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2012-18

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# Nominal and Real Exchange Rate Models in South Africa: How Robust Are They?

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## Abstract

This paper addresses difficulties in modelling exchange rates in South Africa. Real exchange rate models of earlier research seem to be sensitive to the sample period considered, alternative variable definition, data frequency and estimation methods. Alternative exchange rate models proposed in this paper including the stock-flow approach and variants of the monetary model are not fully robust to data frequency and alternative estimation periods, either. Nevertheless, adding openness to the stock-flow approach and augmenting the monetary model with share prices and the country risk premium improves significantly the fit of the models around the large (nominal and real) depreciation episodes of 2002 and 2008. Interestingly, real commodity prices do not help explain the large depreciations. While these models do a reasonably good job in-sample, their out-of-sample forecasting properties remain poor.

**JEL:** E31, F31, O11, P17

**Keyword:** exchange rate, real exchange rate, nominal exchange rate, commodity, Balassa-Samuelson, productivity, monetary model, stock-flow approach, openness, country risk

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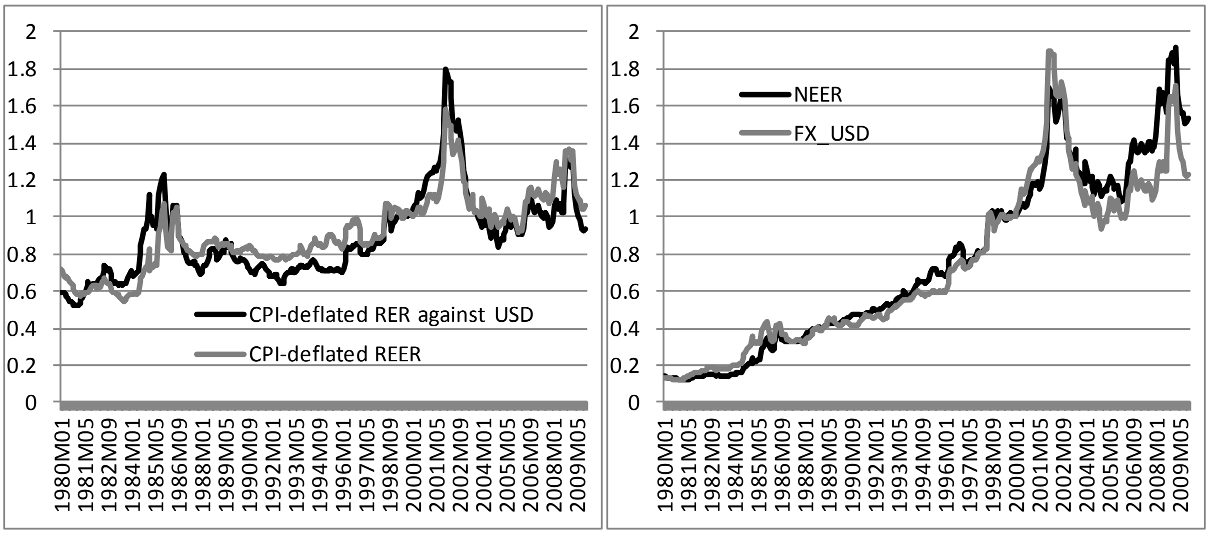
# 1 Introduction

South Africa belongs to the group of resource-rich countries where commodities account for a non-negligible share of exports. Most economists would agree and empirical evidence shows that commodity prices are likely to be an important driver of exchange rates of prominent commodity producing and exporting countries (Cashin et al, 2004; Chen and Rogoff, 2003, Gruen and Kortian, 1996; Bailliu et al, 2007). That commodity prices play an important role in long-run real exchange rate movements in South Africa is also largely confirmed in the existing literature (Aron et al., 2000; Chinn, 1999 and Mtonga, 2006) for real gold prices and MacDonald and Ricci (2004) and Frankel (2007) for real prices of the basket of commodities exported by South Africa), even though some cannot confirm the commodity currency finding (Cashin et al, 2002).

This paper has several ambitions. First, we revisit the commodity price - exchange rate nexus for the case of South Africa. But a more general objective of the paper is to investigate the stability of exchange rate models with regard to the time period used, economic specification, alternative variable definitions and data frequencies. Also, we would like to find out what explains the rand's large depreciation in 2002 and during the recent financial crisis in 2008 (Figure 1). For this purpose, the models of MacDonald and Ricci (2004) and Frankel (2007) constitute our starting point.[2] We compare these models to the stock-flow approach to the real exchange rate augmented with commodity prices and country risk premium. We also estimate nominal exchange rate models on the basis of the monetary model.

Figure 1. Real and nominal exchange rate of the South African rand against the effective basket and the USD, 1980:m1-2009:m6 (2000:m1=1)




Source: Author's calculations based on obtained from Datastream. For more details, see the data appendix.

The rest of the paper is organised as follows. Section 2 describes findings of previous research. Section 3 carries out a sensitivity analysis of the models proposed in the literature, Section 4 provides alternative real and nominal exchange rate models and studies their robustness to various economic and econometric specifications. Section 5 finally summarises our findings.

[2] Earlier papers are not considered here because the estimation results are obtained for sample periods that stop around the mid-1990s. These papers include Aron et al. (2000) and Mtonga (2006) for the real exchange rate and Chinn (1999) and Odedokun (1997) for the nominal exchange rate.

# 2 Previous research

This section summarises the setup and results of the models used in two recent influential papers on South Africa's exchange rate: the paper by MacDonald and Ricci (2004) and by Frankel (2007).

MacDonald and Ricci (2004) estimate a real exchange rate equation in a cointegration framework: the real effective exchange rate is modelled using six explanatory variables: real GDP per capita, openness, net foreign assets, real interest rates, government balances over GDP and real commodity prices. The estimations are carried out for the period from 1970:q1 to 2002:q1 and a sensitivity check is performed with regard to the use of alternative measures of real commodity prices. The results show that the variables are cointegrated with the real exchange rate and that all variables are statistically significant and robust to alternative commodity prices except for the real GDP per capita variable. They compare the estimated cointegrating vector to the observed real exchange rate series: the rand appears to be systematically and increasingly undervalued since the early 1990s. Put differently, the fundamentals used in the paper cannot fully account for the observed depreciation of the rand since the mid-1990s.

Frankel's (2007) modelling choices are different. He analyses the rand's real exchange rate against the US dollar. The period covered is shorter but is more recent as it goes from 1984:q1 to 2007:q1. Finally, he regresses the level real exchange rate on its lagged values, on a real commodity price index, a real interest differential, a dummy capturing capital account liberalisation in 1994 and an interaction term between the interest differential and the dummy. Contrary to MacDonald and Ricci (2004), his model does not reveal major misalignments since the early 1990s. Nevertheless, his model does not fully explain the sharp depreciation in 2002 and seems to track the observed real exchange rate with some lag.

# 3 Setting-up a sensitivity analysis

This section seeks to replicate the results reported in MacDonald and Ricci (2004) and Frankel (2007). While we try to follow the modelling choices of the two papers, our comparison is far to be perfect and hence cannot be taken as a genuine replication of the earlier results. Rather, they can be considered as a check whether these results are robust to changes in the estimation setup. Below we discuss the major differences.

We decided to deviate from the modelling choices of Frankel (2007) mostly because his real exchange rate model that is estimated against the dollar does not consider the nonstationary properties of the series considered: all variables used in his model are clearly I(1) processes that calls upon cointegration analysis.[3] It is very difficult to reconcile the lagged dependent variable (exchange rate) with a long-term cointegrating relationship. Including the lagged (first differenced) dependent variable is more appropriate in an error correction model. Against this background, we do not consider the lagged dependent variable in the cointegrating vector.

The second major difference to our approach is that Frankel uses data on inflation expectations for the computation of the real interest rate. We use observed inflation rates to calculate forward and backward looking short-term and long-term real interest differentials against the US. On the one hand, we do not have access to the data he used in his paper. On the other hand, it is not clear to what extent inflation expectations generated by a structural model of South Africa that he uses are a good measure of actual inflation expectations of financial market analysts, firms and households.

[3] Unit root and stationarity tests indicate that the series under consideration are nonstationary processes. Results for the data series used in this paper are not reported but are available upon request.

Frankel (2007) uses a dummy that captures capital account liberalisation in 1994 and an interaction term of the dummy with the interest rate differential. We only include the interaction term in the cointegrating vector but not the dummy variable.

For the real effective exchange rate, our estimations are based on a dataset that has three major differences compared to the dataset used in MacDonald and Ricci (2004).

