The South African Rand and Fundamentals

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Abstract

This paper revisits the exchange rate-fundamentals debate for the case of the South African Rand; emphasising the role of commodity prices. The exchange rate determination puzzle has been at the heart of exchange rate studies since the Meese-Rogoff (1983) seminal paper. We show that changes in the nominal exchange rate in South Africa respond significantly to changes in international commodity prices. Further, we demonstrate that inclusion of commodity prices improves the in-sample fit of several canonical exchange rate model specifications. In terms of predictive power, our results indicate that inclusion of the commodity price fundamental significantly improves the forecast performance of the standard structural models.

1. Introduction

The connection between exchange rates and macro-economic fundamentals is intuitively and theoretically plausible. Literature documents several fundamentals based theoretical models of exchange rates that worked well in the seventies but have been delivering infamously poor performance when tested empirically against floating exchange rate data from industrialised economies both in terms of in sample estimates and out-of-sample short horizon forecasts. Since the Meese and Rogoff (1983) seminal work that showed that the canonical exchange rate models of the 1970s could not out-perform a random walk, several authors have documented several exchange rate puzzles. These include the purchasing power parity puzzle (Obstfeld and Rogoff (1996), the forward premium puzzle (Fama, 1984), and the excess volatility puzzle (See De Grauwe and Grimaldi, 2005 and Sanidas, 2014).[1]

In spite of the vast contributions to the exchange rate literature, the focus has been on developed industrialised economies and emerging markets. The periphery countries such as those in sub Saharan Africa have been overlooked (see Kablan et al, 2016). Our objective in this paper is to contribute to the vast literature using data from Sub Saharan Africa's most industrialised economy – South Africa with the expectation that lessons from South Africa can be applied by researchers to other smaller economies in the process of liberalising their economies.

Notwithstanding the challenges associated with exchange rate modelling using fundamentals (see Frankel and Rose, 1995 for a comprehensive survey of literature), we argue that there is value in the information that helps foreign exchange market players improve their performance from a policy and commerce standpoint. Exchange rate volatility is a cause of concern for policy makers in South Africa, exacerbated by the country's improved integration into global financial markets. Speculative flows into the financial markets, particularly debt portfolio inflows have been pointed as a major source of volatility (Hassan, 2014). Another source of complications is the so called "financialisation" of commodity markets in which South Africa is a major player. Gao and Süss (2015) estimate that 80% of investors in commodities represent financial investors and Silvennoinen and Thorp, (2013) show why commodities have an appeal as alternative assets for investors. Moosa and Burns (2012, 2014) provide evidence that a forecast-based currency trading strategy outperforms a random walk model based strategy.

[1] See Hodrich 1988, Lewis, 1995 and Sarno, 2005 for surveys.

Further, to the extent that commodity prices transmit exogenous shocks from the global markets to the wider economy, it is important for players to understand the drivers of the exchange rate.[2]

Organisation of the study

This paper is split into two sections. The first part takes a microscopic view into the nexus between the South African Rand and commodity prices. While the connection between exchange rates and fundamentals is subject of much debate in international finance, it is easy to conjecture that countries that transact a significant amount of their exports in commodities would have the values of their exchange rates linked with commodity prices. The exchange rates of such economies are commonly known as "commodity currencies" in the foreign exchange markets, a marker that includes the South African Rand, the Australian dollar and New Zealand dollar. The theoretical connection between the exchange rate and commodity prices is well documented in exchange rate literature.

The first theoretical justification for the link comes from macro-economic and trade theory arguments discussed in Clements and Fry (2006) and Chen and Rogoff (2002). To illustrate this link between the exchange rate and commodity prices, consider a small open commodity exporting economy with a tradable and non-tradable goods sector. An increase in the price of the exported commodity in world markets would affect the demand for non-traded goods through its effect on wages – a channel similar to the regular Balassa-Samuelson effect.[3] Assuming that prices of non-tradable goods are sticky (conceivable in the case of South Africa), the exchange rate instead of prices would have to adjust to preserve efficient resource allocation.[4] Thus, a positive terms of trade shock such as a boom in commodity markets eventually leads to an appreciation of the exchange rate in an environment of nominal price rigidities in the non-tradable sector.

The second channel through which commodity prices can enter the exchange rate determination equation is through the "portfolio balance" class of models (see Frankel, 1993). In this class of models, it is assumed that asset holders allocate portfolios in shares that are well

[2] 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

[3]The Balassa-Samuelson effect owes its name to two economists Balassa (1964) and Samuelson (1964). The model posits that faster productivity in tradable versus non-tradable goods in a given economy compared to international counterparties would eventually raise the price level and therefore the real exchange rate. The model assumes that labour is an important factor of production and is fully mobile across the tradable and no-tradable goods sectors. A rise in productivity of tradable goods will raise wages in the tradable sector. Since labour is assumed to be perfectly mobile across the two sectors, the wages in the non-tradable sector would also rise. Producers in the non-tradable sector would have to raise prices to match higher labour costs since the rise in wages is not matched by increased productivity.

[4] That is, the price of the domestic currency against foreign currency, instead of prices of goods and services would have to adjust upwards to maintain efficient relative price between traded and non-traded goods.

defined functions of their expected rates of return. The portfolio balance approach treats domestic and foreign assets as imperfect substitutes; thus the exchange rate is a function of demand and supply of foreign and domestic assets and not just money. Under the assumption of perfect capital mobility, the exchange rate must adjust instantly to equilibrate the international demand for national assets. For a commodity exporting economy, a boom in the price of the exported commodities in international markets would typically lead to an excess supply of dollars and accumulation of foreign reserves, increasing pressure on the relative demand of their domestic currencies. To equilibrate the demand for the domestic currency, the price of the domestic currency would have to appreciate in terms of the foreign currency. Chaban (2009) characterises a boom in commodity prices as a transfer of wealth from commodity importing to commodity-exporting countries.[5]

The remainder of this paper is organised as follows. In Section 2 we introduce the ARDL and bounds testing approach to uncover the long-run and short run dynamics between the nominal Rand and commodity prices. In Section 3 we consider standard structural exchange rate models. The models are tested empirically using South African data for their in sample fit and out-of-sample short horizon forecast performance. We augment the standard models by a commodity price variable to see if this additional fundamental improves the performance of the standard models.

As a preview of results, the ARDL bounds testing approach provides evidence of a significant link between the nominal Rand exchange rate and nominal commodity prices in the short-run. While evidence of cointegration exists, the long-run relationship is weak and the associated error correction process is slow. Turning to the structural exchange rate models of the Rand, we find that commodity prices are significant and consistent explanatory variables of the changes in the nominal exchange rate. The commodity price variable improves the in-sample fit of the exchange rate models and this evidence is robust to the other major Rand cross rates. Further, inclusion of the commodity price variable improves the out-of-sample forecasting prowess of canonical exchange rate models. Lending support to the purchasing power parity puzzle, our results indicate that the relationship between the rand and monetary models is tighter that the PPP models. These results are of interest to foreign exchange market players, in policy, commerce and research.

[5] See also Edwards, 1994; Isard, 2007; Ricci et al., 2008, Coudert et al (2015)

2 The Rand and commodity prices: the ARDL bounds testing approach

2.1 Introduction

In this section we ask the question whether commodity prices are - as a fundamental important in the determination of the nominal exchange rate of the Rand. South Africa is a major commodity exporting economy and it is partly for this reason that the Rand is commonly denominated as a "commodity currency" in foreign exchange market markets. [6] The conjectured correlation of exchange rates and economies' major source of export revenues has roots in economic theory (See Chen and Rogoff, 2002, MacDonald and Ricci, 2002 Blundell-Wignall et al., 1993, Broda ,2004; Cashin et al., 2004 and more recently Chen et al. 2010; Issa et al., 2008; Cayen et al., 2010 and Ferraro et al, 2015) .

Intuitively, depending on whether a country is a net commodity exporter or (importer), commodity price rises may be expansionary (or serve as tax) and therefore positive (or negative) for the domestic nominal exchange rate. Another related question that we attempt to answer is whether the relationship between the Rand and commodity prices exists in the long run or in the short run. We investigate the short-run relationship in an error correction framework to ascertain whether adjustments in commodity prices are responsible for correcting the system to the long-run equilibrium. We subject our model to various diagnostic tests with respect to robustness and stability. The rest of this section is organised as follows. The next sub-section outlines the methodology and empirical strategy; sub-section 2.3 provides the results of our estimation and we provide the discussion of our results and conclusion in sub-section 2.4.

2.2 Methodology

2.2.1 Empirical model (ARDL)

We employ the Autoregressive Distributed Lag (ARDL) procedure to test the short-run and long-run relationships between the Rand and commodity prices. The ARDL model is chosen in order to address typical problems associated with time series modelling, namely a short sample period, the order of integration problem, serial correlation and endogeneity of regressors.

The ARDL approach was developed and popularised by Pesaran, Shin and Smith (1996), Pesaran and Shin (1998) and Pesaran, Shin & Smith (2001). The ARDL approach has several advantages and strengths over other cointegration methods like the Engle Granger (1987) and Johansen (1995) methods. First, the method is applicable whether the variables involved are purely stationary $I(0)$ or difference stationary $I(1)$, a mixed or mutually cointegrated. Thus, the

[6] For example 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

approach overcomes the requirement for variables to be integrated of the same order as in the Johansen (1995) approach. OLS estimates of the long run coefficients of the ARDL models are consistent provided that the lag structure of the model is identified. Valid inferences on long-run parameters can thus be made using standard asymptotic theory (Pesaran and Shin, 2008). Secondly, the method is suited for small samples because the approach eliminates the need for pre-testing for unit roots. Pesaran, Smith and Akiyama, (1998) show that commonly used standard unit root tests can be problematic in distinguishing the null of a unit root from the stationary alternatives in short sample periods. Thirdly, the ARDL method addresses the problem of serial correlation and endogeneity of regressors by appropriate augmentation of the order of regressors. Harris and Sollis (2003) show that long-run relationships estimated using the ARDL approach will be unbiased even when some of the regressors are endogenous in the model.

Implementation of the ARDL procedure involves two steps. The first step involves testing for the existence of a long-run relationship between the relevant variables in the context of an error correction framework. The test is achieved by computing the F-statistic with respect to the significance of the lagged levels of the variables in the error correction form of the underlying ARDL. The asymptotic distribution for this F-statistic is however non-standard. Pesaran et al (1996, 2001) provide a different test statistic to be used specifically for an ARDL model. They compute two sets of asymptotic critical values for the two polar cases: an upper bound assuming that all the regressors are $I(1)$ and a lower bound assuming that all the regressors are $I(0)$. The new critical values are tabulated from an extensive set of stochastic simulations under differing assumptions for the number of regressors, inclusion of an intercept and deterministic trends. If the calculated F-statistic lies outside the critical value bounds, then the researcher can make conclusions without any need to know whether the underlying variables are $I(0)$ or $I(1)$ or fractionally integrated. Specifically, one can conclude that a long-run relationship exists among variables if the computed F-statistic lies above the upper bound and that no long-run relationship exists if the F-statics lies below the lower bound. If the computed F-statistic lies inside the critical value bounds, inference is inconclusive and knowledge of the order of integration of the underlying variables becomes necessary. In that case, Banmani-Okkooee and Nasir (2004) show that an efficient way of establishing a long-run relationship is applying the ECM version of the ARDL model - if the error correction term is negative and significant, the researcher can conclude that cointegration exists (see also Bahmani-Oskooee, 2001 and Pahlavani et al, 2005).

The second step of the ARDL approach is to estimate the coefficients of the long-run relations and make inferences about their value. This step is valid only if the F-tests in the first stage do not reject the existence of a long-run relationship between the variables – thus the regressors can be considered as the "long-run forcing" variables explaining the dependent variable.

The ARDL model can therefore be thought of as a re-parametrization of the Vector Auto regression (VAR) model.

Starting with a Var (p) model:

$$z_t = \alpha + \beta_t + \sum_{i=1}^{p} \phi_i z_{t-i} + \varepsilon_t \tag{1}$$

Where z represents a vector of variables

Assuming that the elements of z are at most $I(1)$, that is, they don't have explosive roots, equation (1) can be writes as a simple vector error correction model:

$$\Delta z_t = \alpha + \beta_t + \Pi z_{t-1} + \sum_{i=1}^{p-1} \Gamma \Delta z_{t-i} + \varepsilon_t \tag{2}$$

Where $\Delta \equiv 1 - L$ is the difference operator; $\Pi = -(I_{k+1} - \sum_{i=1}^{p} \Phi_i)$ and $\Gamma = -\sum_{j=i+1}^{p} \phi_j$, $i = 1, \dots, p-1$ are the $(k+1)x(k+1)$ matrices of the long-run multipliers and short run dynamic coefficients.

