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The South African rand, fundamentals and commodity prices

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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 use floating nominal exchange rate data for South Africa and find evidence in support of a long-run relationship in the commodity-price augmented PPP and monetary models for South Africa. We demonstrate that inclusion of commodity prices improves the in-sample fit of canonical exchange rate model specifications. With respect to out-of-sample short-horizon forecasts, inclusion of commodity prices does improve accuracy although this result is not robust to model and horizon specification.

Keywords: Commodity prices; Exchange rates; Structural models.

1. Introduction

Recent developments on the South African Rand have rekindled the debate on the drivers of the nominal exchange rate by policy makers and market practitioners. It is not difficult to see why. According to Laubscher (2016), it is probably fair to say that the exchange rate of the Rand, specifically against the US dollar, is the economic indicator that attracts the most interest among South Africans on an almost daily basis. Changes in the exchange rate tend to be simplistically ascribed to purely domestic factors, including political events.

While linking fluctuations to the exchange rate to economic fundamentals such as relative output, money supply, interest rates and inflation has roots in economic theory; the empirical literature show that establishing the link in practice is difficult (see Frankel and Rose, 1995). Further, for commodity exporting economies like South Africa, an additional economic variable - commodity prices are thought to exert a considerable measure of influence on the exchange rate (see Frankel, 2007; Schaling *et al*., 2014).

Standard macro-economic models of the exchange rate, namely purchasing power parity (PPP) and monetary-based models have been tested extensively in the literature. The literature shows that while these models of exchange rates that worked well in the seventies, they have not been helpful 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. In particular since the seminal work by Meese and Rogoff (1983), subsequent research attempts have not been able to overturn their conclusion, popularly known as the exchange rate determination puzzle: that is structural exchange rate models cannot outperform the naïve random walk model in forecasting exchange rates.

Our work marries two stands of literature: the exchange determination puzzle and the commodity currencies debate. There are several studies that have established relationships between commodity export prices and currencies of exporting economies at varying frequencies. These include the seminal work of Chen and Rogoff (2003), Cashin *et al*. (2004), Frankel (2007) and Clements and Fry (2006). Since the work by Chen and Rogoff (2003) on OECD commodity exporting economies, other scholars have found evidence linking currency values and commodity prices in Latin America and other developing countries. These include Hatzinikolaou and Polasek (2003), Swift (2004) and more recently Issa *et al*. (2008), Chen *et al*. (2010) and Cayen *et al.* (2010). Along the lines of MacDonald and Ricci (2004), Schaling *et al*. (2014) found evidence of cointegration between the South African Rand and commodity prices. Similar findings are reported by Sidek and Yusof (2009), and more recently by Kohlscheen (2014) for the Malayan ringgit and Brazilian Real respectively.

Recent contributors to the exchange rate determination puzzle include Moosa and Burns (2014) who describe it as "an undisputed fact of life". Frankel and Rose (1995) question the "value of further time series modelling of exchange rates at high or medium frequencies using macro-economic models". Evans and Lyons (2004) describe it as the "most researched puzzle in macroeconomics", while Abhyankar *et al.* (2005) call it the "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. In the context of South Africa, evidence supporting the standard monetary model of exchange rate determination (being one of the traditional monetary macro models) is mixed (see de Bruyn *et al*., 2012; and Moll, 1999, 2000). For example, evidence supporting purchasing power parity (PPP) is rare and mixed at best. Using recent free-floating era data (post 1994), support has been found for PPP but only after allowing for non-linearity (see Larceda *et al*., 2010). Other modifications of the PPP model include allowing for half-life definitions (Mokoena *et al.*, 2009a) and long memory (Mokoena *et al*., 2009c).

South Africa, like other OECD economies such as Australia, New Zealand and Canada, generates a significant portion of its foreign exchange from export of primary commodities such as gold, platinum, coal and iron ore. These primary commodities are traded on organised exchanges such as the Chicago Board of Trade (CBOT) and New York Mercantile Exchange (NYMEX). The price discovery in these organised exchanges allows one to observe the "world" price of these commodities. Schaling *et al*. 2014, show that South Africa is a price taker in world commodity markets, that is, the country does not influence prices of any one of its commodity exports. For this reason, we expect commodity price fluctuations to represent a source of exogenous shocks to its terms of trade and exert an influence on the value of the nominal exchange rate.

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 seeks to make a contribution to the important debate of exchange rate determination in South Africa, using a newer dataset of the floating Rand.

