THE RELATIONSHIP BETWEEN THE SOUTH AFRICAN RAND AND COMMODITY PRICES: EXAMINING COINTEGRATION AND CAUSALITY BETWEEN THE NOMINAL ASSET CLASSES

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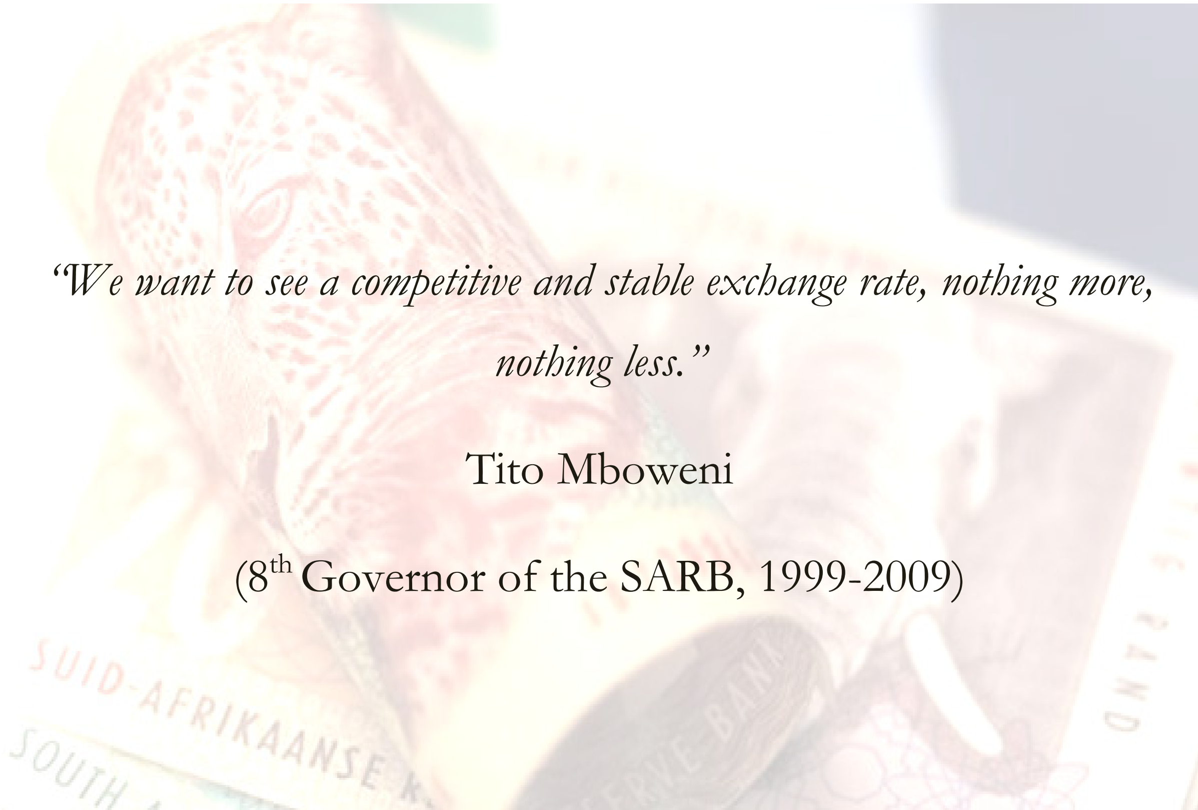
RESEARCH THESIS SUBMITTED TO THE FACULTY OF COMMERCE LAW & MANAGEMENT IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE MASTER OF MANAGEMENT IN FINANCE & INVESTMENT DEGREE
UNIVERSITY OF THE WITWATERSRAND
WITS BUSINESS SCHOOL

Johannesburg

November 2010



"We want to see a competitive and stable exchange rate, nothing more, nothing less."

Tito Mboweni

(8th Governor of the SARB, 1999-2009)

ABSTRACT

We employ OLS analysis on a VAR Model to test the "commodity currency" hypothesis of the Rand (i.e. that the currency moves in sympathy with commodity prices) and examine the associated causality using nominal data between 1996 and 2010. We address the question of cointegration using the Engle-Granger test. We find that level series of both assets are difference stationary but not cointegrated. Further, we find the two variables negatively related with strong and significant causality running from commodity prices to the exchange rate and not vice versa, implying exogeneity to the determination of commodity prices with respect to the nominal exchange rate. The strength of the relationship is significantly weaker than other OECD commodity currencies. We surmise that the relationship is dynamic over time owing to the portfolio-rebalance argument and the Commodity Terms of Trade (CTT) effect and in the absence of an error correction mechanism, this disconnect may be prolonged. For commodity and currency market participants, this implies that while futures and forward commodity prices may be useful leading indicators of future currency movements, the price risk management strategies may need to be recalibrated over time. For monetary policy makers, to manage commodity price risk and concentration risk on the country's exports, we suggest establishment of a self-insurance scheme such as a Commodity Stabilisation Fund established in Chile in 1985.

***Key Words**: Commodity Currency, Currency commodity, Cointegration, causality nominal, real*

DECLARATION

I, Xolani NDLOVU, declare that this research report is my own unaided work. It is submitted in partial fulfilment of the requirements of the Master of Management in Finance and Investment degree at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this university or any other one.

Xolani NDLOVU	**DATE**

ACKNOWLEDGEMENTS

I'm greatly indebted to a number of reviewers whose names I cannot adequately mention in this volume for lack of space that provided valuable comments, recommendations and reactions for improvement. Special mention goes to my supervisor Professor E. Schaling, for his wisdom and guidance especially in narrowing my research idea into testable hypotheses and designing the research process.

Hats off to Professor K. Ojah, the Director of the MFI program at Wits Business School for his invaluable wit and wisdom and guidance through the rich minefield of financial economics. Professor C. Malikane also deserves special mention for referring me to the Dornbusch (1976) paper which inducted me to the world of currency modelling. My thanks also go to Raj Naidoo for all her support and help with university facilities.

My classmates, Caswell, Nondu, Sithembele, Lerato and Monde deserve a special thank you for all the support in various ways.

My heartfelt thanks are also due to my family, for all the moral, financial and parental support. To Freedom, Pretty, Durell, Frank and Simie, you are the best gift God ever gave me for a family. To my granny, thank you for the faith you have always demonstrated in me, you inducted me to my first business school in life.

I wish to record my gratitude to my all-weather friends, Anele and Ntlahla. Thank you for standing with and believing in me at all times, you are the best. Your criticism and encouragement was particularly helpful.

Lastly, I would want to thank the Lord Almighty, to whom I owe everything.

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LIST OF ABBREVIATIONS AND ACCRONYMS

ADF:	Augmented Dickey-Fuller test
AR:	Autoregressive model
AsgiSA:	Accelerated and Shared Growth Initiative for South Africa
AUD:	Australian Dollar
CAD:	Canadian Dollar
CAN:	Canada
CHI:	Chile
C_t	Natural logarithm of commodity price index at month t
DF:	Dickey-Fuller test
DTI:	Department of Trade and Industry (South Africa)
DW:	Durbin Watson
ECM:	Error Correction Model
E_t	Natural logarithm of nominal USDZAR exchange rate at month t
ETF:	Exchange Traded Funds
GBP:	The British Pound Sterling
GDP:	Gross Domestic Product
IFS:	International Financial Statistics
IMF:	International Monetary Fund
JPY:	Japanese Yen
NCSS®:	Number Crunching Statistical Software
NZD:	New Zealand Dollar
NZ:	New Zealand
OECD:	Organisation of Economic Co-operation and Development
OLS:	Ordinary Least Squares method
QLR:	Heteroskedasticity Robust Quandt Likelihood Ratio
SA:	South Africa
SARB:	South African Reserve Bank
USD:	United States Dollar
USDZAR:	United States Dollar/South African Rand exchange rate
VAR:	Vector Autoregressive model
VECM:	Vector Error Correction Model
ZAR:	South African Rand

CHAPTER I: INTRODUCTION

1.1 Background and Problem Statement

The relationship between nominal Rand exchange rate and commodity prices has been contended in the past but we have been unable to find a study specifically focused on this relationship or its associated causality. There may be a justification for the paucity of literature on the relationship between these two asset classes. Top of the list could be the relatively short data series of a unified floating Rand. Empirical exchange rate puzzles concern mainly the behaviour of floating exchange rates between countries with open trade and liberalized capital markets, where the currency values are most likely to reflect various macroeconomic market forces. It is perchance important now to give the unified Rand a chance some fourteen years after the abolition of the dual exchange rate regime in 1995. Exchange rates and economic fundamentals such as commodity prices have grown in importance as transmitters of shocks from the global economy on account of global economic integration and proliferation of free trade.

South Africa is a major commodity exporting[1] economy and it is in part for this reason that the Rand is nonchalantly referred to as a "commodity currency" in financial markets. The "commodity currency" tag originates from the pervasive hypothesis that there is co-movement between the exchange rates of primary commodity producing countries and the world commodity prices.

Identifying the elusive link between economic fundamentals and exchange rates is however not an easy task and may indeed be unrewarding (Simpson 2002). Research over the past two decades has repeatedly demonstrated the empirical failures of various structural exchange rate models. When tested against data from major industrialized economies over the floating exchange rate period, canonical exchange rate models produce notoriously poor in-sample estimations, judged by both standard goodness-of-fit criteria and signs of estimated coefficients. (Chen 2002). Moreover, since Meese and Rogoff (1983) first demonstrated that none of the fundamentals-based structural models could reliably outperform a simple random walk in out-of-sample forecasts; the copious subsequent research attempts have not been able to convincingly overturn this finding. It is these empirical challenges that led Frankel and Rose (1995) to conclude with doubts about "*the value of further time-series modelling of exchange rates at high or medium frequencies using macroeconomic models.*"

[1] E.g. Cashin Cespedes and Sahay (2003) report that gold, coal and iron contributed 46%, 20% and 5% respectively to total exports for South Africa in the period 1991-99

In the light of these empirical black spots, we attempt, using a bivariate model to investigate the link between the nominal exchange rate of the rand and commodity prices. We conjecture that there is value in knowing and exploiting this relationship for corporate South Africa and conduct of monetary policy especially after the abolition of monetary target policy in favour of inflation targeting in 2000. We specifically set to answer the question: Is the Rand indeed a commodity currency i.e. do nominal commodity prices explain the nominal exchange rate movements[2]. We suppose that investigating the relationship at the nominal level is particularly valuable, since these are the readily observable variables in the market that inform most spot transactional decisions in the economy. In the same breath, we seek to find out if there is a long run equilibrium relationship between the two asset prices and investigate existence and direction of Granger causality.

The relationship between commodity prices and exchange rates has been argued in economics literature post the Bretton Woods era employing real and nominal variables. The results are mixed and difficult to generalise. (See Appendix 1 for a survey of recent studies.) Of interest from this survey of literature, Chen and Rogoff (2002) and MacDonald and Ricci (2002) particularly find a long run cointegrating relationship between the real Rand exchange rate and commodity prices.

Other prominent examples of literature focusing on commodity prices influence on exchange rate include Amano and van Norden (1995), Blundell-Wignall and Gregory (1990), Blundell-Wignall et al. (1993), Broda (2004), Cashin et al (2004), Chen(2002). Connolly and Devereux (1992), Devereux and Connolly (1996), Edwards (1988, 1989), Edwards and van Wijnbergen (1987) and Neary (1988) have done extensive work on the dependence of exchange rates on terms of trade. There is however dearth of literature analysing the simultaneous working of the currency and commodities markets.

Whilst there have been attempts to investigate the joint functioning of the currency and commodity markets noted in Clements and Fry (2006)[3], these have only been done in words and very few models have been proposed to formalise their workings. In their study, they developed a formal model of the workings of the currencies and commodity markets using the Kalman Filter and data from three OECD countries, Australia, New Zealand and Canada. While their findings lend very little credence to the commodity currency hypothesis, they may are a useful contribution to the exchange rate determination puzzle.

[2] We expect negative correlation and the regression coefficient to be negatively signed when the Rand denominated exchange rate (USDZAR) is regressed on US Dollar denominated commodity prices.

[3] Such as Swift (2004)

Allied to their work was work by Simpson (2002), which used Australian exchange rate data and commodity price index to explore the joint workings of the two asset markets. The results of Simpson's study, quiet contrary to the findings of Clements and Fry (2006), show strong and stable influence of commodity prices on the Australian Dollar, but an insignificant reverse influence of the exchange rate on commodity prices.

As summarised in Appendix 1, we find that much of the research on exchange rates and commodity prices has been concentrated on the OECD commodity exporting economies. We also have been unable to find a study that has been done focusing specifically on the nominal South African Rand and indexed commodity prices. We seek to complement studies that have been done employing the real Rand exchange rate and commodity prices.

We expect the results of the study to be useful to currency and commodity market participants in South Africa. To the extent that the exchange rate movements can be forecast from commodity prices and vice versa, insights into the relationship may serve in designing price risk management and hedging techniques. Understanding the impact of commodity price fluctuations on exchange rates may provide important monetary policy lessons for commodity-exporting countries like South Africa. If commodity price fluctuations indeed lead exchange rate responses, then spot or futures price signals from the world commodity markets may offer relevant information — or even serve as a potential anchor — for the conduct of monetary policy and inflation control. Commodity exporting countries in the world employ a diverse carte du jour of monetary and exchange rate management techniques which range from inflation targeting under floats to participation in currency unions. South Africa abandoned target of monetary aggregate policy and adopted the inflation target policy in 2000. The new policy has been met with varying reactions from different economic groups. For example there have been calls by labour unions to relook and modify the inflation target policy, and particularly targeting the exchange rate[4].

Next we provide a discussion of the theoretical link between commodity prices and exchange rate.

1.2 Commodity Prices versus Exchange rates

Economic theory suggests a number of channels through which commodity prices fluctuations can affect the exchange rate. We offer a brief discussion of these transmission mechanisms and the reverse mechanism through which the exchange rate may influence commodity prices.

[4] The Africa Report, May 11, 2010: http://www.theafricareport.com/last-business-news/3290731-S.Africa%20unions,%20producers%20want%20rand%20pegged-%20report.html

The first theoretical justification for the link comes from trade in goods discussed in Clements and Fry (2006). Consider the small open economy model with non-traded goods presented in Chen and Rogoff (2002). The model shows that an increase in the world price of a country's commodity exports will exert upward pressure on its real exchange rate, through its effect on wages and the demand for non-traded goods (a channel similar to the standard Balassa-Samuelson effect). In the presence of nominal price rigidities (such as wage negotiations in South Africa), however, the exchange rate, instead of prices, will have to do the adjustment to preserve efficient resource allocation. For example, when the price of non-tradable goods are sticky and unable to respond to the upward pressure induced by a positive terms of trade shock, exchange rate would need to appreciate to restore the efficient relative price between traded and non-traded goods.

Another justification for the relevance of commodity prices in exchange rate determination comes from the portfolio-balance model discussed in Chen (2002). This class of models treats domestic and foreign assets as imperfect substitutes, thus exchange rates are dependent on the supply and demand for all foreign and domestic assets, not just money. For an economy that relies heavily on commodities for export earnings (which is conceivable for South Africa), a boom in the world commodity market would typically lead to a balance-of-payments surplus and an accumulation of foreign reserves, exerting pressure on the relative demand of their home currencies. This would then lead to an appreciation of the domestic currency. Chaban (2009) characterises a boom in commodity prices as a transfer of wealth from commodity importing to commodity-exporting countries.