Assuming that there is only one long-run relationship among the variables, Pesaran *et al* (2001) partition z_t into a dependent variable y_t and a set of "forcing" variables x_t. The matrices α, β, Γ and the long run multiplier Π can also be partitioned as follows:

$$\alpha = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix}, \beta = \begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix}, \ \Gamma_i = \begin{bmatrix} \gamma_{11,i} & \gamma_{12,i} \\ \gamma_{21,i} & \gamma_{22,i} \end{bmatrix}, \Pi = \begin{bmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \Pi_{22} \end{bmatrix}$$

The key assumption that x_t is a long-run forcing variable of y_t implies that the vector $\pi_{21} = 0$, that is, there is no feedback from the level of y_t on Δx_t. Thus, the conditional model for Δy_t and Δx_t can be written as:

$$\Delta y_t = \alpha_1 + \beta_{1t} + \pi_{11} y_{t-1} + \pi_{12} x_{t-1} + \sum_{i=1}^{p-1} \gamma_{11,i} \Delta y_{t-i} + \sum_{i=1}^{p-1} \gamma_{12,i} \Delta x_{t-i} + \varepsilon_{1t} \tag{3}$$

$$\Delta x_t = \alpha_2 + \beta_{2t} + \Pi_{22} x_{t-1} \pi_{12} x_{t-1} + \sum_{i=1}^{p-1} \gamma_{21,i} \Delta y_{t-i} + \sum_{i=1}^{p-1} \gamma_{22,i} \Delta x_{t-i} + \varepsilon_{2t} \tag{4}$$

Under the standard assumptions about the error terms, (3) can be written as follows:

$$\Delta y_t = \delta_1 + \delta_{1t} + \phi y_{t-1} + \theta x_{t-1} + \sum_{i=1}^{p-1} \upsilon_i \Delta y_{t-i} + \sum_{i=1}^{p-1} \varphi_i \Delta x_{t-i} + \omega_t \tag{5}$$

Equation (5) is the "unrestricted" error correction model (ECM). For a long-run relationship to exist among level variables, the parameters ϕ and θ should be non-zero. The null hypothesis of no cointegration is therefore the joint hypothesis that $\phi = \theta = 0$ via a bound test.

The choice of an ARDL model is selected using the Akaike Information Criterion (AIC) or Schwartz Bayesian Criterion (SBC). The chosen model is then estimated by Ordinary Least Squares (OLS). We check the chosen models for serial auto-correlation to confirm that the resulting regression results are not spurious. The bounds test is then conducted to ascertain the existence of long-run relationships between the two variables. Inferences are then made from the resulting long and short run coefficients.

As observed by Ouattare (2004) it is important to note that the variables included in the ARDL model should at most be $I(1)$. If the variables are $I(2)$, then the critical values provided in Pesaran *et al* (1997, 2001) which are computed based on I(0) and I(1) variables are no longer valid. For this reason, we conduct unit root tests.

2.2.2 Stability tests

To check the stability of the estimated coefficients, we apply the cumulative sum of recursive residuals (CUSUM) and cumulative square of recursive residuals (COSUMSQ) tests proposed by Brown, Durbin, and Evans (1975). The latter test is based on "recursive residuals"-defined as uncorrelated sums with zero mean and a constant variance. The stability tests are used when there is a possibility of structural breaks. The null hypothesis is that the coefficient vector is the same in every period against the alternative that it is not. The CUSUM test plots the cumulative sums together with the 5% critical lines.

2.2.3 Model Specification

We estimate a bivariate model of the United States nominal Dollar/South African Rand (USDZAR) exchange rate featuring the United States Dollar nominal non-fuel commodity index between 1996 and 2014. In the spirit of Gregory and Hansen (1996a), Chen and Rogoff (2003), Cashin *et al* (2004) and more recently Bodart *et al* (2012), we specify the model as:

$$s_t = \alpha + \beta com_t + \varepsilon_t \tag{6}$$

Where s_t is the log of the nominal USD/ZAR exchange rate and com_t the log of the nominal non-fuel commodity price index and ε_t is i.i.d error term. The objective of the model is to ascertain the connection between the nominal exchange rate and the commodity price fundamental. Recalling the notoriously poor performance of fundamental based models as detailed by Frankel and Rose (1995), we seek to isolate the interactions between the exchange rate (and its lags) and commodity prices in a model that allows the variables to affect each other over time while at the same time addressing the endogeneity problem of the data generation process. Accordingly, we specify the unrestricted ECM version of (6) as:

$$\Delta s_t = \alpha + \sum_{t=1}^{p} \beta_{0,i} \Delta s_{t-i} + \sum_{i=0}^{p} \beta_{1,i} \, \Delta com_{t-i} + \gamma_0 s_{t-1} + \gamma_1 com_{t-1} + \mu_t \tag{7}$$

Employing the Pesaran *et al* (2001) bounds test for no cointegration, the null for cointegration to be tested is $\gamma_0 = \gamma_1 = 0$ against the alternative of $\gamma_0 \neq \gamma_1 \neq 0$.

2.3 Results of the ARDL model

2.3.1 Data and preliminary analysis

We use the nominal monthly United States dollar/South African Rand bilateral nominal exchange rate (s_t) obtained from the International Finance Corporation (IFS) database for the period 1996-2014.[7] Here the exchange rate is quoted as South African Rand per United States dollar such that an increase in the exchange rate implies depreciation of the Rand and vice versa. For the commodity prices (com_t) , we construct a South Africa-specific commodity price index based on four major export commodities following Cashin etal, (2002). The price data are

[7] www.ifs.org.

obtained from the IMF database while the share of major commodity exports was extracted from the UN Comtrade database (see data appendix A for the specific computation of the commodity index). All data are transformed into natural logarithms for ease of interpretation and are illustrated in Figure 1.[8]

The data series exhibit several structural breaks over the sample period. In this study we employ the methods developed by Bai (1997) and Bai and Perron (1998, 2003a) to ascertain multiple unknown break points. The advantage of this approach is that it allows us to endogenously estimate break points without a priori knowledge of the break dates. Specifically, we employ the "Global Bai-Perron L Breaks vs. None" method and allow for 5 break dates and 15% trimming percentage. We report the results in Table 1.

Figure 1: Data Plots

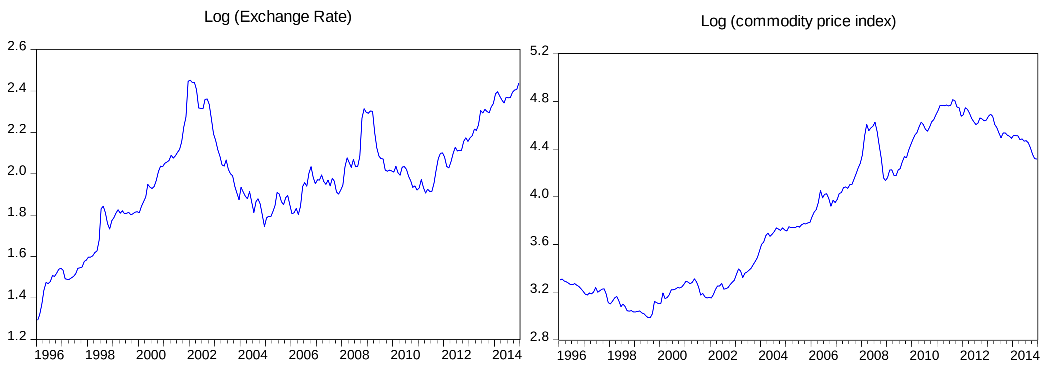


Table 1: Structural break tests

Break test options: Trimming 0.15, Max. Breaks 5

	Exchange Rate	**Commodity Price**	**Model**
Schwarz criterion selected breaks:	4	4	4
LWZ criterion selected breaks:	4	4	4
Estimated break dates:	2000M5; 2003M07; 2008M02 2012M03	1998M1; 2003M07; 2006M05 2012M04	2000M11; 2004M02; 2008M08; 2012M03

The Schwarz and LWZ criteria indicate at most 4 structural breaks in both the Rand and commodity price variables. Tests on the bivariate model also indicate 4 structural breaks. We tested the model with date dummy variables following Pahlavani et al (2005) and tested the dummy variables for significance.[9] The results indicate that only two break dummies are

[8] We estimated our model using real variables and the results do not change much. Results are available on request.
[9] See Bai, and Perron (1998, 2003a) for details.

statistically significant with 95% confidence, namely, January 1998 and March 2012. We note that the two major structural breaks roughly coincide with two crises that have plagued South Africa and Asia, namely the Asian crisis of 1998 (see Bundia and Ricci 2005 for a detailed account) and the combination of the platinum strikes and Marikana massacre in 2012.[10] Accordingly, we include two dummy variables (D_1 and D_2) to control for the two breaks in our ARDL estimation.[11]

The basic descriptive statistics are illustrated in Table 2.

Table 2: Basic descriptive statistics

	Log(Nom Exch)	Log(Nom Comm)
Mean	1.972387	4.727368
Median	1.970603	4.618012
Std. Dev.	0.249762	0.320625
Skewness	-0.272907	0.204826
Kurtosis	2.857658	1.560134
Jarque-Bera	3.022653	21.28978
Probability	0.220617	0.000024
Observations	228	228

The variables appear to be non-stationary although it is not possible to ascertain the order of integration from visual inspection of Figure 1. The nominal exchange rate appears to be highly kurtotic with negative skewness. It is noteworthy that the commodity prices have positive skewness alongside a negative skewness for the exchange rate. This property suggests that extreme movements in the commodity prices are associated with increases than decreases. The corresponding extreme movements in the exchange rate are associated with appreciation. Higher volatility in the two variables has tended to match commodity price booms and exchange rate appreciation in our sample.

The ARDL model requires that the variables be at most $I(1)$ as the bounds test's critical values are invalid for variables of integration of order higher than $I(1)$. For this reason we test and present the unit root tests in Table 3. The results confirm that both variables are difference stationary $I(1)$. We proceed to estimate the ARDL model for the two asset prices.

[10] Mpofu and Peters (2016) note the Marikana massacre on 16 August 2012 led to the Rand/US dollar, Rand/British Pound and Rand/Euro depreciating by 1.86 percent, 2.21 percent and 2.31 percent respectively from the date before the strike began. See also Breckenridge (2014), Wehmhoerner (2012). On account of the 1998 Asian crises: between end-April and end-August in 1998, the rand depreciated by 28 percent in nominal terms against the U.S. dollar. This was accompanied by increases of around 700 basis points in short-term interest rates and long term bond yields, while sovereign U.S. dollar-denominated bond spreads increased by about 400 basis points. At the same time share prices fell by 40 percent and output contracted during the third quarter of 1998 (quarter on-quarter).

[11] We estimated the model without the dummy variables. The results are significantly different as measured by stability diagnostics and the rejection of the cointegration null.

2.3.2 Estimation results of the ARDL model

We present the results of the long run estimation in Table 4, the short run error correction model in Table 5 and the bounds test for cointegration in Table 6. One of the most important aspects of the ARDL approach is the choice of the lag order. We follow Pesaran and Smith (1998) and choose the lag order of the model based on the Schwartz Bayesian Information Criterion (SBIC). The authors argue that the SBIC method tends to define a more parsimonious model in the case of short samples. Accordingly, our choice of the SBIC is motivated by our small sample size. However, we include the model chosen by the Akaike's Information Criteria (AIC) for robustness. For these information criteria, the optimal number of lags for each of the variables in the ARDL are specified as (3, 1) and (2, 1) under the AIC and SBIC respectively.

Table 3: Unit root tests

Variable	ADF TEST STATISTIC		PHILIPS PERRON TEST	
Levels	**Constant with trend**	**Constant without trend**	**Constant with trend**	**Constant without trend**
Log (Nom exch)	-2.5096	-1.5857	-2.3960	-1.5293
Log(Nom Comm)	-1.8772	-0.7633	-1.8127	-0.7388
First Differences				
ΔLog (Nom exch)	-10.5214	-10.9841	-10.4536	-11.0558
ΔLog(Nom Comm)	-9.9844	-10.5672	-10.0271	-10.6113

Notes: The Critical values for rejection are -4.0296, -3.4444 and -3.1471 at a significant level of 1%, 5% and 10% respectively for models with a constant and linear trend and -3.4812, -2.8830, -2.5787 at a significant level of 1%, 5% and 10% respectively for models without a linear trend. The optimal lag for the ADF test was chosen based on the Schwartz Information Criterion and the truncation parameter for the PP test was selected using the Newey-West truncation method.

2.3.3 The dynamic relationship between the Rand and commodity prices

Our results provide support for the nexus between commodity prices and the nominal exchange rate of the Rand in South Africa. When we control for structural breaks, the ARDL model indicates that the two asset prices are cointegrated (Table 4). The F-test reading of 6.49 is greater than the upper bound critical value (5.73) under the SBIC model. The null of no cointegration is rejected at 10% level of significance under the AIC model and is inconclusive at 5% level or better.

Table 4: Bounds test for cointegration

Null Hypothesis: No long-run relationships exist

	Lag length Selection Criteria			
	AIC		**SBIC**	
$F - Statistic$	5.386809		6.494787	
Significance	**I0 Bound**	**I1 Bound**	**I0 Bound**	**I1 Bound**
5%	4.94	5.73	4.94	5.73

These results lead us to examine an alternative way of establishing cointegration suggested by Kremers *et al* (1992), Bannerjee et al (1998) and Bahnani-Oskooee (2001). These authors demonstrate that a negative and significant lagged error term within the bounds testing approach is suggests cointegration among the relevant time series variables.

Table 5: Estimated short-run error correction model

Dependent variable Δs_t

	Lag length Selection Criteria	
	AIC	**SBIC**
Δs_{t-1}	0.306497***[4.807785]	0.270204*** [4.440215]
Δs_{t-2}	-0.123536**[-1.966008]	
ΔCom	-0.380419***[-4.838679]	-0.368531*** [-4.671488]
D_1	-0.000013*[-0.000385]	-0.000249 [-0.007574]
D_1	0.022137[0.675743]	0.027746[0.845261]
ECT	-0.046157***[-3.395775]	-0.056253***[-4.218481]
R^2	0.982065	0.982184
DW-Stat	1.944319	1.876995
F-stat	1697.436***	2012.220***

*Notes: *, **, *** indicate statistical significance at 10%, 5% and 10% level of significance respectively.*

Turning to the results in Table 5, although the error correction term coefficient is small , it is clear that it is significantly different from zero and is negatively signed under both the AIC and SBIC models. These results corroborate the bounds test suggesting that the two variables are cointegrated. Our estimations suggest that when there is an exogenous shock to the system and the exchange rate is above (or below) the equilibrium level, approximately 0.05% adjustment will be achieved in the first month under both models. The speed of adjustment of the exchange rate to the shocks in the commodity markets appears to be very slow. This result may indicate that while the commodity price variable matters in the exchange rate equation, its influence in the short run is relatively muted at monthly frequency. The negative sign of the error correction term is important and suggests that the error correction process is stable and convergent.