- First, our estimation period starts in 1980:Q1 instead of 1970:Q1 because we could collect data for the five components of the commodity price index (including gold, coal, iron, copper and platinum) starting only in 1980.
- Second, MacDonald and Ricci (2004) use a variable on the fiscal balance without specifying the exact definition of the series (general or central government or whether it is cash based or not). We have three data series on government balances in South Africa that differ quite substantially. We therefore decided to use the government debt to GDP ratio that is also a proxy for the country risk premium.
- Third, MacDonald and Ricci (2004) do not provide the countries that constitute the foreign benchmark and the corresponding weights used for the calculation of the effective exchange rate as well as for the effective foreign variables. Hence, we use the (normalised) weights for South Africa's 4 biggest trading partners (USA, euro area proxied by Germany, UK and Japan) published by the South African Reserve Bank (SARB).

The different time spans covered in the two papers and additional observations since the end of 2007 provide three natural benchmark periods for studying model stability:

- 1980:q1 to 2002:q1 => the MacDonald and Ricci (2004) sample for the end
- 1980:q1 to 2007:q1 => the Frankel (2007) sample
- 1980:q1 to 2009:q1 => sample period of this paper
- 1994:q1 to 2009:q1 => sample period that considers changes after capital market liberalisation and that makes the use of dummies to capture that change unnecessary.

Overall, we carry out sensitivity analysis around the following dimensions:

- Time span
- Data frequency (quarterly vs. monthly)
- Variable definition
- Estimation method (for MacDonald and Ricci, 2004)

# 3.1 Estimation issues

We use cointegration analysis to investigate the sensitvity of previous research as the variables considered turn out to be I(1) processes. For the cointegration analysis, we employ dynamic ordinary least squares (DOLS) and the Johansen cointegration technique. Here we briefly describe the two approaches.

We use dynamic ordinary least squares (DOLS) to estimate the long-run relationship. Stock and Watson (1993) show that DOLS accounts for the endogeneity of the regressors and serial correlation in the residuals by incorporating lags and leads of the regressors in first differences:

$$Y_t = \beta_0 + \sum_{i=1}^{n} \beta_i X_{i,t} + \sum_{i=1}^{n} \sum_{j=-k_1}^{k_2} \gamma_{i,j} \Delta X_{i,t-j} + \varepsilon_t \qquad (7)$$

where $k_1$ and $k_2$ denote, respectively, leads and lags. The length of leads and lags is determined on the basis of the Schwarz information criteria. The presence of cointegration is assessed using three methods:

- Residual-based cointegration test where stationarity of the residuals obtained from the long-term relationship ($Y_t = \beta_0 + \sum_{i=1}^{n} \beta_i X_{i,t} + \varepsilon_t$).Critical values of the ADF statistics are obtained using the formula proposed by McKinnon (1991): $C_k(p,T) = \beta_\infty + \beta_1 T^{-1} + \beta_2 T^{-2}$ where p and T are the significance level and the sample size respectively, and the betas are parameters of response surface estimates.
- The error correction term as a test of cointegration is used as Kremers, Ericsson and Dolado (1992) argue that it is more powerful than the residual-based Dickey-Fuller test.
- Johansen's trace statistics is used to verify the number of cointegration relationships in a VAR (vector autoregressive) framework

$$Y_t = (m_0 + m_1 t + (1 + \alpha\beta^{'})Y_{t-1}) - \sum_{i=1}^{p-1} \Phi_i \Delta Y_{t-i} + \varepsilon_t \quad (8)$$

The critical values are tabulated by Osterwald-Lenum (1992) and the test statistics are corrected for small samples if necessary in accordance with Reimers (1992).[4] Nevertheless, it is known that the trace statistic tend to overreject the null of no cointegration and indicates more cointegrating vectors than (Hjalmarsson an Österholm, 2007). Therefore, we use the trace statistic to see whether or not the series investigated are cointegrated but would worry too much if it would indicate 2 cointegration relationships. Overall, we will take as an evidence for cointegration if at least two out of the three tests suggest that the variables are cointegrated.

# 3.2 Results of the sensitivity analysis

Tables 1a and 1b report the estimation results for the Frankel (2007) and MacDonald and Ricci (2004) models. Before diving into the details, it needs to be emphasised that the real commodity price variable we used reflects the weights and the different commodities included in the real commodity price index used in the two papers (see appendix A) and that we use monthly data in addition to quarterly data used in both papers.

Table 1a shows that for the period 1980:q1 to 2007:q1, the model estimates are comparable to those reported in Frankel (2007). A higher real interest differential is associated with an appreciation of the CPI- and PPI-based real exchange rate, the interaction term has the opposite sign and commodity price increases go hand in hand with a real appreciation. Furthermore, and importantly, the variables seem to be connected via a long-run cointegrating vector. The error correction terms are significantly negative and the trace statistic indicates the presence of one cointegrating vector at the 1% level. Two comments are of order: First, the coefficient estimates on the real commodity price index are substantially higher (between 0.6 and 0.7) than those reported in Frankel (2007) (around 0.15). Second, the fit of the long-term model is around half of that of the model including the lagged real exchange rate.

Looking at the three additional periods, Table 1a suggests that the results do not change much for 1980:q1-2002:q1 but it also shows that cointegration cannot be warranted for the sample running until 2009:q1 and for the period that starts in 1994:q1. These findings remain unchanged when we run the same set of regressions on monthly data.

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[4] $(T - nk)/T$ where T is the number of observations, n is the number of variables and k is the lag length.

Table 1b displays results obtained for the MacDonald and Ricci (2004) modelling framework. While Johansen's trace statistic is able to reject the null of no cointegration at the 1%, the two other tests cannot confirm this result for the benchmark period of 1980:q1 to 2002:q1. Nevertheless, finding cointegration is generally not a problem for the additional periods and when looking at monthly data. For 1980:q1 to 2007:q1 and 1980:q1 to 2009:q1, the question that arises is that there might be more than just one cointegrating vectors as the trace tests indicate the presence of up to 4 cointegrating vectors. Results based on monthly data suggest that the multiple cointegration finding may be less of a problem.

Whereas the lack of cointegration is not a major issue, the sign, significance and stability of the coefficient estimates of the explanatory variables are of major concern. The two variables that are very robust to alternative specifications in terms time span, econometric estimation methods and data frequency are relative GDP per capita and the openness variables. Regarding the other variables, the results show that:

- First, some variables tend to have the wrong sign. For instance, the estimations suggest that an increase in public debt goes in tandem with an appreciation of the real effective exchange rate. This is not very intuitive given that a higher debt and thus a higher country risk should translate into currency depreciation. For the benchmark period of 1980 to 2002, commodity prices have the wrong sign while the sign switches for the remaining alternative periods.
- Second, some variables tend to be statistically insignificant such as net foreign assets.
- Third, estimation results in terms of sign and significance may differ whether the estimations are obtained using DOLS or a VECM. This is for instance the case of openness for three periods at the quarterly frequency: higher openness leads to depreciation on the basis of DOLS estimates and to appreciation using VECM estimates.
- Fourth, data frequency also matters. For 1980 to 2002, the real interest differential has a depreciating effect on the exchange rate when using quarterly data and an appreciating effect if monthly data are used.

Overall, it appears that the real exchange rate model of MacDonald and Ricci (2004) are not particularly robust to an alternative definition of the country risk variable (replacing government balances by the public debt to GDP ratio), to the shortening of the time span from 1970 to 2002 to 1980 to 2002, to alternative time spans and to a change in data frequency.

**Table 1a.** Estimation results, Frankel model, real exchange rate against the USD

| | **Quarterly data** | | | | | **Monthly data** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | CPI-based | PPI-based | CPI-based | | | CPI-based | | | |
| | **1980-2007** | **1980-2007** | **1980-2009** | **1980-2002** | **1994-2009** | **1980-2002** | **1980-2007** | **1980-2009** | **1994-2009** |
| **COINTEGRATION TESTS** | | | | | | | | | |
| UR | -1.562 (0) | -2.356 (0) | -0.087 (0) | -1.487 (0) | -0.024 (0) | -2.426 (2) | -2.031 (1) | -2.133 (1) | -1.66 (1) |
| ECT | -0.096** | -0.14** | -0.031 | -0.11** | -0.031 | -0.052** | -0.038** | -0.014 | -0.033** |
| JOH r=0 | 57.06** | 58.23** | 44.13* | 52.6** | 21.67 | 44.9* | 49.14** | 52.31** | 20.17 |
| JOH r=1 | 29.28* | 29.08* | 19.21 | 27.75* | 2.95 | 23.03 | 28.25* | 23.48 | 3.5 |
| **COEFFICIENT ESTIMATES** | | | | | | | | | |
| C | 0.089** | 0.072** | 0.083** | 0.017 | 0.261** | 0.079** | 0.106** | 0.06** | 0.123** |
| RIR | -0.029** | -0.036** | -0.037** | -0.039** | -0.039** | -0.034** | -0.023** | 0.013** | -0.019** |
| RIR*1994 | 0.018** | 0.025** | 0.02** | 0.026** | | 0.017** | 0.015** | -0.023** | |
| Commodity | -0.726** | -0.633** | -0.69** | -0.72** | -0.968** | -0.761** | -0.687** | -0.36** | -0.308** |
| No. obs | 107 | 107 | 114 | 87 | 59 | 265 | 325 | 352 | 178 |
| ECM - $adj-R^2$ | 0.204 | 0.217 | 0.156 | 0.153 | 0.167 | 0.176 | 0.167 | 0.171 | 0.175 |
| ECM - SIC | -2.594 | -2.702 | -2.495 | -2.525 | -2.499 | -3.899 | -3.846 | -3.757 | -3.817 |
| LR - $adj-R^2$ | 0.599 | 0.586 | 0.685 | 0.7 | 0.873 | 0.675 | 0.559 | 0.314 | -0.371 |
| LR - SIC | -0.704 | -1.093 | -0.579 | -1.059 | -1.318 | -1.114 | -0.73 | -0.284 | -0.46 |

Notes: UR is the residual based cointegration test and ECT denotes the error correction term for the DOLS model. JOH r=0 and JOH r=1 are the trace statistics. ECM and LR refer to the error correction model and the long-run relationship estimated using DOLS, respectively. * and ** mean statistical significance at the 10% and 5% levels. All variables are taken in natural logs, the only exception is the real interest differential. SIC is the Schwarz information criterion.