The reverse theoretical influence of the exchange rate on commodity prices is postulated by Clements and Fry (2006). Consider a country which has a commodity currency and is large enough a producer[5] of a particular commodity that it has clout to influence world prices. A commodity boom appreciates the country's currency through the transmission mechanism described above making the country's exports expensive to foreigners (assuming the country invoices in domestic currency, e.g. the OPEC[6] Cartel). This squeezes its exporters, the volume of

[5] The assumptions of a dominant commodity producer invoicing in domestic currency make this hypothesis implausible in reality. For example Chen (2002) argues that commodity price fluctuations essentially represent a source of exogenous shocks to the terms of trade of three OECD countries. Further Chen and Rogoff (2002) provide discussions of and tests for the exogeneity of commodity prices in Australia, Canada, and New Zealand. They also show that world commodity prices better capture the exogenous component of terms of trade shocks than standard measures of terms of trade, an argument countered by Clements and Fry (2006) who argue that commodity currencies models failing to account for endogeneity between currency and commodity returns may be miss-specified. Further, their argument is correct if foreign demand for imports is elastic

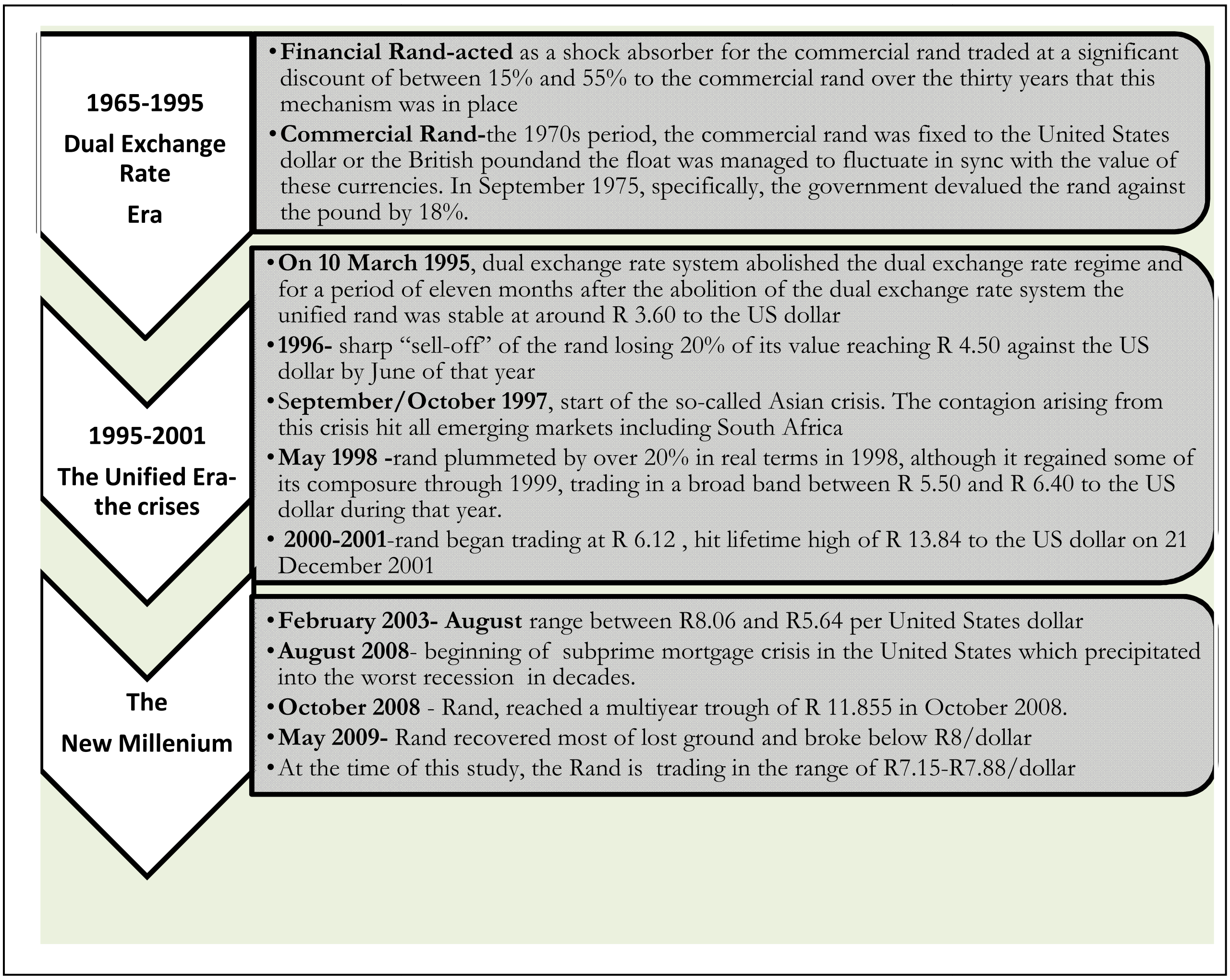
[6] Empirical evidence suggests that real exchange rates of oil producing economies respond much less to the oil prices than other commodity currencies see Coudert, Couharde and Mignon (2008) and Korhonen & Juurikkala (2007).

exports fall. But if the country is a sufficiently large producer of a given commodity, the reduced exports have the effect of increasing world prices further. Thus the appreciation of the currency leads to a still higher world price and a further appreciation. The interaction of the commodity currency and pricing power leads to an amplification of the initial commodity boom. To convey the symmetric relationship with commodity currencies, commodities whose prices are substantially affected by currency fluctuations can be called **"currency commodities"** (Clements and Fry, 2006)

1.3 History of South African Rand

We summarise the history in Figure 1 below:

Figure 1: History of the Rand



Source: Author

Much of the history of the Rand refers to the dual exchange rate regime. In this period there were two exchange rates referred to as the commercial rand rate (managed floating) the financial rand rate[7]. The dual exchange rate system was abolished in 1995 paving way for the modern day unified Rand.

The unified exchange rate system marked yet another milestone in the country's integration into the global capital market. This heightened integration into the trading and financial global market however has brought newer challenges to the exchange rate management puzzle. The 2001 Rand crises for example led to the setting up of a commission of inquiry by the government to investigate the causes.[8] The commission identified a number of factors among others, low export prices, and leads in payments for imports and lags in export receipts.
While the country's commodity exports have benefited from a global commodities boom over the years, the current account deficit increased. These developments fuelled long-standing concerns over the effect of real exchange rates on manufacturing industries' cost competitiveness (Golub 2000), concerns which were consistent with survey evidence on the effect of exchange rates' levels and volatility on South African industrial sectors (FEASability 2006).

The unified exchange rate may be systematically affected by monetary policy and other policies, concern over the real-economy effects of the value of the rand and its volatility has led to suggestions for modification of inflation targeting (Frankel, 2007a). Further, AsgiSA, the framework for shared growth to 2014 adopted by the government of South Africa, identifies six binding constraints to be addressed in order to achieve its goals on growth and distribution, and places **'the volatility and level of the currency' at the top of the list[9].** These factors motivate the importance of understanding the drivers of the exchange rate.

1.4 Objectives of the study

In summary, the objectives of this study are itemized as follows:

1. To explore by time series methods of OLS, scatter plots, cointegration and Error Correction modelling the short and long-term relationship between indexed commodity prices and the nominal value of the USD/ZAR exchange rate.
2. To explore causality between the above two variables and test for exogeneity of commodity prices using the Granger causality tests.
3. To suggest currency and commodity price risk management strategies for South African commodity exporting firms

[7] IMF, (2006) 167-168.
[8] South Africa, 2002
[9] Republic of South Africa, 2006

4. To put forward to South African Monetary policy makers, some insights into the overall exchange rate and commodity exports management.

1.5 Data & Methodology

We investigate coinciding monthly USDZAR nominal exchange rate data and the US Dollar denominated commodity price index for the period January 1996 to March 2010. In order to capture the speed of adjustment of in asset prices monthly rather than quarterly data was selected consistent with Simpson (2002).

We extract exchange rate data from the Thomson Reuters[10] database. Thompson Reuters collects, stores and broadcasts live real time foreign exchange rates for traders around the globe. We analyse monthly averages, constructed from daily closing prices for the respective months. We transform the nominal exchange rates into a nominal exchange rate index (2005M6=100)to make them comparable to the commodity index and take natural logarithms. The period 1996-2010 is selected to capture the dynamics of the floating rand post the dual exchange rate regime and to capture the three episodes of the South African Rand crises of 1998, 2001 and 2008.
For commodity prices, we use the non-fuel commodity price index published by the IMF[11]. The IMF publishes world export-earnings-weighted price index (2005=100) for over forty primary commodities traded on various exchanges. The index has 35 commodities representing approximately 42.9% of South Africa's exports (See data table in Appendices II, III and IV). We particularly employ this index to exclude the effects of the weight of petroleum products[12] in the all-commodities index which may bias our estimations. We find this choice of data consistent with Chen & Rogoff (2002) and Simpson (2002).

We employ Ordinary Least Squares regression methods to investigate the interaction of the two markets. *"Regression analysis is concerned with the study of the dependence of one variable, on one or more other variables, the explanatory variables, with a view to estimating and/or predicting the mean or average value of the former in terms of the known or fixed /values of the latter"* (Gurajarati, 2003:18) Scatter plots and correlation analysis are employed to ascertain some stylised facts about the data. The Dickey Fuller (1981) tests are applied to the series to establish the Univariate characteristics of the level series and their first differences. We use the Engle-Granger test to ascertain the existence of cointegration between the two variables. Cointegration[13] analysis on level series is employed to ascertain the long run equilibrium relationship of the nominal prices of the two asset classes. It

[10] www.thomsonreuters.com
[11] http://www.imf.org/external/np/res/commod/index.asp
[12] Petroleum energy products have a weight of 53.6 in the all-commodities index
[13] Cointegration has been found on multivariate models using real values of the exchange rate and commodity prices. See Appendix 1 for the survey of literature.

allows one to examine the deviation from long-run equilibrium conditions for a stationary combination of dynamic variables, which individually are non-stationary. If a shock is introduced at some point, economic forces should drive the cointegrating variables toward the new long run equilibrium conditions. If the level series are indeed cointegrated, we employ Error Correction modelling to ascertain the short term relationship of the two variables. The Engle Granger (1987) methodology is applied to test for existence of and direction of causality.

1.6 Outline of the study

The remainder of this paper is organised as follows. The next chapter reviews the relevant literature on the relationship of exchange rates and commodity prices. Chapter III develops a theoretical framework in which the hypotheses would be tested. Chapter VI develops the econometric methodology in consonance with the theoretical findings of the previous section and describes the time series data used in the empirical section. Chapter V discusses the empirical results and Chapter VI concludes. The Appendix contains the derivation of key results as well as the description and sources of the variables used in the empirical section.

CHAPTER II: REVIEW OF LITERATURE

2.1 Introduction

The increasing volatility in currencies and commodity prices after the breakdown of the Bretton-Wood system have spawned a number of empirical and theoretical papers on the influence of commodity prices on exchange rates and reverse influence of exchange rates on commodity prices. The importance of commodity prices and exchange rates as transmitters of shocks, particularly for developing countries continues to impress a compelling need for understanding the actual behaviour of these variables and building theoretical models capable of mimicking the empirical evidence. In this chapter we review this body of literature. First we present an overview of fundamental modelling of exchange rates. Then we review literature on the influence of commodity prices on exchange rate ("commodity currencies") followed by a review of literature on the reciprocal link, which involves pricing power in world markets ("currency commodities"). Finally, we review literature on the joint influence of currency and commodity prices.

2.2 Fundamental modelling of exchange rates

An attempt to establish the connection between economic fundamentals and exchange rates has been one of the most controversial issues in international finance (Chen & Rogoff, 2002). The research area abounds with empirical puzzles such as the Meese-Rogoff (1983) forecasting puzzle and purchasing power parity theories. Frankel & Rose (1995) and Froot & Rogoff (1995) in their comprehensive survey of literature summarize the various difficulties in empirically relating exchange rate behaviour to shocks in macroeconomic fundamentals.

On one hand there are substantial econometric problems involved in fundamental modelling of exchange rates which are difficult to overcome (Pilbeam, 1998). Fundamental models of exchange rate determination for example, have estimation problems. The models often suffer from misspecification or the models themselves may not be linear or they may have omitted variables bias (Meese, 1990). Evidence supporting the purchasing power parity (PPP) hypothesis for example is inconclusive and mixed (Simpson, 2002).

On the other hand Chen, Rogoff and Rossi (2008) argue that the time series regressions in exchange rate modelling do not take into account potential parameter instabilities. In their study, using real exchange rate data they note that structural breaks are a serious concern in time series analysis. They report parameter instability tests on commodity exporting countries' currencies that include Australia, New Zealand and Canada based on Andrews (1993)'s Heteroskedasticity Robust Quandt Likelihood Ratio for the bivariate Granger-causality regressions (see Appendix IX). Taking the structural breaks into consideration, they find evidence of Granger causality from commodity prices to real exchange rates of the countries that they studied (see Appendix X).

The ultimate objective however is in the information that can assist in profitable currency risk management and forecasting and assisting price risk management for firms. While South Africa abandoned the monetary aggregate policy in favour of inflation targeting policy in 2000, there is concern over the real-economy effects of the value of the exchange rate and its volatility. There have been suggestions for modification of this policy (Frankel, 2007a). It is for these and other reasons that fundamental exchange rate models despite their problems have been and continue to be popular among economic researchers.

2.3 The Influence of commodity prices on exchange rate

In an attempt to for find out how real exchange rates of primary commodity exporters reacted to changes in the relative prices of their exports, Bleaney (1996) used ninety-two years of Australian data in his work. The results show significant negative correlation between these two variables. Oddly though, the real Australian dollar exchange rate did not show significant downward trend observed in the commodity prices. To solve this paradox, Bleaney then used pure time series analysis of the respective series and concluded that the apparent long-run decline in the relative price of primary commodities was due to inadequate quality adjustment in the price series for manufacturers.

Brindal (1998), employing monthly nominal data, reported that the AUD and commodity prices had been joined at the hip for the year 1997 to June of that year. He found that Australia's trade relies heavily on commodity exports with 9 of the top 10 exports being primary products. At the time of his work, the AUD/USD exchange rate was 0.61, which was down from 0.7452 in July 1997, when the Asian crisis began. He concluded that the nexus between currency and commodity price exists for other commodity dependent countries such as New Zealand, Canada, South Africa and Chile.

Chen (2002) in his paper investigating the empirical disconnect between exchange rates and economic fundamentals that is at the heart of several exchange rate puzzles tested some macro-models using nominal exchange rate data augmented by commodity prices for three OECD economies. In contrast to the literature characterized by notoriously poor in-sample fits and out-of-sample forecast failures, he found that for three major OECD primary commodity producers, nominal exchange rates exhibit a robust response to movements in the world prices of their corresponding commodity[14] exports. Moreover, he found that incorporating commodity

[14] He finds long run elasticities of exchange rates with respect to commodity prices of 0.92, 0.46 and 1.51 for Australia, Canada and New Zealand respectively.

export prices into standard exchange rate models can generate a marked improvement in their in-sample performance.

Chen and Rogoff, (2002), some of the most published researchers on commodity currencies, investigated the determinants of real exchange rate movements for three OECD economies (Australia, Canada, and New Zealand). They note that "*because commodity products are transacted in highly centralized global markets, an exogenous source of terms of trade fluctuations can be identified for these major commodity exporters."* Their findings for Australia and New Zealand especially, were that the US dollar price of their commodity exports has a strong and stable influence on their floating real exchange rates, with the magnitude of the effects consistent with predictions of standard theoretical models.

Hatzinikolaou & Polasek (2003) used nominal post-float Australian data (184:2003) in a multivariate and cointegration commodity-view model of the nominal Australian dollar. They found that the nominal Australian dollar is indeed a commodity currency, with long run elasticity of the exchange rate with respect to commodity prices estimated at 0.939. This finding was consistent with Chen (2002), and Chen and Rogoff (2003), with the former using nominal and the latter using real exchange rate data. The long-run elasticity was higher than the "conventional wisdom" elasticity of 0.5 (See Clements and Freebairn, 1991, p.1). The existence of cointegration is however in conflict with Simpson (2002), who found no evidence of cointegration in his bivariate model (See Appendix I for a comprehensive survey of these findings). They further found that Purchasing Power Parity and Uncovered interest parity belong to the cointegrating relationship with exchange rates as long as commodity prices are included in the cointegrating relations. Further they conclude that their model outperforms the random walk model in the medium run in apparent defiance of the conclusion of Meese and Rogoff (1983) that fundamental models cannot outperform a random walk model.

Cashin, Cespedes and Sahay (2003) examined whether the real exchange rates of commodity-exporting countries and the real prices of their commodity exports move together over time. Using IMF data on the world prices of 44 commodities and national commodity export shares, they constructed new monthly indices of national commodity export prices for 58 commodity-exporting countries over 1980-2002. They found evidence of a long-run relationship between national real exchange rate and real commodity prices for about one third of the commodity-exporting countries in their sample that included Australia. They concluded that the long-run real exchange rate of these 'commodity currencies' was however not constant over time (as implied by Purchasing Power Parity based models), but time varying being dependent on movements in the real price of commodity exports.