The short-run model also shows that the coefficient of Δcom has the expected sign and is statistically significant (-0.37). Therefore a 10% increase in commodity prices is associated with a 3.9% appreciation in the value of the nominal exchange rate. The R^2 reading is quite large for both the AIC and SBC models; the F-statistic is also statistically significant suggesting that the model fits the data well. This result clearly lends support to the notion that the value of the South African Rand moves in in line with commodity prices.

While our results point to the presence of a cointegration relationship between the two nominal prices, the long-run elasticity of the commodity price with respect to the nominal exchange rate (Table 6) is not only very small (0.06) but statistically insignificant at all conventional levels.[12] Combined with a small error correction term, we conclude that while our results show equilibrium between the two variables, the long run relationship is weak and the correction process slow. The relationship is however significant and strong in the short run. We suspect that factors such as structural changes in the South African economy and integration with global financial markets have varying effects on the relationship of the two variables in the long run. These results motivate the substance of the next section, where we test the standard fundamental models of the exchange rate, augmented by the commodity prices variable.

Table 6: Estimated long-run coefficients

Dependent Variable s_t

	Lag length Selection Criteria	
	AIC	**SBIC**
Com	0.058084 [0.307233]	0.061023 [0.361420]
D_1	0.426522***[2.939885]	0.418157*** [3.917558]
D_1	0.353238***[2.550612]	3.317079*** [3.317079]
Constant	1.366334 [1.547200]	1.347535*[1.693135]

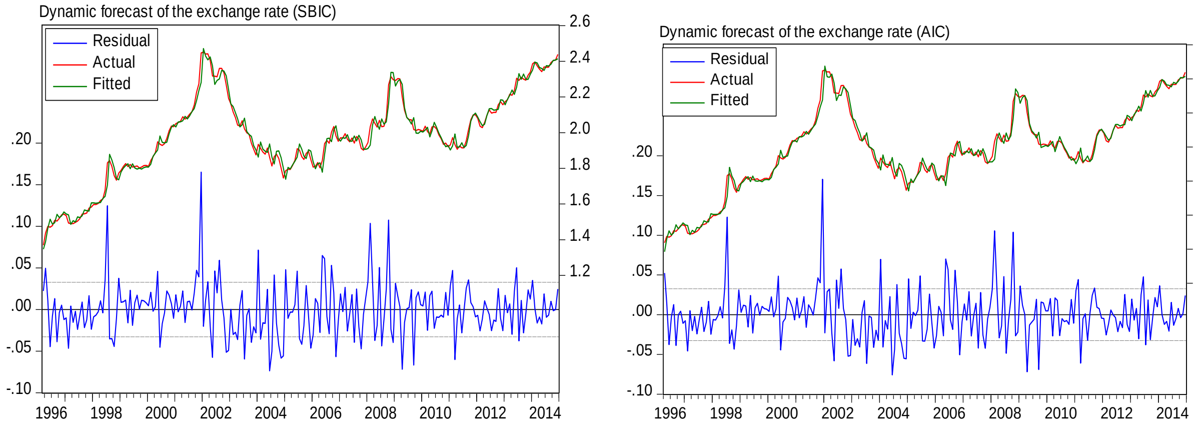
*Notes: *, **, *** indicate statistical significance at 10%, 5% and 10% level of significance respectively.*

2.3.4 Stability tests

According to Pesaran and Pesaran (1997), the stability of the coefficients of the ARDL model must be investigated. First we consider the dynamic forecast of our model against the actual variables over the sample period. A look at the plots in Figure 2 suggests that our model fits the data quite well. The residuals appear to be stable over the sample period as well. The model also passes the tests of autocorrelation and heteroscedasticity (see Table 8).

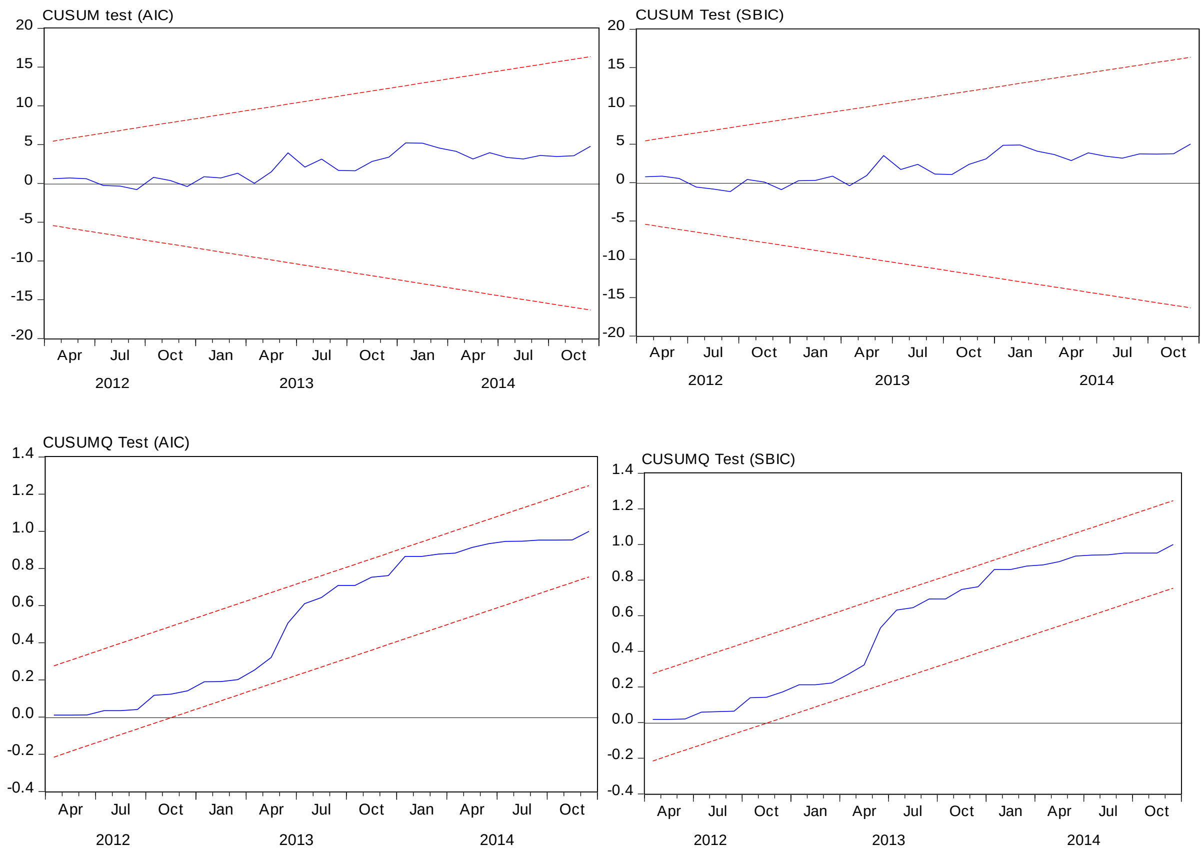
[12] We obtain very similar results when we test the model using the real effective exchange rate and the real commodity prices(i.e. nominal commodity prices deflated by the Manufacturing Value Index [MUV])

Figure 2: Plots of actual and forecast values of the exchange rate



Additionally, we examine the graphical representation of the CUSUM and CUSUMQ following Brown, Durbin, and Evans (1975), Bahnani-Oskooee (2001) and Pahlavani (2005) in Figure 3.

Figure 3: Plots of CUSUM and CUSUMQ statistics for coefficient stability



The null hypothesis (that is the regression equation is correctly specified) cannot be rejected if the plot of the CUSUM and CUSUMQ remain within the 5% critical band over the sample period. It is clear from this figure that the plots of both CUSUM and CUSUMQ are within the 5% critical boundaries and confirm the stability of the coefficients of our model under both the AIC and SBIC information criteria.

Table 7: Tests of autocorrelation and heteroscedasticity

Breusch-Godfrey Serial Correlation LM Test :*Null Hypothesis: no residual autocorrelations*		
	AIC	**SBIC**
F-statistic	1.343499[0.1962]	1.546031[0.1100]
Heteroscedasticity Test: Harvey :*Null: no heteroscedasticity in residuals*		
F-statistic	1.680714[0.1149]	2.042979[0.1612]

Notes: p-values in [ ] parenthesis

2.4 Discussion and conclusion

The objective of this empirical investigation was to establish the nexus between the Rand and commodity prices between 1996 and 2014. The choice of the sample period was motivated by the objective of analysing the relationship during the floating regime of the South African exchange rate. Structural empirical exchange rate models usually concern the behaviour of exchange rate in open and liberalised capital markets where exchange rate values are likely to reflect the impact of fundamentals more accurately. We follow the techniques of Bai and Perron (1998, 2003a) to endogenously determine structural break dates within the time series data. The stability of our model improves remarkably with the inclusion of the dummy variables to control for the two significant structural breaks suggested by our tests.

We allow the lags to be included in the ARDL model to be determined by both AIC and SBIC information criteria. The question whether the two variables are cointegrated is answered by the bounds test as well as examination of the significance and sign of the error correction term. The results of the bunds test reject the null of no cointegration at 5% and 10% levels of significance under the SBIC and AIC models respectively. Further, examination of the error correction terms shows that the coefficient is negative and significant. We conclude therefore that the two asset prices have a long-run relationship. The error correction term, which indicates the speed of adjustment which restores the dynamic relationship to equilibrium, is quite small. The coefficients (-0.06 and -0.05 under the SBIC and AIC respectively) imply that deviations from the long-term equilibrium path in the exchange rate are corrected by approximately 0.05% over the following month. The long run elasticity is not statistically different from zero suggesting weak cointegration and slow error correction process. The model passes tests of structural stability as indicated by the CUSUM and CUSUMQ statistics. The model residuals are also robust to autocorrelation and are homoscedastic.

In this bivariate specification, we provide evidence of the link between the South African bilateral exchange rate with the United States and commodity prices. We demonstrate evidence of the nexus between the two variables without making a priori assumptions about their order of integration and without the restriction of requiring symmetrical lag orders – conditions that must be satisfied with other cointegration techniques such as the Johansen (1995) maximum likelihood method. For an open economy like South Africa, it is important to consider programs that protect the exchange rate and the economy from exogenous shocks in the commodity markets as the exchange rate appears to be a potential transmitter of the shocks to the wider economy. These findings motivate the substance of the next section. We incorporate the commodity price fundamental into well-established exchange rate macro-models to evaluate their performance for South Africa.

3. The Rand and fundamentals: the role of commodity prices

3.1 Introduction

The previous section of this paper answered the question of whether commodity prices are a relevant fundamental in the determination of the exchange rate in South Africa. While the bivariate model may be plagued by potential omitted variables bias, our intention was to provide empirical evidence on the nexus between the Rand and commodity prices. In this section, we intend to incorporate the commodity price fundamental in testing standard structural exchange rate models.

The extensive literature on exchange rate economics clearly shows that identifying the elusive connection between exchange rates and economic fundamentals is no easy task. The well documented "exchange rate disconnect puzzle" comes to mind.[13] In the context of South Africa, evidence in favour of the standard monetary model of exchange rate determination is mixed (see de Bruyn et al., 2012; Hassan and Simeone, 2011 and Moll, 1999, 2000). Evidence in favour of PPP is rare and mixed at best. Using recent floating era data, support has been found for PPP but only after allowing for non-linearity in the data generation process (see Larceda et al., 2010). Other modifications to the PPP model include allowing for half-life definitions (Mokeona et al., 2009a) and long memory (Mokoena et al., 2009c).

[13] The exchange rate disconnects puzzle is the missing link between exchange rate and a menu of economic and financial fundamentals that theory suggests should drive exchange rates (Obstfeld and Rogoff, 2000)

In this study, we argue that another plausible modification of the standard exchange rate models is the inclusion of the commodity price variable. In the spirit of Chen (2002), we conjecture that the commodity price variable may be a potential omitted variable in the standard models for South Africa (which depends on the export of its primary commodities for a significant portion of its foreign exchange revenues).[14] Moreover, there is reasonably long market determined exchange rate time series data available since South Africa abandoned the dual exchange rate regime in favour of a floating exchange rate in 1995.[15]

Specifically, this section intends to answer the following questions about the Rand: 1) in the context of standard structural models, does the commodity price fundamental help explain movements in the Rand? 2) Without the commodity price fundamental, do standard exchange rate models fit the data better? 3) Does inclusion of the commodity price fundamental improve the out-of-sample forecasting ability of the standard models?

The section is organised as follows. The next subsection specifies the variants of the standard PPP and monetary models to be tested. We provide a discussion of our data sources and preliminary analysis in subsection 3.4 while a discussion of our methodology and empirical strategy is provided in subsection 3.5. In-sample estimation results in sub section 3.6 and results of the out-of-sample forecasts in subsection 3.7 while subsection 3.8 concludes.