Our contribution is three fold. Firstly, we use 19 years of monthly United States Dollar/Rand nominal exchange rate data from the free floating exchange rate era of the Rand. Empirical exchange rate models are mainly concerned with the behaviour of floating exchange rates between countries which are open to trade and have liberalised capital markets, where the currency values are most likely to reflect various market forces. We therefore eliminate the potential problems associated with using data that does not reflect market forces and makes our findings comparable to other developed commodity exporters with free floating currencies. Secondly, the study combines the commodity currencies and structural exchange rate literature to understand if commodity prices may serve as a potential omitted variable in the structural exchange rate models of the South African Rand. Finally, we hope that our findings provide potential pointers for market players to improve forecasting accuracy of the Rand. Recent studies (see Moosa and Burns, 2012, 2014) show that improving forecast accuracy of models of financial asset prices is valuable in terms of improving corporate performance. Moosa and Burns (2014) for example, demonstrate that a forecasting based currency trading strategy outperforms a simple carry trade strategy based on the random walk model. Moreover, 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.

Our approach follows Chen (2004). We attempt to find out if augmenting the structural macro-economic exchange rate models with the commodity price fundamental variable improves their performance. We test one Purchasing Power Parity (PPP) model used in the literature and two variants of the monetary model. We attempt to answer three questions: 1) In the context of standard structural models, does the commodity price fundamental help to 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?

As a preview of results, we find that commodity prices are significant and consistent explanatory variables of the changes in the nominal bilateral exchange rate of the USD/Rand. The commodity price variable improves the in-sample fit of all fundamental driven exchange rate models and this evidence is robust to the other major Rand cross such as the Euro and British Pound. However, evidence in favour of improvement in short horizon out of sample forecasts is mixed, appearing stronger for the PPP model and mixed for the monetary model specifications. These results are of interest to foreign exchange market players, in policy, commerce and research.

The remainder of this paper is organised as follows. The next section provides a brief history of the Rand. In Sections 3 and 4 we specify the structural models and the augmented variants to be tested, while in Sections 5 and 6 a description of our data sources and estimation procedure are provided. Estimation results are discussed in Section 7 and Section 8 concludes.

2. Brief history of the South African rand

The Rand was established as the official South African currency on 14 February 1961 – and has since developed into a liquid emerging market currency, most commonly traded against the US dollar. The name of the currency derives from the Witwatersrand ("White-waters-ridge"), the ridge where most of South Africa's gold deposits were found and where Johannesburg was built.[1]

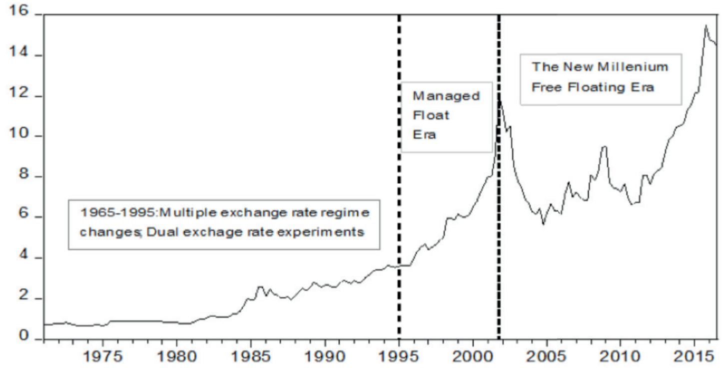
We characterise the history of the Rand into three major episodes illustrated in Figure 1, namely, the multiple-exchange rate regime era, the managed float era and the new millennium. The period 1960-1995 was characterised by significant attention to stabilisation measures in the foreign exchange markets, mainly as coping mechanisms from political and economic pressures associated with the Apartheid regime.[2] During this period, exchange rate stability was itself an objective of policy, explained in part by the fact that South Africa was a signatory to the Bretton Woods agreement to manage fixed exchange rates.[3] These multiple regime changes are summarised in Table 1.

[1] https://www.oanda.com/currency/iso-currency-codes/ZAR

[2] Apartheid was a system of racial segregation in South Africa enforced through legislation by the National Party (NP), the governing party from 1948 to 1994. Under apartheid, the rights, associations, and movements of the majority black inhabitants and other ethnic groups were curtailed, and white minority rule was maintained.

[3] See Wakeford, 2002, Van de Merwe, 1996, De Kock Commission, 1985)

FIGURE 1: HISTORY OF THE RAND



Source: Authors

South Africa's political crisis escalated in the early 90s until 1993 when the government agreed to share power with the African National Congress (ANC) for five years after the first all-race election. After the political reconciliation of 1994 and subsequent removal of economic sanctions, the dual exchange rate: commercial and financial Rand exchange rates were unified on 12 March 1995 and the dual exchange rate regime was discontinued.