Turning to South Africa, Bhundia and Ricci (2004) investigated the South African Rand crises of 1998 and 2001 to find out causes and lessons from the crisis. Among other explanations[15] of the crisis, they find that commodity prices were likely to have played a part in the rand weakness in 1998. That year, global demand for commodities had weakened significantly on the back of the Asian financial crisis putting downward pressure on the market prices of some of South Africa's commodity exports and probably contributed to the large depreciation of the rand in July of that year.[16] In their empirical analysis, they found that that a one percent fall in the real price of commodities exported by South Africa is associated in the long run with a real exchange depreciation of 0.5 percent.

Their findings were echoed by Wood (1998) who noted that the South African Rand was hit by the deteriorating of the outlook for export prices in the wake of the monetary squeeze in East Asia during 1997 with key exports such as gold, coal, aluminium and steel all being expected to suffer lower price conditions during 1998. He concludes that whilst the Asian currency crisis has often been ascribed to crony capitalism and weak banking systems, the collapse in various currencies may have a greater cause in falling Asian demand led by a collapse in world commodity prices.

Frankel (2007b) undertook an econometric investigation of the determinants of the real value of the South African rand over the period 1984-2006. His findings show that there was substantial weight on the lagged exchange rate, which can be attributed to a momentum component. However, economic fundamentals were significant (with elasticity of 0.72) and important especially true of an index of the real prices of South African mineral commodities, which even drive out real income as a significant determinant. We consider literature analysing the influence of exchange rate on commodity prices next.

2.4 The Influence of exchange rate on commodity prices

The influence of exchange rate on commodity prices was first analysed by Ridler and Yandle (1972) as cited in Dupont and Juan Ramon (1996). For a given commodity, the authors started from an equilibrium situation between the world demand for imports (which depends only on the world price of the commodity in importers' currency) and the world supply of exports (which depends only on the world price of the commodity in exporters' country). They then performed comparative static to obtain the percentage change in the dollar (numeraire) price of the commodity as a weighted average of the percentage change in exporters' and

[15] Other leading causes noted include capital outflows and incorrect response by SARB

[16] SARB, *Quarterly Bulletin*, December 1998

importers' nominal exchange rates in terms of the numeraire currency.[17] The authors did not explicitly consider real exchange rates or other supply and demand variables.

In a supply and demand framework, Dornbusch (1985) studied the effects of real exchange rate and income on commodity prices. Assuming that a given commodity is traded in an integrated world market with only two consuming blocs, the United States and Rest of the world and assuming an entirely demand-driven model and that the world demand for the commodity depends on the real price of the commodity in terms of GDP deflators, he concluded that a real appreciation (depreciation) of the dollar with respect to the rest of the world decreases (increases) the commodity world demand inducing the commodity real price in terms of U.S. deflator to fall (rise).

Borensztein and Reinhart (1994) extended the Dornbusch (1985) model also assuming demand comprising two blocs, the United States and the rest of the world. Incorporating in the exogenous commodity supply the volume of primary commodities imported by the industrial countries as a proxy for the supply shocks of the 1980s, and by taking a broader view of world demand, they incorporated in their model, output developments in Eastern Europe and the former Soviet Union. Their major score over the Dornbusch (1985) study was their empirical estimations which yielded the expected magnitude (between 0 and -1) for the elasticity of the real commodity price with respect to the real bilateral exchange rate between the two blocs considered. They further postulated that with their extensions to supply and demand, their econometric projections can better explain the decline in the real commodity prices since early 1980s and remedy much of the systematic over-prediction of the demand driven model.

Another 1980s classic paper on the influence of exchange rates on commodities was done by Sjaastad (1985). In his paper he analyzed the effects of the bilateral real exchange rates among the major currencies on the real (dollar based) price of the commodity. He advanced the hypothesis that changes in the exchange rates among major currencies will cause commodity prices to fluctuate independently of the movements in the general price levels of the major countries. Specifically, he notes *"that fluctuations of the U.S. dollar strongly influence the (dollar) prices of internationally traded goods and is particularly evident during the intense real appreciation of the dollar from early 1980 until early 1985."* During that period the dollar appreciated by more than 90 percent against the Deutsche Mark (and by 45 percent in real terms), while the IMF dollar-based commodity price index fell by 30 percent." He considered an internationally-traded homogeneous

[17] They derived the following formula: $\Delta P= (\eta_s/ (\eta_s - \eta_d))P +((\eta_d/(\eta_s-\eta_d))K$ where ΔP is the percentage change in the commodity price, R and K are the weighted average percentage change in exporters' and importers' nominal exchange rates in terms of the numeraire currency, and η_s and η_d are price elasticity of the world supply of exports and the world demand for imports.

commodity, the price of which obeys the law of one price. Unlike Dornbusch (1985), he assumed that worldwide there are "N" trading blocs, that the numeraire currency, the dollar, is the currency of bloc 1, and that each bloc's commodity excess demand depends on the commodity price deflated by the general price level and on other supply and demand variables. A salient conclusion of Sjaastad's model is that the country that has the most influence in determining the world price of a commodity is not always the country in whose currency the commodity price is denominated[18]. For example, rand denominated share price of a South African company heavily exporting to Europe would be affected by changes in the Euro-Rand exchange rate, whereas the rand denominated share price of a South African company which does not trade with Europe would be quiet independent from movements in the Euro-rand rate.

The Sjaastad (1985) model was applied by Sjaastad and Scacciavillani (1993) to analyze the gold market for the period 1982-90. They use a dynamic econometric specification to study the effect of fluctuations in the real exchange rate among the major currencies on fluctuations in the price of gold. They found compelling evidence that *"The major gold producers of the world (South Africa, Russia and Australia) appear to have no significant influence on the world price of gold."* The paper further notes that volatility of the exchange rates among the major currencies since the dissolution of the Bretton Woods international monetary system has been a major source of price instability in the gold market although they did not claim their empirical findings for the gold case can be generalized to other commodities.

Dupont and Juan-Ramon (1996) extended the Sjaastad and Scacciavillani (1993) model for gold to construct a supply and demand multi-country model, with world market clearing, which incorporates speculative and non-speculative demands for inventories and "static" and "rational" expectations. They estimated the model using several econometric methods on monthly data from January 1972 to January 1992 for 65 commodity prices. They found that, for a small group of commodities, the dollar-denominated price is significantly influenced by the deutsche mark and the yen[19]. Moreover the empirical results showed that geographical proximity matters, and that supply & demand elasticities are important in determining the commodity prices in world markets above and beyond the size of the share of those commodities in world trade.

[18] A plausible finding which supports the OPEC cartel, see Coudert, Couharde and Mignon (2008) and Korhonen & Juurikkala (2007).

[19] For example, the U.S. import price of sugar is insensitive to fluctuations in either the dollar/Deutsche mark or dollar/Yen, whereas the European import price of sugar, denominated in dollar, is in fact dominated by the Deutsche mark, at least for short-term elasticities.

2.5 The Joint Influence of commodity prices and exchange rate

From extensive literature survey, we find that while other scholars have hypothesised the joint working of the currency and commodity markets, there are very few that have put up a formal model to analyse this relationship.

Influence of the exchange rate on commodity prices has been found between exchange rates and oil prices. For example, Amano and van Norden (1998) found a robust relationship between the real domestic price of oil and real exchange rates for Germany, Japan and the United States. In part, the paper offered an explanation of why the real oil price captured exogenous terms of trade shocks and why such shocks could be the most important factor in determining real exchange rates in the long run.

Simpson (2002), in an attempt to find causality between the nominal Australian dollar and commodity prices uses monthly data between1986 and 2001 and OLS methods to find whether or not these time series are cointegrated and whether or not uni-directional and/or two way causality exists. Consistent with other scholars, among them, Chen and Rogoff (2003) he finds that the variables exhibit dual causality and negative correlation (-0.8952), with the significantly stronger causality running from commodity prices to AUD/USD exchange rate. He notes his results as implying exogeneity in commodity prices. He concludes that from his results, foreign exchange participants in Australia may use commodity price information to adjust their exchange rate expectations in the short-term in a sensible way.

Clements and Fry, (2006) also analysed the simultaneous workings of commodity and currency markets. Using the Kalman filter to jointly estimate the determinants of the prices of these currencies and commodities, they included in the specification an allowance for spill-overs between the two asset types. Their results, quiet contrary to the majority of findings by other scholars, suggested that there is less evidence that currencies are affected by commodities than commodities are affected by the currencies. Spillovers from commodities to currencies contributed less than 1 percent to the volatility of the currency returns, whilst spillovers from currencies to commodities generally contributed between 2 and 5.2 percent to the commodities. They concluded that commodity currencies models failing to account for endogeneity between currency and commodity returns may be misspecified, a path-breaking observation[20].

Chaban (2009) analyzed the relationship among the prices of natural resources, returns on equity and nominal exchange rates of three OECD countries Australia, Canada and New Zealand. He found that the portfolio-rebalancing motive of Hau and Rey[21] is weaker for these

[20] This lends credence to the exchange rate determination puzzle of Meese and Rogoff (1983). See Appendix 2

[21] Hau, H., Rey, H., 2006. Exchange rates, equity prices, and capital flows Review of Financial Studies 19 (1), 273–317

countries. He notes that one possible explanation of this finding is that commodity prices due to their flexibility play a special role in the transmission of shocks by linking equity markets across countries and reducing the need for portfolio rebalancing. He argues that a positive supply shock in the U.S. that affects U.S. equity returns positively is transmitted to commodity-exporting countries through commodity prices. Booming commodity prices drive domestic equity returns up and appreciate commodity currencies. Therefore, commodity prices reduce the need to rebalance portfolios, since equity markets move together.

2.6 Conclusion

There is clearly mixed findings on the influence of commodity prices on exchange rates or vice versa. Findings are also mixed depending on whether nominal or real variables were used. This makes it difficult therefore to generalise particular findings from one country to another. Our attempt is to add to this body of literature by considering nominal variables for the South African Rand employing the OLS and VAR analysis model employed by Simpson (2002).

CHAPTER III: THEORETICAL FRAMEWORK

3.1 Introduction

In this chapter we describe and a theoretical framework in which this empirical study would be carried out. We specify a theoretical model of a commodity producing open economy and provide a theoretical basis for exchange rate modelling using VAR analysis, cointegration and Error Correction modelling.

3.2 Exchange rate Model of a commodity producing economy

We employ the framework developed by Simpson (2002)[22]. The model assumes a relatively large, open, commodity exporting economy[23]. We consider the economy which produces one exportable commodity. The exportable good is associated with the production of primary commodities (agriculture and mineral products). We assume that the terms of trade for this good play a pole role in the determination of the country's exchange rate in line with the work of De Gregorio and Wolf (1994) and Obstfeld and Rogoff (1996). We theorise that a boom in commodity price markets would exert upward pressure on the real exchange rate through its effect on wages and demand for non-traded goods[24]. Assuming that the nominal consumer prices are sticky and unable to respond to the upward pressure induced by a positive terms of terms shock as in Dornbusch (1976), the nominal exchange rate would need to appreciate to restore efficient resource allocation.

Further, we also consider the country to be a dominant exporter of the commodity. Examples could include oil from Saudi Arabia, wool from Australia and several minerals from Australia such as iron ore, tantalite and possibly coal. This situation is well known in international economics, manifesting in the formation of cartels among exporting nations and price-stabilisation schemes. To demonstrate the link between the exchange rate and international commodity prices, we suppose there is a major depreciation of the currency of the country. If costs do not rise equi-proportionally, so that it is a real depreciation, the improved revenue enhances the bottom line and domestic producers of the commodity have an incentive to expand production and export more. But the expansion of exports depresses the world price as, by assumption, the country is the dominant exporter of the commodity. In this case, the

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[22] Based on Blundell-Wignall and Gregory (1990)

[23] South Africa is a fairly open economy with trade/GDP ratio 40 year average of 52.5%, comparable to OECD economies like Greece, Poland and France. See http://www.dti.gov.za/econdb/raportt/ra5385KK.html. The economy (measured by GDP) is the largest in Africa, ranked 32nd in the world with GDP estimated at nearly USD300 billion by IMF.
See http://www.imf.org/external/pubs/ft/weo/2010/01/weodata/weorept.aspx

[24] A channel similar to the standard Balassa-Samuelson effect

depreciation of the currency leads to a depression of the world price. For such an economy therefore, the exchange rate influences the world price of the commodity. Sjaastad and co-authors have elaborated this framework and considered a number of implications of this rich framework in a series of papers.[25] Accordingly, the relationship between the commodity prices and the exchange rate can be modelled in the form of a Vector Autoregressive Model VAR (p)[26]:

$$E_t = \upsilon_0 + \sum_{i=0}^{p} \upsilon_i \, E_{t-i} + \sum_{i=0}^{p} \theta_i \, C_{t-i} + e_t \tag{1}$$

$$C_t = \mu_0 + \sum_{i=0}^{p} \mu_i \, C_{t-i} + \sum_{i=0}^{p} \sigma_i \, E_{t-i} + u_t \tag{2}$$

Where, E_t *is the natural log of the exchange rate at time t*

C_t *is the natural log of Commodity prices at time t.*

And p is the maximum lag length

Given equation (1) and (2), a number of hypotheses can be advanced to investigate the relationship between the two asset classes. The VAR posits that the exchange rate at a point in time is dependent on lags of itself and lags of commodity prices. Similarly equation (2) suggests that the commodity prices are dependent on lags of themselves and the lags of the exchange rate. We employ Ordinary Least Squares methodology to estimate the VAR. The first step in empirical estimation is the univariate characteristics which show whether the variables have unit root or not. Time series variables have unit root if they exhibit a stochastic trend. But when the series are differenced, the resulting time series will be stationary, for this reason, they are also called difference stationary series (Koop, 2006, p151). Using OLS regression on difference stationary time series is very dangerous and it is always better to work with difference than levels: if the time series data is difference stationary then there is a problem of increasing variance over time which means OLS and test of significance are invalid, the so-called spurious regression problem. (Maddala & Woo, 1998)

25 See Sjaastad (1985, 1989, 1990, 1998a,b, 1999, 2000, 2001), Sjaastad and Manzur (2003) and Sjaastad and Scacciavillani (1996). See also Dornbusch (1987), Gilbert (1989, 1991) and Ridler and Yandle (1972). For a recent application, see Keyfitz (2004).

26 This is a special VAR methodology used by Simpson (2002).

If the variables are non-stationary, it is reasonable to expect that the error term, ($e_t = E_t - \alpha - \beta C_t$) will also be have unit root and it cannot be a serially uncorrelated random error with constant variance (Simpson, 2002). If E_t and C_t are both integrated non-stationary series, and if a linear combination of them is stationary, the series are said to be cointegrated. We test for existence of cointegration using the Engle-Granger test.

Cointegration can be viewed as the statistical expression of the nature of long-run equilibrium relationships. If E_t and C_t are linked by some long-run relationship, from which they can deviate in the short run but must return to in the long run, residuals will be stationary.

If cointegration doesn't exist between the two variables, we reformulate the VAR into first differences and apply OLS methodology. If the series are non-stationary and cointegrated, then a long run multiplier or the long run influence of commodity prices on the exchange rate and vice versa can be estimated. The short run relationship between them can be expressed as a Vector Error Correction Model (VECM), an important theorem known as the Granger Representation Theorem (Koop, 2006, p174).