**Table 1b.** Estimation results, MacDonald and Ricci model, real effective exchange rate

| | **Quarterly data** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **1980:Q1-2002:Q1** | | **1980:Q1-2007:Q1** | | **1980:Q1-2009:Q2** | | **1994:Q1-2009:Q2** | |
| | DOLS | trace | DOLS | trace | DOLS | trace | DOLS | trace |
| UR/Rr=0 | -1.672 | 129.5** | -4.549* | 105.83** | -4.781* | 155.61** | -3.685 | 139.74** |
| R=1 | | 89.25 | | 76.97** | | 109.77** | | 85.97 |
| R=2 | | 62.69 | | 51.67** | | 79.33** | | 52.24 |
| R=3 | | 38.64 | | 29.16* | | 50.88** | | 31.09 |
| ECT/r=4 | -0.01 | 21.62 | -0.242** | 10.48 | -0.259** | 26.47 | -0.246** | 13.85 |
| R=5 | | 6.01 | | 1.97 | | 8.21 | | 4.6 |
| R=6 | | 0.3 | | 0.81 | | 0.18 | | 0 |
| | DOLS | VAR | DOLS | VAR | DOLS | VAR | DOLS | VAR |
| C | -0.208 | 0.052 | 0.123** | -0.073 | 0.122** | -0.178 | 0.077** | -0.282 |
| RIR | 0.076* | -0.037** | -0.014** | 0.066** | -0.014** | 0.264** | -0.008** | 0.044** |
| CAPITA | -1.008 | 2.015** | -1.056** | 0.008 | -0.994** | -3.411 | -0.491 | -0.876 |
| OPEN | 0.345 | -0.891** | 0.767** | 1.542** | 0.72** | 10.292** | 0.804** | 0.577** |
| DEBT | -2.386** | 0.927** | -0.193** | 0.617 | -0.176** | 1.532 | 0.104 | 0.798** |
| NFA | -4.833** | -0.472 | -0.226 | 1.575 | -0.148 | 4.61 | 0.587** | 1.328** |
| Commodity | 0.719 | -0.658** | -0.152** | 0.567 | -0.179** | 1.92 | -0.177 | 0.759** |
| No. obs | 63 | | 78 | | 83 | | 45 | |
| ECM - $adj-R^2$ | 0.26 | | 0.36 | | 0.339 | | 0.28 | |
| ECM - SIC | -2.728 | | -2.924 | | -2.887 | | -2.694 | |
| LR - $adj-R^2$ | 0.953 | | 0.885 | | 0.894 | | | |
| LR - SIC | -2.011 | | -1.947 | | -1.979 | | | |
| | **Monthly data** | | | | | | | |
| | **1980:M1-2002:M3** | | **1980:M1-2007:M3** | | **1980:M1-2009:M6** | | **1994:M1-2009:M6** | |
| | DOLS | trace | DOLS | trace | DOLS | trace | DOLS | trace |
| UR/ r=0 | -5.824** | 139.97** | -5.871** | 149.49** | -5.694** | 157.02** | -4.239 | 122.51* |
| R=1 | | 88.84 | | 94.46** | | 101.32** | | 80.58 |
| R=2 | | 56.86 | | 58.76 | | 64.98* | | 46.05 |
| R=3 | | 33.53 | | 37.04 | | 39.93 | | 27.48 |
| ECT/r=4 | -0.064** | 18.01 | -0.068** | 20.06 | -0.073** | 20.97 | -0.072* | 12.28 |
| R=5 | | 7.45 | | 7.29 | | 6.45 | | 5.41 |
| R=6 | | 0.1 | | 1.3 | | 0.27 | | 0.24 |
| | DOLS | VAR | DOLS | VAR | DOLS | VAR | DOLS | VAR |
| C | 0.087** | 0.076 | 0.103** | 0.006 | 0.108** | 0.089 | 0.078** | -0.141 |
| RIR | -0.011** | -0.011 | -0.015** | 0.001 | -0.015** | -0.022 | -0.01** | 0.011 |
| CAPITA | -1.562** | 2.425** | -1.075** | 2.159** | -1.006** | 2.411** | -0.982 | -6.515** |
| OPEN | 0.764** | -1.604** | 0.742** | -2.707** | 0.704** | -4.129** | 0.747** | -0.656** |
| DEBT | -0.565** | 0.493 | -0.157** | -0.595** | -0.132** | -1.422** | 0.069 | 0.289 |
| NFA | -0.053 | 0.093 | -0.045 | -0.053 | -0.019 | -0.568 | 0.162** | 0.239 |
| Commodity | 0.079* | -0.809** | -0.149** | -0.576** | -0.183** | -0.824** | -0.142* | 1.251** |
| No. obs | 258 | | 318 | | 339 | | 180 | |
| ECM - $adj-R^2$ | 0.233 | | 0.226 | | 0.236 | | 0.179 | |
| ECM - SIC | -4.006 | | -3.996 | | -3.977 | | -3.858 | |
| LR - $adj-R^2$ | 0.882 | | 0.889 | | 0.897 | | 0.808 | |
| LR - SIC | -2.172 | | -2.135 | | -2.168 | | -2.265 | |

Notes: see Table 1a.

# 4 Alternative exchange rate models

## 4.1 Alternative real exchange rate models

We have seen previously that the real exchange rate models proposed in the literature are sensitive to alternative data specifications. The Frankel model is not stable over time and it probably is too narrow in focus while the MacDonald-Ricci model is not very robust across many dimensions probably because the included explanatory variables may be strongly correlated with each other.

Against this backdrop, we estimate real exchange rate models that have a wider focus than the Frankel model and that include a lower number of variables than the MacDonald-Ricci model. A convenient way of doing this is if we use the stock-flow approach to the real exchange rate, according to which the real exchange rate based on the CPI ( $Q^{CPI}$ ) can be linked to the dual productivity differential (PROD) and to net foreign assets (NFA)[5]. The basic stock-flow model can be augmented with real commodity prices (COMR). The reduced-form equation used is the following:

$$Q^{CPI} = f(\overset{+/-}{PROD}, \overset{+/-}{NFA}, \overset{-}{COMR}) \tag{6}$$

In general, the sign on the productivity variable is not straightforward. NOEM models predict that an increase in productivity in the open sector leads to a depreciation of the real exchange rate of the open sector (positive sign). However, the overall impact depends also on whether this effect is counterbalanced by the traditional B-S effect. The productivity variable of the open sector can also reflect nonprice competitiveness in the open sector and thus lead to a real appreciation (Egert et al, 2006).

The sign on net foreign assets is not unambiguous either. Generally, an increase in the net foreign assets position is usually associated with an appreciation of the real exchange rate because of capital inflows related to increasing payments received on net foreign assets (positive sign). However, in emerging market economies, domestic savings may be insufficient to finance the high growth potential. Thus, foreign savings are needed, the inflows of which reduce (increase) net foreign assets (net foreign liabilities) and cause the real exchange rate to appreciate. This implies a negative sign. However, there is a threshold for the net foreign assets position beyond which the sign is likely to switch because the domestic economy has to start servicing its foreign liabilities. Any additional increase in net foreign liabilities would lead to an appreciation of the real exchange rate.

We used three measures for real commodities prices. 1) a price index calculated using the same commodities and weights as in Frankel (2007), 2.) a price index calculated using the same commodities and weights as in MacDonald and Ricci (2004) and 3.) the price of gold. All three series are deflated using the US CPI index. A rise in real commodity prices is expected to lead to a real appreciation because it can cause nontradable prices to increase due to a number of reasons linked to the Dutch Disease[6] and because of the appreciation of the nominal exchange rate due to the inflow of export revenues and and FDI going to the commodity sector.