TABLE 1: EXCHANGE RATE REGIMES IN SOUTH AFRICA

Dates	**Exchange Rate Regime**
Feb 1961-July 1971	Fixed exchange rate regime: Rand pegged to the British pound
August 1971-November 1971	Fixed exchange rate regime: Rand pegged to the US Dollar
December 1971-September 1972	Fixed exchange rate regime: Rand pegged to the British pound
October 1972-May 1974	Fixed exchange rate regime: Rand pegged to the US Dollar
June 1974-May 1975	Crawling peg regime: Rand pegged to basket of currencies
June 1975-May 1979	Fixed Exchange rate regime: Rand pegged to the US Dollar
June 1979-Jan 1983	Dual exchange rate regime: crawling peg for commercial Rand; free floating financial Rand
Feb 1983-Aug 1985	Unified exchange rate: managed float.
September 1985-Feb 1995	Dual exchange rate regime: managed float for commercial Rand; free float for financial Rand
March 1995-Jan 2000	Unified exchange rate: Managed float Rand
Feb 2000-present	Unified exchange rate: free floating Rand with inflation targeting policy

Source: Authors compilation

For a period of eleven months after the abolition of the dual exchange rate system the unified Rand was stable at around R3.60 to the US dollar. This period was followed the contagion arising from the Asian crisis of 1997 that hit the Rand which plummeted by over 20% in real terms in 1998 although it regained its composure through 1999 trading in a broad range between R5.50 and R6.40 to the dollar. Official interventions from the South African Reserve Bank (SARB) continued during this period to stabilise the exchange rate and were also part of broader reforms to integrate the country into the global economy.

The current free-floating regime of the Rand began in 2000 when the SARB adopted inflation targeting as a framework for monetary policy. Adoption of inflation targeting meant that the Reserve Bank overtly focused on a target inflation benchmark as the variable with the short-term interest rate as a policy instrument. For efficacy and credibility of a central bank, inflation targeting precludes pre-commitment to an exchange rate target (Masson, *et al*. 1998). Accordingly, the SARB ceased its forward book in the forex market in February 2004 (IMF, 2004; Mboweni, 2004). Thus while the Reserve Bank occasionally participates in the foreign exchange markets in South Africa, mainly for reserve accumulation, the current exchange rate regime is closest to a free float. This regime and increased integration with global financial markets implies that the pricing of the currency can be recognised with international economic forces. The Rand has continued to weaken in the new regime (post 2000) and has become one of the most liquid emerging market economies – trading as a proxy for emerging market currencies in terms of expressing both negative and positive sentiments (Kissi, 2013).

In 2001 the currency lost 40% against the US dollar over a relatively short period, promoting the government to appoint the Myburgh Commission of Inquiry (2002) which investigated the factors behind the rapid depreciation.[4] In December 2001, the currency reached a record low at R13.84/US dollar although the currency appreciated 75% between this period and September 2004 (Hodge, 2005). The 2008 global financial crisis also affected the Rand, having it fall to multi year lows of R11.86 in October 2008.

This period was followed by several months of recovery until the second quarter of 2011. From this period the Rand has weakened sharply from levels of around R6.75 to close 2014 at R11.6. A host factors have been cited as responsible

[4] The commission noted factors such as strength of the US dollar against other majors; higher relative inflation in South Africa, contagion effects from the Argentina crisis and economic problems in neighbouring Zimbabwe as factors behind the rapid collapse.

for the collapse of the exchange rate. Concern over South Africa's worsening current account is cited by van der Merwe (2012) alongside labour market disturbances across the mining sector that resulted in the so called "Marikana Massacre". Other factors cited for the weakness include a rating downgrade, weakening growth, large external deficits and exposure to the slowdown of the Chinese economy. According to a Morgan Stanley research note in 2013, the Rand was classified with the Brazilian Real, the Indonesian Rupiah, the Indian rupee and the Turkish Lira as the "Fragile Five" or troubled emerging market currencies.[5] Speculation around the unwinding of the monetary stimulus package by the US Federal Reserve Bank, (the so called taper tantrum), the end of the commodity prices super cycle, Chinese growth concerns and the European sovereign debt crisis combined to make the Rand the worst performing currency of the 16 major currencies tracked by Bloomberg (Bonorchis, 2013).

At the time of writing, i.e. February 2018, the Rand has set an all-time low at R17.83/US dollar on 10 January 2016 largely blamed on the President Jacob Zuma's surprise firing of Finance Minister Nhlanhla Nene and the subsequent appointment of little known Des van Rooyen as his replacement.

3. Structural exchange rate models

Standard exchange rate models posit that exchange rates are determined by macroeconomic fundamentals such as relative money supplies, inflation rates, interest rates and output. Several decades of research have produced several fundamentals based exchange models used in policy modelling. Frankel and Rose (1995) and Cheung *et al*. (2005) provide a comprehensive survey. In this section we review the purchasing power parity (PPP) model and variants of the monetary model. The monetary model, first introduced by Frankel (1976) is often referred to as the workhorse of international finance.

The first model that we consider here is based on the concept of relative purchasing power. According to the PPP hypothesis, the nominal exchange rate is the ratio of the countries' price levels, according to the law of one price. Specifically, we follow the assumption that the exchange rate reflects the ratio of purchasing power between countries. Thus, we have:

$$s_t = a + p_t^* - p_t + \varepsilon_t \tag{1}$$

[5] See https://www.businessinsider.com.au/morgan-stanley-fragile-5-emerging-markets-2013-9#the-indian-rupee-3

All variables are logarithms. s_t is the nominal exchange rate quoted as units of domestic currency per foreign currency such that a larger number represents depreciation of the home currency; p *and* p^* are the domestic and foreign CPIs respectively and ε_t is a stationary disturbance.

