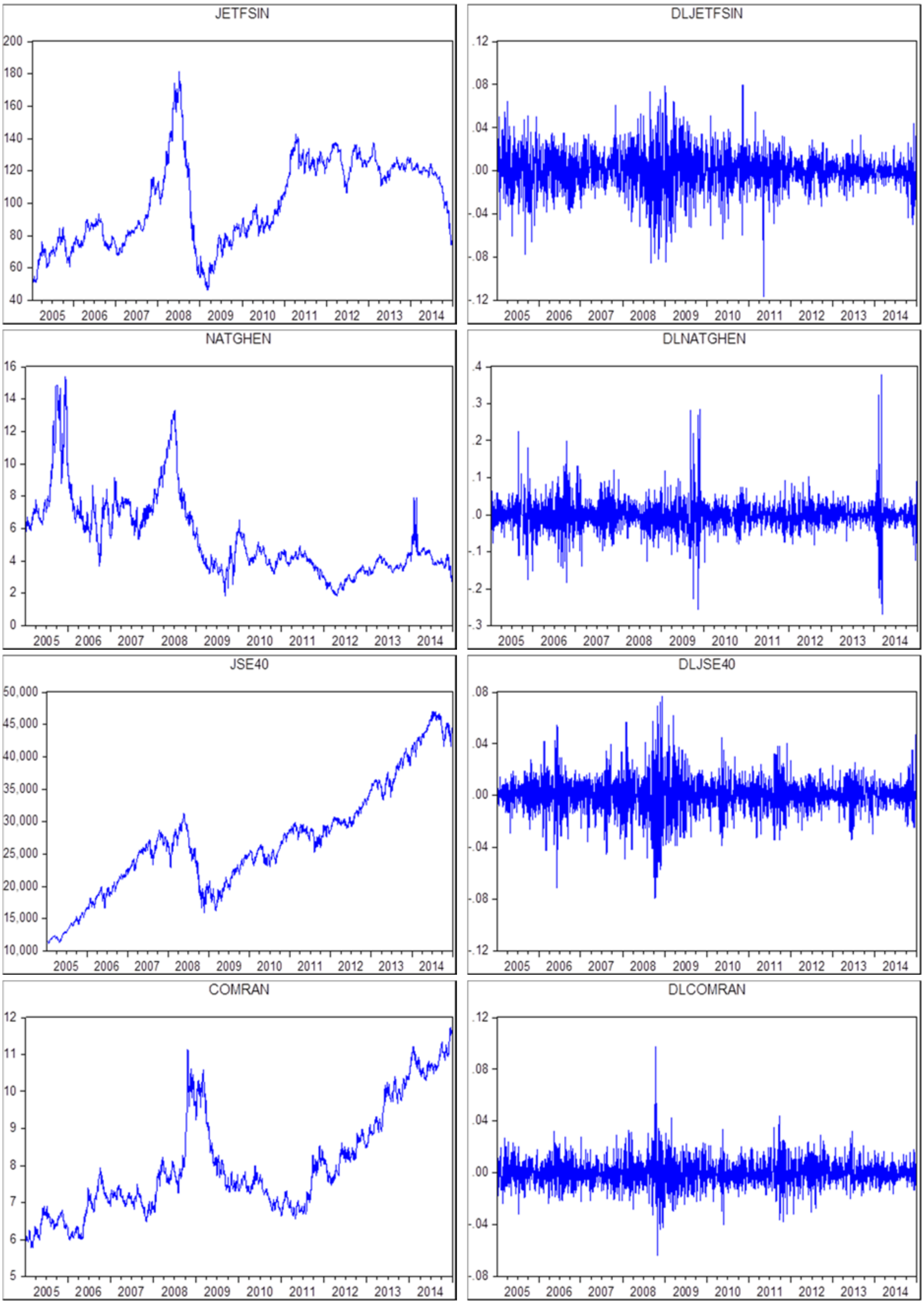
5. Empirical Results

The first view of the data is shown in a graphical form in Figure 1, showing the movements of the datasets. Two graphs are shown for each datasets, the daily price on the line graph as well as on the log differenced graphs.