Table 2a hereafter shows the estimation results for the quarterly and monthly real effective exchange rate models obtained for the four sample periods. Using our criterion of two tests out of three evidencing cointegration, the series are cointegrated for the model including relative GDP per capita, net foreign assets and real commodity prices, irrespective of the time period and data frequency considered. The net foreign assets variable is a very robust driver of the real effective exchange rate as its sign and significance do not change across different time spans and data frequencies even though its size is considerable higher for quarterly data than for monthly data. The GDP per capita variable is always negatively signed but it is not always significant. Finally, a rise in the real commodity price index is found to generate an

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[5] See eg. Faruqee (1995); Aglietta et al.(1998) and Alberola et al.(1999, 2002).

[6] The relative price of nontradables may rise for three reasons. First, as part of the resource movement effect (when a rise in commodity price draws labour and capital from the non-commodity sectors to the commodity sector), nontradable prices increase because of the excess demand for nontradables, which is brought about by a fall in the supply owing to less labor in the nontradable sector. Second, as nominal and real wages increase in the commodity sector, wages will also rise in other parts of the economy provided wages tend to equalize across sectors. As a consequence of wage increases in the non-tradable sector, the relative price of non-tradable goods increases. Third, the relative price of nontradables rises in the event that higher profits and wages in the oil sector and the related tax revenues are spent on nontradable goods and provided the income elasticity of demand for nontradables is positive. This latter effect is also called the *spending effect*.

appreciation of the rand for three out of four sample sizes but the coefficient estimate for this variable become insignificant for the period from 1994 to 2009.[7]

We now add openness to the model (Table 2b). Openness seems to be a very robust driver of the rand's real effective exchange rate. A rise in openness always leads to a real depreciation – an effect usually observed in other empirical studies. Nevertheless, the cointegration finding is rather weak for the period of 1994q1 to 2009:q1. Furthermore, the GDP per capita variable switches sign (quarterly data), or becomes insignificant (monthly data) for this period and net foreign assets become insignificant for the quarterly estimations.[8]

When replacing openness with country risk (public debt) in the equations yields unsatisfactory results:[9] the public debt variable is either insignificant or has a negative sign meaning that higher country risk is reflected in currency appreciation.

[7] These results are unchanged when adding a linear trend to the specification.
[8] These results are unchanged if we add a linear trend tot he specification.
[9] These results are not reported here but are available upon request.

**Table 2a.** Estimation results, stock-flow model including commodity prices, real effective exchange rate

| | Quarterly data | | | | Monthly data | | | |
|---|---|---|---|---|---|---|---|---|
| | **1980-2002** | **1980-2007** | **1980-2009** | **1994-2009** | **1980-2002** | **1980-2007** | **1980-2009** | **1994-2009** |
| **COINTEGRATION TESTS** | | | | | | | | |
| UR | -2.627 (0) | -3.187 (0) | -3.624 (3) | -1.728 (0) | -3.438 (1) | -3.839 | -3.21 (1) | -2.158 (1) |
| ECT | -0.177** | -0.201*** | -0.129** | -0.203*** | -0.072*** | -0.074*** | -0.05*** | -0.061** |
| r=0 | 49** | 57.47*** | 56.85*** | 57.33*** | 55.83*** | 55.01*** | 49.67** | 47.73** |
| r=1 | 25.09 | 29.53* | 29.69** | 25.6 | 24.54 | 33.37** | 26.83* | 20.48 |
| **COEFFICIENT ESTIMATES** | | | | | | | | |
| **C** | 0.08*** | 0.075*** | 0.04* | 0.056** | 0.095*** | 0.083*** | 0.054*** | 0.049*** |
| **CAPITA** | -0.251 | -0.107 | -0.583*** | -2.504* | -0.216** | -0.191*** | -0.622*** | -1.143 |
| **NFA** | 1.197*** | 0.913*** | 0.954*** | 0.813*** | 0.473*** | 0.406*** | 0.416*** | 0.368*** |
| **COMMODITY** | -0.419*** | -0.501*** | -0.195*** | 0.108 | -0.468*** | -0.462*** | -0.188*** | -0.064 |
| No. of obs | 84 | 104 | 111 | 60 | 258 | 318 | 339 | 180 |
| ECM - $adj-R^2$ | 0.102 | 0.12 | 0.049 | 0.131 | 0.092 | 0.091 | 0.072 | 0.111 |
| ECM - SIC | -2.654 | -2.709 | -2.622 | -2.654 | -3.89 | -3.879 | -3.825 | -3.846 |
| LR - $adj-R^2$ | 0.768 | 0.773 | 0.72 | 0.444 | 0.73 | 0.764 | 0.717 | 0.44 |
| LR - SIC | -1.481 | -1.468 | -1.205 | -1.291 | -1.529 | -1.564 | -1.325 | -1.454 |

Notes: *, ** and *** indicate statistical significance at the 10%, 5 % and 1% levels. For the rest, as for Table 1a

**Table 2b.** Estimation results, stock-flow model including commodity prices and openness, real effective exchange rate

| | Quarterly data | | | | Monthly data | | | |
|---|---|---|---|---|---|---|---|---|
| | **1980-2002** | **1980-2007** | **1980-2009** | **1994-2009** | **1980-2002** | **1980-2007** | **1980-2009** | **1994-2009** |
| **COINTEGRATION TESTS** | | | | | | | | |
| UR | -2.657 (0) | -3.207 (0) | -3.257 (0) | -1.855 (0) | -3.772 (0) | -4.503** (0) | -4.604** (0) | -3.864 (1) |
| ECT | -0.154** | -0.199*** | -0.158** | 0.04 | -0.078*** | -0.085*** | -0.068*** | -0.088** |
| r=0 | 69.73** | 85.03*** | 81.34*** | 77.63*** | 88.87*** | 97.59*** | 87.93*** | 81.53*** |
| r=1 | 41.54 | 56.78*** | 52.75** | 39.7 | 41.92 | 52.8** | 48.24** | 42.1 |
| **COEFFICIENT ESTIMATES** | | | | | | | | |
| **C** | 0.075*** | 0.092*** | 0.08*** | 0.03* | 0.073*** | 0.078*** | 0.064*** | 0.034*** |
| **CAPITA** | -0.721*** | -0.585*** | -0.827*** | 4.736*** | -0.601*** | -0.612*** | -0.834*** | 0.704 |
| **NFA** | 0.383 | 0.208 | 0.134 | 0.177 | 0.139** | 0.137*** | 0.077** | 0.154*** |
| **COMMODITY** | -0.182** | -0.288*** | -0.148*** | -1.025*** | -0.279*** | -0.286*** | -0.159*** | -0.369*** |
| **OPENNESS** | 0.644*** | 0.706*** | 0.811*** | 0.914*** | 0.618*** | 0.672*** | 0.821*** | 0.922*** |
| No. of obs | 84 | 104 | 111 | 60 | 258 | 318 | 339 | 180 |
| ECM - $adj-R^2$ | 0.289 | 0.347 | 0.303 | 0.257 | 0.123 | 0.15 | 0.15 | 0.126 |
| ECM - SIC | -2.848 | -2.973 | -2.899 | -2.761 | -3.907 | -3.932 | -3.899 | -3.841 |
| LR - $adj-R^2$ | 0.842 | 0.86 | 0.856 | 0.908 | 0.816 | 0.855 | 0.863 | 0.798 |
| LR - SIC | -1.751 | -1.882 | -1.808 | -2.484 | -1.878 | -2.018 | -1.97 | -2.352 |

Notes: *, ** and *** indicate statistical significance at the 10%, 5 % and 1% levels. For the rest, as for Table 1a

We now turn to see how the models discussed above are able to track the evolution of the real exchange rate series, in particular the large depreciations around 2002 and 2008. We consider models reported in Table 1a, 2a and 2b. Variants of the MacDonald-Ricci (2004) model are not taken into consideration because of the problems we encountered earlier with regard to the coefficient estimates.