The PPP model is central to exchange rate modelling. Additional restrictions can be imposed on the PPP relation to build the popular monetary class models of the exchange rate. In equation (2) assuming money market equilibrium, that is, that the log of real money demand depends linearly on the log of real income and nominal interest rates, we have:

$$m_t - p_t = \beta_y y_t - \beta_i i_t + \varepsilon_t \qquad (2)$$

Where, as before all variables are logs, m_t is the domestic money stock; y_t is domestic income and i_t is domestic short-term nominal interest rate and ε_t represents a stationary disturbance.

Assuming that we have an identical equation for a foreign country (here the US), and equalized income elasticities and interest semi-elasticities of money demand across countries, the relative CPIs would cancel out and the exchange rate would become a function of relative money stocks, interest rate differentials and relative real income for the two countries as follows:

$$s_t = \alpha + (m_t^* - m_t) - \beta_y(y_t^* - y_t) + \beta_i(i_t^* - i_t) + \varepsilon_t \qquad (3)$$

In equation (3), the short term nominal interest rate differential reflects inflation risk premia, which is, with increasing domestic inflation, investors would sell domestic currency and invest in foreign bonds market exerting downward pressure on the domestic exchange rate. Assuming that the uncovered interest parity (UIP) condition holds, we have:

$$i_t^* - i_t = E_t(s_{t+1} - s_t) \qquad (4)$$

Equation (4) reflects international asset markets equilibrium and assumes that domestic and foreign assets are perfect substitutes. Following Killian (1999) and Chen (2004), the UIP condition can be incorporated into equation (3) to give a first order expectational differential equation for the exchange rate. The exchange rate can be expressed as the expected present value of relative money stock and relative real income. Assuming that relative money stock and real income follow a driftless random walk, we obtain the following reduced form exchange rate equation:

$$s_t = \alpha + (m_t^* - m_t) - \beta_y(y_t^* - y_t) + \varepsilon_t \qquad (5)$$

Equations (3) and (5) are two variants of the flexible price monetary model of the exchange rate. The foregoing models have been tested extensively using data from industrialised economies without much empirical success. In this study, we test three linear specifications of the fundamental based models. Defining a vector of fundamentals f_t as explanatory variables, we have:

$$s_t = \alpha + f_t + \varepsilon_t \tag{6}$$

The vector of fundamentals f_t is model dependent and is described by the specifications that are tested in this study as follows:

Relative PPP Model:

$$f_t = \beta_p(p_t^* - p_t) + \varepsilon_t \tag{7}$$

Asset Approach Flexible Price Monetary Model:

$$f_t = \beta_m(m_t^* - m_t) - \beta_y(y_t^* - y_t) + \varepsilon_t \tag{8}$$

Flexible Price Monetary Model:

$$f_t = \beta_m(m_t^* - m_t) - \beta_y(y_t^* - y_t) + \beta_i(i_t^* - i_t)\varepsilon_t \tag{9}$$

The coefficient β_p is the coefficient of relative CPIs and β_m is the elasticity with respect to money stock and should, in theory be equal to unity. The coefficient β_y is the income elasticity of money demand and β_i is the interest semi-elasticity.

4. Commodity price shocks and exchange rates

The linkage between exchange rates and commodity prices is well documented in the economic literature (see Clements and Fry, 2006, Chen and Rogoff, 2003, Chen, 2002, and Ndlovu, 2011) for a comprehensive review of literature on the relationship between commodity prices and commodity currencies). The literature discusses two channels namely the trade channel and the "portfolio balance" class of models.

Under the trade channel, consider a small open commodity exporting economy with tradable and non-tradable goods sectors. 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 well documented Balassa-Samuelson effect.[6] Assuming that prices of non-tradable goods are sticky, the exchange rate instead of prices would have to adjust to preserve

[6] 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.

efficient resource allocation. 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.

Under the portfolio balance model, the exchange rate is treated as a function of demand and supply of national assets; domestic and foreign assets are treated as perfect substitutes. 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 in 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.

Chen (2004) argues that these channels may be working simultaneously in reality. It is thus justifiable to include a terms of trade measure in exchange rate modelling. Identifying a good terms of trade measure is no easy task. Chen and Rogoff (2003) show that the traditional terms of trade measure, being the ratio of the relative price of exports to imports is usually complicated by several issues. These complications include price stickiness, potential mechanical correlations and endogenous pricing behaviour.[7] For commodity exporting economies such as South Africa, where export commodities are traded in a few global exchanges, this measure of the terms of trade is however easily identifiable and measurable. In our experiments, we incorporate a commodity price index in testing the performance of the fundamentals based structural models discussed above. Specifically, in the spirit of Chen (2004), we test the following three commodity price augmented models:

Augmented Relative PPP Model:

$$s_t = a - \beta_1 p_t^{com} + \beta_2 (p_t - p_t^*) + \varepsilon_t \tag{10}$$

Augmented Asset Approach Flexible Price Monetary Model:

MM1 Model:

$$s_t = a - \beta_1 p_t^{com} + \beta_2 (m_t - m_t^*) - \beta_3 (y_t - y_t^*) + \varepsilon_t \tag{11}$$

[6 cont] 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.