If cointegration exists on the level data series of commodity prices and the exchange rate, for illustration purposes we rewrite equations (1) and (2) as a VAR (1) as follows:

$$E_t = \vartheta_0 + \vartheta_1 E_{t-1} + \varphi_1 C_{t-1} + e_t \tag{3}$$

$$C_t = \mu_0 + \mu_1 C_{t-1} + \sigma_1 E_{t-1} + u_t \tag{4}$$

Subtracting E_{t-1} and C_{t-1} from both sides of equation (3) and (4) respectively, yields the following equations:

$$\Delta E_t = E_t - E_{t-1} = \vartheta_0 + (\vartheta_1 - 1)E_{t-1} + \varphi_1 C_{t-1} + e_t \tag{5}$$

$$\Delta C_t = C_t - C_{t-1} = \mu_0 + (\mu_1 - 1)C_{t-1} + \sigma_1 E_{t-1} + u_t \tag{6}$$

It can be shown that if the exchange rate and commodity prices both have unit root and if they are cointegrated the coefficients in Equations 5 and 6 must satisfy the following restriction:

$$\vartheta_1 = 1 + \frac{\varphi_1 \mu_1}{\sigma_1 - 1} \quad Setting\ \beta_2 = \frac{1 - \sigma_2}{\mu_1} \quad and\ \gamma_1 = \frac{\varphi_1 \mu_1}{\sigma_1 - 1}\ and\ \gamma_2 = \mu_1$$

$$and\ \vartheta_0^* = \vartheta_0 + \gamma_1 \beta_1\ and\ \mu_0^* = \mu_0 + \gamma_2 \beta_1$$

And when these restriction equations are substituted into Equations 5 and 6 the equations will become:

$$\Delta E = \vartheta_0^* + \gamma_1(E_{t-1} - \beta_1 - \beta_2 C_{t-1}) + e_t \quad (7)$$

$$\Delta C_t = \mu_0^* + \gamma_2(E_{t-1} - \beta_1 - \beta_2 C_{t-1}) + u_t \quad (8)$$

This representation of the VAR is known as an Error Correction Model (ECM) and says that changes in exchange rates and commodity prices from period *t* -1 to *t* both depend on the quantity: $\varepsilon_t = E_{t-1} - \beta_1 - \beta_2 C_{t-1}$

This quantity represents deviation **ε**, in period t-1, from the long-run equilibrium path: $E = \beta_1 + \beta_2 C$

Thus changes in exchange rates and commodity prices (or corrections to exchange rates and commodity prices) depend on the magnitude of the departure of the system from its long-run equilibrium in the previous period. The shocks *e* and *u* lead to short-term departures from the cointegrating equilibrium path and then there is a tendency to correct back to equilibrium.
Finally we test for existence and direction of Granger causality between the two variables. We employ the Granger causality test (Engle and Granger, 1987) in an attempt to model uni-directional causality in time series analysis of financial asset prices (Simpson, 2002).

Granger (1988) observed that cointegration between two or more variables is sufficient for the presence of causality in at least one direction. "Granger causality" is a term for a specific notion of causality in time-series analysis[27]. The idea of Granger causality is a pretty simple one: A variable X Granger-causes Y if Y can be better predicted using the histories of both X and Y than it can using the history of Y alone. Conceptually, the idea has several components:

- *Temporality: Only past values of X can "cause" Y and vice-versa.*
- *Exogeneity: Sims (1980) points out that a necessary condition for X to be exogenous of Y is that X fails to Granger-cause Y.*
- *Independence: Similarly, variables X and Y are only independent if both fail to Granger-cause the other.*

Granger causality is thus a pretty powerful tool, in that it allows one to test for relationships that one might otherwise assume away or otherwise take for granted.

[27] Clive Granger, the UCSD econometrician, gets all the credit for this, even though the notion was apparently first advanced by Weiner twenty or so years earlier.

The Granger test depends critically on the choice of the lag length. An arbitrary choice of lag length could result in potential model misspecifications where too short a lag length may result in estimation bias while too long a lag causes a loss of degrees of freedom and thus estimation efficiency (Lee 1997). Monthly data lags of zero, one, two and three are tested in this study, due to the relatively small number of data points on Rand dollar exchange rate and commodity prices as in Simpson (2002).

VAR analysis, cointegration and the Engle Granger Test have firm roots in exchange rate modelling literature. Prominent examples include Cheung and Lai (1993 a, b), Martinez (1999)[28] in Mexico, Cheng (1999)[29] and Simpson (2002).

Cheung and Lai (1993 a, b), Im et al (1995) Wu (1996), Wu and Chen (1999), Maddala and Wu (1998), Smith (1999)[30], Eun and Jeong (1999)[31] used the cointegration technique to examine PPP theory[32].

Others who have employed these techniques on the South African Rand include Chinn (1999), Sichei etal (2001), and more recently, Ricci and MacDonald (2002).

In an extensive survey of literature however, we are unable to find any study focused on the relationship of the nominal rand and indexed commodity prices using VAR analysis, cointegration and Error Correction Models.

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[28] Martinez (1999) applied cointegration and vector autoregression techniques to Mexican international reserves, exchange rates and changes in domestic credit. As a matter of interest, Martinez discovered that, despite the presence of nonstationarity, a long-run relationship existed between these variables.

[29] Cheng (1999) re-examined causality between the USD and the yen in a multivariate framework with the aid of cointegration and error correction modelling. Phillips-Perron and Johansen tests were performed. As a point of interest findings were that causality ran from interest rates to exchange rates in the short-term and that there was no causality between prices and exchange rates in the short term. Causality was found running from relative prices and interest rates to exchange rates in the long-term, thus supporting the PPP hypothesis.

[30] Smith (1999) found that for many commodities floating exchange rates did not cause a significant increase in overall domestic currency price variation when also considering a good's overseas price variation.

[31] Eun and Jeong (1999) found that flexible exchange rates do not insulate the domestic price levels from foreign inflation shocks especially in the long run in the post-Bretton Woods era. Interestingly, a significant proportion of a country's domestic inflation rate is attributable to foreign inflation shocks and all foreign countries are found to import United States inflation during the sample period as they used to do under the Bretton Woods system.

[32] During the 1990s several studies have applied the panel unit-root tests of Levin and Lin (1992) to lend support to the validity of long-run PPP in industrial countries. Wu (1996) and Wu and Chen (1999) applied tests provided by Im et al (1995) and Maddala and Wu (1998) to re-examine the PPP hypothesis in Pacific Basin countries but failed to find supporting evidence.

3.3 The Hypotheses

With this theoretical framework, the hypotheses to be tested in this study are formally stated in a null format as follows:

Ho1: The nominal USDZAR exchange rate and indexed commodity prices or their first difference changes are not significantly related.

Ho2: Cointegration does not exist between the nominal USDZAR exchange rate and indexed commodity price series.

Ho3: There is no significant uni-directional and/or two-way causality between nominal USDZAR exchange rates and indexed commodity prices or their first difference changes.

3.4 Conclusion

Having laid down the theoretical underpinnings under which the study will be carried out and specified the hypotheses to be tested, we proceed to describe data sources in the next section. We also detail the econometric methodology used to empirically test the hypotheses.

CHAPTER IV: ECONOMETRIC METHODOLOGY AND DATA

4.1 Introduction

In this chapter we build on the theoretical framework to construct an econometric methodology which is the road map through which the hypotheses is tested.

4.2 The Data

All data series in this study were collected and formulated over the 1996M1 to 2010M3 sample period. We describe the data series used in our estimation and their sources:
For the exchange rate, nominal USD/ZAR[33] exchange rate data extracted from the Thomson Reuters[34] database. Thompson Reuters collects, stores and broadcasts live real time foreign exchange rates for traders around the globe. We reconstruct daily exchange rate data to monthly averages.

We transform exchange rate data into an exchange rate index with the base year 2005M6 coinciding with the base year for the commodity price index from IMF such that:

$$S_t = \frac{S_t}{S_{tB}} * 100 \qquad (9)$$

Where S_t *= nominal USDZAR at month t*

S_{tB} *= nominal exchange rate for the base year and month: 2005M6*

Finally, we transform the exchange rate index into natural logarithms, such that,

$$\ln(S_t) = E_t \qquad (10)$$

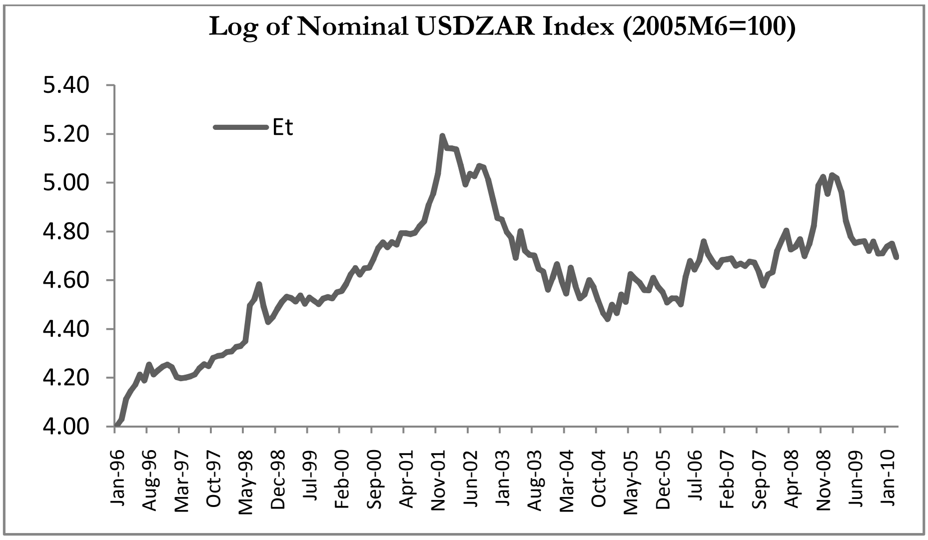
Where S_t *= nominal USDZAR at month t*

And E_t*= natural logarithm of exchange rate index at month t*

We select the period 1996-2010 to capture the dynamics of the floating rand and to capture the three episodes of the South African Rand crises of 1996, 1998, 2001 and 2008. In order to capture the speed of adjustment in asset prices monthly rather than quarterly data was selected. Figure 2 illustrates and Table 1 summarises the descriptive characteristics of the nominal exchange rate data (S_t) series.

[33] Throughout this study we employ the European definition of the exchange rate, i.e. ZAR/USD1
[34] www.thomsonreuters.com

Figure 2: Log of USDZAR 1996M1 to 2010M3



For the commodity prices we employ the IMF non-fuel commodity price index. We selected the index to counter the effect of the weight of petroleum commodities not produced in South Africa[35]. The IMF publishes the world export-earnings-weighted price index for over forty products traded on various exchanges. The monthly commodity index (2005M6=100) includes various commodity classes among food and agricultural and mining industrial inputs. We consider the index, containing approximately 43%[36] of South African commodity exports, to be a fair barometer of changes in prices of commodities exported by South Africa (see Appendices II, III and IV). The commodity price series have roots in economics literature having been employed by Chen & Rogoff (2002) and Simpson (2002).

The price index is denominated in United States Dollars, quiet suitable for South Africa, which has its commodity exports invoiced in US Dollars[37]. Like exchange rates, to capture the speed of adjustment, monthly rather than quarterly data were selected.

We further transform commodity price index into natural logarithms as follows:

$$ln(P_{ct}) = C_t \tag{11}$$

Where P_{ct} = *the nominal price index at month t*

And C_t= *the natural logarithm of the commodity price index at month t*

Figure 3 illustrates C_t for the sample period. Commodity prices have been fairly volatile over time[38], like the USDZAR exchange rate. We note that the commodity price collapse of 1998

[35] The petroleum commodities account for approximately 53% of the all-commodity index.
[36] See data Tables in Appendices II, III and IV
[37] http://thedti.gov.za/econdb/raportt
[38] Some scholars attribute this to speculative influences on commodity price developments See Krugman (2008) and IMF (2006). Others point to portfolio shifts by investors – partly triggered by lax monetary policy –increasing the demand and therefore prices of commodity prices. See Calvo (2008)

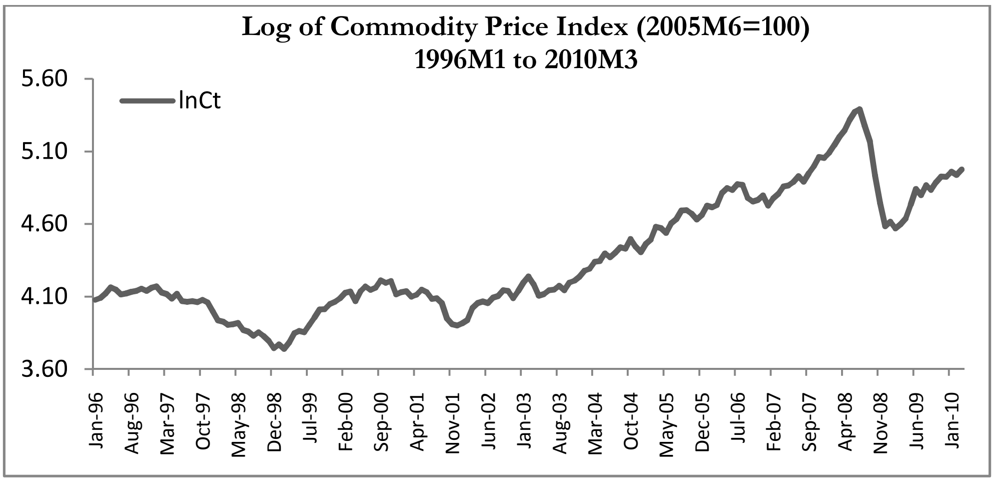
and late 2001 coincided with the respective Rand crises. Descriptive statistics for actual nominal commodity price index the data sets are presented in Table 1.

Table 1: Descriptive statistics for USDZAR and Commodity Price Index

	Exchange Rate	*Commodity Index*
Mean	6.9450	86.10
Standard Error	0.1277	2.99
Median	6.8525	64.77
Mode	4.4978	62.77
Standard Deviation	1.6701	39.04
Sample Variance	2.7891	1523.91
Kurtosis	0.4367	1.01
Skewness	0.5952	1.24
Range	8.3305	176.91
Minimum	3.6395	42.08
Maximum	11.9700	218.99
Sum	1187.5960	14722.81
Count	171.0000	171.00

We use the NCSS[39] statistical package to analyse the data. In view of our relatively small sample size, significance level of 10% is acceptable.

Figure 3 Log of Commodity Price Index 1996M1 to 2010M3



4.3 Econometric Methodology

4.3.1 A first look at the data

We first examine some basic stylised facts about the data. Economic time series tend to show some stylised facts such as trending or co-trending, high correlation with each other, meandering and shocks applied to them tend to show some degree of persistence. We examine

[39] Number Crunching Statistical Software, © Jerry Hintze (2007), NCSS, LLC Kaysville Utah www.ncss.com

scatter plots and correlation. We employ them on the natural logarithms of the level series of USDZAR exchange rate and the commodity price index and their first differences.

4.3.2 Univariate characteristics of data

First we test for stationarity properties in the time series data. Times series variables have unit root[40] if their autocorrelations are near one and will not drop with increasing lag length. Such series will have a long memory and will tend to exhibit trend behaviour (Koop, 2006, p147). We employ the Dickey Fuller test for unit root (Dickey & Fuller, 1981). We specify an AR (1) model for the exchange rate series in equation (12). The model specified has an intercept (α) (a random walk with a drift), which allows for changes in the exchange rate to be non-zero over time.

$$E_t = \alpha + \beta E_{t-1} + e_t \tag{12}$$

Equation (12) can be rewritten as:

$$\Delta E_t = \alpha + \rho E_{t-1} + e_t \tag{13}$$

$$where\ \rho = \beta - 1$$

Such that the hypothesis that the exchange rate series have unit root can be represented as:

$$H_0: \rho = 0 \text{ Against } \quad H_1: \rho \neq 0 \tag{14}$$

For the commodity prices variable, we specify the AR (1) model as:

$$C_t = \delta + \theta C_{t-1} + u_t \tag{15}$$

Equation (15) can be re-written as:

$$\Delta C_t = \delta + \lambda C_{t-1} + u_t \tag{16}$$

$$where\ \lambda = \theta - 1$$

Such that the hypothesis that commodity prices have unit root can be represented as:

$$H_0: \lambda = 0 \text{ Against } \quad H_1: \lambda \neq 0 \tag{17}$$

40 Or non-stationary; A unit root is so named because it is the root of a polynomial.

4.3.3 Engle-Granger Test for Cointegration and Error Correction Modelling

When then test for unit root confirms that both exchange rate and commodity price series are non-stationary, we proceed to apply the Engle-Granger test for cointegration (Engle and Granger 1987). Non-stationarity and presence of cointegration in time series data are important statistical properties that make sound economic sense in the manner in which variables are related. One interpretation of cointegrated variables is that they share *common stochastic trends* (Stock/Watson 1988). We proceed in the following manner:

First we run a regression on equation 18 (see Engle & Granger 1987):

$$E_t = \alpha + \beta C_t + e_t \quad (18)$$

[41]

The asymptotic distribution of β is not standard, but the test suggested by Engle and Granger was to estimate $\hat{\beta}$ by OLS and the test for unit roots[42] in:

$$\hat{e}_t = E_t - \alpha - \hat{\beta} C_t \quad (19)$$

We specify an AR (1) model in terms of $\hat{e}_t$ in equation (20)

$$\hat{e}_t = \phi + \mu \hat{e}_{t-1} + u_t \quad (20)$$

Equation (20) can be re-written as:

$$\widehat{\Delta e}_t = \phi + \vartheta \hat{e}_{t-1} + u_t, \quad (21)$$

$$where\ \vartheta = \mu - 1$$

Such that Engle Granger Test for existence of cointegration amounts to the DF test of the hypothesis that:

$$H_0: \vartheta \neq 0 \qquad \text{Against } H_1: \vartheta = 0 \quad (22)$$

If we fail to reject the hypothesis in equation 22, it would imply that a linear combination of E_t and $C_t$is stationary. If this is the case the USDZAR exchange rate and commodity price index are cointegrated. This implies that both variables exhibit a long-run equilibrium relationship such that $E_t = \alpha + \beta C_t$ and the error term represents a short-term deviation from that equilibrium relationship. If the variables are cointegrated, we can apply least squares

[41]We obtain the same results for $C_t = \alpha + \beta E_t + e_t$

[42] Using the Dickey Fuller methodology, (Dickey & Fuller 1981)

estimation of VAR in equation (1) and (2) and obtain consistent long-run estimates of ϑ and μ. The short-run relationship can be modelled through an Error Correction Model (ECM).