3.2 Model specifications

The starting point in our analysis concerns the standard workhorse of exchange rate determination models – the Purchasing Power Parity (PPP). According to the PPP hypothesis, the exchange rate is the ratio of the countries' price levels, according to the law of one price. We follow Chen (2002) to specify two commodity-price augmented variants of the PPP model:

PPP1Model: $$s_t = a - \beta_1 p_t^{com} + \beta_2(p_t - p_t^*) + \varepsilon_t \qquad (8)$$

PPP2 Model: $$s_t = a - \beta_1 p_t^{com} + \beta_2 p_t - \beta_3 p_t^* + \varepsilon_t \qquad (9)$$

All variables are logarithms. s_t is the nominal exchange rate quoted as units of domestic currency/foreign currency such that a larger number represents depreciation of the home

[14] The UN Comrade data shows that exports of gold, platinum, coal and iron ore accounted for an average of 35% of South African exports between 2005 and 2014. See Appendix A for details.

[15] Further, new evidence in the search for answers to the exchange rate disconnect puzzle suggests that forecast based trading strategies outperform the random-walk based trading strategies (see Moosa and Burns, 2012, 2015). Our results are therefore likely to be of value to traders and portfolio managers.

currency. p^{com} is the log of South Africa-specific commodity price index; $p \, and \, p^*$ are the domestic and foreign CPIs respectively and ε_t is a stationary disturbance. The commodity price variable enters the equations with a negative sign since we expect an upward movement of commodity prices to appreciate the exchange rate (a downward movement according to the chosen currency quotation style).

Building on the PPP models, we specify two variants of the flexible price monetary model, as follows:[16]

MM1 Model: $$s_t = a - \beta_1 p_t^{com} + \beta_2(m_t - m_t^*) - \beta_3(y_t - y_t^*) + \varepsilon_t \quad (10)$$

MM2 Model: $$s_t = a - \beta_1 p_t^{com} + \beta_2(m_t - m_t^*) - \beta_3(y_t - y_t^*) + \beta_4(i_t - i_t^*) + \varepsilon_t \quad (11)$$

Where $m_t \, and \, m_t^*$ are the domestic and foreign money stocks; $y_t \, and \, y_t^*$ are domestic and foreign incomes and $i_t \, and \, i_t^*$ are domestic and foreign interest rates; ε_t represents a stationary disturbance. Coefficients $\beta_2, \beta_3 \, and \, \beta_4$ represent elasticity with respect to money stock, money demand and interest rates respectively. The reduced form monetary models in equations (13) and (14) posit that the exchange rate is determined by the relative money stock, relative real income and the nominal interest income differentials. Like the PPP model, we augment the models with the commodity price variable.

3.3 Data characteristics

We test the models in equations 8-11 using the South African Rand United States Dollar (USD/ZAR) bilateral exchange rate and for robustness, we consider the performance of the models against other major Rand cross rates namely the Pound-Sterling/Rand (GBP/ZAR) and the Euro-Rand (EUR/ZAR). In all cases the exchange rates are measured as monthly averages in Rand per base currency. All exchange rate series are from the IFS database. The money supply variable is measured as M1 in all cases except for the UK where we use M0 in USD billions, extracted from the IFS database. Inflation is measured as CPI in all cases while we use the three month Treasury bill rate in percent/annum in all cases with both series obtained from the IFS database. The real GDP numbers were obtained from the World Bank database measured in billions of USD. Given that the data is measured in quarterly intervals, we use linear interpolation to obtain monthly numbers as suggested by Sjuib, (2009).[17] For the commodity

[16] Details on these models are provided in Bilson (1978), Frankel (1976), and MacDonald and Taylor (1994)

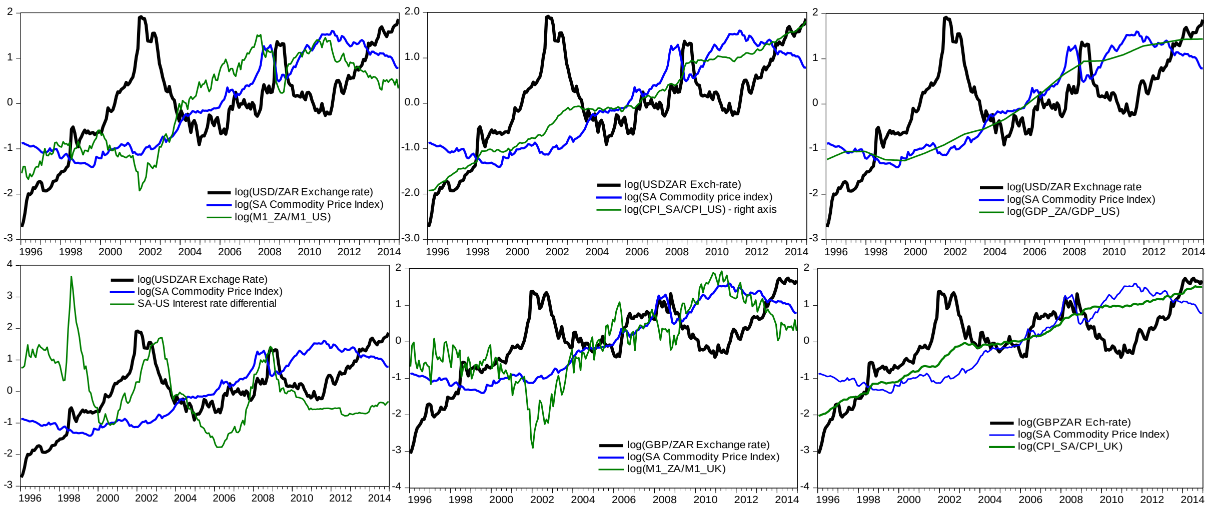
[17] See also Kodongo and Ojah(2012)

price variable, we construct a South Africa-specific production-weighted commodity price index based on four major export commodities following Cashin etal, (2002). The price data are obtained from the IMF database while the share of major commodity exports was extracted from the UN Comtrade database (see data appendix A for the specific computation of the commodity index). Figure 4 illustrates the graphical representation of the data series. All the variables appear to be non-stationary. We formally test each series for unit roots.

In Tables 9-12 we report the unit root tests for each of the variables under study. We employ the augmented Dickey Fuller (ADF) test (Dickey and Fuller, 1979, Dickey and Fuller, 1981) for tests for the null of autoregressive unit root. We perform the tests for different specifications of the ADF model, one including a trend and a constant and one without. For robustness we add the Philips-Perron test (Phillips and Perron, 1988) to check the robustness of the ADF tests. The results of the tests, as expected, fail to reject the null of unit root on levels. Both tests however uniformly reject the null of unit roots on first differences. Both tests suggest that all the variables are $I(1)$.

Additionally, we test the four different specifications for cointegration. We use the Johansen (1988, 1995) full system maximum likelihood estimation method. The results of the multivariate cointegration tests reported in Table 13. The results indicate that except for the trivariate PPP model for EUR variables in Model 2, the UK version of Model 3 and 4, cointegration is detected in all cases.

Figure 4: Data plots



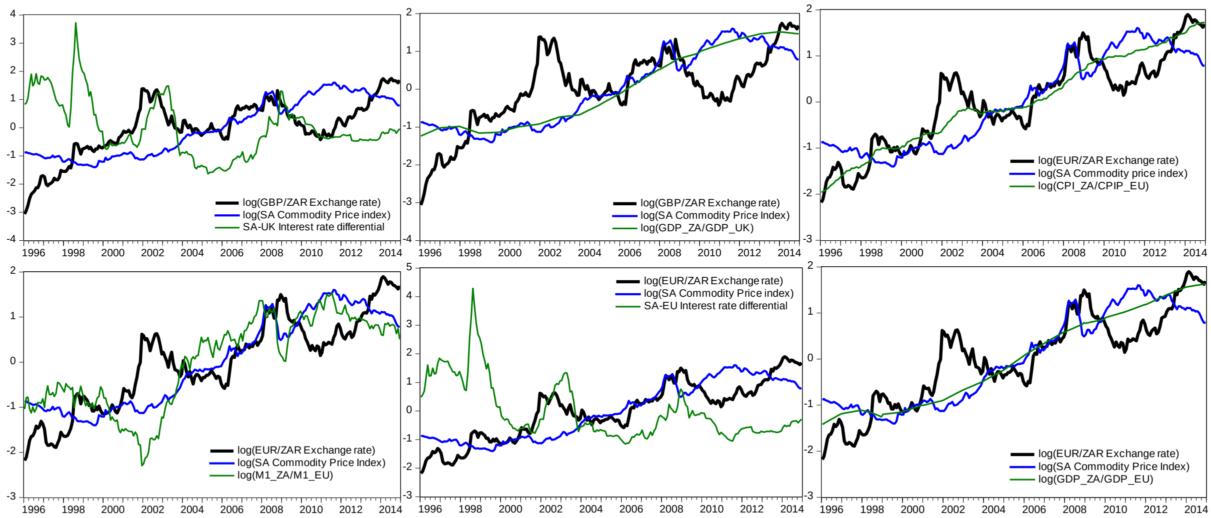


Table 8: Representative Tests for unit root (South Africa Variables)

Null hypothesis: variables have unit root or non-stationary

Variable	ADF TEST STATISTIC		PHILIPS PERRON TEST	
Levels	**Constant with trend**	**Constant without trend**	**Constant with trend**	**Constant without trend**
Log (Nominal USD exch-rate)	-2.5096	-1.5857	-2.3960	-1.5293
Log (Nominal GBP exch-rate)	-2.2170	-2.4965	-2.0685	-2.6037
Log (Nominal EUR exch-rate)	-3.0562	-1.5360	-2.8913	-1.5482
Log(Commodity price Index)	-1.8772	-0.7633	-1.8127	-0.7388
Log(Money Supply)	-1.4895	-1.2959	-1.6869	-1.2936
Log(CPI)	-2.3069	-1.5973	-2.3859	-1.4283
Log (Real GDP)	-2.0936	-2.0682	-0.8908	-0.8097
Interest Rate	-3.5610	-3.2684	-3.1285	-2.7288
First Differences				
ΔLog (Nominal USD exch-rate)	-10.5214	-10.9841	-10.4536	-11.0558
ΔLog (Nominal GBP exch-rate)	-12.6666	-12.0289	-12.6666	-12.0289
ΔLog (Nominal EUR exch-rate)	-12.2599	-11.7054	-12.1278	-11.6480
ΔLog(Commodity price Index)	-9.9844	-10.5672	-10.0271	-10.6113
ΔLog(CPI)	-10.7911	-11.2256	-11.0640	-11.4644
ΔLog(Money Supply)	-13.7374	-14.7410	-13.7309	-14.7305
ΔLog (Real GDP)	-3.3455	-3.1858	-3.0396	-2.9585
ΔInterest Rate	-9.9786	-9.1913	-9.7857	-8.8630

Table 9: Representative Tests for unit root (USA Variables)

Null hypothesis: variables have unit root or non-stationary

Variable	ADF TEST STATISTIC		PHILIPS PERRON TEST	
Levels	**Constant with trend**	**Constant without trend**	**Constant with trend**	**Constant without trend**
Log(Money Supply)	0.1074	-2.0931	-0.0223	4.0642
Log(CPI)	-2.2015	-1.0725	-3.0385	-1.1246
Log (Real GDP)	-2.5569	-1.6123	-1.3796	-2.3869
Interest Rate	-3.7775	-2.2350	-2.7475	-1.2614
First Differences				
ΔLog(CPI)	-8.9037	-11.3815	-7.6475	-8.0917

ΔLog(Money Supply)	-4.6923	-5.7754	-14.9500	-14.9006
ΔLog (Real GDP)	-3.2518	-3.8392	-4.1988	-3.5106
ΔInterest Rate	-7.2661	-3.7328	-13.7077	-12.1440

Table 10: Representative Tests for unit root (UK Variables)
Null hypothesis: variables have unit root or non-stationary

Variable	**ADF TEST STATISTIC**		**PHILIPS PERRON TEST**	
Levels	**Constant with trend**	**Constant without trend**	**Constant with trend**	**Constant without trend**
Log(Money Supply)	-1.8581	-1.0052	-2.7413	-1.0758
Log(CPI)	-1.7994	1.0694	-2.3292	1.1885
Log (Real GDP)	-2.4571	-1.7683	-2.4606	-1.7648
Interest Rate	-2.6283	-1.0251	-2.7849	-0.7514
First Differences				
ΔLog(CPI)	-2.1774	-5.0694	-17.4920	-29.2864
ΔLog(Money Supply)	-15.1755	-3.7170	-28.4711	-16.3631
ΔLog (Real GDP)	-10.4051	-15.4543	-14.7313	-154543
ΔInterest Rate	-6.6963	-7.2957	-6.6964	-7.3529

Table 11: Representative Tests for unit root (EU Variables)
Null hypothesis: variables have unit root or non-stationary

Variable	**ADF TEST STATISTIC**		**PHILIPS PERRON TEST**	
Levels	**Constant with trend**	**Constant without trend**	**Constant with trend**	**Constant without trend**
Log(Money Supply)	-2.2914	-0.5721	-2.2546	-0.6027
Log(CPI)	-0.8850	-1.3852	-1.1751	-1.3120
Log (Real GDP)	-1.4590	-2.4482	-1.7271	-3.1061
Interest Rate	-2.6933	-1.5035	-2.7769	-1.5533
First Differences				
ΔLog(CPI)	-5.2349	-11.2582	-12.7853	-11.5327
ΔLog(Money Supply)	-4.3134	-13.9563	-10.6794	-13.9124
ΔLog (Real GDP)	-3.5413	-4.1217	-5.7297	-6.3582
ΔInterest Rate	-5.2759	-9.6377	-7.0663	-10.0864

Notes: The Critical values for rejection are -4.0296, -3.4444 and -3.1471 at a significant level of 1%, 5% and 10% respectively for models with a constant and linear trend and -3.4812, -2.8830, -2.5787 at a significant level of 1%, 5% and 10% respectively for models without a linear trend. The optimal lag for the ADF test was chosen based on the Schwartz Information Criterion and the truncation parameter for the PP test was selected using the Newey-West truncation method.