[7] For example, with sticky producer prices and perfect pass-through, terms of trade and real exchange rates will move one-to one mechanically with no causal interpretation. The same is true when all goods are priced in local currencies, though the correlation will be of the opposite sign.

Augmented Flexible Price Monetary Model:
MM2Model:

$$s_t = a - \beta_1 p_t^{com} + \beta_2(m_t - m_t^*) - \beta_3(y_t - y_t^*) + \beta_4(i_t - i_t^*) + \varepsilon_t \qquad (12)$$

Where p_t^{com} represents the nominal price index of major commodity exports for South Africa. Refer to Appendix for details.

5. Data description and measurement

We test the structural models of the bilateral nominal exchange rate of the South African Rand against three major currencies namely the United States Dollar (USD) the Pound-Sterling and the Euro using monthly data from January 1996 to December 2014. This sample reflects the floating era of the exchange rate. In all cases the nominal exchange rates are measured as monthly averages in Rand per base currency. The money supply variable is measured as M1 in all cases except for the UK where we use M0 in USD billions. Inflation is measured as CPI in all cases while we use the three month Treasury-bill rate in percent/ annum in all cases. The real GDP numbers are 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). With the exception of the GDP data from the World Bank database, all the other data was extracted from the IFS database of the IMF. For commodity prices, we construct a South Africa-specific production or export weighted production-weighted commodity price index based on four major export commodities following Cashin et al. (2004) and more recently Kohlscheen *et al* (2016).[8] The details are contained in the data appendix. Figure 2 illustrates the data series. All the variables appear to be non-stationary.

In Tables 2-5 we report the augmented Dickey Fuller (ADF) test (Dickey and Fuller, 1979, Dickey and Fuller, 1981) and Philips-Perron test (Phillips and Perron, 1988) for a unit root. Both tests suggest that all the variables are I(1).

Additionally, we test the three different specifications for cointegration (Table 6). Except for the PPP model for EUR/ZAR and the monetary models for the GBP/ZAR, cointegration is detected in all cases.

[8] Our earlier work in Schaling *et al* (2014) employed the IMF index and South African exchange rate data. The rationale for using a country specific index is to analyse the relation between the exchange rates and fundamentals with greater precision. Use of a country specific index over the IMF commodity price index is expected to help us analyse the relationship independent of variations in global risk appetite and carry.