We rewrite the VAR in equations (1) and (2) in the form of a Vector Error Correction Model (VECM):

$$\Delta E_t = \vartheta + \lambda e_{t-1} + \sum_{i=1}^{p} \delta_i \Delta E_{t-i} + \sum_{i=1}^{p} \omega_i \Delta C_{t-i} + \varepsilon_t \qquad (23)$$

$$\Delta C_t = \mu + \gamma u_{t-1} + \sum_{i=1}^{p} \psi_i \Delta C_{t-i} + \sum_{i=1}^{p} \tau_i \Delta E_{t-i} + \epsilon_t \qquad (24)$$

Where e_{t-1} and u_{t-1} are lagged values of the error term from the cointegrating equations (12) and (15)[43]

The VECM suggests that changes in exchange rates and commodity prices depend on deviations from a long-term equilibrium that is defined by the cointegrating relationship. The quantity e_{t-1} or u_{t-1} can be thought of as an equilibrium error and if it is non zero, then the model is out of equilibrium and should "correct" in the next period back to equilibrium. Thus the model captures short run properties in the error term (Koop, 2006, p175).

Rejection of hypothesis in equation (22) means that the series are both non-stationary but are not cointegrated and thus OLS is not a suitable estimation technique and it is likely to produce spurious regression problems. The problems may manifest in an apparently highly significant relationship between the exchange rate and commodity prices (even when $\beta = 0$ in equation 18). This should be detected by a low Durbin Watson (DW) Statistic (Durbin and Watson, 1971)[44]. In that case it would be more useful reformulate the VAR into first differences of the series (Koop 2006, p178). We rewrite the VAR (p) in equations (1) and (2) by first differences:

$$\Delta E_t = \vartheta + \sum_{i=1}^{p} \gamma_i \Delta E_{t-i} + \sum_{i=1}^{p} \varphi_i \Delta C_{t-i} + e_t \qquad (25)$$

$$\Delta C_t = \mu + \sum_{i=1}^{p} \varrho_i \Delta C_{t-i} + \sum_{i=1}^{p} \sigma_i \Delta E_{t-i} + u_t \qquad (26)$$

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[43] See Koop (2006), p 199

[44] High R^2 and very low Durbin-Watson statistics (R^2>d), See Durbin & Watson (1971)

4.3.4 *Granger Causality*

We attempt to detect Granger causality and its direction in the data series. The basic idea is that, E_t Granger causes C_t if past values of E_t can help explain C_t and vice versa. We employ the OLS regression analysis to estimate causality under two scenarios: when the variables have unit root and are cointegrated and when the variables have unit root and are not cointegrated (Koop 2006, p186).

a) Causality: when there is unit root and cointegration

When unit root and cointegration are present in the time series, we estimate the VECM IN equations (23) and (24) and examine the P-values of the coefficients for significance at the 10% level of significance. If coefficients of past values of the explanatory variable are statistically significant, we conclude that they Granger-cause the dependent variable. This methodology produces reliable evidence of Granger causality (Koop, 2006, p186). Accordingly we set the null hypothesis that change in commodity prices Granger cause change in USDZAR exchange rate:
From equation (23):

$$H_0: \omega_i \ or \ \lambda \neq 0 \text{ Against } H_1: \omega_i \ or \ \lambda = 0 \tag{27}$$

We also set the hypothesis that change in USDZAR exchange rate Granger cause change in commodity prices, from equation (24):

$$H_0: \tau_i \ or \ \gamma \neq 0 \quad \text{Against } H_1: \tau_i \ or \ \gamma = 0 \tag{28}$$

b) Causality: unit root and no cointegration

When the time series data are non-stationary but not cointegrated, we employ the methodology set out above on the first differences of the data. We examine the coefficients for the past explanatory variables of the VAR set out in equations (25) and (26) for significance at the 10% level of significance. We set the hypothesis that commodity prices Granger-cause the USDZAR exchange rate:
From equation 25:

$$H_0: \varphi_i \neq 0 \qquad \text{Against} \qquad H_1: \varphi_i = 0 \tag{29}$$

We also set the hypothesis that the exchange rate Granger causes commodity prices:
From equation 26:

$$H_0: \sigma_i \neq 0 \qquad \text{Against} \qquad H_1: \sigma_i = 0 \tag{30}$$

4.3.5 Lag Length selection

The Granger test depends critically on the choice of the lag length. An arbitrary choice of lag length could result in potential model misspecifications where too short a lag length may result in estimation bias while too long a lag causes a loss of degrees of freedom and thus estimation efficiency (Lee 1997). The importance of lag length determination is demonstrated by Braun and Mittnik (1993) who show that estimates of a VAR whose lag length differs from the true lag length are inconsistent as are the impulse response functions and variance decompositions derived from the estimated VAR. Lütkepohl (1993) indicates that over-fitting (selecting a higher order lag length than the true lag length) causes an increase in the mean-square forecast errors of the VAR and that under-fitting the lag length often generates autocorrelated errors. Hafer and Sheehan (1989) find that the accuracy of forecasts from VAR models varies substantially for alternative lag lengths.

In this study we employ the sequential OLS test and eliminate methodology (See Koop 2006, p 132-3). We test monthly data lags of zero, one two and three in-step with Simpson (2002).

4.4 Conclusion

We note that the model employed in this study may suffer from misspecification. This may arise as a result of omitted variables bias, i.e. the case where omitted variables are highly correlated with commodity prices and/or exchange rate (see Koop 2006, p 100-2).
Notwithstanding the possibility of misspecification, this particular model offers the possibility of making accurate forecasts when the underlying economic model is unknown (Hill, Griffiths and Judge, 1997) or known but where there are restrictions on the collection of data relating to the other variables in the underlying economic model. This is the case with exchange rates, which are dependent on several factors, some of which have country specific effects, for example commodity prices (Viney, 2000). We proceed to test the model in the next chapter.

CHAPTER V: ESTIMATION RESULTS & EVALUATION

5.1 Introduction

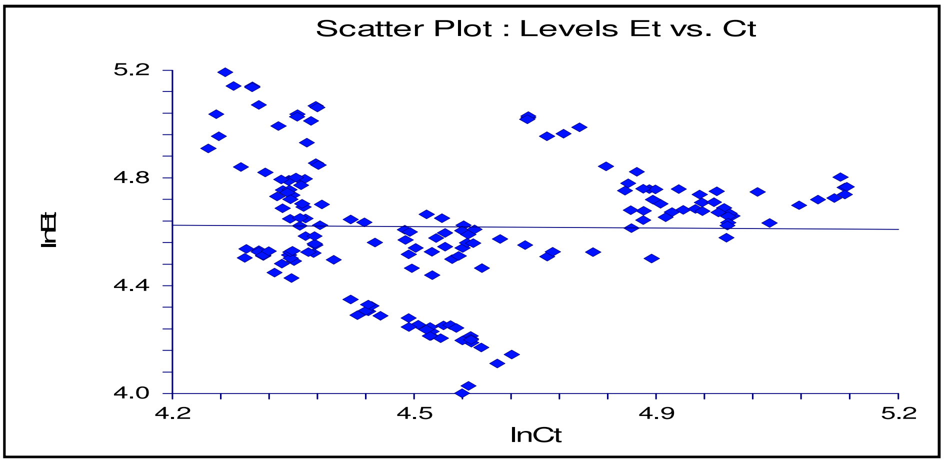
We present estimation results of the model. First we present stylised facts about the data. Next we show the time series have unit root using the DF tests. The subsequent sections contain results for the Engle Granger test for cointegration and Granger causality.

5.2 Data Stylised Facts

5.2.1 Level Variables

We show that E_t and C_t have negative correlation with a coefficient of -0.0138. Figure 4 illustrates. The correlation coefficient is very close to zero and may suggest very little or no relationship at all at level series.

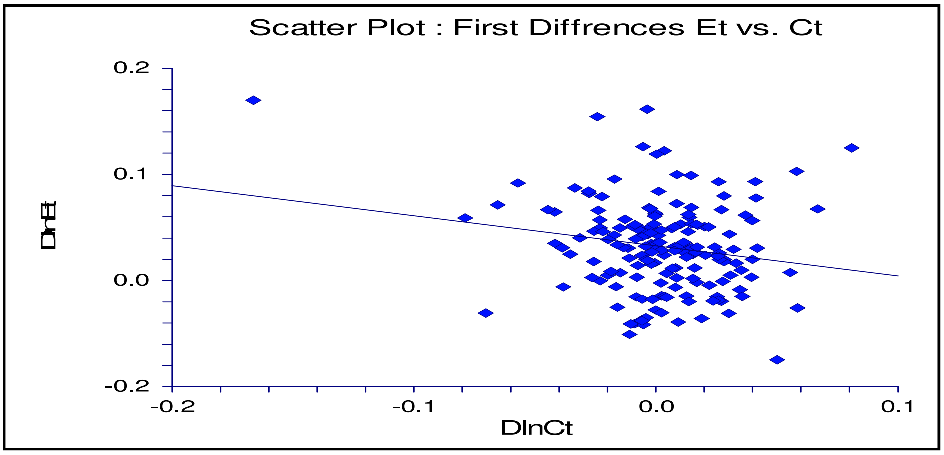
Figure 4: Scatter Plot: E_t vs. C_t



5.2.2 First Differences

The correlation coefficient on the returns of the two assets is -0.1882, stronger than level series. Figure 5 illustrates that a commodities boom is associated with an appreciation of the Rand. We proceed to formally examine the relationship in the subsequent sections.

Figure 5: Scatter plot ΔE_t vs. ΔC_t



5.3 Tests for stationarity

5.3.1 The Dickey Fuller test for unit root

Results for the estimation of equations (13) and (16) are presented in Table 2. Using the Dickey Fuller critical value of -2.58 (See Appendix V for Table of DF Critical values), we fail to reject the presence of unit root[45] hypotheses set out in equations 14 and 17 at the 10%, significance or better. We conclude that both time series are non-stationary. Both series show serial correlation and long memory. (See Appendix VI for correlation matrices for level variables lagged up to five months).

Table 2: Dickey Fuller Unit root Tests Results

$\Delta E_t = \alpha + \rho E_{t-1} + e_t \text{ and } \Delta C_t = \delta + \lambda C_{t-1} + \varepsilon_t$

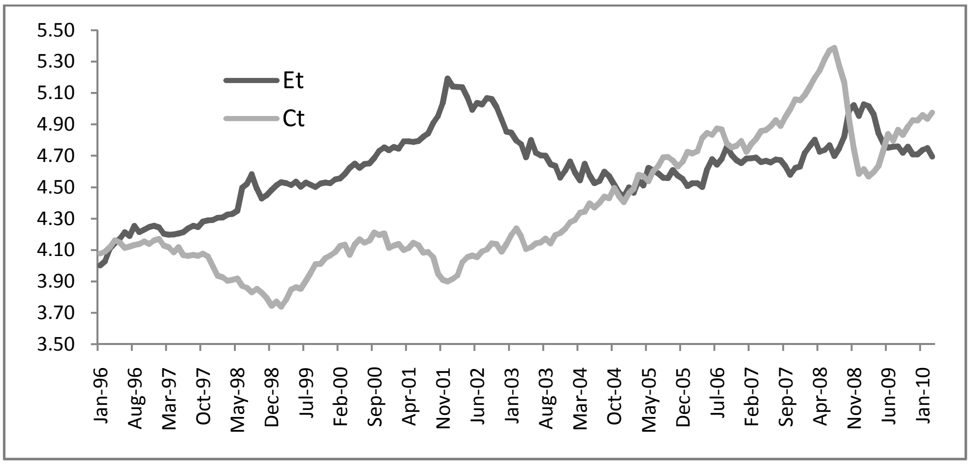
Independent Variable	*Regression Coefficient*	*T-Value*	*DF Critical Value at 10%*
Exchange rate (E_{t-1})	-0.0397	-2.219	-2.58
Commodity Prices (C_{t-1})	0.0002	0.0250	-2.58

5.4 Test for Cointegration

5.4.1 Graphical Illustration

We have concluded that both series have unit root. We now test the hypothesis that the series are cointegrated. First we examine a graphical illustration in Figure 6 to see if they are any signs of co-trending.

Figure 6: USDZAR exchange rate and commodity prices



45 Unit-root tests provide another basis for assessing whether a time series is non-stationary and integrated of a particular order. A unit root is so named because it is the root of a polynomial. Having a unit-root makes a series non-stationary. If the unit-root is greater than –1 or less than 1 this describes a stationary time series process. The tests used are usually the Dickey-Fuller test (Dickey and Fuller, 1981) and the Phillips-Perron test (Phillips and Perron, 1988).

The graph posits a negative relationship with the troughs on the commodity prices corresponding with peaks on the exchange rate series. Based on Figure 6, there doesn't appear to be much graphical support for co-trending. We proceed to formally test existence of cointegration.

5.4.2 Engle-Granger Test for Cointegration

We present regression results of equation (21) in Table 3.

Table 3: Engle Granger Test for cointegration:

$\widehat{\Delta e_t} = \phi + \vartheta \hat{e}_{t-1} + u_t,$

Variable	***Regression Coefficient***	***T-Value***	***Dickey Fuller Critical Value at 10%***
Intercept	*0.0004*	*0.3836*	*-2.58*
Error term ($\hat{e}_{t-1}$)	*-0.0396*	*-2.530*	*-2.58*

Using the DF test critical value of -2.58, results suggest rejection of null hypothesis set out in equation 22 and therefore that the error term has unit root. This indicates that the error terms are non-stationary and non-homoskedastic. Therefore there is no possibility that the series are cointegrated at 10% level of significance. The relationship cannot therefore be modelled by way of a Vector Error Correction Model (VECM). We estimate the model instead using first differences.

5.5 Estimating the VAR on first differences

We present results from the estimation of equation 25 and 26 in Tables 4, 5, 6 and 7.