Table 12: Johansen Test for Cointegration

	Number of Cointegrating relationships	
Base Country	Trace Statistic	Eigenvalue Statistic
Model 1: log(Exch-rate); log(Commodity Price); log(CPI_SA/CPI_foreign)		
USA	1	1
UK	1	1
EU	1	1

Model 2: log(Exch-rate); log(Commodity Price); log(CPI_SA) log(CPI_foreign)

USA	2	2
UK	2	1
EU	0	0

Model 3: log(Exch-rate); log(Comm Price); log(Mon Supply_SA/Mon Supply_foreign); log(GDP_SA/GDP_foreign)

USA	1	1
UK	0	0
EU	0	1

Model 4: log(Exch-rate); log(Comm Price); log(Mon Supply_SA/Mon Supply_foreign); log(GDP_SA/GDP_foreign); Interest differentials

USA	2	1
UK	0	0
EU	0	1

3.4 The Dynamic OLS (DOLS) estimator

We employ Stock and Watson's (1993) Dynamic OLS (*DOLS)* to estimate the cointegrating vectors in our model. The DOLS method possesses some advantages of alternative methods of estimating cointegrating systems. The Johansen maximum likelihood estimator, for example is known to be plagued by small sample bias and producing widely dispersed estimates (Chen, 2002). Further, the Johansen maximum likelihood approach, being a full information approach, is vulnerable to the problem that parameter estimates in one equation may be affected by misspecification in other equations. The DOLS method addresses this problem by its design as a robust single equation method which has been shown to have the same asymptotic optimality properties as the Johansen distribution (Al-Azam and Hawdon, 1999; Masih and Masih 1996a). The DOLS methodology overcomes the regressors endogeneity problems associated with simple OLS regressions by the inclusion of leads and lags of first differences of the regressors, and for serially correlated errors by a General Least Squares (GLS) procedure.

The DOLS procedure basically involves regressing any cointegrated *1 (1)* variables on other *1 (1)* variables, any *1 (0)* variables and leads and lags of the first differences of any *1(1)* variables. It the context of structural models the model is represented in the following econometric specification:

$$s_t = \beta_0 + \beta_1 f_t + \sum_{j=-p}^{p} \delta_j \Delta f_{t-j} + u_t \qquad (12)$$

Where s_t is the exchange rate

f_t is the matrix of fundamental explanatory variables

β_1 is the cointegrating vector; that is, represents the long-run cumulative multipliers or, alternatively, the long-run effect of a change in f on s_t and $(-)p$ and p are the lag lead lengths respectively. AS pointed out earlier, the lags and leads of Δf are added to the DOLS model for the purpose of making its stochastic error term independent of all past innovations in stochastic regressors. We also employ the heteroscedasticity consistent covariance (HAC) method proposed by Newey and West (1987) to address the problem of heteroscedasticity and autocorrelation in the regression errors. Finally, we carry out unit root tests on the residuals to ascertain whether our estimations are spurious.[18]

3.5 Dynamic OLS estimation results

We report the Stock-Watson DOLS parameter estimates with all variables appearing in levels for the USD/ZAR, GBP/ZAR and EUR/ZAR models in Tables 15-17. We report the long run elasticities of the level regressors on the nominal exchange rate with asymptotic standard errors in parenthesis. We show the estimates of the models with and without the commodity prices variable.

The commodity price variable appears with the correct sign and is significant in all but the monetary models based on the GBP and EUR. On average, the commodity price variable enters all models with a negative elasticity of -0.56, -0.36 and -0.25 in the dollar, GBP and EUR based models respectively. The data fits the PPP dollar based models fairly well as well as the other Rand crosses; all appearing with correct signs and significant. In all cases the adjusted R^2 reading improves notably by inclusion of the commodity price variable, suggesting an improvement of fit. Turning to the stability of the models, inclusion of the commodity price variable further improves the ADF statistic for stationarity of residuals across all PPP and monetary models. These findings are robust to the other Rand crosses as well.

Turning to the monetary models of the Rand however, we note that these models generally perform poorly across all the base currencies, judged by the size and direction of coefficients. While the money supply variable is consistently significant across all models, it enters the models against our a priori expectations with a negative sign. The same observation applies to the output variable which, in addition to a positive sign, appears in most models with an unreasonably large coefficient and is not always significant. The inclusion of the commodity price variable does not to change the signs in all cases. On the interest rate differential, the exchange rate is consistently unresponsive across all bases except the GBP. The estimated elasticity of the GBP exchange rate, while it appears significant with a correct sign, is

[18] Choi *et. al.*, (2008) point that a regression is technically called a spurious regression when its stochastic error is unit-root nonstationary

quantitatively very small. This finding suggests that South Africa is an unlikely destination of dollar and Euro carry trades.[19] Hassan (2014) demonstrates that most of the carry trade turnover in South Africa is between the Japanese Yen and the Rand. The stability tests indicate that the monetary models (without the commodity price variable) may be spurious regressions at 10% level or better. This is particularly so for MM2 for the USD and EUR bases.

In sum, we note that the inclusion of the commodity price variable increases the performance of the structural models of the Rand. The size of the estimated coefficients of the commodity price variable is close to the earlier findings from the bivariate ARDL model as well as other authors such as MacDonald and Ricci (2003). These findings support the view that the South African exchange rate is a commodity currency and that the commodity price variable is potentially an omitted variable in canonical structural exchange rate models for commodity exporting economies. Indeed, while the link between exchange rates and fundamentals remains an elusive one, future theoretical models of exchange rates stand to benefit from inclusion of this important fundamental.[20]

Table 13 Estimating the Cointegrating relationships under Dynamic OLS [Base: US]

	PPP1	PPP1 + Comm Price	PPP2	PPP2 + Comm Price	MM1	MM1 + Comm Price	MM2	MM2 + Comm Price
Log(Com Price) [-]		-0.36***		-0.56***		-0.66***		-0.67***
		(0.04)		(0.06)		(0.13)		(0.11)

19 A carry trade is a class of currency speculation strategies designed to profit from a favourable interest-rate deferential, when the high-interest currency does not depreciate substantially (as to erode the interest carry.) relative to the low-interest currency. The simplest way to implement the carry trade is to borrow in the low-interest currency (the funding currency), buy the high-interest currency (the target currency) in the spot market, deposit the proceeds or buy fixed-income securities denominated in the target currency, and finally convert the terminal payoff back into the funding currency facing the exchange rate risk. This is the conventional (textbook) understanding of the carry trade. But it can also be implemented through the derivatives market, for example selling the currency forward when it is at a significant forward premium, or using currency options to hedge the exchange rate risk component (Hassan 2014).

20 Similar observations are made for the other OECD countries namely, Canada, Australia and New Zealand by Chen (2002).

Log(CPI_ZA/CPI_US)[+]	5.05***	8.90***						
	(0.58)	(0.62)						
Log(CPI_ZA) [+]			1.49***	1.41***				
			(0.21)	(0.18)				
Log(CPI_US) [-]			-2.50***	-0.49				
			(0.58)	(0.66)				
Log(M1_ZA/M1_US)[+]					-2.67***	-1.56***	-2.90***	-1.59*
					(0.92)	(0.78)	(0.96)	(0.89)
Log(GDP_ZA/GDP_US)[-]					-14.35*	22.34**	-13.67**	23.04***
					(7.75)	(8.86)	(8.89)	(8.13)
Tbill_ZA-Tbill_US [-]							-0.0003	-0.00001
							(0.0002)	(0.0002)
Residual ADF Test	-3.83	-5.13	-3.97	-4.91	-3.61	-4.20	-3.12	-4.19
Adjusted R^2	0.81	0.89	0.82	0.92	0.86	0.90	0.85	0.90
No. of Observations	221	221	221	221	221	221	221	221

Notes: The following notes are applicable to the results in tables 15 and 16.

a) *The output shows the estimated models with and without the commodity prices variable. The expected signs of the coefficients are shown in parenthesis[ ] against the variables on the tables*
b) *The Stock-Watson (1993) dynamic OLS (DOLS) methodology is used to obtain super consistent estimators of the cointegrating vectors with approximate asymptotic standard errors reported in parenthesis ( ) against the coefficient estimates.*
c) **, **, *** denotes statistical significance at 10%, 5% and 1% level respectively.*
d) *A South-Africa specific commodity prices, constructed according to Cashin et al (2003) is the production weighted average of the top four commodity exports from South Africa, priced in USD. See data appendix A for details.*
e) *The models were estimated up to $j = \pm 3$ lags of each dependent variable to orthogonalise.*
f) *The residuals ADF test statistic is shown for each model. The null is hypothesis is: residuals have unit root against the alternative that the residuals are stationary. Non-stationarity of residuals suggests that the model may be spurious. The Critical values for rejection are -3.4812, -2.8830, -2.5787 at a significance level of 1%, 5% and 10% respectively.*

Table 14: Estimating the Cointegrating relationships under Dynamic OLS [Base: UK]

	PPP1	PPP1 + Comm Price	PPP2	PPP2 + Comm Price	MM1	MM1 + Comm Price	MM2	MM2 + Comm Price
Log(Com Price) [-]		-0.48***		-0.49***		-0.12		-0.35***
		(0.04)		(0.05)		(0.15)		(0.09)

Log(CPI_ZA/CPI_UK)[+]	4.02*** (0.77)	9.57*** (0.73)						
Log(CPI_ZA) [+]			2.06*** (0.43)	2.34*** (0.33)				
Log(CPI_UK) [-]			-3.63*** (0.94)	-2.52 (0.77)				
Log(M1_ZA/M1_UK)[+]					-4.32*** (0.39)	-4.40*** (0.62)	-4.13*** (0.36)	-3.86** (0.34)
Log(GDP_ZA/GDP_UK)[-]					-5.06 (5.80)	1.80 (7.63)	3.96 (4.18)	23.18*** (5.46)
Tbill_ZA-Tbill_UK [-]							-0.02*** (0.004)	-0.05*** (0.003)
Residual ADF Test	-2.76	-4.22	-3.57	-4.29	-3.26	-3.41	-3.90	-4.45
Adjusted R^2	0.75	0.89	0.81	0.89	0.90	0.90	0.94	0.96
No. of Observations	221	221	221	221	221	221	221	221

Table 15: Estimating the Cointegrating relationships under Dynamic OLS [Base: EU]

	PPP1	**PPP1 + Comm Price**	**PPP2**	**PPP2 + Comm Price**	**MM1**	**MM1 + Comm Price**	**MM2**	**MM2 + Comm Price**
Log(Com Price) [-]		-0.29*** (0.05)		-0.31*** (0.08)		-0.21** (0.11)		-0.19 (0.12)
Log(CPI_ZA/CPI_EU)[+]	5.41*** (0.46)	8.18*** (0.71)						
Log(CPI_ZA) [+]			1.77*** (0.39)	1.61*** (0.50)				
Log(CPI_EU) [-]			-3.34** (1.21)	-1.17 (1.78)				
Log(M1_ZA/M1_EU)[+]					-4.46*** (1.16)	-3.66*** (1.15)	-4.30*** (1.22)	--3.61*** (1.18)
Log(GDP_ZA/GDP_EU)[-]					22.46 (9.27)	34.17 (9.90)	21.72 (9.50)	32.75*** (10.03)
Tbill_ZA-Tbill_EU [-]							0.00 (0.00)	0.00 (0.00)
Residual ADF Test	-2.98	-3.84	-3.52	-3.72	-3.23	-2.76	-2.76	-2.82
Adjusted R^2	0.88	0.92	0.90	0.91	0.85	0.86	0.86	086
No. of Observations	221	221	221	221	221	221	221	221

3.6 Exchange rate predictability from fundamentals

One of the most contested areas of research in international monetary economics is that of exchange rate predictability from macro-economic fundamentals. Since the Meese and Rogoff (1983) work on exchange rate and fundamentals, the empirical failure of structural exchange rate models to outperform the random walk model in out of sample forecasting has become, as Moosa and Burns (2014) observe, "an undisputed fact of life". There are several subsequent research projects - led by Frankel and Rose (1995) - that have lent currency to this conclusion who question the "value of further time series modelling of exchange rates at high or medium frequencies using macro-economic models". Evans and Lyons (2004) further note that the Meese and Rogoff puzzle is the "most researched puzzle in macroeconomics", echoing Abhyankar et al (2005) who describe it as a "major puzzle in international finance". Bacchetta and van Wincoop (2006) conclude that the notoriously poor performance of existing macro-exchange rate models is most likely the major weakness of international macro-economics.

While the Meese-Rogoff conclusion has been remarkably resilient over the years, there have been some researchers who claim that it is possible to outperform the naïve random walk model, as judged by the root mean square error and other similar metrics. This class of models has been put forward prominently by Mark (1995), Mark and Sul, (2001), Chinn and Meese, (1995) and MacDonald, (1999). These models have however been challenged by several scholars. Killan (1999), Berkowitz and Giorgianni (2001) and Berben and Dijk (1998) question the robustness and the inference procedures used in these models. Further criticism has been levelled on the models' assumption of a stable cointegrating relationship.[21]

There are several reasons that have been put forward explaining the poor performance of macro-exchange rate models. In their 1983 paper, Meese and Rogoff point out that the failure of fundamentals based models to out-forecast the random walk model may stem from simultaneous equation bias, sampling error, stochastic movements in the true underlying parameters or misspecification. The authors suggest four sources of misspecification, namely uncovered interest parity, proxies for inflationary expectations, goods markets specification and the money demand function. Harvey (2006) corroborates the claim of misspecification of the monetary model – he points out that the monetary model is a stock rather than a flow model. Imposition of proportionality and symmetry restrictions have also been blamed as sources of misspecification by Neely and Sano (2002) and Tawadros, (2001). Chen (2002) suggests that the problem with fundamental based models may stem from potential omitted variable bias. For most countries, while it is difficult to conjecture what the potential missing variable may be, a

[21] See also Cheung et al (2005) who show that a wide range of models rate not successful in predicting exchange rates.

potential omitted variable for commodity-dependent economies may stem from commodity prices. Commodity prices are not only identifiable for such economies but also "easily quantifiable" Chen (2002).