FIGURE 2: DATA PLOTS

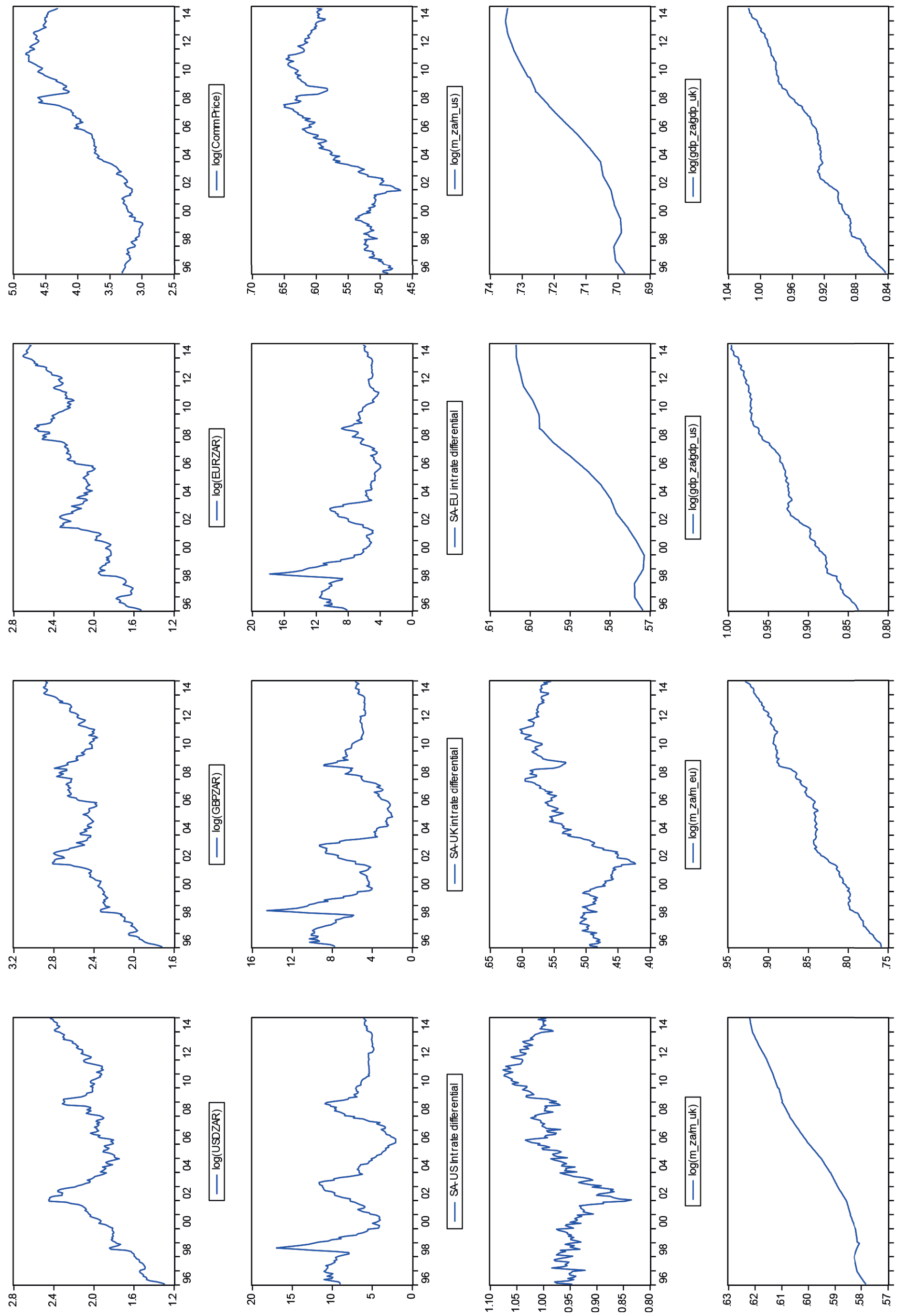


TABLE 2: REPRESENTATIVE TESTS FOR UNIT ROOT (SOUTH AFRICA VARIABLES)

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 Differential	-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 Differential	-9.9786	-9.1913	-9.7857	-8.8630

TABLE 3: REPRESENTATIVE TESTS FOR UNIT ROOT (USA VARIABLES)

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 Differential	-7.2661	-3.7328	-13.7077	-12.1440

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. This rejection rule also applies to Tables 4 and 5.

TABLE 4: REPRESENTATIVE TESTS FOR UNIT ROOT (UK VARIABLES)

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 Differential	-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 Differential	-6.6963	-7.2957	-6.6964	-7.3529

TABLE 5: REPRESENTATIVE TESTS FOR UNIT ROOT (EU VARIABLES)

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 Differential	-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 Differential	-5.2759	-9.6377	-7.0663	-10.0864

TABLE 6: JOHANSEN TEST FOR COINTEGRATION

	Number of Cointegrating relationships	
Base Country	**Trace Statistic**	**Eigenvalue Statistic**
PPP: log(Exch-rate); log(Commodity Price); log(CPI_SA) log(CPI_foreign)		
USA	2	2
UK	2	1
EU	0	0
MM1: 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
MM2: log(Exch-rate); log(Comm Price); log(Mon Supply_SA/Mon Supply_foreign); log(GDP_SA/GDP_foreign); Interest differential		
USA	2	1
UK	0	0
EU	0	1

6. Estmation procedure

We employ Stock and Watson's (1993) Dynamic OLS (DOLS) to estimate the cointegrating vectors. The procedure basically involves augmenting OLS regressions with lead and lag values of the first difference of each regressor. The DOLS method possesses some advantages of alternative methods of estimating cointegrating systems. The maximum likelihood approaches to cointegration, being a full information approaches, are 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, for example, 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.

In our specification, the cointegrating vector β between the exchange rate s_t and a set of fundamental variables f_t is estimated using the DOLS specification below:

$$s_t = \alpha + \beta f_t + \sum_{j=-q}^{r} \delta_j \Delta f_{t-j} + u_t \tag{13}$$

β is the cointegrating vector; that is, represents the long-run cumulative multipliers; the long-run effect of a change in f on s_t and (-)q and r are the lag and lead lengths respectively. 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. 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.[9]

7. Exchange rate determination

7.1. In sample fit: contemporaneous regressions

In Tables 7-9 we report the DOLS parameter estimates pre and post inclusion of commodity prices with all variables appearing in levels for the USD/ZAR,

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

GBP/ZAR and EUR/ZAR models. The asymptotic standard errors are reported in parenthesis ( ). The expected signs of the coefficients are shown in parenthesis [ ] on the first column of Tables 7-9.

The results indicate that commodity prices are a significant and consistent explanatory variable of the exchange rate in the PPP and monetary model specifications. In the USD based equations a 1% increase in commodity prices leads to a 0.63% appreciation of the Rand. This result is robust to other Rand crosses as well.