All three commodities were the affected by the global financial crisis of 2008, however the log differenced graphs show that crude oil and natural gas was highly affected. The natural gas log differenced graph shows a very volatile change in prices at the beginning of 2014. The FTSE/JSE Top 40 Index and the ZAR was affected by the global financial crisis for a short period before the volatility stabilised within a tighter range.

Fig. 1: Graphical representation of movement in the five datasets





Source: Researcher’s own data

Strong positive correlations (bold values which are 0.74 and above) are shown in the correlation matrix in Table 1 between the following dataset combinations:

- FTSE/JSE Top 40 Index and crude oil
- FTSE/JSE Top 40 Index and jet kerosene
- Crude oil and jet kerosene

A relatively strong negative relationship exists between the FTSE/JSE Top 40 Index and natural gas.

Table 1: Correlation Matrix

	LJSE40	LCRUDBFO	LJETFSIN	LNATGHEN	LCOMRAN
LJSE40	1	**0.7709**	**0.7420**	**-0.4901**	0.6891
LCRUDBFO	**0.7709**	1	**0.9812**	-0.3647	0.2927
LJETFSIN	**0.7420**	**0.9812**	1	-0.2775	0.2883
LNATGHEN	**-0.4901**	-0.3647	-0.2775	1	-0.4240
LCOMRAN	0.6891	0.2927	0.2883	-0.4240	1

Source: Researcher's own data

The descriptive statistics of the five datasets are shown in Table 2.

Table 2: Descriptive Statistics (7 January 2005 to 31 December 2014)

	LJSE40	LCRUDBFO	LJETFSIN	LNATGHEN	LCOMRAN
Mean	10.1520	4.4124	4.5743	1.6079	2.0668
Median	10.1755	4.4372	4.5787	1.5019	2.0288
Maximum	10.7596	4.9695	5.2021	2.7337	2.4627
Minimum	9.3258	3.5184	3.8373	0.5988	1.7544
Std. Dev	0.3325	0.3032	0.2737	0.4159	0.1715
Skewness	-0.3564	-0.4373	-0.2909	0.3228	0.5283
Kurtosis	2.8091	2.1509	2.2117	2.6550	2.2823
Jarque-Bera	59.0763	161.2360	104.1429	58.1372	176.9945
Probability	0	0	0	0	0
Sum	26435.79	11489.91	11911.39	4186.909	5381.927
Sum Sq Dev	287.8482	239.2634	194.9288	450.3215	76.5210
Observations	2604	2604	2604	2604	2604

Source: Researcher's own data

The Augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1981) and Phillips-Perron (PP) (Perron, 1989) tests need to be run in test for unit roots which is required to continue with the analysis. The results indicate if the data included in the study is stationary or not. The null hypotheses are:

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

The results of the test ADF and PP tests are shown in Table 3.

Table 3: Unit Roots Test using the Augmented Dickey-Fuller and Phillips-Perron method

ADF	**Level**		**1st Difference**	
	Intercept	**Trend and Intercept**	**Intercept**	**Trend and Intercept**
JSE40	-1.8255	-2.7273	-50.6858***	-50.6849***
COMRAN	-1.1077	-2.2253	-49.9169***	-49.9095***
JETFSIN	-2.3828	-1.5008	-51.4365***	-51.5003***
NATGHEN	-2.1413	-3.4191	-40.5198***	-40.514***
CRUDBFO	-2.1243	-1.2816	-51.9105***	-51.9583***
PP	**Level**		**1st Difference**	
	Intercept	**Trend and Intercept**	**Intercept**	**Trend and Intercept**
JSE40	-1.806	-2.4886	-51.4254***	-51.4497***
COMRAN	-1.0751	-2.2147	-49.9191***	-49.9115***
JETFSIN	-2.4498	-1.6819	-51.5397***	-51.5662***
NATGHEN	-2.1098	-3.4926***	-47.5567***	-47.5482***
CRUDBFO	-2.1222	-1.2859	-51.9025***	-51.9492***