Following our earlier attempt to assess the commodity-augmented exchange rate models' performance based on several goodness of fit criteria and direction of causality implied by economic theory, we attempt in this section to assess the predictive power of such models in short horizon forecasts of the South African exchange rate. While other scholars have done extensive work on statistical evaluation of forecast models (such as Moosa and Burns, 2014), our objective here is to evaluate whether the addition of the commodity price fundamental improves the performance of standard macro-models.

3.6.1 Forecasting approach

Our forecasting approach in this section is based on the error correction. As an empirical regularity, the time path of cointegrated variables is influenced by the error correction mechanism, that is, the extent of any deviation from long-run equilibrium. Christoffersen and Diebold (1998) show why inclusion of the error correction term improves the forecasting power of exchange rate models. The error correction term measures the extent of deviation of a system of variables from their long-run path and the error correction coefficient measures the rate at which this deviation is corrected.

In a recent study, Moosa and Vaz (2016) evaluate the forecast performance of error correction based models against their first difference equivalents over short horizons. They conclude that the ECM based framework has no forecast superiority over what is offered by the distributed lag structure of dependent and explanatory variables. The authors further argue against imposition of theory-based restrictions in exchange rate models.[22] Our approach follows this view and does not impose theory-based restrictions on cointegrating vectors but rather allows them to be determined by the data.[23] This approach is closer to the Meese-Rogoff, (1983) rolling regression framework. Additionally, our objective is to evaluate the forecast performance of models before and after inclusion of the commodity price variable. We therefore allow the coefficients in the standard exchange rate models to adjust to reflect the effect of inclusion (or exclusion) of this additional variable. We test two monetary exchange rate models specified

[22] Moosa and Vaz (2016) argue that imposition of theory-imposed restrictions presumes that the underlying theories are valid, without empirically testing them. Because the theories are far from being perfect, imposing theory-based restriction is therefore a "hazardous endeavour".

[23] This approach may be suitable in the South African context. The theoretical restrictions are based on theories developed for major industrialised countries with relatively longer floating exchange rate period.

earlier and their corresponding commodity augmented versions. We also test the PPP version that incorporates the price symmetry (PPP1).

We follow Faust et al (2001) to specify a basic unconstrained short horizon k forecast error correction model (ECM) of the following form:

$$\Delta s_{t+k} = \ s_{t+k} - s_t = \alpha_k + \emptyset_k z_t + \nu_{\mathrm{t}} \tag{13}$$

Where $z_t = \beta f_t - s_t$ and α_k and $\emptyset_k$ are estimated coefficients. f_t is the fundamental value of the exchange rate suggested by the exchange rate model and β is the cointegrating vector as in equation (15) and ν_{t} is a stationary disturbance. The intuition in the ECM is that if the exchange rate is cointegrated with fundamentals as implied by the structural models and assuming that the exchange rate is the variable that does the correction back to equilibrium, then deviations from the "fundamental" value of the exchange rate should help predict future exchange rate.[24] For equation (16) to be a valid ECM, $\emptyset_k$ must be negative and statistically significant; that is, if the current exchange rate is below its equilibrium value implied by fundamentals, the exchange should appreciate in the next period to correct the error. For our estimation, we rely on the value of βestimated from data.

For our three models under investigation, the fundamental value of the exchange rate (f_t) is predicted by the following relations:

$$f_t = p_t - p_t^* \tag{14}$$

$$f_t = (m_t - m_t^*) - (y_t - y_t^*) \tag{15}$$

$$f_t = (m_t - m_t^*) - (y_t - y_t^*) + (i_t - i_t^*) \tag{16}$$

Equation (13) is the basic error correction version of the standard macro-exchange rate models. Augmenting equation (13) with the commodity prices variable and substituting z_t with the error correction term yields:

$$s_{t+k} - s_t = \alpha_k + \emptyset_k[\big(\beta f_t - \beta_{1,k} p_t^{com}) - s_t]\big) + \nu_{\mathrm{t}} \tag{17}$$

[24] For a comprehensive discussion of the ECM forecasting model of the exchange rate see also Christoffersen and Diebold (1998) and Moosa and Vaz (2016).

Therefore a test of the null $\emptyset_k = 0$ agaisnt $\emptyset_k < 0$ is a test of exchange rate predictability from fundamentals. We evaluate each of the out of sample forecast for the standard models with and without the commodity price variable.

To carry out recursive out-of-sample estimates we follow Mark (1995), Faust et al (2001), Chen (2002) and Moosa and Burns (2014). We estimate the model in equations (16) and (20) over part of the sample period, $t = 1,2, \dots, m$ and then a k period ahead forecast generated for the point in time $m + k$. To generate the next forecast, this procedure is repeated and the models are estimated over the period , $t = 1,2, \dots, m + 1$ so that the new forecast generated is for the point in time $m + k + 1$. It is clear from this procedure that the estimated forecast log exchange rate $(s_{t+k} - s_t) \equiv \hat{s}_{m+k}$. Using this notation therefore, this estimation procedure is repeated until $\hat{s}_n$ by estimating the models of the period $t = 1,2, \dots, n - k$ where n is the total sample size.

The forecast log exchange rate therefore, pre and post augmentation with the commodity variable can be represented as:

$$\hat{s}_{m+k} = \hat{\alpha}_k + \widehat{\emptyset}_k z_{m+k} \tag{18}$$

$$\hat{s}_{m+k} = \hat{\alpha}_k - \hat{\beta}_k p_{m+k}^{com} + \widehat{\emptyset}_k z_{m+k} \tag{19}$$

Where $\hat{\alpha}_k$ and $\widehat{\emptyset}_k$ are the estimated values of α_k and $\emptyset_k$ respectively. The forecast level of the exchange rate is therefore given by:

$$\hat{S}_{m+k} = \exp(\hat{s}_{m+k}) \tag{20}$$

The recursive regression procedure is preferred for its forecasting superiority as argued by Moosa and Burns (2014). This methodology ensures that all information is available at the time of the forecast. Similar arguments are made by Nordhaus (1987), Marcelino (2002) and Marcelino et al (2001).

3.6.2 Forecast Evaluation

Evaluation of forecast accuracy of various models is achieved through use of an array of tests that evaluate the magnitude of the forecast error. From equation (21), once the forecast of the exchange rate $\hat{S}_t$ is known for the period $t = m + k, \dots, n$, the forecast value can be compared with the actual series S_t to calculate various quantitative measures of forecast accuracy. One such measure of forecast accuracy, employed in our analysis is the Root Mean Squared Error (RMSE) calculated as:[25]

$$\text{RMSE} = \sqrt{\frac{1}{n-k-k+1}\sum_{t=m+k}^{n}\left(\frac{(\hat{S}_t - S_t)}{S_t}\right)^2} \qquad (21)$$

The RMSE depends on the scale of the dependent variable. It is used to compare forecast performance of the same series across different models. The basis of the evaluation is that the smaller the error, the better the forecasting ability of that model.[26]

To evaluate the forecast accuracy of the exchange rate models relative to the random walk model, we report Theil's inequality coefficient (U). The U coefficient reaches the lower boundary $U = 0$ for perfect forecasts and assumes a value of 1 when the exchange rate models being evaluated deliver forecast with same standard error as the naïve random walk model. The coefficient increases monotonically as the standard error forecasting of the random walk model improves relative to that of the exchange rate models. In sum, the random walk model outperforms the standard exchange rate models if $U > 1$. Theil's U coefficient is calculated as the RMSE ratio of the estimated model to that of the random walk as:

$$U = \frac{\sqrt{\frac{1}{n-m-k+1}\sum_{t=m+k}^{n}\left(\frac{(\hat{S}_t - S_t)}{S_t}\right)^2}}{\sqrt{\frac{1}{n-m-k+1}\sum_{t=m+k}^{n}\left(\frac{S_t - S_t}{S_t}\right)^2}} \qquad (22)$$

3.6.3 Forecasting performance of commodity-price augmented exchange rate models

We report the forecast performance of the three specifications of the exchange rate models, pre and post augmentation by the commodity price in Table 16.[27] The literature is replete with controversy on the tests for robustness of the different measures of forecast

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[25] The Meese-Rogoff (1983) paper and many subsequent studies used the RMSE to evaluate forecast accuracy of the standard exchange rate models against the random walk model without testing for the statistical significance of the difference. Other papers however have attempted use the Diebold and Mariano (1995) test. Corraddi, et al (2001) provide the conditions under which the Diebold and Mariano test can be used for tests of cointegrated systems. Clark and McCracken (2001) propose an array of tests for forecast comparisons for nested linear models. More recently, Moosa and Burns(2014) revisit the AGS test suggested by Ashley et al (1980)

[26] See also Chen and Yang (2004) for a discussion on stand-alone and relative forecast measures.

[27] We report findings only for the USD/ZAR exchange rate.

accuracy.[28] Our analysis of forecast accuracy in this section is illustrative only – we don't evaluate the statistical significance of the forecast measures against the random walk model. We therefore evaluate performance of the exchange rate models with and without the commodity prices variable using the simple measures of RMSE and the U-coefficient without assessment of their statistical significance.[29]

Results from the PPP model with price symmetry indicate that the forecast error improves with forecast horizon. The U-statistics also indicate that the model improves in its performance relative to the random walk as the forecast horizon increases. This picture is consistent with the commodity-price augmented version of the PPP model. Comparing the performance of the models pre and post augmentation indicates that addition of the commodity price variable does improve the forecast accuracy of the model. This result is important in our subsequent assessment of the monetary models as the PPP model is an important building block in the flexible price monetary models.

The link between the exchange rate and monetary variables appears to be stronger than CPI.[30] Notably however, in contrast to the PPP model, the forecast accuracy of the monetary models appears to diminish with an increase in the forecast horizon judged by the size of both the RMSE and the Theil coefficient. Incorporating the commodity prices variable fails to overturn this pattern. In terms of improving forecast accuracy, commodity prices improve the forecast performance of the MM1 model, however that doesn't appear to be the case for model MM2. This observation is important in the context of Rapach and Wohar (2002) who argue that augmented structural exchange rate models can be viewed as "weaker' versions of the original theoretical models.[31] Without testing for statistical significance of the forecast evaluation criteria, the monetary models overwhelmingly outperform the naïve random walk model at all forecast horizons.

Table 16: Forecast Evaluation

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[28] The forecast accuracy criteria, for example, have been shown to suffer from small-sample size bias in coefficient estimates and in asymptotic standard errors in error correction frameworks (see Killian, 1997, Berkowitz and Giorgianni (1997 and Mark and Sul, 2001). Alternative methods to correct for sample bias such as bootstrapping have also been proposed but the robustness of findings of long-horizon forecast has been challenged (See Moosa, 2013). Moosa and Burns (2014) challenge the very notion of the "puzzle" with respect to the Meese and Rogoff paper that judged the performance of the standard exchange rate models against the random walk using the RMSE and related criteria. They propose alternative measures of forecast accuracy such as direction accuracy and profitability. Other scholars propose introduction of dynamics to the exchange rate models to improve their forecasting power (see Taylor 1995, Cheung et al, 2005, Tawadros, 2001, Hwang, 2001 and Aarle et al 2000).

[29] Chen, (2002) adopts a similar approach but uses only the Theil U statistic as a measure of forecast accuracy.

[30] Mark and Sul (2001) find a similar relationship for Australia and New Zealand.

[31] In their particular case, augmentation meant incorporating a linear trend in the cointegrating vector that allowed for a deterministic Balassa–Samuelson effect in real exchange rates.

	PPP1	PPP1 + Comm Price	MM1	MM1 + Comm Price	MM2	MM2 + Comm Price
One Month						
RMSE	0.048349	0.046074	0.018390	0.018314	0.017841	0.017841
U	1.000936	0.900597	0.444043	0.439620	0.422673	0.423115
Six Months						
RMSE	0.045954	0.045154	0.023991	0.023893	0.024110	0.024120
U	0.930706	0.915338	0.518645	0.516302	0.521849	0.522084
Twelve Months						
RMSE	0.041691	0.040431	0.022587	0.022497	0.022679	0.022688
U	0.925007	0.897531	0.524767	0.522553	0.527165	0.527390

3.7 Discussion and conclusions

Evidence in favour of the canonical structural exchange rate models is at best mixed in the existing empirical literature. Judged by conventional goodness of fit criteria and signs of estimated coefficients, the models generally perform poorly despite their theoretical appeal. Moreover, since Meese and Rogoff (1983)'s seminal work, subsequent research has failed to convincingly overturn their conclusion on the forecast superiority of the naïve random walk model over standard exchange rate models. Several explanations have been put forward for what some authors have described as the "major puzzle in international finance" with Chen (2002) suggesting that the reasons for failure of theoretical exchange rate models may be due to "potential omitted variable bias".[32] While this argument has intuitive appeal, questions have been raised over augmentation of the exchange rate models with for example, trend specification, stock prices and commodity prices. The problems associated with endogeneity, observability and measurability of the potential omitted variables has led to some authors to suggest that the augmented models can be viewed as weaker versions of the canonical models (see Rapach and Wohar, 2002 and de Bruyn et al, 2012). However, to the extent that the data can help players in the exchange rate markets to improve performance, both from a policy and commerce stand point, we argue that there is merit in further attempts to solve the exchange rate determination puzzle, especially for an emerging market like South Africa.