Table 4: Exchange rate as dependent variable

$$\Delta E_t = \vartheta + \sum_{i=1}^{p} \gamma_i \Delta E_{t-i} + \sum_{i=1}^{p} \varphi_i \Delta C_{t-i} + e_t$$

Independent Variable	***Regression Coefficient***	***T-Value***	***P-Value***	***Lower 90% C.L.***	***Upper 90% C.L.***
Intercept	*0.0045*	*1.210*	*0.2281*	*-0.0017*	*0.0107*
ΔC_{t-1}	*-0.3264*	*-2.358*	*0.0195*	*-0.5554*	*-0.0974*
ΔE_{t-1}	*0.0182*	*0.230*	*0.8183*	*-0.1124*	*0.1488*

Estimated model: $\Delta E_t = 0.0045 + 0.0182 \Delta E_{t-1} - 0.3264 \Delta C_{t-1}$ *(31)*

The sequential lag length selection procedure employed reduces the model to a VAR (1) (see Appendix VII). We note that commodity price changes belong to the exchange rate equation with a long run elasticity of -0.3264, ceteris paribus. The regression coefficient is correctly signed to support the commodity currency hypothesis of the Rand. The R^2 reading shows that commodity prices variability account for approximately 3.23% of the variability in the exchange rate and is statistically significant at 10% level. We note that this number is very low. Further we note that these coefficients are significantly lower than those found in the OECD economies using the comparable data series (See Appendix 1for comparisons)

Table 5: Analysis of variance on ΔE_t

Model Term	*R^2*	*F-Ratio*	*P-Value*	*Power (10%)*
ΔC_{t-1}	*0.0323*	*3.136*	*0.0461*	*0.7140*
ΔE_{t-1}	*0.0003*	*5.561*	*0.0195*	*0.7592*
Model	*0.0364*	*0.053*	*0.8183*	*0.1089*

We present results of part of the model with commodity prices as the dependent variable below:

Table 6: Commodity prices as the dependent variable

$$\Delta C_t = \mu + \sum_{i=1}^{p} \varrho_i \Delta C_{t-i} + \sum_{i=1}^{p} \sigma_i \Delta E_{t-i} + u_t$$

Independent Variable	*Regression Coefficient*	*T-Value*	*P-Value*	*Lower 90% C.L.*	*Upper 90% C.L.*
Intercept	*0.0016*	*0.860*	*0.3909*	*-0.0015*	*0.0101*
ΔE_{t-1}	*-0.0968*	*-2.466*	*0.147*	*0.1617*	*-0.0319*
ΔC_{t-1}	*0.4312*	*-2.466*	*0.0000*	*0.3173*	*0.5451*

Estimated model: $\Delta C_t = 0.0016 + 0.4312\Delta C_{t-1} - 0.0968\Delta E_{t-1}$ *(32)*

Table 7: Analysis of variance on ΔC

Model Term	*R^2*	*F-Ratio*	*P-Value*	*Power (10%)*
ΔE_{t-1}	*0.0278*	*6.082*	*0.1470*	*0.7914*
ΔC_{t-1}	*0.1793*	*39.225*	*0.0000*	*1.0000*
Model	*0.2412*	*26.382*	*0.0000*	*1.0000*

The results from Table 6 suggest that only commodity prices lagged one month belong to the equation. Changes in the exchange rate, although correctly negatively signed, are statistically insignificant at the 10% level of significance. The R^2 reading of 0.0278 suggests that exchange rate variability accounts for approximately 2.78% of the variability in commodity prices. This number is not only small but also statistically insignificant at the 10% level of significance. The results suggest exogeneity in the determination of commodity prices with respect to the exchange rate and support the rejection of the "currency commodity" hypothesis for South Africa. They compare well to the findings of Simpson (2002) on the AUD.

5.6 Granger Causality tests

We now present evidence of Granger causality from the results of the estimation. We test hypotheses that Granger causality exists set out in equations 29 and 30.

First when the exchange rate is the dependent variable, results from Table 4 show that:

$$\varphi = -0.3264$$

The coefficient is statistically significant at the 10% level of significance.

Accordingly, we fail to reject the hypothesis (equation 29) that commodity prices Granger cause the USDZAR exchange rate. The negative sign supports the hypothesis that the South African Rand is a commodity currency and changes in the commodity markets are contemporaneously reflected in the exchange rate.

From Table 6, we note that:

$$\sigma = -0.0968$$

This coefficient is however is not only close to zero but statistically insignificant at the 10% level of significance or better. We therefore reject the hypothesis that USDZAR exchange Granger causes commodity prices (equation 30). The R^2 is also small and statistically insignificant at the 10% level of significance. This finding implies that the open economy model with endogenously determined commodity prices may not be suitable for South Africa. Moreover it is in order to surmise that South Africa is a price-taker in the world commodity markets.

5.7 Conclusion

We demonstrated that USD denominated commodity prices and USDZAR exchange rate have unit root, are not cointegrated and are negatively correlated. The estimation results suggest that there is causality running from commodity prices returns to the nominal exchange rate returns and not vice versa. We provide overall concluding remarks and recommendations to currency and commodity market participants in the next chapter.

CHAPTER VI: CONCLUSION

6.1 Introduction

We extend the current literature on the importance of the commodity prices/exchange rate relationship for commodity exporting countries with a particular case of South Africa. We investigate the stylised facts and employ OLS analysis on VAR model, Granger causality method combined with Error Correction Modelling. We provide here our concluding remarks. We also suggest some insights on managing commodity price and exchange rate risk for firms and implications on overall exchange rate management for monetary policy makers in South Africa.

6.2 Methodology

On the Univariate characteristics of data, we find the series to be difference stationary, but not cointegrated and therefore spurious regression problems when the model is estimated on level variables. In the absence of cointegration, we reformulate the VAR on first differences[46] of data and the model produces expected results. We then employ Granger causality tests on the VAR formulated on first differences as it was not possible to use Error Correction modelling in the absence of a cointegrating relationship. In sum, we successfully tested the hypotheses set out in the study using the proposed OLS methodology and first difference data, although further studies may benefit from employing more sophisticated models such as the Kalman factor[47], a longer period of study and allowing for structural breaks[48].

6.3 Literature

In a wide survey of literature on the relationship of commodity prices and exchange rates, we find a great deal of work that has been done supporting either the "commodity currency" or "currency commodity" notion. We find that results differ markedly depending on whether the variables employed are real or nominal. The inconsistent results lend credence the Meese and Rogoff (1983) exchange rate determination puzzle. There is a dearth of literature relating the South African Rand to commodity prices, notwithstanding the fact that the currency is often lumped together with other commodity producing counterparts as a "commodity currency". We suppose that this may be a result of a relatively short life of the unified Rand. This paper is a contribution to the Rand-commodity prices specific literature.

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[46] Such as in Patterson, (2000) and Simpson (2002)
[47] See Clements and Fry (2006)
[48] See Chen Rogoff and Rossi (2008)

6.4 Empirical Results

The results indicate that there is a negative relationship between commodity price changes and exchange rate changes in South Africa in the short term. The strength of the relationship is however significantly weaker than that found in other commodity exporting countries such as the Australian dollar[49] and New Zealand Dollar. Thus, the first null hypothesis of this study is rejected. This provides evidence that exchange rate changes adjust contemporaneously to commodity price changes but not vice versa.

We also find that the nominal primary data in the series in this study are not cointegrated. Even if we were to find evidence of cointegration on first differences of the series, from an economic viewpoint that evidence would need to be treated with scepticism at it would say nothing about the relationship between the level variables[50]. We therefore fail to reject the second hypothesis that there is no cointegrating relationship between the two asset classes. Findings by other scholars suggest that the ratio of commodity currencies and commodity prices is at least mean reverting (e.g. Hughes 1994). Further cointegration investigation may benefit from the use of a longer study time frame.

We find evidence of significant and stronger causality running from commodity prices first differences to exchange rate first differences (significant at the 10% level). We find that causality from the nominal exchange rate to commodity prices is statistically insignificant and very close to zero. These findings support the rejection of Null hypothesis 3 that there is zero uni-directional and/or two-way causality between nominal USDZAR exchange rate changes and indexed commodity price changes.

Our findings are consistent with Simpson (2002) and suggest an open economy assumption of endogenously determined commodity prices may be inappropriate when modelling exchange rate movements in South Africa. This evidence however is at odds with the conclusion of Clements and Fry (2006) who concluded that commodity currency models failing to account for endogeneity between currency and commodity returns may be misspecified.

Further we suppose that the relatively weaker relationship of the two variables when compared to the developed markets may be a result of the portfolio balance hypothesis of Chen (2002). While there is co-movement in the two asset markets, there may be decoupling of direction when financial markets are risk propense and fund managers rebalance portfolios off riskier assets to safe havens like US treasuries. Commodities like gold which have assumed an

[49] For example Simpson (2002), found the negative elasticity of exchange rate changes with respect to commodity price changes to be -0.8952, with R squared value of 0.4498, statistically significant at 10% level of significance. Compare with South Africa's -0.3264 with R squared value of 0.0278 also statistically significant at 10% level of significance. Also see Appendix I

[50] Also noted in Simpson (2002)

investment status over the years tend to benefit from "flight to safety" by investors in Exchange Traded Funds (ETFs)[51]. In down trending financial markets therefore, portfolio managers would typically sell off South African assets like equities (causing the Rand to depreciate) while investing in commodities like gold (thus causing a boom in commodity markets). Such episodes observed in the 2008-2010 gold price boom versus a massive depreciation of the rand. This episode coincides with the credit market crisis. In the absence of a cointegrating relationship and therefore error correction mechanism, this chasm between the two nominal asset prices may be prolonged.

Another plausible explanation comes from the trade off between windfall gains from a commodity boom and oil-led inflation. South Africa is an importer of significant oil[52] and thus a boom in commodities will benefit the currency to the extent that the negative effect of oil prices is offset by windfall gains from commodity exporters on terms of trade, all things held constant. It has been shown that the commodity terms of trade (CTT)[53] for South Africa have been very volatile since 2000. It seems logical therefore that the exchange rate management may benefit from exact knowledge of the effect of interplay of these factors, which is beyond the scope of this paper.

6.5 Implications and recommendations

6.5.1 Firms

First, we conclude that the Rand is a commodity currency at nominal level, but not cointegrated with commodity prices. We also note that in-light of the possible decoupling of this relationship and effect of rising oil prices, firms may not employ uniform strategies in managing their currency and commodity exposures over time. These may need to be recalibrated to take advantage of or to avoid the negative effects of the foregoing developments.

Second, we find that commodity price changes lead changes in the exchange rate. In terms of the risk management, in a downward trending commodity market, it may be preferable for a risk-averse commodity exporter to forward sell commodities as well as invoiced USDs. An arbitrage opportunity thus may not exist in the currency market because as commodity prices fall exchange rates depreciates and more Rand will be received for the sale of the USD export proceeds. The hedge of currency may be partial (for example, in proportion to the degree of systematic risk in the market as shown by the beta coefficient for commodity prices when changes in exchange rates are regressed against changes in commodity prices).

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[51] World Gold Council 2010 Q1Report http://www.gold.org/assets/file/pub_archive/pdf/GDT_Q1_2010.pdf

[52] Estimated at 67% of consumption by Global Trade Atlas, see http://www.gtis.com/english/GTIS_GTA.html

[53] See SARB Report on Policy implications of Commodity Prices Movements, (2008) and Appendix XI

Thirdly, in an upward trending commodity market, a risk-taking exporter may sell USD forward for Rand in the currencies market and remain unhedged in the commodity market. As commodity prices rise, the Rand tends to appreciate. Therefore an exporter may benefit from this boom by locking the USDZAR rate in the forward market. A value maximising opportunity may exist in both the commodity and the foreign exchange markets, depending on the strength of the trend. For these specific kinds of firm decisions one would need to undertake further research on the effect of individual commodities prices (for example, gold, crude oil and coal).

6.5.2 Monetary policy makers

Monetary policy makers may infer future commodity price dynamics and therefore the exchange rates from the forward and futures prices in the commodity markets in a logical manner.

For their part, monetary policy makers must manage the commodity price risk to the economy in a manner that pacifies price and commodity concentration risk on exports. Because the country, as a developing market may be constrained in its access to sophisticated commodity hedging instruments, we recommend that a self-insurance be considered, such as a Commodity Stabilisation Fund (CSF). During periods of high commodity prices and therefore high exports earnings, the country would accumulate foreign currency in a reserve fund which it would draw down in periods of low commodity prices. The problem would thus be very similar to that of a liquidity-constrained individual who also has a demand for precautionary savings. Such a fund was established in Chile in 1985[54].

6.6 Overall conclusions

We have shown that there exists a negative although not cointegrating relationship between nominal Rand and commodity prices, and that the relationship is weaker than that of developed commodity producing economies. We have also shown that, while the strength of uni-directional causality from commodities to the exchange rate is lower than that of developed commodity exporters, it does exist for the Rand. We conclude that the relationship between the two assets prices is dynamic over time due to the portfolio balance hypothesis and the terms of trade effect of oil prices. These findings have significant implications in the manner in which currency and commodity markets participants manage exposures in the currency and commodity markets in South Africa. We suggest some hedging strategies for firms and some insights for the overall macro-economic management of the exchange rate and commodity prices for monetary policy.

[54] See Arrau & Classens (1992)

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APPENDIX I: SURVEY OF COMMODITY CURRENCY LITERATURE

Authors	Currency	Econometric methodology	Nominal/Real Variables	Regression [55]Coefficient	Cointegration/Causality
Chen (2002)	AUD NZD CAD	Dynamic Ordinary Least Squares (DOLS) on multivariate models	Nominal	AUD = 0.8 NZD = 1.4 CAD = +0.3	Cointegration was found for AUD and NZD, inconclusive for CAD
Simpson (2002)	AUD	Ordinary Least squares on bivariate model	Nominal	AUD = -0.8	No cointegration but found causality from commodity Prices to exchange rate
Clements & Fry (2006)	AUD NZD CAD	Kalman Filter and a multivariate latent factor model	Real	AUD = -0.247[56] NZD = -0.169 CAD = -0.398	Found more spill over effects from exchange rates to commodity prices and very little spill over effects from the commodity prices to the exchange rate
Chen & Rogoff (2002)	AUD NZD CAD	Dynamic Ordinary Least Squares (DOLS)	Real	AUD = +0.8 NZD = +0.24 CAD = +1.1	They find cointegration and causality from commodity prices to the exchange rate
Cashin, Cespedes and Sahay (2003	AUD NZD NZD ZAR	OLS and Engle-Granger Cointegration approach	Real		Cointegration was found only for AUD among OECD countries
MacDonald and Ricci (2002)	ZAR	Johansen Cointegration approach on multivariate model	Real	ZAR = -0.5	They find evidence of a long run cointegrating relationship between ZAR and commodity prices
Hatzinikolaou & Polasek (2003)	AUD	A Multivariate cointegration model	Nominal	AUD = 0.939 AUD = 0.67[57]	Found existence of long run equilibrium relationship and an error correction mechanism between the two variables

Source: Author

[55] Regression Coefficient of commodity prices with respect to the exchange rate
[56] All coefficients of the commodity prices variable were found to be statistically insignificant