Judging by the goodness of fit criteria, the USD based models fit the data fairly well – the adjusted R^2 reading improves notably by the inclusion of the commodity price variable. The gains on the adjusted R^2 for the other Rand crosses are only marginal.

The monetary models of the Rand generally perform poorly across all 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 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 quantitatively very small. This finding suggests that South Africa is an unlikely destination of dollar and Euro carry trades.[10] Hassan (2014), for example, 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.

To summarise, commodity prices are significant contemporaneous explanatory variables of changes in the nominal exchange rate. While inclusion of the

[10] 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).

commodity prices in standard structural models improves their fit, the puzzle still remains – the monetary models still perform poorly judged by the signs and magnitude of estimated coefficients. The results supports the view those terms of trade shocks are important in exchange rate determination in South Africa.

TABLE 7: COINTEGRATING RELATIONSHIP WITH DYNAMIC OLS [BASE: US]

	PPP	**PPP + Comm Price**	**MMI**	**MMI + Comm Price**	**MM2**	**MM2 + Comm Price**
Log(Com Price) [-]		-0.5600*** (0.0601)		-0.6612*** (0.13)		-0.6602*** (0.1101)
Log(CPI_ZA) [+]	1.4915*** (0.2104)	1.4145*** (0.1823)				
Log(CPI_US) [-]	-2.5012*** (0.5822)	-0.4905 (0.6569)				
Log(M1_ZA/M1_US) [+]			-2.6712*** (0.9204)	-1.5601*** (0.7835)	-2.9012*** (0.9633)	1.5878* (0.8908)
Log(GDP_ZA/GDP_US)[-]			-14.3548* (7.7533)	22.3425** (8.8644)	-13.6702** (8.8904)	23.0412*** (8.1322)
Tbill_ZA-Tbill_US [-]					-0.0003 (0.0002)	-0.00001 (0.0002)
Residual ADF Test	-3.9728	-4.9111	-3.6058	-4.2012	-3.1244	-4.1929
Adjusted R^2	0.8200	0.9212	0.8633	0.9009	0.8540	0.9010
No. of Observations	221	221	221	221	221	221

Notes: The following notes are applicable to the results in Tables 8 and 9.

1. 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.
2. The dynamic OLS (DOLS) methodology is used to obtain super consistent estimators of the cointegrating vectors with asymptotic standard errors reported in parenthesis ( ).
3. *, **, *** denotes statistical significance at 10%, 5% and 1% level respectively.
4. A South-Africa specific commodity prices, is the production weighted average of the top four commodity exports from South Africa, priced in USD. See data appendix for details.
5. The models were estimated up to $j=\pm3$ lags of each dependent variable to orthogonalise.
6. 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 8: Cointegrating Relationship with Dynamic OLS [Base: UK]

	PPP	PPP + Comm Price	MMI	MMI + Comm Price	MM2	MM2 + Comm Price
Log(Com Price) [-]		-0.4921*** (0.0506)		-0.1230 (0.1511)		-0.3512*** (0.0901)
Log(CPI_ZA) [+]	2.0612*** (0.4315)	2.3385*** (0.3310)				
Log(CPI_UK) [-]	-3.6301*** (0.9420)	-2.5212 (0.7711)				
Log(M1_ZA/M1_UK) [+]			-4.3236*** (0.3948)	-4.4002*** (0.6228)	-4.1259*** (0.3612)	-3.8602** (0.3422)
Log(GDP_ZA/GDP_UK)[-]			-5.0620 (5.8014)	1.8019 (7.6282)	3.9608 (4.1780)	23.1800*** (5.4600)
Tbill_ZA-Tbill_UK [-]					-0.0202*** (0.0041)	-0.0533*** (0.0034)
Residual ADF Test	-3.5702	-4.2923	-3.2600	-3.4119	-3.9044	-4.4505
Adjusted R^2	0.8108	0.8942	0.9037	0.9008	0.9403	0.9648
No. of Observations	221	221	221	221	221	221

Table 9: Cointegrating Relationship with Dynamic OLS [Base: EU]

	PPP	PPP + Comm Price	MMI	MMI + Comm Price	MM2	MM2 + Comm Price
Log(Com Price) [-]		-0.3102*** (0.0848)		-0.1230 (0.1511)		-0.3512*** (0.0901)
Log(CPI_ZA) [+]	1.7700*** (0.3914)	1.6110*** (0.5029)				
Log(CPI_EU) [-]	-3.3433** (1.2117)	-1.1709 (1.7839)				
Log(M1_ZA/M1_EU) [+]			-4.4608*** (1.1633)	-3.6623*** (1.1526)	-4.3040*** (1.2232)	--3.6105*** (1.1822)
Log(GDP_ZA/GDP_EU)[-]			22.4600 (9.2701)	34.1712 (9.9010)	21.7244 (9.5029)	32.7492*** (10.0330)
Tbill_ZA-Tbill_EU [-]					0.0000 (0.0000)	0.0000 (0.0000)
Residual ADF Test	-3.5212	-3.7201	-3.2325	-2.7601	-2.7642	-2.8223
Adjusted R^2	0.9000	0.9144	0.8508	0.8642	0.8638	0.8638
No. of Observations	221	221	221	221	221	221

7.2. Simulated out of sample forecasts

In this section we evaluate whether commodity price augmented structural models perform better than standard structural models in pseudo-out of sample forecasts.