In this study we present evidence indicating that not only are commodity prices consistent explanatory variables of the bilateral USD/ZAR exchange rate but that they are also significant explanatory variables of the major Rand crosses as well. We use post-float data for South Africa and find evidence in favour of a long-run relationship in the commodity-price augmented PPP

[32] See Abhyankar et al (2005)

and monetary models for South Africa, supporting findings from other scholars such as Lacerda et al (2007) and Mokoena et al (2009a, 2009b and 2009c).

Our analysis indicates that a 10% rise in commodity prices is associated with between 3.6% and 6.7% appreciation of the USD/ZAR exchange rate. The GBP and EUR crosses appreciate by 2.9% and 4.9% on average respectively.[33] In terms of the type of models, while addition of the commodity price variable improves the in-sample fit of the PPP models, evidence of such improvement, measured in terms of expected a priori signs suggested by economic theory is mixed for monetary models. De Bruyne et al (2012) find similar problems using 101 years of South African data.

We further test the predictive prowess of the standard exchange rate models in the spirit of the Meese and Rogoff paper. We find that the commodity price variable does indeed improve the forecast accuracy of the standard models although the results are not robust to model specification. The forecast accuracy test results suggest a tighter fit between the exchange rate and monetary variables (monetary model) than relative prices (PPP). While the forecasting results are presented for illustrative purposes only, without tests for statistical significance, they nevertheless invite further investigations using inference procedures that are robust to potential biases associated with small samples.

While the value of empirical time series modelling of exchange rates using macro-economic variables has been called to question (see Frankel and Rose, 1995), our study makes a contribution to the important debate of exchange rate determination in South Africa, using newer dataset of the floating Rand. Recent studies (see Moosa and Burns, 2012, 2015) argue that improving forecast accuracy of models of financial asset prices is valuable in terms of improving corporate performance. The authors, for example, demonstrate that a forecasting based currency trading strategy outperforms a simple carry trade strategy based on the random walk model. Results from South Africa, a bell-weather emerging commodity exporting economy with relatively developed financial markets, offers important lessons for other commodity-dependent African economies that are in the process of liberalising their financial markets. Using higher frequency data, improved forecast accuracy measures such as direction accuracy and profitability measures to test theoretical models against floating exchange rate data is a promising area of future research for commodity exporting emerging economies.

[33] The fit of the models with the UK and EUR bases improves marginally when we use the GBP and EUR denominated commodity price models.

REFERENCES

Aarle, B.V., Boss, M., Hlouskova, J., 2000. Forecasting the euro exchange rate using vector error correction models. Review of World Economics 136, 232–258.

Abhyankar, A., Sarno, L., Valente, G., 2005. Exchange rates and fundamentals: evidence on the economic value of predictability. Journal of International Economics 66, 325–348.

Al-Azam, A., Hawdon, D., 1999. Estimating the demand for energy in Jordan: A Stock-Watson Dynamic OLS (DOLS) approach, Working Paper, Surrey Energy Economic Centre, Guildford, UK. (See http://www.econ.surrey.ac.uk/Research/WorkingPapers/seed97.pdf).

Antonakakis, N., Kizys, R., 2015. Dynamic spillovers between commodity and currency markets. International Review of Financial Analysis 41, 303–319. doi:10.1016/j.irfa.2015.01.016

Ashley, R., Granger, C., Schmalensee, R., 1980. Advertising and aggregate consumption: an analysis of causality. Econometrica 48, 1149–1167.

Aye, G.C., Balcilar, M., Bosch, A., Gupta, R., Stofberg, F., others, 2013. The out-of-sample forecasting performance of non-linear models of real exchange rate behaviour: The case of the South African Rand.

Bacchetta, P., van Wincoop, E., 2006. Can information heterogeneity explain the exchange rate determination puzzle? American Economic Review 96, 552–576.

Bagdatoglou, G., Kontonikas, A., 2009. A New Test of the Real Interest Rate Parity Hypothesis: Bounds Approach and Structural Breaks.

Bahmani-Oskooee, M., A. Nasir, 2004. ARDL approach to test the productivity bias hypothesis. Rev. Develop. Economics. Journal., 8: 483-488.

Bai, J., 1997. Estimating Multiple Breaks One at a Time, Econometric Theory, 13, 315–352.

Bai, J.,Perron, P., 1998. Estimating and Testing Linear Models with Multiple Structural Changes, Econometrica, 66, 47–78.

Bai, J., Perron, P., 2003a. Computation and Analysis of Multiple Structural Change Models, Journal of Applied Econometrics, 6, 72–78.

Bai, J., Perron, P., 2003b. Critical Values for Multiple Structural Change Tests," Econometrics Journal, 18, 1–22.

Balassa, B., 1964. The Purchasing Power Parity Doctrine: A Reappraisal. Journal of Political Economy, 72, 2, 584-596

Bannerjee, A., Dolado, J., Mestre, R., 1998. Error-correction mechanism tests for cointegration in the single equation framework. Journal of Time Series Analysis, 19: 267-83.

Bank of International Settlements., 2013.Triennial Central Bank Survey Foreign exchange turnover in April 2013: preliminary global results.' Monetary and Economic Department, September 2013.

Berben, R.B., van Dijik, D.J., 1998. Does the absence of cointegration explain the typical findings in long run horizon regressions?, Econometrics Institute, Erasmus University Retterdam, Report 9814.

Berkowitz, J., Giorgianni, L., 2001. Long-horizon exchange rate predictability? Review of Economics and Statistics 83, 81-91.

Bhundia, A. J., Ricci, L. A., 2005. The Rand Crises of 1998 and 2001: What have we learned?, Post-Apartheid South Africa: The first ten years. Nowak, M. and Ricci, L. A. eds. Washington D.C.: IMF, 156-73.

Bilson, J., 1978, Rational expectations and the exchange rate.

Bodart, V., Candelon, B., Carpantier, J.-F., 2012. Real exchange rates in commodity producing countries: a reappraisal. Journal of International Money and Finance 31, 1482-1502.

Blundell-Wignall, A.,Gregory, R G., 1990. Exchange Rate Policy in Advanced Commodity Exporting Countries: The Case of Australia and New Zealand", OECD Department of Economics and Statistics, Working Paper, number 83

Breckenridge, K., 2014. Marikana and the limits of bio politics: themes in recent scholarship of South African Mining. Africa, 84, pp 151-161 doi:10.1017/S0001972013000624

Broda, C., 2004. "Terms of Trade and Exchange Rate Regimes in Developing Countries" Journal of International Economics 63: 31-58.

Brown, R.L., Durbin, J. and Evans, J.M., 1975. Techniques for Testing the Constancy of Regression Relationships over Time, Journal of the Royal Statistical Society, Ser.B, vol.37, pp.149 – 192.

Camacho-Gutiérrez, P., 2010. Dynamic OLS estimation of the US import demand for Mexican crude oil.

Cashin, P., Céspedes, L., Sahay, R., 2004. Commodity Currencies and the Real Exchange Rate Journal of Development Economics, Vol. 75, 239-68.

Cayen, J.P., Coletti, D., Lalonde, R., Maier, P., 2010. What Drives Exchange Rates? New Evidence from a Panel of U.S. Dollar

Exchange Rates. Bank of Canada W.P., pp. 2010e2015

Chaban, M., 2009. Commodity currencies and equity flows. Journal of International Money and Finance 28, 836–852. doi:10.1016/j.jimonfin.2008.08.004

Chen, Y., 2002. Exchange rates and fundamentals: evidence from commodity economies. Mimeograph, Harvard University.

Chen Y., K. S. Rogoff (2003), .Commodity Currencies, Journal of International Economics 60, 133-169

Chen, Y., Rogoff, K.S., Rossi, B., 2010. Can exchange rates forecast commodity prices? Q. J. Econ. forthcoming.

Chen, Z., Yang, Y., 2004. Assessing Forecast Accuracy Measures Iowa State University

Cheung, Y.-W., Chinn, M.D., Pascual, A.G., 2005. Empirical exchange rate models of the nineties: are they fit to survive? Journal of International Money Finance 24, 1150–1175.

Chinn, M., Meese, R., 1995. Banking on currency forecasts: how predictable is change in money? Journal of International Economics 38, 161–178.

Choi, C.Y., Hu, L., Ogaki M., 2008. Robust Estimation for Structural Spurious Regressions and a Hausman-type Cointegration Test, Journal of Econometrics, 142, 327-351.

Chowdhury, K., 2013. Dynamics and Structural Breaks in Tourist Arrivals in Australia, in: Proceeding of 8th Annual London Business Research Conference. pp. 1–23.

Christoffersen, P.F., Diebold, F.X., 1998. Contegration and long-horizon forecasting. Journal of Business and Economic Statistics. 16, 450–458.

Clark, T., McCracken, M., 2001. Tests of equal forecast accuracy and encompassing for nested models, Journal of Econometrics 105, 85-110.

Clements, K. W., Fry R., 2006. Commodity Currencies and Currency Commodities CAMA Working Paper Series 19/2006

Corradi V., Swanson, N., Olivetti, C., 2001. Predictive ability with cointegrated variables, Journal of Econometrics 104 (2), 315-358.

Coudert, V., Couharde, C., Mignon, V., 2015. On the impact of volatility on the real exchange rate – terms of trade nexus: Revisiting commodity currencies. Journal of International Money and Finance 58, 110–127. doi:10.1016/j.jimonfin.2015.08.007

De Bruyn, R., Gupta, R., Stander, L., 2013. Testing the monetary model for exchange rate determination in South Africa: Evidence from 101 years of data. Contemporary Economics 7, 19–32.

De Grauwe P., Grimaldi M., 2005. The exchange rate and its fundamentals in a complex world, Rev. Int. Econ. 13 (3) (2005) 549–575.

Dickey, D.A., Fuller W.A., 1979. Distribution of the Estimators for Autoregressive Time Series with a Unit Root, Journal of the American Statistical Association, 74, 427–431.

Dickey, D. A., Fuller, W. A., 1981. Likelihood Ratio Statistics for Autoregressive Time Series Within a Unit-root. Econometrica, 49, 1022-1057

Diebold, F.X., Mariano, R., 1995, Comparing predictive accuracy, Journal of Business and

Economics Statistics 13,253-262.

Edwards, S., 1994. Real and monetary determinants of real exchange rate behaviour: theory and evidence from developing countries. In: Williamson, J. (Ed.), Estimating Equilibrium Exchange Rates. Institute for International Economics, Washington D.C., pp. 61‑92.

Engle, R. F., Granger, C. W. J., 1987. Cointegration and Error Correction: Representation, Estimation and Testing, Econometrica, Vol. 55, pp. 251-276.

Evans, M.D., Lyons, R.K., 2005. Meese–Rogoff Redux: micro-based exchange rate forecasting. American Economic Review 95, 405–414.

Fama, E. F., 1984, Forward and Spot Exchange Rates, Journal of Monetary Economics, Vol. 14, No. 3, pp. 319-338.

Faust, J., Rogers, J., Wright, J., 2001. Exchange rate forecasting: the errors we've really made, mimeo.

Ferraro, D., Rogoff, K., Rossi, B., 2015. Can oil prices forecast exchange rates? An empirical analysis of the relationship between commodity prices and exchange rates. Journal of International Money and Finance 54, 116–141. doi:10.1016/j.jimonfin.2015.03.001

Frankel, J., 2012. What small countries can teach the world. Business Economics 47, 97–103.

Frankel, J., 2007. On the rand: Determinants of the South African exchange rate. South African Journal of Economics 75, 425–441.

Frankel, J., Rose, A., 1995. Empirical research on nominal exchange rates. In: Grossman, G.M., Rogoff, K. (Eds.), Handbook of International Economics. NBERWorking Paper, vol. 4865. North Holland, Amsterdam, 1689– 1729.

Frenkel, J., 1976, A monetary approach to the exchange rate: doctrinal aspects and empirical evidence, Scandinavian Journal of Economics, 78 (2), 200-224.

Gao, L., Süss, S., 2015. Market sentiment in commodity futures returns. Journal of Empirical. Finance. 33, 84–103.

Gregory, A., Hansen, B., 1996. Residual-based tests for cointegration in models with regime shifts. Journal of Econometrics 70, 99-126.Harris, R. and Sollis, R., 2003. Applied Time Series Modelling and Forecasting, West Sussex: Wiley.

Harvey, J., 2006. Post Keynesian versus Neoclassical Explanations of Exchange Rate Movements: A Short Look at the Long Run. Journal of Post Keynesian Economics.28(2): 161–79.

Hassan, S., 2014. Speculative Flows, Exchange Rate Volatility and Monetary Policy: South African Experience, in: Pretoria, Paper Presented at the South African Reserve Bank Conference on Fourteen Years of Inflation Targeting in South Africa and the Challenge of a Changing Mandate, Held in Pretoria

Hassan, S., Simione, F., 2011. Exchange rate determination under monetary policy rules in a financially underdeveloped economy: a simple model and application to Mozambique. Journal of International Development, forthcoming. New York: Wiley. (ERSA Working Paper 192.)

He, W., others, 2011. Effects of the exchange rate on sectoral profits, value added, wages and employment. University of Alberta.

Hodrick, R., 1988. The empirical evidence on the efficiency of forward and futures foreign exchange markets. Fundamentals of Pure and Applied Economics. Harwood Academic, NY, USA.