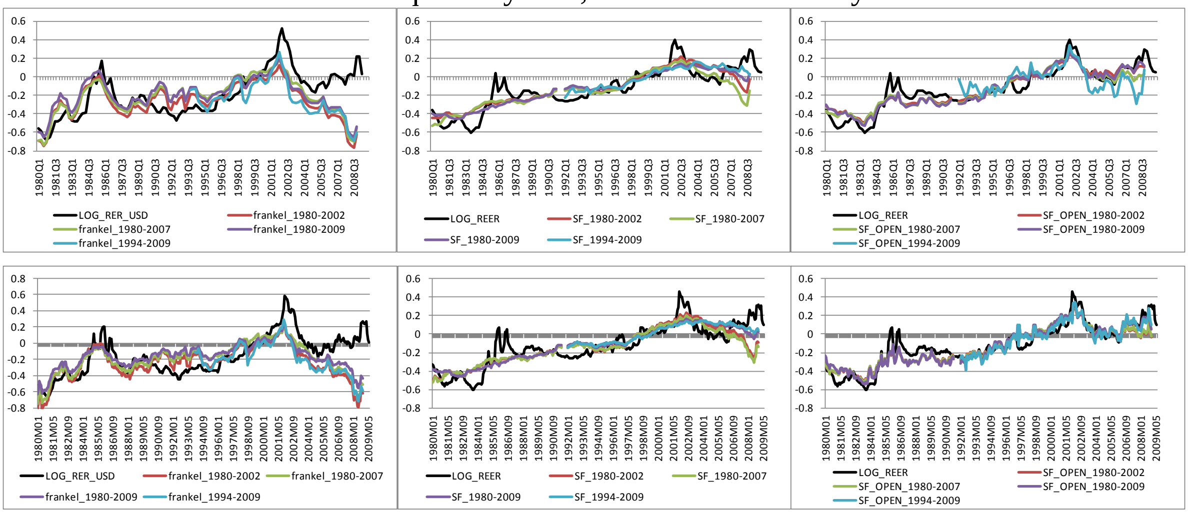
Figure 2 shows the fit of the individual models until 2009 even if a model is estimated only until 2002 or 2007. In this case, the fit of the model for the periods of 2002-2009 and 2007-2009 can be thought of as the out-of-sample forecast of the model, while the fit computed for the period for which the model is estimated shows in-sample forecasts. We do not carry out proper forecast accuracy comparisons because we focus on the two large depreciation episodes for which the figures are very informative.

The Frankel model can explain only part of the 2002 depreciation episode and it absolutely cannot follow the real exchange rate of the rand vis-à-vis the dollar. This indicates that the out-of-sample forecasting properties of the models estimated until 2002 and 2007 and the in-sample forecasting properties of the models estimated until 2009 are rather poor.

Stock-flow models including GDP per capita, net foreign assets and real commodity prices are not capable of explaining the dramatic depreciation around 2002 either. Nevertheless, they do not move as far away from the observed real exchange rate than the Frankel model.[10] It can be observed that models that are estimated until 2009 stay closer to the observed series than those that are estimated on a sample that stops in 2002 or 2007. This again is an indication that while these models seem to provide a little better in-sample forecasts for the exchange rate at period end, they perform rather poorly in terms of out-of-sample forecasts.

The stock-flow models augmented with openness appear to track exchange rate movements much better than the previous two classes of models. First, the models do a seemingly good job in explaining the large depreciation in 2002. Second, they can explain the evolution of the real exchange rate after 2002 and the depreciation in 2008. Nevertheless, the quarterly model estimated for 1994-2009 is very volatile after 2002, showing the reason of the no-cointegration finding for this model. In addition, while overall performing clearly better in-sample than the models analysed above, the model including openness estimated until 2002 has a worse fit towards the end of the full sample than those estimated until 2007 and 2009

**Figure 2.** Real exchange rate models, fit vs. actual series, 1980-2009
first row: quarterly data, second row: monthly data




Notes: Calculations based on the estimated equations reported in Tables 1a, 2a and 2b.

## 4.2 Alternative nominal exchange rate models

Instead of analysing the real exchange rate, one can also directly look at the drivers of the nominal exchange rate using the monetary model to the exchange rate. The basic monetary model includes relative money supplies, relative real GDP and the interest rate differential:

$$e_t = (m_t - m_t^*) - \beta_1 (y_t - y_t^*) + \beta_2 (i_t - i_t^*) \qquad (1)$$

where $e_t$ is the nominal exchange rate, expressed as units of domestic currency units over one unit of foreign currency (an increase means depreciation of the domestic currency). Equation (1) shows that a relative rise in money supply results in a nominal currency depreciation. An increase in relative real income causes a nominal depreciation. Regarding the effects of the interest rate, a rise in the long-term interest rate differential is related to a currency depreciation, in line with the uncovered interest parity condition. The basic monetary model can be extended in various ways to account for additional factors influencing the nominal exchange rate:

[10] Note that the Frankel model relates to the real exchange rate against the dollar while the stock-flow model is estimated for the real effective exchange rate. Figure 1 shows, however, that the two series move very closely together.

a.) ***Commodity prices:*** The standard monetary model can be tailored to capture the features of oil and commodity exporting countries. El Shazy (1989) introduces a wealth term in the money demand function of the net oil exporting domestic economy. The wealth term is related to the real value of oil reserves and is expressed as the relative price of oil exports to that of foreign tradable prices ($rp_t^{OIL} = p_t^{OIL} - p_t^*$) times expected oil reserves ($res_t^{OIL}$). Real commodity prices ($comr_t$) can be added to the money demand function using a similar line of reasoning that leads to the following testable equation:

$$e_t = m_t - m_t^* - \beta_1(y_t - y_t^*) - \beta_2(i_t - i_t) + \beta_3 comr_t \qquad (2)$$

b.) ***Balassa-Samuelson effect***: The Balassa-Samuelson augmented monetary model can be derived under the assumptions of money market equilibrium and that PPP holds for the open sector ($e = p_t^T - p_t^{T*}$)[11]. This gives the following relation where a rise in the productivity differential ($(a_t^T - a_t^{NT}) - (a_t^{T*} - a_t^{NT*})$) is expected to be associated with a nominal currency appreciation:

$$e_t = m_t - m_t^* - \beta_1(y_t - y_t^*) + \beta_2(i_t - i_t^*) - (1-\phi)((a_t^T - a_t^{NT}) - (a_t^{T*} - a_t^{NT*})) \qquad (3)$$

c.) ***Stock prices***: The literature on money demand functions emphasises that omitting asset prices such as stock prices is an important source of instability. Friedman (1988) argues that stock prices can influence money demand in four different ways. *The income effect* from a rise in wealth implies a positive relationship between stock prices and money as part of the capital gains may be held in liquid assets. *The substitution effect* can counteract the income effectwhen agents shift their liquid assets into more attractive stocks. *The transaction effect* says that if an increase in stock prices goes in tandem with higher transaction volumes requires more liquid assets to handle the transactions. *The volatility effect* occurs if an increase in stock prices is accompanied by more volatility, and if agents reallocate their assets away from more risky assets into less risky liquid assets. Overall, the impact of stock prices on money holdings is ambiguous. Consequently, if integrated into the monetary model, stock prices ($p_t^S$) can have a negative or positive effect on the nominal exchange rate:

$$e_t = m_t - m_t^* - \beta_1(y_t - y_t^*) + \beta_2(i_t - i_t^*) - \beta_4(p_t^S - p_t^{S*}) \qquad (4)$$

d.) ***Country risk premium***: If economic agents are risk averse, they may require a risk premium. Introducing a risk premium to the uncovered interest rate parity equation where $E_t(\Delta e_{t+k}) = -\theta(e_t - \bar{e}_t)$ allows us to append the risk premium ($\lambda_t$) to the monetary model (Frankel, 1979):

$$e_t = m_t - m_t^* - \beta_1(y_t - y_t^*) + \beta_3(i_t^{LT} - i_t^{LT*}) + \lambda_t \qquad (5)$$

Tables 3a to 3d show the estimation results for four variants of the monetary model for the nominal effective exchange rate: the basic monetary model and its versions augmented with real commodity prices, share prices and country risk premium. We do not report estimates for the model that accounts for the Balassa-Samuelson effect because the sign of the Balassa-Samuelson variable (productivity differential) is always positive instead of the expected negative sign implying the effect leading to a nominal depreciation.

A first general observation is that cointegration can be established only for the periods 1980-2007 and 1980-2009 but not for 1980-2002 and 1994-2009, irrespective of the data frequency

[11] For details, see Clements and Frankel (1980) and Crespo-Cuaresma et al (2005a,b).

and model specification considered. There are only two exceptions: the quarterly model including commodity prices for 1994 to 2009 and the monthly model including country risk for 1980 to 2002.

The coefficient estimates of the basic monetary model are always significantly different from zero and are in line with theoretical considerations set out above. An increase in relative GDP is associated with a nominal appreciation, whereas higher relative money supply and interest differential go in tandem with a nominal depreciation. The components of the basic monetary model are very robust to the inclusion of real commodity prices, real share prices or the country risk premium.

As far as the augmented versions of the monetary model are concerned, we can observe that the real commodity price variable is statistically significant with the expected negative sign for 1980-2007 but not for 1980-2009. If real share prices are added, real commodity prices have negative and statistically significant coefficient estimates. Nevertheless, statistical significance decreases again if real share prices are replaced by the country risk premium variable. Real share prices have a positive sign as well as the risk premium variable suggesting that a rise in both variables is associated with a nominal depreciation of the rand.[12]

We again compare the nominal effective exchange rate estimated on the basis of the above models and the actual exchange rate. Figure 3 depicts the fitted and observed series.[13] The basic monetary model seem to track well the overall development of the nominal effective exchange rate. Nevertheless, it fails to capture the two large depreciation periods and the appreciation that occurred between the two episodes. In addition, the quarterly model estimated from 1980:q1 to 2002:q1 appears to systematically underestimate the exchange rate since 2000.