Source: Researcher's own data

*** Statistically significant at a 1% level of significance

The results of the unit root tests in Table 3 show that all the variables are stationary at first difference at a 1% significance level. This indicates that the single and multiple regressions need to be run using data that is logged. The single regression outputs of interest are shown in the following tables.

Table 4: Summary of Single Regression outputs above 0.55

Dependent	**Independent**	**R-Squared**	**F-stat**	**Prob**	**t-stat**	**Prob**
LJETFSIN	**LCRUDBFO**	0.962811	67365.7	0	44.15176	0
LJETFSIN	**LJSE40**	0.550513	3186.821	0	56.45193	0
LCRUDBFO	**LJSE40**	0.594317	3811.875	0	61.74038	0

Source: Researcher's own data

The R-Squared as shown in the regression results, shows the percentage of total variation in the dependent variable explained by variation in the independent variable (Cameron and Windmeijer, 1995). The following relationships indicate a relatively strong and strong relationship as the R-Squared results are above 0.55 as displayed in Table 4 which is in line with the three relationships which showed a high correlation shown in Table 1:

- FTSE/JSE Top 40 Index and crude oil
- FTSE/JSE Top 40 Index and jet kerosene
- Crude oil and jet kerosene

The confirmation that the above relationships exist in the single regression analysis, leads to the examination of the relationships between multiple datasets. Table 5 shows that there is a statistical significant relationship between both relationships investigated, however the relationships are only relatively strong.

Table 5: Multiple Regression outputs

Dependent	Independent	Adjusted R-Squared	F-Stat	Intercept	Intercept t-stat	Ind Coeff	Ind t-stat
LJSE40	**LJETFSIN**	0.6451	1577.918***	7.0698	0.6451***	0.1993	2.4221**
	LNATGHEN					-0.2048	-18.2705***
	LCRUDBFO					0.5666	7.3944***
LCOMRAN	**LJETFSIN**	0.64394	1177.889	-2.29355	-27.99459	0.5312	12.4882***
	LNATGHEN					-0.0762	-12.3895***
	LCRUDBFO					-0.8127	-20.3268***
	LJSE40					0.5555	54.8468***

Source: Researcher's own data
Note: All variables were logged
***Statistically significant at 1% level of significance
** Statistically significant at 5% level of significance

In Table 5, the Adjusted R-Squared shows that the model explains a relatively large portion of the total variation in the dependent variable for the FTSE/JSE Top 40 Index and the ZAR as the dependent variables.

The model with the FTSE/JSE Top 40 Index as the dependent variable, crude oil results in the largest percentage change with a coefficient of 0.5666. Crude oil also causes the largest percentage change with the ZAR as the dependent variable with a coefficient of -0.8127.

The remainder of the analysis focuses on the whether or not the 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 empirical results for the VAR model and Johansen cointegration test will be explained in order to determine if the datasets are cointegrated.

The first VAR model and Johansen cointegration test examined below will be for the relationship between the FTSE/JSE Top 40 Index and the three commodities, with an optimal lag length of three lags. The optimal lag length was determined by the Schwarz information criterion and the Hannan-Quinn information criterion.

The results for the ZAR against the FTSE/JSE Top 40 Index and three commodities, with four lags as the optimal lag length will be shown last. The optimal lag length was determined by the Final prediction error and the Akaike information criterion.