Hwang, J.-K., 2001. Dynamic forecasting of monetary exchange rate models: evidence from cointegration. International Advances in Economic Research 7, 51–64.

International Monetary Fund., 2004. South Africa: staff report for the 2004 Article IV consultation. Washington D C: International Monetary Fund.

Issa, R., Lafrance, R., Murray, J., 2008. The turning black tide: energy prices and the Canadian Dollar. Can. J. Econ. 41 (3), 737e759.

Johansen, S., 1995, Likelihood-Based Inference in Cointegrated Vector Autoregressive Models (New York: Oxford University Press).

Kablan, S., Ftiti, Z., Guesmi, K., 2016. Commodity price cycles and financial pressures in African commodities exporters. Emerging Markets Review. doi:10.1016/j.ememar.2016.05.005

Kejriwal, M., Perron, P., 2008. Data dependent rules for selection of the number of leads and lags in the dynamic OLS cointegrating regression. Econometric Theory 24, 1425–1441.

Kilian, L., 1999. Exchange rates and monetary fundamentals: what do we leam from long horizon regressions? Journal of Applied Econometrics 14,491-510.

Kodongo, O., Ojah, K., 2012. The dynamic relation between foreign exchange rates and International portfolio flows: Evidence from Africa's capital markets, International Review of Economics and Finance, 24: 71-87.

Kremers, J., Ericsson, N., and Dolado, J., 1992. The Power of Cointegration Tests. Oxford Bulletin of Economics and Statistics 54:325–348.

Lacerda, M., Fedderke, J. W. & Haines, L. M., 2010. Testing for purchasing power parity and uncovered interest parity in the presence of monetary and exchange rate regime shifts. The South African Journal of Economics, 78(4), 363-382.

Lewis, K., 1995. Puzzles in international financial markets. In: Grossman, G.M., Rogoff, K., eds., Handbook of International Economics, North Holland, Elsevier, Amsterdam, 1913-

1972.

MacDonald, R., 1999. Exchange rate behaviour: are fundamentals important? The Economic Journal 109.

Macdonald R., Ricci L., 2002. Estimating the real equilibrium exchange rate for South Africa, Strathclyde University and IMF, IMF Working Paper, F31, F41

MacDonald, R. and M. Taylor, 1994, The monetary model of the exchange rate: long-run relationships, short-run dynamics and how to beat a random walk, Journal of International Money and Finance 13, 276-90.

Marcellino, M., 2002. Instability and Non-Linearity in the EMU. Working Paper, IEP-Universita Bocconi.

Marcellino, M., Stock, J., Watson, M., 2001. Macroeconomic Forecasting in the Euro Area: Country Specific versus Area-Wide Information. Working Paper,

Innocenzo Gasparini Institute for Economic Research, p. 201.

Mark, N., 1995. Exchange rates and fundamentals: evidence on long-horizon prediction, American Economic Review 85,201-218.

Mark, N., Sul, D., 2001. Nominal exchange rates and monetary fundamentals: evidence from small post-Bretton Woods panel, Journal of International Economics 53,29-52.

Masih, A. M. M., Masih R., 1996. Energy consumption, real income and temporal causality: Results from a multi-country study based on cointegration and error-correction modeling techniques. Energy Economics 18 (3): 165-183.

Meese, R., Rogoff, K.S., 1983a. "Exchange rate models of the seventies. Do they fit out of sample? J. Int. Econ. 14, 3e24.

Meese, R., Rogoff, K.S., 1983b. "The out of sample failure of empirical exchange rate models. In: Frankel, J. (Ed.), Exchange Rates and International Macroeconomics. University of Chicago Press.

Mokoena, T. M., Gupta, R., van Eyden, R., 2009a. Testing for fractional integration in SADC real exchange rates. The South African Journal of Economics, 77(4), 531-537.

Mokoena, T. M., Gupta, R., van Eyden, R., 2009b. Testing for PPP using SADC real exchange rates. The South African Journal of Economics, 77(3), 351-362

Mokoena, T. M., Gupta, R., van Eyden, R., 2009c. Half-life deviations from PPP in the SADC. Applied Econometrics and International Development, 9(1), 141-148.

Moll, P. G., 1999. Money, interest rates, income and inflation in South Africa. The South African Journal of Economics, 67(1), 34–64.

Moll, P. G., 2000. The demand for money in South Africa: parameter stability and predictive capacity. The South African Journal of Economics, 68(2), 190–211.

Moosa, I.A., Vaz, J.J., 2016. Cointegration, error correction and exchange rate forecasting. Journal of International Financial Markets, Institutions and Money. doi:10.1016/j.intfin.2016.04.007

Moosa, I., Burns, K., 2014. The unbeatable random walk in exchange rate forecasting: Reality or myth? Journal of Macroeconomics 40, 69–81. doi:10.1016/j.jmacro.2014.03.003

Moosa, I.A., Burns, K., 2012. Can exchange rate models outperform the random walk? Magnitude, direction and profitability as criteria. Econ. Int. 65, 473–490.

Mpofu, T., Peters, A., 2016. The Impact of Monetary Policy Announcements and Political Events on the Exchange Rate: The Case of South Africa. School of Economics, University of Cape Town, South Africa accessed at https://editorialexpress.com/cgi-bin/conference/download.cgi?db_name=CSAE2016&paper_id=610

Myburgh, J., 2002. Commission of Inquiry into the rapid depreciation of the rand and related matters: final report dated 30 June. Retrieved August 2003, from http//www.doj.gov.za/commssionsrandfinal.html.

Nason, J.M., Rogers, J.H., 2008. Exchange rates and fundamentals: a generalization. Federal Reserve Bank of Atlanta Working Paper.

Ndlovu, X., 2010. The relationship between the South African rand and commodity prices: examining cointegration and causality. MM finance dissertation, Wits Business School.

Neely, C., Sarno, L., 2002. How Well Do Monetary Fundamentals Forecast Exchange Rates. Federal Reserve Bank of St. Louis Review, 51–74, September Issue

Newey, W. K. and West, K.D., 1987. A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix," *Econometrica*, 55, 703-708.

Nordhaus, D., 1987. Forecasting efficiency: concepts and applications. Review of Economics and Statistics 69, 667–674

Obstfeld, M., Rogoff K., 1996. Foundations of International Macroeconomics. Cambridge, MA: MIT Press.

Obstfeld, M., Rogoff K., 2000b, "The Six Major Puzzles in International Macroeconomics: Is There a Common Cause?" in *NBER Macroeconomics Annual 2000*, ed. by Ben S. Bernanke and Kenneth Rogoff (Cambridge, Massachusetts: MIT Press).

Ouattara, B., 2004a. The Impact of Project Aid and Programme Aid on Domestic Savings: A Case Study of Côte d'Ivoire. Centre for the Study of African Economies Conference on Growth, Poverty Reduction and Human Development in Africa, April (2004).

Pahlavani, M., Wilson, E., Worthington, A.C., 2005. Trade-GDP nexus in Iran: An application of the autoregressive distributed lag (ARDL) model.

Pesaran, H.M., Pesaran, B., 1997. Working with Microfit 4.0: Interactive Econometric Analysis. Oxford University Press.

Pesaran, M.H., Akiyama, T., Smith, R.P., 1998. Energy Demand in Asian Developing Economies, Oxford University Press, Oxford.

Pesaran, H., Shin, Y., 1998. Econometrics and Economic Theory in the 20th Century, Cambridge University Press, chapter 11, pp. 371–413.

Pesaran, H., Shin, Y., Smith, R., 2001. Bounds Testing Approaches to the Analysis of Level Relationships, Journal of Applied Econometrics 16(3), 289–326.

Pesaran, H., Shin, Y., Smith, R., 1996. Testing for the Existence of a Long-run Relationship, Cambridge Working Papers in Economics (9622).

Phillips, P. C. B., Perron, P., 1988. Testing for a Unit-root in Time Series Regression. Biometrika, 75, 335-436.

Rapach, D. E., Wohar, M. E., 2002. Testing the monetary model of exchange rate determination: new evidence from a century of data. Journal of International Economics, 58(2), 359-385.

Ricci, L.A., Milesi-Ferretti, G.M., Lee, J., 2008. Real exchange rates and fundamentals: a cross-country perspective. IMF Working Paper 08/013, International Monetary Fund.

Samuelson, P. A., 1964. Theoretical Notes on Trade Problems. The Review of Economics and Statistics, 46, 145-154.

Sanidas, E., 2014. Four harmonic cycles explain and predict commodity currencies' wide long term fluctuations. Technological Forecasting and Social Change 87, 135–151. doi:10.1016/j.techfore.2013.11.008

Sarno, L., Valente, G., Wohar, M.E., 2004. Monetary fundamentals and exchange rate dynamics under different nominal regimes. Economic Inquiry 42, 179–193.

Silvennoinen, S., Thorp, S., 2013. Financialization, crisis and commodity correlation dynamics. Working Paper 267. Quantitative Finance Research Center, University of Technology Sydney, Ultimo, New South Wales, Australia.

Sjuib, F., 2009. Causal Chain in Macroeconomic Variables: Evidence from Recent Experience in Indonesia. International Research Journal of Finance and Economics (25*): 90-96.

Stock, J. H., Watson M., 1993. A Simple Estimator Of Cointegrating Vectors In Higher Order Integrated Systems," Econometrica, 61, 783-820.

Subramaniam, T., 2010. Dynamic cointegration link between energy consumption and economic performance: empirical evidence from Malaysia. International Journal of Trade, Economics and Finance 1, 261.

Tawadros, G., 2001. The predictive power of the monetary model of exchange rate determination. Applied Finance and Economics 11, 279–286

Taylor, M.P., 1995. The economics of exchange rates. Journal of Economic Literature. 33, 13–47.

Weeks, J., Mungule, O.K., 2013. Determinants of the Zambian Kwacha. International Growth Centre at the London School of Economics in Partnership with Oxford University. Working Paper.

Wehmhoerner, A., 2012. The Marikana Massacre Watershed in the history of post-apartheid South Africa? Foundation for European Progressive Studies accessed at http://www.feps-europe.eu/assets/fc256af1-7cd2-4f6e-b184-4caea82c9d3/2012%2009%2018%20marikana%20massacre%20-%20arnold%20wehmhoerner.pdf

1 Appendices

Appendix A: Construction of the South Africa Specific commodity Index

The country specific commodity price will be constructed following Deaton and Miller (1996) and Cashin, Cespedes and Sahay (2004).The nominal country specific commodity index p_t^{com} is constructed as a geometrically weighted index of the nominal prices of 4 individual commodity exports where for South Africa:

$$p_t^{com} = exp\left[\sum_{k=1}^{K}(W_k\,(lnP_k))\right] \qquad (B1)$$

Where $W_k\ = [(P_{jk}Q_{jk})/(\sum_k P_{jk}\,Q_{jk})]$

$P_k\ is\ the\ dollar\ world\ price\ of\ commodity\ k\ (taken\ form\ the\ IFS\ database)$

$W_k is\ the\ weighting\ item\ which\ is\ the\ value\ of\ exportsof\ commodity\ k\ in\ the\ total$

$value\ of\ all\ K\ commodity\ exports\ for\ the\ constant\ period\ j;and$

$Q\ is\ the\ quantity\ of\ exports\ of\ commodity\ k\ (taken\ from\ the\ UN\ COMTRADE\ database.$

The four major commodity exports considered in the computation of the index are gold, platinum, coal and iron ore. We calculate the 2005-2014 average total value of primary commodity exports; the four individual main commodity weights are calculated by dividing the 2005-2014 average value of each individual commodity export by the 2005-2014 average total value of primary commodity exports. Table B2 indicates the ten year aggregates and the averages for each commodity export. We show the calculation of the individual commodity weights on Table B1. All commodity weights are gross export weights as found in the UN COMTRADE data provided by the UN Statistical Department. Once the commodity export weights are calculated, these weights are held fixed over the sample period and are used to weight the individual (US dollar-based) price indices of the same individual commodities—taken from the IMF's IFS—to form, a geometric weighted-average index of (US dollar-based) nominal commodity-export prices (base 2010M06 = 100).

Table A1: Weighting of the individual commodities in the commodity index

	%age of total exports	**Weight in the index**
Platinum	12	0.34
Gold	10	0.29
Coal	7	0.20
Iron	6	0.17
Aggregate	35	

Table A2 Breakdown of exports by major commodity

Year	Total Exports (USDb)	Platinum		Gold		Coal		Iron Ore		Agregate
		Exports (US$b)	%age of exports	Exports (US$b)	%age of exports	Exports (US$b)	%age of exports	Exports (US$b)	%age of exports	
2005	46,99	5.32	11%	4.25	9%	3.27	7%	0.942	2%	**29%**
2006	52,60	8.01	15%	5.10	10%	3.13	6%	1.16	2%	**33%**
2007	64,02	9.82	15%	9.47	15%	3.37	5%	1.60	2%	**38%**
2008	73,97	9.80	13%	5.88	8%	4.76	6%	2.40	3%	**31%**
2009	53,86	6.77	13%	6.26	12%	4.20	8%	3.14	6%	**38%**
2010	71,48	9.33	13%	8.52	12%	5.54	8%	5.46	8%	**40%**
2011	92,98	10.99	12%	10.37	11%	7.52	8%	9.01	10%	**41%**
2012	98,87	7.93	8%	8.66	9%	6.79	7%	7.75	8%	**31%**
2013	95,11	8.41	9%	6.61	7%	5.83	6%	8.46	9%	**31%**
2014	90,61	6.50	7%	4.73	5%	5.19	6%	6.74	7%	**26%**
Average			**12%**		**10%**		**7%**		**6%**	**35%**

Source: UN Comtrade database; author's own computations