The model including real commodity prices does have a slightly improved fit compared to the basic version: while it also misses the depreciation in 2002, it seems to capture a little better the end-period developments of the exchange rate. Nevertheless, this is only true for the estimated obtained for a sample ending in 2009. The models estimated on samples ending in 2002 and 2007 have bad out-of-sample fit.

Concerning the model incorporating share prices, the only major difference is that the model obtained for the period from 1994 to 2009 models well both depreciation periods. The other models perform similarly to the earlier variants of the monetary model presented above.

Finally, the monetary model augmented with the country risk premium fits the data very well after 2004 but it still is not capable of fully explaining the depreciation in 2002. Nevertheless, Figure 3 suggests huge differences for the quarterly and monthly models. The fit of the quarterly models estimated for 1980 to 2002 and 1994 to 2009 are way out of line with the observed exchange rate after 2000. Nevertheless, the fit of the monthly models is much better. Models obtained for 1980-2007, 1980-2009 and 1994-2009 all match the observed data very well after 2003.

[12] The coefficient estimates on relative GDP and money supply become unstable if we add a linear trend to the specification.

[13] Figure 3 shows data from 1990 to 2009. See the appendix for fit from 1980 to 2009.

**Table 3a.** Monetary model, nominal effective exchange rate

| | Quarterly data | | | | Monthly data | | | |
|---|---|---|---|---|---|---|---|---|
| | **1980-2002** | **1980-2007** | **1980-2009** | **1994-2009** | **1980-2002** | **1980-2007** | **1980-2009** | **1994-2009** |
| **COINTEGRATION TESTS** | | | | | | | | |
| UR | -1.196 | -3.564) | -3.677 | -3.029 | -3.124 | -3.807 | -3.964* | -2.163 |
| ECT | -0.068 | -0.132** | -0.156** | -0.115* | -0.039** | -0.047** | -0.054** | -0.042** |
| r=0 | 35.64 | 49.86** | 59.8** | 43.85 | 40.9 | 55.5** | 59.81** | 34.57 |
| r=1 | 16.61 | 25.18 | 30.53** | 23.25 | 19.51 | 28.66* | 30.43** | 18.09 |
| **COEFFICIENT ESTIMATES** | | | | | | | | |
| **C** | -0.539** | -0.381** | -0.399** | -0.355** | -0.325** | -0.359** | -0.393** | -0.378** |
| **RELTIVE GDP** | -2.457** | -2.511** | -2.209** | -2.432** | -2.472** | -2.582** | -2.234** | -2.276** |
| **RELATIVE M3** | 0.992** | 1.113** | 1.156** | 1.185** | 1.146** | 1.109** | 1.15** | 1.173** |
| **IRL** | 0.054** | 0.046** | 0.051** | 0.045** | 0.04** | 0.043** | 0.049** | 0.046** |
| No. of obs | 87 | 107 | 116 | 62 | 265 | 325 | 352 | 186 |
| ECM - $adj-R^2$ | 0.14 | 0.215 | 0.217 | 0.28 | 0.185 | 0.192 | 0.196 | 0.24 |
| ECM - SIC | -2.733 | -2.815 | -2.757 | -2.679 | -4.091 | -4.05 | -3.97 | -3.895 |
| LR - $adj-R^2$ | 0.985 | 0.978 | 0.979 | 0.829 | 0.976 | 0.978 | 0.978 | 0.832 |
| LR - SIC | -1.399 | -1.26 | -1.256 | -0.988 | -1.422 | -1.375 | -1.342 | -1.199 |

Notes: *, ** and *** indicate statistical significance at the 10%, 5 % and 1% levels. For the rest, as for Table 1a

**Table 3b.** Monetary model augmented with real commodity prices
Nominal effective exchange rate

| | Quarterly data | | | | Monthly data | | | |
|---|---|---|---|---|---|---|---|---|
| | **1980-2002** | **1980-2007** | **1980-2009** | **1994-2009** | **1980-2002** | **1980-2007** | **1980-2009** | **1994-2009** |
| **COINTEGRATION TESTS** | | | | | | | | |
| UR | -2.401 (0) | -3.39 (3) | -3.661 (3) | -2.737 (1) | -3.193 (1) | -3.779 (1) | -3.955 (1) | -2.274 (0) |
| ECT | 0 | -0.147*** | -0.155*** | -0.139** | -0.023 | -0.05*** | -0.054*** | -0.051** |
| r=0 | 67.77* | 66.64* | 74.96** | 69.19** | 89.48*** | 75.3** | 78.01*** | 60.06 |
| r=1 | 38.06 | 34.33 | 42.55 | 37.34 | 40.75 | 45.04* | 43.22 | 35.31 |
| **COEFFICIENT ESTIMATES** | | | | | | | | |
| **C** | -0.482*** | -0.294*** | -0.391*** | -0.067 | -0.438*** | -0.275*** | -0.381*** | -0.08 |
| **RELTIVE GDP** | -2.714*** | -2.283*** | -2.156*** | 0.923 | -2.64*** | -2.402*** | -2.172*** | 0.99* |
| **RELATIVE M3** | 1.54*** | 1.042*** | 1.153*** | 0.859*** | 1.376*** | 1.064*** | 1.148*** | 0.862*** |
| **IRL** | 0.054*** | 0.038*** | 0.051*** | 0.018 | 0.051*** | 0.036*** | 0.048*** | 0.022*** |
| **COMMODITY** | 0.689*** | -0.175** | -0.02 | -0.472*** | 0.389*** | -0.144*** | -0.024 | -0.468*** |
| No. of obs | 87 | 107 | 116 | 62 | 265 | 325 | 352 | 186 |
| ECM $adj-R^2$ | 0.125 | 0.22 | 0.217 | 0.35 | 0.171 | 0.194 | 0.201 | 0.287 |
| ECM SIC | -2.677 | -2.788 | -2.725 | -2.732 | -4.056 | -4.038 | -3.961 | -3.937 |
| LR $adj-R^2$ | 0.989 | 0.979 | 0.978 | 0.867 | 0.982 | 0.978 | 0.978 | 0.873 |
| LR SIC | -1.62 | -1.245 | -1.175 | -1.144 | -1.474 | -1.373 | -1.31 | -1.429 |

Notes: *, ** and *** indicate statistical significance at the 10%, 5 % and 1% levels. For the rest, as for Table 1a

**Table 3c.** Monetary model augmented with real commodity prices and real share prices
Nominal effective exchange rate

| | Quarterly data | | | | Monthly data | | | |
|---|---|---|---|---|---|---|---|---|
| | **1980-2002** | **1980-2007** | **1980-2009** | **1994-2009** | **1980-2002** | **1980-2007** | **1980-2009** | **1994-2009** |
| **COINTEGRATION TESTS** | | | | | | | | |
| UR | -3.021 (0) | -3.478 (0) | -3.799 (0) | -4.317 (0) | -3.188 (1) | -3.977 (1) | -4.217 (1) | -3.877 (0) |
| ECT | 0.045 | -0.163*** | -0.173*** | 0.035 | -0.038** | -0.055*** | -0.058*** | -0.008 |
| r=0 | 94.08* | 94.55** | 103.4*** | 103.16** | 121.79*** | 110.29*** | 110.78*** | 99.68** |
| r=1 | 62.19 | 58.75 | 65.11* | 65.35* | 67.29* | 72.25** | 68.36* | 56.66 |
| **COEFFICIENT ESTIMATES** | | | | | | | | |
| **C** | -0.584*** | -0.293*** | -0.376*** | -1.262*** | -0.335*** | -0.261*** | -0.346*** | -0.569*** |
| **RELTIVE GDP** | -4.238*** | -1.28*** | -1.057*** | -6.814*** | -1.755*** | -1.446*** | -1.107*** | -1.402*** |
| **RELATIVE M3** | 1.988*** | 0.839*** | 0.886*** | 1.443*** | 1.129*** | 0.864*** | 0.881*** | 1.009*** |
| **IRL** | 0.06*** | 0.039*** | 0.049*** | 0.159*** | 0.044*** | 0.036*** | 0.046*** | 0.078*** |
| **COMMODITY** | 1.288*** | -0.369*** | -0.271*** | -0.504*** | 0.018 | -0.329*** | -0.266*** | -0.627*** |
| **SHARE PRICES** | -0.277** | 0.242*** | 0.285*** | 1.37*** | 0.167*** | 0.233*** | 0.286*** | 0.65*** |
| No. of obs | 87 | 107 | 116 | 62 | 265 | 325 | 352 | 186 |
| ECM $adj-R^2$ | 0.13 | 0.237 | 0.244 | 0.358 | 0.177 | 0.194 | 0.201 | 0.287 |
| ECM SIC | -2.645 | -2.776 | -2.729 | -2.697 | -4.046 | -4.024 | -3.948 | -3.913 |
| LR $adj-R^2$ | 0.991 | 0.981 | 0.982 | 0.979 | 0.977 | 0.98 | 0.981 | 0.927 |
| LR SIC | -1.484 | -1.261 | -1.271 | -2.143 | -1.421 | -1.435 | -1.437 | -1.835 |