The VAR model was estimated using three and four lags respectively for both relationships investigated. The VAR for the first relationship investigated indicates that there are 17 significant relationships. The following significant explanatory variables and related lag periods are:

- Crude oil: Crude oil (-1)
- Jet kerosene: FTSE/JSE Top 40 Index (-3), Crude oil (-1, -2, -3), Jet kerosene (-1, -2)
- Natural gas: Crude oil (-3), Jet kerosene (-1, -2, -3), Natural gas (-1, -2, -3)
- FTSE/JSE Top 40 Index: FTSE/JSE Top 40 Index (-1), Crude oil (-1), Jet kerosene (-1)

Table 6: Summary of all assumptions of the Johansen cointegration test

Data Trend Test Type	None No Intercept	None Intercept	Linear Intercept	Linear Intercept	Quadratic Intercept

	No Trend	No Trend	No Trend	Trend	Trend
Trace	1	1	1	1	1
Max-Eig	1	1	1	1	1

Source: Researcher's own data

Selected (0.05 level) Number of Cointegrating Relations by Model, the critical values are based on MacKinnon-Haug-Michelis (1999)

Table 6 shows that there is only one cointegrating relationships under all the assumptions of the Johansen cointegration test.

Table 7: Maximum Eigenvalue Statistics and Trace Statistics

Hypothesized number of Cointegrating Equations	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.022473	76.18059	47.85613	0
At most 1	0.00499	17.08482	29.79707	0.6338
At most 2	0.001566	4.078165	15.49471	0.8971
At most 3	0.000001	0.002524	3.841466	0.9576
Hypothesized number of Cointegrating Equations	**Eigenvalue**	**Maximum Eigenvalue Statistic**	**0.05 Critical Value**	**Prob.****
None *	0.022473	59.09577	27.58434	0
At most 1	0.00499	13.00666	21.13162	0.4516
At most 2	0.001566	4.075642	14.2646	0.8513
At most 3	0.000001	0.002524	3.841466	0.9576

Source: Researcher's own data

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

Max-eigenvalue 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

Table 7 shows the maximum eigenvalue test and trace statistics when a linear deterministic trend is assumed. The null hypothesis based on the maximum eigenvalue statistics and trace statistic of no cointegrating equations can be rejected.

The results for the relationship between the ZAR and the FTSE/JSE Top 40 Index and three commodities are illustrated below.

The VAR test indicates that there are 25 significant relationships. The following significant explanatory variables and related lag periods are:

- Crude oil: South African Rand (-4), Crude oil (-1)
- Jet kerosene: South African Rand (-1), Crude oil (-1, -2, -3, -4), Jet kerosene (-1, -2)
- Natural gas: Crude oil (-3), Jet kerosene (-1, -2), Natural gas (-1, -2, -3, -4)
- FTSE/JSE Top 40 Index: FTSE/JSE Top 40 Index (-1, -4), Crude oil (-1), Jet kerosene (-1, -2)
- South African Rand: South African Rand (-1), FTSE/JSE Top 40 Index (-4), Jet kerosene (-1, -4)

Table 8: Summary of all assumptions of the Johansen cointegration test

Data Trend Test Type	None No Intercept No Trend	None Intercept No Trend	Linear Intercept No Trend	Linear Intercept Trend	Quadratic Intercept Trend
Trace	3	1	1	1	1
Max-Eig	1	1	1	1	1

Source: Researcher's own data

Selected (0.05 level) Number of Cointegrating Relations by Model, the critical values are based on MacKinnon-Haug-Michelis (1999)

The Johansen cointegration test results in Table 8 shows that there is only one cointegrating relationship under all the assumptions, except for one assumption which has 3 long run relationships.