To evaluate the simulated out of sample forecasts, we rely on the framework pioneered by Meese and Rogoff (1983). Our analysis is based on the dynamics of error correction and a forecast equation of the following form:

$$\Delta s_{t+k} = \ s_{t+k} - s_t = \alpha_k + \lambda_k[\beta_t f_t - s_t] + \nu_t \tag{14}$$

Where λ is an estimated coefficient, k is the forecast horizon, f_t is the fundamental value of the exchange rate suggested by the exchange rate model and β_t is the cointegrating vector as in equation (13) and v_t is a stationary disturbance. The equation basically says that if the exchange rate falls below its long-run value implied by economic fundamentals, an appreciation should occur in future. Therefore a one sided test of the null $\lambda_k = 0$ against $\lambda_k > 0$ is a test of exchange rate predictability for k horizons from fundamentals.

Our approach uses the rolling window procedure to generate out-of-sample exchange rate forecast for the PPP and two specifications of the monetary models. 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 of this additional variable.

We use a nine year estimation window which gives us an evaluation period of 108 observations. We employ the recursive out-of-sample forecast procedure for three horizons: $k = 1$, $k = 6$ and $k = 12$. For $k = 1$ for example, we estimate a set of coefficients for each model, pre and post inclusion of the commodity price 108 times and then evaluate the performance of the model between January 2006 and December 2014.

To evaluate the forecast performance of the exchange rate models, we rely on the Root Mean Squared Error (RMSE) and Theil's inequality coefficient (U). The basis of the evaluation using the RMSE is that the smaller the error, the better the forecasting ability of that model. 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 $U > 1$.

We report the forecast performance of the three specifications of the USD-base exchange rate models, pre and post augmentation by the commodity price in Table 10. We 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.

Results from the PPP model 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 inclusion of the commodity price variable does improve the forecast accuracy of the model. This result is important for our subsequent assessment of the monetary models, as the PPP model is an important building block of the flexible price monetary models.

The link between the exchange rate and monetary variables appears to be stronger than CPI.[11] 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, and not MM2. Without testing for statistical significance of the forecast evaluation criteria, the monetary models overwhelmingly outperform the naïve random walk model at all forecast horizons.

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

TABLE 10: FORECAST EVALUATION [BASE: US]

	PPP	**PPP + Comm Price**	**MMI**	**MMI + Comm Price**	**MM2**	**MM2 + Comm Price**
One Month						
RMSE	0.0483	0.0460	0.0183	0.0183	0.0178	0.0178
U	1.0009	0.9005	0.4440	0.4396	0.4226	0.4231
Six Months						
RMSE	0.0459	0.0451	0.0239	0.0238	0.0241	0.0241
U	0.9307	0.9153	0.5186	0.5163	0.5218	0.5220
Twelve Months						
RMSE	0.0416	0.0404	0.0225	0.0224	0.0226	0.0226
U	0.9250	0.8975	0.5247	0.5225	0.5271	0.5273

8. Conclusion

Evidence in favour of 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 the seminal work by Meese and Rogoff (1983), 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".[12]

While this argument has intuitive appeal, questions have been raised over augmentation of the exchange rate models with for example, 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 forecasting 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

[12] See Abhyankar *et al* (2005).

rate but that they are also significant explanatory variables of other major Rand crosses as well. We use floating nominal exchange rate data for South Africa and find evidence in favour of a long-run relationship in the commodity-price augmented PPP 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).

In terms of the type of models, while addition of the commodity price variable improves the in-sample fit of the PPP model, evidence of such improvement, measured in terms of expected a priori signs suggested by economic theory is mixed for monetary models. De Bruyne *et a*l (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 Meese and Rogoff (1983). 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). Therefore while there are marginal improvements in the performance of structural exchange rate models for the South African Rand, this additional fundamental is far from being the silver bullet of the exchange rate determination puzzle.

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 for future research for commodity exporting emerging economies.

Biographical Notes

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Data Appendix

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:

$$p_t^{com} = exp\left[\sum_{k=1}^{K}(W_k\,(lnP_k))\right] \quad \text{(A1)}$$

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 A2 indicates the ten year aggregates and the averages for each commodity export. We show the calculation of the individual commodity weights on Table A1. 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 Commodoties in the Commodities Index

	Percentage 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 (US$b)**	**Platinum**		**Gold**		**Coal**		**Iron ore**		**Aggregate**
		Exports (US$b)	%	Exports (US$b)	%	Exports (US$b)	%a	Exports (US$b)	%	
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