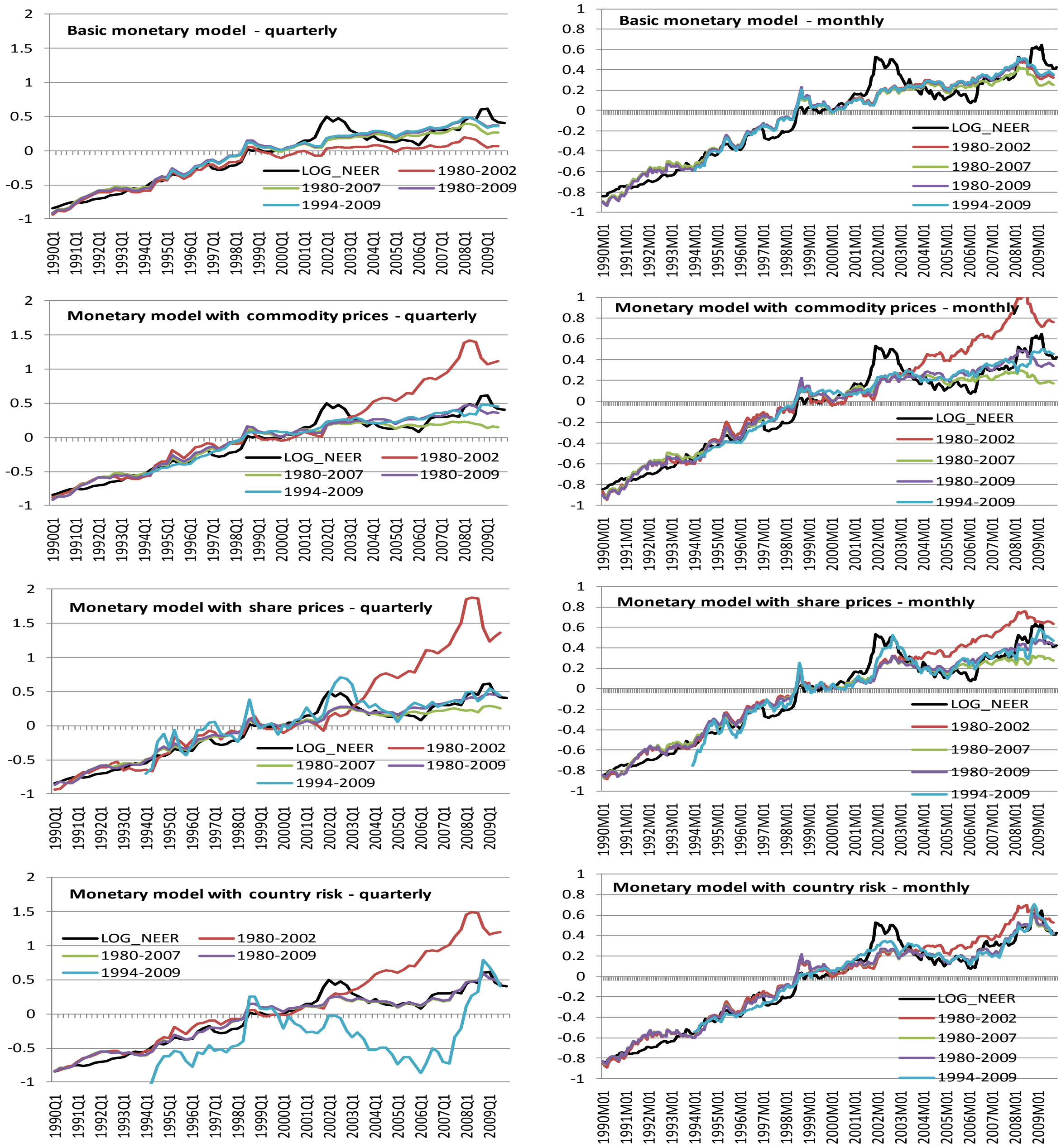
Notes: *, ** and *** indicate statistical significance at the 10%, 5 % and 1% levels. For the rest, as for Table 1a

**Table 3d.** Monetary model augmented with real commodity prices and country risk premium
Nominal effective exchange rate

| | Quarterly data | | | | Monthly data | | | |
|---|---|---|---|---|---|---|---|---|
| | **1980-2002** | **1980-2007** | **1980-2009** | **1994-2009** | **1980-2002** | **1980-2007** | **1980-2009** | **1994-2009** |
| **COINTEGRATION TESTS** | | | | | | | | |
| UR | -2.516 (0) | -3.304 (3) | -3.662 (3) | -1.254 (0) | -3.196 (1) | -3.809 (1) | -4.086 (1) | -3.859 (1) |
| ECT | -0.005 | -0.161*** | -0.169*** | -0.001 | -0.04** | -0.053*** | -0.057*** | -0.11*** |
| r=0 | 96.1** | 97.06** | 106.42*** | 84.38 | 112.17*** | 108.8*** | 106.52*** | 88.34 |
| r=1 | 61.17 | 52.72 | 61.65 | 51.1 | 61.32 | 60.06 | 60.43 | 60.65 |
| **COEFFICIENT ESTIMATES** | | | | | | | | |
| **C** | -0.344*** | -0.389*** | -0.37*** | -1.481*** | -0.379*** | -0.339*** | -0.334*** | -0.028 |
| **RELTIVE GDP** | -2.646*** | -0.84* | -0.877** | 3.138 | -1.826*** | -1.227*** | -1.13*** | -0.78** |
| **RELATIVE M3** | 1.554*** | 1.041*** | 1.05*** | 0.831*** | 1.178*** | 1.067*** | 1.065*** | 0.968*** |
| **IRL** | 0.041*** | 0.052*** | 0.05*** | 0.156*** | 0.048*** | 0.046*** | 0.046*** | 0.011** |
| **COMMODITY** | 0.679*** | -0.101 | -0.114* | -0.182 | 0.096 | -0.079* | -0.09*** | -0.199*** |
| **CONTRY RISK** | 0.109 | 0.462*** | 0.45*** | 1.646*** | 0.225*** | 0.386*** | 0.409*** | 0.755*** |
| No. of obs | 87 | 107 | 116 | 62 | 265 | 325 | 352 | 186 |
| ECM $adj-R^2$ | 0.121 | 0.255 | 0.295 | 0.395 | 0.182 | 0.212 | 0.249 | 0.395 |
| ECM SIC | -2.634 | -2.8 | -2.799 | -2.755 | -4.052 | -4.046 | -4.01 | -4.079 |
| LR $adj-R^2$ | 0.992 | 0.981 | 0.983 | 0.99 | 0.977 | 0.98 | 0.982 | 0.944 |
| LR SIC | -1.739 | -1.286 | -1.33 | -2.874 | -1.398 | -1.428 | -1.492 | -2.206 |

Notes: *, ** and *** indicate statistical significance at the 10%, 5 % and 1% levels. For the rest, as for Table 1a

**Figure 3.** Real exchange rate models, fit vs. actual series, 1990-2009




Notes: Calculations based on the estimated equations reported in Tables 3a to 3d.

# 5 Concluding Remarks

In this paper, we sought to address the stability and robustness of exchange rate models of the South African rand. Our empirical results showed that real exchange rate models of earlier research were sensitive to the sample period considered, alternative variable definitions, data frequencies and estimation methods. Alternative exchange rate models proposed in this paper - the stock-flow approach and variants of the monetary model - were also found to be not fully robust to data frequency and alternative estimation periods, either. In particular, it was difficult to establish cointegration for all periods considered and some coefficients estimates appeared to be unstable across the time and data frequency dimensions.

Nevertheless, adding openness to the stock-flow approach and augmenting the monetary model with share prices and the country risk premium improved significantly the fit of the models around the large (nominal and real) depreciation episodes of 2002 and 2008. While these models seem to do a reasonably good job in terms of in-sample forecasting, their out-of-sample forecasting properties remain poor.

Furthermore, while our results suggest that real commodity prices are important drivers of the real and nominal exchange rate, we also showed that coefficient estimates of that variable were somewhat sensitive to model specification and other parameters of the estimations and that including real commodity prices in real and nominal exchange rate models did not help too much improve the in-sample fit of the models. In particular, commodity prices cannot explain the large deprecations observed around 2002 and 2008.

# References

Aglietta, M., C. Baulant and V. Coudert. 1997. Why the euro will be strong: an approach based on equilibrium exchange rates. CEPII document de travail No. 18. Paris.

Alberola, E., S. G. Cervero, H. Lopez and A. Ubide. 1999. Global Equilibrium Exchange Rates: Euro, Dollar, “Ins,” “Outs,” and Other Major Currencies in a Panel Cointegration Framework. IMF Working Paper No. 175.

Alberola, E., S. G. Cervero, H. Lopez and A. Ubide. 2002. Quo vadis Euro? The European Journal of Finance. 8. 352-370.