Table 9: Maximum Eigenvalue Statistics and Trace Statistics

Hypothesized number of Cointegrating Equations	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.021332	97.40595	69.81889	0.0001
At most 1	0.008482	41.36451	47.85613	0.1773
At most 2	0.005402	19.22477	29.79707	0.4768
At most 3	0.001643	5.14584	15.49471	0.7931
Hypothesized number of Cointegrating Equations	**Eigenvalue**	**Maximum Eigenvalue Statistic**	**0.05 Critical Value**	**Prob.****
None *	0.021332	56.04144	33.87687	0
At most 1	0.008482	22.13975	27.58434	0.2133
At most 2	0.005402	14.07893	21.13162	0.3586
At most 3	0.001643	4.274745	14.2646	0.8293

Source: Researcher's own data

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

Max-eigenvalue 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

Table 9 shows the maximum eigenvalue test and trace statistics when a linear deterministic trend is assumed. The null hypothesis based on the maximum eigenvalue statistics and trace statistic of no cointegrating equations can be rejected.

6. Conclusion and implications

The relationships between the three energy commodities, crude oil, jet kerosene and natural gas; and the FTSE/JSE Top 40 Index were investigated. The relationship between the three commodities and the FTSE/JSE Top 40 Index against the ZAR was also investigated to determine the impact of the variables on the ZAR.

The empirical results of the study indicate that there are significant relationships in the long run of the five financial datasets included. The first set of hypotheses related to the movement relationships present between the datasets according to the correlation and single regression results; show the following relationships are present:

- FTSE/JSE Top 40 Index and crude oil
- FTSE/JSE Top 40 Index and jet kerosene
- Crude oil and jet kerosene

In the multiple regression, the model with the FTSE/JSE Top 40 Index as the dependent variable, crude oil results in the largest percentage change with a coefficient of 0.5666. Crude oil also causes the largest percentage change with the ZAR as the dependent variable with a coefficient of -0.8127. The Johansen cointegration test indicates that there is a cointegrating relationship between both models investigated.

Further opportunities for study include further analyses of energy commodities as well as similar study on other combinations of commodities. The results of the study are important to market participants as the movement in the commodity price does have an effect on the FTSE/JSE Top 40 Index and the ZAR which can influence the monetary policy in South Africa.

References

Asteriou D, Hall SG: Applied Econometrics, 2nd edition. Palgrave Macmillan, United Kingdom (2011)

Cameron AC, Windmeijer FAG (1995) An R-squared measure of goodness of fit for some common nonlinear regression models. Journal of Econometrics 77(2):329-342

Dickey DA, Fuller WA (1981) Likelihood ratio Statistics for Autoregressive Time Series with a Unit Root. Econometrica 49(4):1057- 1072

Johansen S (1991) Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models. Econometrica 59(6):1551-1580

Le Roux CL (2014) Predictive Relationships between Metal Commodities and the FTSE/JSE Top 40 Index. In: Proceedings of the 2nd International Conference on Economics, Finance and Management Outlooks (ICEFMO), Malaysia, 20-21 December 2014. PP. 24-37. PAK Publishing Group (2014)

Le Roux CL (2015a) Relationships between Soft commodities, the FTSE/JSE Top 40 Index, and the South African Rand. In: Tsounis N., Vlahvei A. (eds.) Procedia Economics and Finance, International Conference on Applied Economics (ICOAE), Kazan, 2-4 July 2015.Vol. 24, pp. 353-362. Elsevier (2015)

Le Roux C.L (2015b) Relationships between chemical commodities, the FTSE/JSE Top 40 Index, and the South African Rand. In: Abstracts of the World Finance & Banking Symposium, Hanoi, 17-18 December 2015

Luetkepohl H (2011) Vector Autoregressive Models. European University Institute Working Papers ECO 2011/30

Nazlioglu S, Soytas U (2011) Oil price, agricultural commodity prices, and the dollar: A panel cointegration and causality analysis. Energy Economic 34(4):098-1104

Panagiotidis T, Rutledge E (2004) Oil and Gas Markets in the UK: Evidence for from a Cointegrating Approach. Energy Economic 29(2):329-347
Perron P (1989) The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis. Econometrica 57(6):1361-1401
Watson MW (1994) Vector Autoregressions and Cointegration. Handbook of Econometrics 4:2844 – 2910, Amsterdam