[57] The short term dynamic elasticity obtained from the ECM

APPENDIX II: IMF NON-FUEL INDEX OF COMMODITY PRICES

Table 6.
Specifications for Commodity prices

Commodities	World Export Weights 2002-2004	Price Specifications	Unit
Non-fuel commodities	100		
Edibles	50.3		
Food	45.3		
Cereals	9.7		
Wheat	4.5	U.S. No. 1 hard red winter, ordinary protein, prompt shipment, FOB Gulf of Mexico ports (USDA, Grain and Feed Market News, Washington, DC).	$/Mt
Maize	2.8	U.S. No. 2 yellow, prompt shipment, FOB Gulf of Mexico ports (USDA, Grain and Feed Market News, Washington, D.C.). 1/	$/Mt
Rice	1.7	Thai, white milled, 5 percent broken, nominal price quotes, FOB Bangkok (USDA, Rice Market News, Little Rock, Arkansas). 2/	$/Mt
Barley	0.7	Canadian No. 1 Western Barley, spot price (Winnipeg Commodity Exchange) 1/	$/Mt
Vegetable oils/protein meals	12.0		
Soybeans	3.3	Soybean futures contract (first contract forward) No. 2 yellow and par Chicago Board of Trade 1/	$/Mt
Soybean meal	2.3	Soybean Meal Futures (first contract forward) Minimum 48 percent protein Chicago Board of Trade 1/	$/Mt
Soybean oil	1.2	Crude Soybean Oil Futures (first contract forward) exchange approved grades Chicago Board of Trade 1/	$/Mt
Palm oil	1.9	Crude Palm Oil Futures (first contract forward) 4-5 percent FFA Bursa Malaysian Derivatives Berhad 1/	$/Mt
Sunflower/Safflower Oil	0.5	Sunflower Oil, crude, US export price from Gulf of Mexico (DataStream)	$/Mt
Olive Oil	0.8	United Kingdom ex-tanker prices, crude extra virgin olive oil, 1%> ffa (free fatty acid) (DataStream). 1/	$/Mt
Fishmeal	0.5	Peru Fish meal/pellets 65% protein, CIF (DataStream) 1/	$/Mt
Groundnuts	0.6	40/50 (40 to 50 count per ounce), in-shell, cif Argentina (DataStream)	$/Mt
Rapeseed Oil	0.9	Crude, fob Rotterdam 1/ (Datastream)	$/Mt
Meat	10.1		
Beef	3.9	Australian and New Zealand, frozen boneless, 85 percent visible lean cow meat, U.S. import price FOB port of entry.	Cts/lb
Lamb	0.7	New Zealand, PL, frozen, wholesale price at Smithfield Market, London (National Business Review, Auckland, New Zealand).	Cts/lb
Swine Meat	3.1	51-52% (.8 - .99 inches of backfat at measuring point) lean Hogs, USDA average base cost price of back fat measured at the tenth rib (USDA).	Cts/lb
Poultry	2.4	Georgia docks, ready to eat whole body chicken, packed in ice, spot price (USDA).	Cts/lb
Seafood	8.6		
Fish	6.9	Fresh Norwegian Salmon, farm bred, export price (NorStat).	US$/kg
Shrimp	1.8	Mexican, west coast, white, No. 1, shell-on, headless, 26 to 30 count per pound, wholesale price at New York (World Bank).	US$/lb
Sugar	2.4		
Free market	1.6	CSCE contract No. 11, nearest future position (Coffee, Sugar and Cocoa Exchange, New York Board of Trade).	Cts/lb
United States	0.1	CSCE contract No. 14, nearest future position (Coffee, Sugar and Cocoa Exchange, New York Board of Trade).	Cts/lb
EU	0.6	EU import price, unpacked sugar, CIF European ports. Negotiated price for sugar from ACP countries to EU under the Sugar Protocol (EU Office in Washington D.C.). 1/	Cts/lb
Bananas	1.1	Central American and Ecuador, first class quality tropical pack, Chiquita, Dole and Del Monte, U.S. importer's price FOB U.S. ports (Sopisco News, Guayaquil).	$/Mt
Oranges	1.3	Miscellaneous Oranges, French import price (FruiTROP and World Bank).	$/Mt

Beverages	**4.9**		
Coffee	2.3		
Other milds	1.5	International Coffee Organization, Other Mild Arabicas New York cash price. Average of El Salvador central standard, Guatemala prime washed and Mexico prime washed, prompt shipment, ex-dock New York 1/	Cts/lb
Robusta	0.9	International Coffee Organization, Robustas New York cash price. Cote d'Ivoire Grade II and Uganda standard, prompt shipment, ex-dock New York. Prior to July 1982, arithmetic average of Angolan Ambriz 2 AA and Ugandan Native Standard, ex-dock New York. 1/	Cts/lb
Cocoa beans	1.8	International Cocoa Organization cash price. Average of the three nearest active futures trading months in the New York Cocoa Exchange at noon and the London Terminal market at closing time, CIF U.S. and European ports (The Financial Times, London). 1/	$/Mt
Tea	0.8	Mombasa auction price for best PF1, Kenyan Tea. Replaces London auction price beginning July 1998.	Cts/Kg
Industrial Inputs	49.7		
Agricultural raw materials	**20.9**		
Timber	9.1		
Hardwood	3.2		
Logs	1.0	Malaysian, meranti, Sarawak best quality, sale price charged by importers, Japan (World Bank, Washington, D.C.). From January 1988 to February 1993, average of Sabah and Sarawak in Tokyo weighted by their respective import volumes in Japan. From February 1993 to present, Sarawak only. 3/	$/Cm
Sawnwood	2.3	Malaysian sawnwood, dark red meranti, select and better quality, standard density, C&F U.K. Port (Tropical Timbers, Surrey, England). 3/	$/Cm
Softwood	5.9		
Logs	1.0	Average export price of Douglas-fir, Western hemlock and other softwoods exported from Washington, Oregon, Northern California and Alaska. (Pacific Northwest Research Station, USDA Forest Service, Portland, OR). 3/	$/Cm
Sawnwood	4.9	Average export price of Douglas-fir, Western hemlock and other sawn softwood exported from Canada.	$/Cm
Cotton	1.8	Middling 1-3/32 inch staple, Liverpool Index "A", average of the cheapest five of fourteen styles, CIF Liverpool (Cotton Outlook, Liverpool). From January 1968 to May 1981 strict middling 1-1/16 inch staple. Prior to 1968, Mexican 1-1/16. 2/	Cts/lb
Wool	1.3		
Fine	0.6	19 micron (AWEX, Australian Wool Exchange) Sidney, Australia	Cts/Kg
Coarse	0.7	23 micron (AWEX, Australian Wool Exchange) Sidney, Australia	Cts/Kg
Rubber	1.5	Singapore Commodity Exchange, No. 1 Rubber Smoked Sheets, 1st contract (Bloomberg, R01 Comdty)	Cts/lb
Hides	7.1	U.S., Chicago packer's heavy native steers, over 53 lbs.,wholesale dealer's price, (formerly over 58 lbs.), FOB shipping point (Wall Street Journal, New York). Prior to November 1985, U.S. Bureau of Labor Statistics, Washington, D.C. 1/	Cts/lb

Metals	**28.9**		
Copper	7.7	London Metal Exchange, grade A cathodes, spot price, CIF European ports (Wall Street Journal, New York and Metals Week, New York). Prior to July 1986, higher grade, wirebars, or cathodes. 1/	$/Mt
Aluminum	10.5	London Metal Exchange, standard grade, spot price, minimum purity 99.5 percent, CIF U.K. ports (Wall Street Journal, New York and Metals Week, New York). Prior to 1979, U.K. producer price, minimum purity 99 percent. 1/	$/Mt
Iron ore	3.6	Brazilian, Carajas fines, 67.55 percent FE (iron) content, contract price to Europe, FOB Ponta da Madeira (Companhia Vale do Rio Doce, Rio de Janeiro, Brazil). 4/	Cts/DMTU
Tin	0.4	London Metal Exchange, standard grade, spot price, CIF European ports (Wall Street Journal, New York, New York). From Dec. 1985 to June 1989 Malaysian, straits, minimum 99.85 percent purity, Kuala Lumpur Tin Market settlement price. Prior to November 1985, London Metal Exchange (Wall Street Journal, New York and Metals Week, New York). 1/	$/Mt
Nickel	3.0	London Metal Exchange, melting grade, spot price, CIF Northern European ports (Wall Street Journal, New York and Metals Week, New York). Prior to 1980 INCO, melting grade, CIF Far East and American ports (Metal Bulletin, London). 1/	$/Mt
Zinc	1.7	London Metal Exchange, high grade 98 percent pure, spot price, CIF U.K. ports (Wall Street Journal and Metals Weeek, New York). Prior to January 1987, standard grade. 1/	$/Mt
Lead	0.6	London Metal Exchange, 99.97 percent pure, spot price, CIF European ports (Wall Street Journal, New York and Metals Week, New York). 1/	$/Mt
[illegible]	[illegible]	[illegible]	[illegible]

Source: https://www.imf.org/external/np/res/commod/Table2-091410.pdf

APPENDIX III: COMPOSITION OF RSA EXPORTS, MARCH 2010

Code	EXPORT (R'000)			Proportion 2010	
Name	Jan-10	2010	2009	%Total	Cum.
71.NATURAL OR CULTURED PEARLS,PRECIOUS OR SEMI-PREC IOUS STO	9 152 102	9 152 102	128 366 147	25.20%	25.20%
26.ORES, SLAG AND ASH	4 293 341	4 293 341	49 993 819	11.80%	37.10%
27.MINERAL FUELS,MINERAL OILS AND PRODUCTS OF THEIR DISTILLA	3 862 534	3 862 534	52 282 738	10.60%	47.70%
72.IRON AND STEEL	3 775 237	3 775 237	47 063 030	10.40%	58.10%
84.NUCLEAR REACTORS,BOILERS,MACHINERY AND MECHANICAL APPLIAN	2 209 069	2 209 069	31 554 213	6.10%	64.20%
87.VEHICLES(EXCLUDING RAILWAY OR TRAMWAY ROLLING- STOCK)AND	2 195 004	2 195 004	40 400 115	6.10%	70.30%
08.EDIBLE FRUIT AND NUTS;PEEL OF CITRUS FRUIT OR MELONS	1 102 919	1 102 919	13 614 849	3.00%	73.30%
76.ALUMINIUM AND ARTICLES THEREOF	1 079 882	1 079 882	13 301 580	3.00%	76.30%
29.ORGANIC CHEMICALS	716 799	716 799	7 570 866	2.00%	78.20%
28.INORGANIC CHEMICALS;ORGANIC OR INORGANIC COMPOUND OF PREC	512 730	512 730	7 920 473	1.40%	79.70%
22.BEVERAGES,SPIRITS AND VINEGAR	498 432	498 432	8 589 786	1.40%	81.00%
73.ARTICLES OF IRON OR STEEL	409 017	409 017	7 594 220	1.10%	84.60%
47.PULP OF WOOD OR OF OTHER FIBROUS CELLULOSIC MATERIAL;WAST	392 087	392 087	4 316 545	1.10%	85.70%
48.PAPER AND PAPERBOARD;ARTICLES OF PAPER PULP, OF PAPER OR	381 919	381 919	5 457 834	1.10%	86.70%
74.COPPER AND ARTICLES THEREOF	308 461	308 461	4 032 722	0.90%	87.60%
94.FURNITURE;BEDDING,MATTRESSES,MATTRESS SUPPORTS, CUSHIONS	289 268	289 268	3 822 527	0.80%	88.40%
38.MISCELLANEOUS CHEMICAL PRODUCTS	267 522	267 522	4 202 327	0.70%	89.10%
03.FISH AND CRUSTACEANS,MOLLUSCS AND OTHER AQUATIC INVERTEBR	263 532	263 532	3 241 519	0.70%	89.80%
75.NICKEL AND ARTICLES THEREOF	250 889	250 889	2 424 663	0.70%	90.50%
20.PREPARATIONS OF VEGETABLES, FRUIT, NUTS OR OTHER PARTS OF	197 325	197 325	3 286 178	0.50%	91.00%
24.TOBACCO AND MANUFACTURED TOBACCO SUBSTITUTES	163 638	163 638	1 516 617	0.50%	92.50%
51.WOOL,FINE OR COARSE ANIMAL HAIR;HORSEHAIR YARN AND WOVEN	160 161	160 161	2 048 090	0.40%	92.90%
40.RUBBER AND ARTICLES THEREOF	144 889	144 889	2 464 653	0.40%	93.30%
44.WOOD AND ARTICLES OF WOOD;WOOD CHARCOAL	136 265	136 265	2 480 877	0.40%	93.70%
33.ESSENTIAL OILS AND RESINOIDS;PERFUMERY,COSMETIC OR TOILET	125 825	125 825	1 857 268	0.30%	94.10%
32.TANNING OR DYEING EXTRACTS;TANNING AND THEIR DERI VATIVES	108 659	108 659	1 752 314	0.30%	94.40%
10.CEREALS	104 411	104 411	4 207 171	0.30%	94.60%
79.ZINC AND ARTICLES THEREOF	103 341	103 341	218 932	0.30%	94.90%
49.PRINTED BOOKS,NEWSPAPERS,PICTURES AND OTHER PRO DUCTS OF	100 169	100 169	472 191	0.30%	95.20%
31.FERTILIZERS	100 117	100 117	1 811 786	0.30%	95.50%
17.SUGARS AND SUGAR CONFECTIONERY	89 380	89 380	3 406 867	0.20%	95.70%
34.SOAP,ORGANIC SURFACE-ACTIVE AGENTS,WASHING PREPA- RATIONS	88 575	88 575	1 397 479	0.20%	96.00%
86.RAILWAY OR TRAMWAY LOCOMOTIVES,ROLLING-STOCK AND PARTS TH	87 550	87 550	1 412 099	0.20%	96.20%
41.RAW HIDES AND SKINS(EXCLUDING FURSKINS) AND LEATHER	83 910	83 910	1 148 648	0.20%	96.40%
21.MISCELLANEOUS EDIBLE PREPARATIONS	80 192	80 192	1 499 853	0.20%	96.70%
02.MEAT AND EDIBLE MEAT OFFALS	69 932	69 932	962 713	0.20%	97.50%
15.ANIMAL OR VEGETABLE FATS AND OILS AND THEIR CLEA VAGE PRO	59 797	59 797	870 613	0.20%	97.60%
81.OTHER BASE METALS;CERMETS;ARTICLES THEREOF	56 108	56 108	656 805	0.20%	97.80%
30.PHARMACEUTICAL PRODUCTS	53 721	53 721	1 311 839	0.10%	98.00%
11.PRODUCTS OF THE MILLING INDUSTRY; MALT; STARCHES; INULIN;	53 280	53 280	922 523	0.10%	98.10%
70.GLASS AND GLASSWARE	48 138	48 138	1 095 699	0.10%	98.20%

36.EXPLOSIVES;PYROTECHNIC PRODUCTS;MATCHES;PYROPHO- RIC ALLO	39 397	39 397	733 955	0.10%	98.30%
04.DAIRY PRODUCE;BIRD'S EGGS;NATURAL HONEY;EDIBLE PRODUCTS O	36 897	36 897	627 233	0.10%	98.40%
19.PREPARATIONS OF CEREALS,FLOUR,STARCH OR MILK; PASTRYCOOKS	36 552	36 552	572 378	0.10%	98.50%
68.ARTICLES OF STONE,PLASTER,CEMENT,ASBESTOS,MICA OR SIMILAR	35 640	35 640	508 846	0.10%	98.60%
12.OIL SEEDS AND OLEAGINOUS FRUITS;MISCELLANEOUS GRAINS,SEED	35 275	35 275	1 314 250	0.10%	98.70%
07.EDIBLE VEGETABLES AND CERTAIN ROOTS AND TUBERS	32 941	32 941	416 020	0.10%	98.80%
69.CERAMIC PRODUCTS	31 695	31 695	509 058	0.10%	98.90%
83.MISCELLANEOUS ARTICLES OF BASE METAL	29 891	29 891	552 323	0.10%	99.00%
97.WORKS OF ART,COLLECTORS' PIECES AND ANTIQUES	27 605	27 605	233 767	0.10%	99.10%
06.LIVE TREES AND OTHER PLANTS;BULBS,ROOTS AND THE LIKE;CUT	26 647	26 647	480 124	0.10%	99.10%
56.WADDING,FELT AND NONWOVENS;SPECIAL YARNS;TWINE, CORDAGE,R	23 989	23 989	271 726	0.10%	99.20%
18.COCOA AND COCOA PREPARATIONS	21 041	21 041	365 731	0.10%	99.30%
89.SHIPS,BOATS AND FLOATING STRUCTURES	18 914	18 914	703 167	0.10%	99.30%
63.OTHER MADE UP TEXTILE ARTICLES;SETS;WORN CLOTHING AND WOR	17 728	17 728	598 492	0.00%	99.50%
09.COFFEE, TEA, MATE AND SPICES	17 622	17 622	319 620	0.00%	99.50%
37.PHOTOGRAPHIC OR CINEMATOGRAPHIC GOODS	17 434	17 434	244 889	0.00%	99.60%
16.PREPARATIONS OF MEAT,OF FISH OR OF CRUSTACEANS, MOLLUSCS	16 553	16 553	386 943	0.00%	99.60%
01.LIVE ANIMALS	14 849	14 849	262 259	0.00%	99.70%
52.COTTON	12 157	12 157	83 098	0.00%	99.70%
57.CARPETS AND OTHER TEXTILE FLOOR COVERINGS	11 960	11 960	226 833	0.00%	99.70%
62.ARTICLES OF APPAREL AND CLOTHING ACCESSORIES,NOT KNITTED	11 555	11 555	301 577	0.00%	99.80%
59.IMPREGNATED,COATED,COVERED OR LAMINATED TEXTILE FABRICS;T	10 636	10 636	153 175	0.00%	99.80%
61.ARTICLES OF APPAREL AND CLOTHING ACCESSORIES, KNITTED OR	9 752	9 752	290 963	0.00%	99.80%
78.LEAD AND ARTICLES THEREOF	8 482	8 482	194 664	0.00%	99.90%
05.PRODUCTS OF ANIMAL ORIGIN,NOT ELSEWHERE SPECIFIED OR INCL	6 165	6 165	130 159	0.00%	99.90%
43.FURSKINS AND ARTIFICIAL FUR: MANUFACTURES THEREOF	3 394	3 394	43 572	0.00%	100.00%
42.ARTICLES OF LEATHER;SADDLERY AND HARNESS;TRAVEL GOODS,HAN	2 549	2 549	120 355	0.00%	100.00%
58.SPECIAL WOVEN FABRICS;TUFTED TEXTILE FABRICS;LACE TAPESTR	2 131	2 131	75 245	0.00%	100.00%
13.LAC;GUMS,RESINS AND OTHER VEGETABLE SAPS AND EXTRACTS	1 814	1 814	31 016	0.00%	100.00%
14.VEGETABLE PLAITING MATERIALS;VEGETABLE PRODUCTS NOT ELSEW	157	157	5 723	0.00%	100.00%
53.OTHER VEGETABLE TEXTILE FIBRES;PAPER YARN AND WOVEN FABRI	156	156	10 583	0.00%	100.00%
50.SILK	11	11	1 618	0.00%	100.00%
Total CHAPTERS	36 279 921	36 279 921	512 802 515	100.00%	100.00%

Source: ***South Africa Export Data: http://thedti.gov.za/econdb/raportt***

APPENDIX IV: SOUTH AFRICAN EXPORTS IN THE NFC INDEX

COMMODITY ITEM	% OF SA EXPORTS	WEIGHT IN INDEX
Cereals	3.7	9.7
Vegetable Oils	0.4	12.1
Meat	0.6	10.1
Seafood	0.2	8.6
Sugar	0.7	2.4
Edible Fruits	0.2	2.4
Beverages	3.0	4.9
Agricultural industrial inputs	5.4	20.9
Metals and ores	28.7	28.9
	42.9	**100**

Sources:

1. **IMF Non-fuel Index:**
   https://www.imf.org/external/np/res/commod/Table2-091410.pdf
2. **South Africa Export Data:**
   http://thedti.gov.za/econdb/raportt

APPENDIX V: TABLE OF DICKEY-FULLER CRITICAL VALUES

True Model Used to Generate the Data:	$y_t = y_{t-1} + \varepsilon_t$

1. Model Estimated:	**Dickey-Fuller**	$\boldsymbol{\Delta y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 t + \varepsilon_t}$		
	Phillips-Perron	$\boldsymbol{y_t = \acute{\alpha}_0 + \acute{\alpha}_1 y_{t-1} + \acute{\alpha}_2 \left(t - \frac{n}{2}\right) + \acute{\varepsilon}_t}$		
Hypothesis	Test Statistic	Critical Values		
		10%	5%	1%
$a_1 = 0$; $\acute{\alpha}_1 = 1$	t-based	-3.15	-3.45	-4.04
$a_0 = 0$; $\acute{\alpha}_0 = 0$	t-based	2.73	3.11	3.78
$a_2 = 0$; $\acute{\alpha}_2 = 0$	t-based	2.38	2.79	3.53
$a_1 = a_2 = 0$; $\acute{\alpha}_1 = 1$ & $\acute{\alpha}_2 = 0$	F-based	5.47	6.49	8.73
$a_0 = a_1 = a_2 = 0$; $\acute{\alpha}_0 = \acute{\alpha}_2 = 0$ & $\acute{\alpha}_1 = 1$	F-based	4.16	4.88	6.50

2. Model Estimated:	Dickey-Fuller	$\boldsymbol{\Delta y_t = \alpha_0 + \alpha_1 y_{t-1} + \varepsilon_t}$		
	Phillips-Perron	$\boldsymbol{y_t = \acute{\alpha}_0 + \acute{\alpha}_1 y_{t-1} + \acute{\varepsilon}_t}$		
Hypothesis	Test Statistic	Critical Values		
		10%	5%	1%
$a_1 = 0$; $\acute{\alpha}_1 = 1$	t-based	-2.58	-2.89	-3.51
$a_0 = 0$; $\acute{\alpha}_0 = 0$	t-based	2.17	2.54	3.22
$a_0 = a_1 = 0$; $\acute{\alpha}_0 = 0$ & $\acute{\alpha}_1 = 1$	F-based	3.86	4.71	6.70

3. Model Estimated:	Dickey-Fuller	$\boldsymbol{\Delta y_t = y_{t-1} + \varepsilon_t}$		
	Phillips-Perron	$\boldsymbol{y_t = \acute{\alpha}_1 y_{t-1} + \acute{\varepsilon}_t}$		
Hypothesis	Test Statistic	Critical Values		
		10%	5%	1%
$a_1 = 0$; $\acute{\alpha}_1 = 1$	t-based	-1.61	-1.95	-2.60

Source: Dickey and Fuller (1981) Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root," Econometrica, Vol. 49, July 1981, pages 1062 and 1063,

APPENDIX VI: CORRELATION MATRICES OF LEVEL VARIABLES

a) *Level series natural logarithm of exchange rate*

	E_{t-1}	E_{t-2}	E_{t-3}	E_{t-4}	E_{t-5}	E_t
E_{t-1}	1.0000	0.9776	0.9535	0.9282	0.9035	0.9768
E_{t-2}	0.9776	1.0000	0.9782	0.9545	0.9299	0.9522
E_{t-3}	0.9535	0.9782	1.0000	0.9786	0.9557	0.9266
E_{t-4}	0.9282	0.9545	0.9786	1.0000	0.9794	0.9012
E_{t-5}	0.9035	0.9299	0.9557	0.9794	1.0000	0.8756
E_t	0.9768	0.9522	0.9266	0.9012	0.8756	1.0000

b) *Level series of natural logarithm of commodity Index*

	C_{t-1}	C_{t-2}	C_{t-3}	C_{t-4}	C_{t-5}	C_t
C_{t-1}	1.0000	0.9925	0.9794	0.9622	0.9432	0.9925
C_{t-2}	0.9925	1.0000	0.9924	0.9791	0.9618	0.9796
C_{t-3}	0.9794	0.9924	1.0000	0.9923	0.9788	0.9627
C_{t-4}	0.9622	0.9791	0.9923	1.0000	0.9922	0.9439
C_{t-5}	0.9432	0.9618	0.9788	0.9922	1.0000	0.9241
C_t	0.9925	0.9796	0.9627	0.9439	0.9241	1.0000

APPENDIX VII: LAG LENGTHS TESTS FOR VARS

a) Equation 25:

$$\Delta E_t = \vartheta + \sum_{i=1}^{p} \gamma_i \Delta E_{t-i} + \sum_{i=1}^{p} \varphi_i \Delta C_{t-i} + e_t$$

Lag length p=3

Independent Variable	Regression Coefficient b (i)	Standard Error Sb(i)	T-Value to test H0:B(i)=0	Prob Level	Reject H0 at 10%?	Power of Test at 10%
Intercept	0.0038	0.0039	0.992	0.3225	No	0.2674
ΔC_{t-1}	-0.3335	0.1579	-2.112	0.0362	Yes	0.7185
ΔC_{t-2}	0.0919	0.1677	-0.548	0.5846	No	0.1141
ΔC_{t-3}	0.0888	0.1584	0.561	0.5758	No	0.1053
ΔE_{t-1}	0.0005	0.0808	0.006	0.9954	No	0.1068
ΔE_{t-2}	0.0099	0.0798	0.124	0.9016	No	0.1024
ΔE_{t-3}	0.0087	0.0797	-0.109	0.9133	No	0.1042

Lag length p=2

Independent Variable	Regression Coefficient b(i)	Standard Error Sb(i)	T-Value to test H0:B(i)=0	Prob Level	Reject H0 at 10%?	Power of Test at 10%
Intercept	0.0041	0.0038	1.088	0.2780	No	0.2819
ΔC_{t-1}	-0.3037	0.0828	-1.972	0.0503	Yes	0.7064
ΔC_{t-2}	-0.0611	0.0824	-0.394	0.6945	No	0.1273
ΔE_{t-1}	0.0096	0.0792	0.121	0.9042	No	0.1161
ΔE_{t-2}	0.0098	0.0794	0.123	0.9019	No	0.1030

b) Equation 26:

$$\Delta E_t = \vartheta + \sum_{i=1}^{p} \gamma_i \Delta E_{t-i} + \sum_{i=1}^{p} \varphi_i \Delta C_{t-i} + e_t$$

Lag length p=3

Independent Variable	Regression Coefficient b(i)	Standard Error Sb(i)	T-Value to test H0:B(i)=0	Prob Level	Reject H0 at 10%?	Power of Test at 10%
Intercept	0.0012	0.0037	0.614	0.5400	No	0.2358
ΔC_{t-1}	0.3710	0.0800	4.674	0.0000	Yes	0.9695
ΔC_{t-2}	0.1435	0.0828	1.700	0.0911	Yes	0.4546
ΔC_{t-3}	-0.0287	0.0794	-0.369	0.7127	No	0.1010
ΔE_{t-1}	-0.1029	0.0763	-2.596	0.0103	Yes	0.5543
ΔE_{t-2}	-0.0140	0.0761	-0.351	0.7262	No	0.2645
ΔE_{t-3}	0.0324	0.0760	0.812	0.4179	No	0.2789

Lag length p=2

Independent Variable	Regression Coefficient b(i)	Standard Error Sb(i)	T-Value to test H0:B(i)=0	Prob Level	Reject H0 at 10%?	Power of Test at 10%
Intercept	0.0015	0.0036	0.784	0.4341	No	0.2909
ΔC_{t-1}	0.3689	0.0787	4.678	0.0000	Yes	0.9701
ΔC_{t-2}	0.1247	0.0783	1.6919	0.1074	No	0.4191
ΔE_{t-1}	-0.0943	0.0752	-2.398	0.0176	Yes	0.5190
ΔE_{t-2}	-0.0103	0.0755	-0.258	0.7964	No	0.2499

APPENDIX VIII: RESIDUAL SERIAL CORRELATION RESULTS

a) *Level exchange rate regressed on level commodity price index*

Serial Correlation of Residuals Section

Lag	*Serial Correlation*	*Lag*	*Serial Correlation*	*Lag*	*Serial Correlation*
1	0.9585	9	0.6455	17	0.3277
2	0.9131	10	0.6043	18	0.2909
3	0.8690	11	0.5674	19	0.2577
4	0.8256	12	0.5239	20	0.2257
5	0.7828	13	0.4823	21	0.1884
6	0.7460	14	0.4418	22	0.1538
7	0.7126	15	0.4021	23	0.1164
8	0.6820	16	0.3635	24	0.0870

Above serial correlations significant if their absolute values are greater than 0.152944

Durbin-Watson Test for Serial Correlation

Parameter	**Value**	**Did the Test Reject H0: Rho(1) = 0?**
Durbin-Watson Value	0.0471	
Prob. Level: Positive Serial Correlation	0.0000	Yes
Prob. Level: Negative Serial Correlation	1.0000	No

b) *First difference exchange rate regressed on first difference commodity prices index*

Serial Correlation of Residuals Section

Lag	*Serial Correlation*	*Lag*	*Serial Correlation*	*Lag*	*Serial Correlation*
1	-0.0049	9	0.0931	17	0.0429
2	0.0114	10	-0.0768	18	-0.0441
3	0.0115	11	0.0980	19	0.0104
4	0.0508	12	-0.0376	20	0.0701
5	-0.0355	13	-0.0799	21	-0.0228
6	-0.1161	14	0.0233	22	0.0793
7	0.0893	15	-0.0072	23	-0.1439
8	0.0701	16	-0.0949	24	0.0190

Above serial correlations significant if their absolute values are greater than 0.153393

Durbin-Watson Test For Serial Correlation

Parameter	**Value**	**Did the Test Reject H0: Rho (1) = 0?**
Durbin-Watson Value	2.0011	
Prob. Level: Positive Serial Correlation	0.5006	No
Prob. Level: Negative Serial Correlation	0.4951	No

APPENDIX IX: ANDREWS (1993) QLR TEST FOR INSTABILITIES

AUS	NZ	CAN	CHI	SA
A. P-values for stability of (β_{0t}, β_{1t}) in $\Delta C_{t+1} = \beta_{0t} + \beta_{1t}\Delta E_t + \beta_2 C_t$				
0***	0.63	0.13	0.56	0***
(2004:1)				(2005:3)
B. P-values for stability of (β_{0t}, β_{1t}) in: $\Delta E_{t+1} = \beta_{0t} + \beta_{1t}\Delta C_t + \beta_2 E_t$				
0***	0.02**	0.05**	0***	0***
(2002:2)	(2002:3)	(2002:2)	(2004:4)	(2005:3)

Note: The table reports p-values for Andrews (1993) QLR test of parameter stability. Asterisks mark rejection at the 1% (***), 5% (**), and 10% (*) significance levels respectively, indicating evidence of instability. When the test rejects the null hypothesis of parameter stability, the estimated break-dates are reported in the parentheses.

Source: Rossi (2005b)

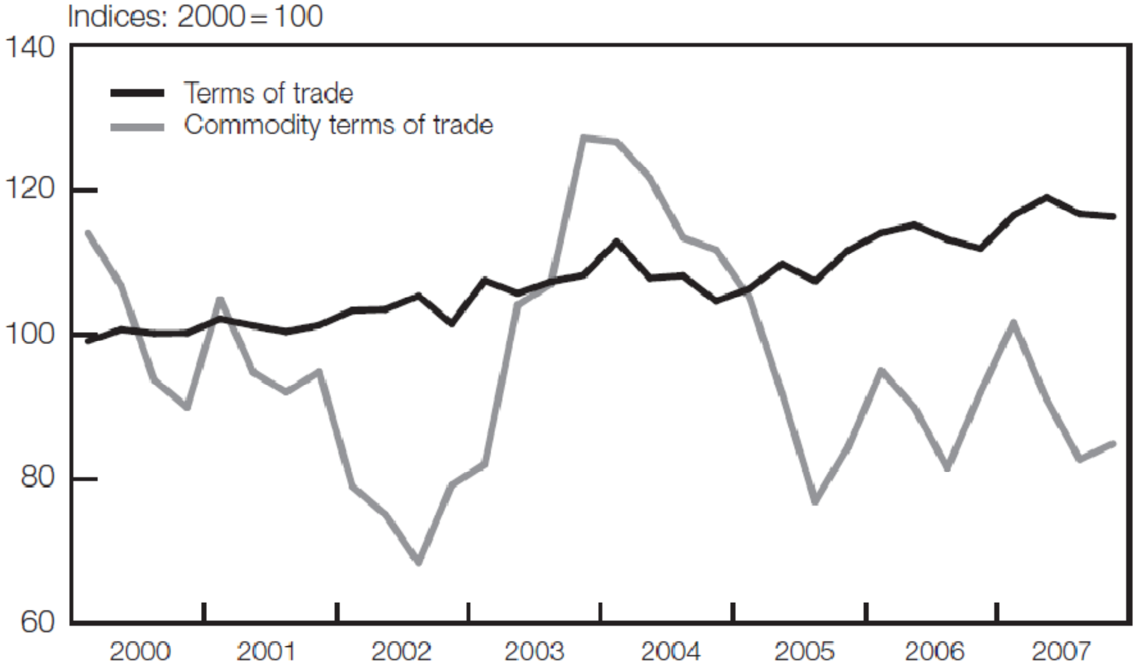
APPENDIX X: GRANGER-CAUSALITY TEST ROBUST TO INSTABILITIES

AUS	NZ	CAN	CHI	SA
A. P-values for H0: $\beta_{0t} = \beta_{1t} = 0$ in $\Delta C_{t+1} = \beta_{0t} + \beta_{1t}\Delta E_t + \beta_2 C_t$				
0***	0.30	0.05**	0.22	0***
B. P-values for H0: $\beta_{0t} = \beta_{1t} = 0$ in $\Delta E_{t+1} = \beta_{0t} + \beta_{1t}\Delta C_t + \beta_2 E_t$				
0***	0.02**	0.36	0***	0***

Note: The table reports p-values for testing the null of no Granger-causality that are robust to parameter instabilities. Asterisks mark rejection at the 1% (***), 5% (**), and 10% (*) significance levels respectively, indicating evidence in favour of Granger-causality.

Source: Rossi (2005b)

APPENDIX XI: SOUTH AFRICAN COMMODITY TERMS OF TRADE



Source: South African Reserve Bank