Bailliu, Jeannine, Ali Dib, Takashi Kano and Lawrence Schembri. 2007. Multilateral Adjustment and Exchange Rate Dynamics: The Case of Three Commodity Currencies. Bank of Canada Working Paper No. 2007-41.

Broome, Simon and Bruce Morley. 2003. Stock prices and the monetary model of the exchange rate: An empirical investigation. Mimeo.

Cashin, Paul, Luis F Cespedes and Ratna Sahay 2004. Commodity currencies and the real exchange rate. Journal of Development Economics 75(1). 239-268.

Chen, Yu-chin and Kenneth Rogoff 2003. Commodity currencies. Journal of International Economics 60(1). 133-160

Chinn, Menzie D. 1999. A monetary model of the South African Rand. African Finance Journal. 1(1). 69-91.

Clements, K. W. and Frenkel, J. A. 1980. Exchange rates, money, and relative prices: The dollar–pound in the 1920s. Journal of International Economics. 10. 249–62.

Crespo-Cuaresma, Jesus., Jarko Fidrmuc and Maria-Antoinette. Silgoner. 2005b. On the road: The path of Bulgaria, Croatia and Romania to the EU and the euro. Europe-Asia Studies. 57. 843-858.

Crespo-Cuaresma, Jesus., Jarko Fidrmuc and Ronald MacDonald. 2005a. The monetary approach to exchange rates in the CEECs. Economics of Transition. 13 (2). 395-416.

Egert, Balazs, Kirsten Lommatzsch and Amina Lahrèche-Révil. 2006. Real exchange rates in small open OECD and transition economies: Comparing apples with oranges? Journal of Banking and Finance. 30(12). 3393-3406.

El Shazly, MR. 1989. The oil-price effect on the dollar/pound rate of exchange. International Economic Journal. 3(3). 73–83.

Faruqee, H. 1995. Long-Run Determinants of the Real Exchange Rate: A Stock-Flow Perspective. IMF Staff Papers. 42(1). 80-107.

Frankel, Jeffrey 2007. On The Rand: Determinants Of The South African Exchange Rate. South African Journal of Economics 75(3), 425-441.

Friedman, Milton. 1988. Money and stock market. Journal of Political Economy. 96(2). 221-245.

Gruen, David and Tro Kortian 1996. Why Does the Australian Dollar Move so Closely with the Terms of Trade? Reserve Bank of Australia Research Discussion Papers No. 9601.

Hjalmarsson, Erik and Pär Österholm. 2007. Testing for Cointegration using the Johansen Methodology when Variables are Near Integrated. IMF Working Paper 141/07.

Kremers, Jeroen J.M., Neil. R. Ericsson and Juan J. Dolado. 1992. The power of cointegration tests. Oxford Bulletin of Economics and Statistics. 54(3). 325-348.

MacDonald, Ronald and Luca Antonio Ricci 2004. Estimation Of The Equilibrium Real Exchange Rate For South Africa. South African Journal of Economics 72(2). 282-304.

MacKinnon, J. G. 1991. Critical values for co-integration tests, in R.F. Engle and C.W.J. Granger (eds.). Long-run economic relationships. Oxford University Press. 267-276.

Mtonga, Elvis 2006. The real exchange rate of the rand and competitiveness of South Africa's trade. MPRA Paper 1192. University Library of Munich.

Odedokun, M. 1997. The monetary approach to analyzing floating exchange rate behaviour in developing countries: evidence from Sub-saharian African Countries, 1986-1992. Journal of Development Economics, 52(2), pp 463-481.

Osterwald-Lenum, Michael. 1992. A note with quantiles of the asymptotic distribution of the maximum likelihood cointegration rank test statistics. Oxford Bulletin of Economics and Statists. 54(3). 461-472.

Reimers, H-E. 1992. Comparison of tests for multivariate cointegration. Statistical Papers. 33. 335-359.

Stock,J. and M. Watson. 1993. A simple estimator of cointegrating vectors in higher order integrated systems. Econometrica, 61 (4).

# Appendix A. – Data Sources and Description

## *Real exchange rate models*

**Real exchange rate deflated by the CPI (monthly):** nominal exchange rate multiplied by foreign prices over domestic prices.

*Nominal exchange rate*

South African rand/USD: IFS/IMF (via Datastream, code: SAI..AF)
South African rand/euro: derived using the ZAR/USD exchange rate and the USD/EUR exchange rates. USD/EUR: Bank of England (via Datastream, code: BDXRUSE)
South African rand/GBP: derived using the USD/GBR cross rate, Datastream, code: UKOCC015
South African rand/JPN: derived using the USD/JPN cross rate IFS/IMF (via Datastream, code: JPI..AF)

*CPI*

South Africa: Main Economic Indicators/OECD (via Datastream code: SAOCP009F)
US economy: Main Economic Indicators/OECD (via Datastream, code: USOCP009E)
Euro area proxied by Germany: Main Economic Indicators/OECD (via Datastream, code: BDOCP009F)
United Kingdom: Main Economic Indicators/OECD (via Datastream, code: UKOCP009F)
Japan: Main Economic Indicators/OECD (via Datastream, code: JPOCP009F)

**Real exchange rate deflated by the PPI (monthly)**

*Nominal exchange rate*

*PPI*

South Africa: IFS/IMF (via Datastream code: SAI63...F)
US economy: IFS/IMF (via Datastream, code: USI63...F)

**Real interest rate differential (monthly):** nominal interest rate deflated by y-o-y CPI, (t+4/t for the Frankel model and t/t-4 for the MacDonald and Ricci model), relative to trading partners

*Long-term interest rates* (long-term government bond yield) (monthly)

South Africa: IFS/IMF (via Datastream, code: SAI61...)
US economy: IFS/IMF (via Datastream, code: USI61...)
Euro area proxied by Germany: IFS/IMF (via Datastream, code: BDI61...)
United Kingdom: IFS/IMF (via Datastream, code: UKI61...)
Japan: IFS/IMF (via Datastream, code: JPI61...)

**Real commodity prices** (monthly)**:**

*Frankel definition*, weighted nominal prices deflated by US CPI

**Gold, 56.22%,** UK London gold price, Datastream code: UKI..C..A
**Coal, 18.23%,** IMF, http://www.imf.org/external/np/res/commod/index.asp
**Iron, 8.9%,** IMF, http://www.imf.org/external/np/res/commod/index.asp
**Oil, 9.01%,** IMF, http://www.imf.org/external/np/res/commod/index.asp
**Aluminium, 7.64%,** IMF, http://www.imf.org/external/np/res/commod/index.asp

*MacDonald-Ricci definition*, weighted nominal prices deflated by US CPI

**Gold, 71%,** UK London gold price, Datastream code: UKI..C..A
**Coal, 17.7%,** IMF, http://www.imf.org/external/np/res/commod/index.asp
**Iron, 3.9%,** IMF, http://www.imf.org/external/np/res/commod/index.asp
**Copper, 3.8%,** IMF, http://www.imf.org/external/np/res/commod/index.asp
**Platinum, 3.6**%, London Platinum Free Market $/Troy oz, Datastream code: PLATFRE

*Real gold price*: nominal gold price deflated by US CPI

**Real GDP per capita, relative to trading partners**

*Real GDP* (quarterly data, interpolated to monthly frequency if needed)

South Africa: Main Economic Indicators/OECD (via Datastream, code: SAOSN029C), NSA
US economy: Quarterly National Accounts/OECD (via Datastream, code: USOEXP03D)
Euro area proxied by Germany: IFS/IMF (via Datastream, code: BDI99BVRG)
United Kingdom: Quarterly National Accounts/OECD (via Datastream, code: UKOEXP03D)
Japan: Quarterly National Accounts/OECD (via Datastream, code: JP2EXP03D (prior to 2004, JPGDP...D (after 2004))

*Population*

South Africa (annual): Main Datastream, code: SAI99Z..O
US economy (quarterly): Datastream, code: USPOPNIQH
Euro area proxied by Germany (quarterly): Datastream, code: BDPOPTOTP
United Kingdom (quarterly): Datastream, code: UKESENP.O
Japan (annual): Datastream code: JPI99Z..O

**Net foreign assets** (1970:m1 – 2007:m3), net foreign assets of the banking sector over nominal GDP
Net foreign assets, South Africa, IFS/IMF monetary survey (Datastream code: SAI31N..A)
Nominal GDP, if needed interpolated linearly from quarterly to monthly frequency

South Africa: IFS/IMF (via Datastream, code: SAI99B.CB)

**Openness,** Export + import of goods over nominal GDP
*Total trade*. Main Economic Indicators/OECD, exports from South Africa and imports to South Africa (via Datastream, exports: SAOXT$03A, imports: SAOXT$09A)
Nominal GDP, see net foreign assets

**Government debt to GDP relative to trading partners**
*Government debt* (monthly)

South Africa (monthly): Central government debt, Datastream code: SAI99B.CB
US economy (quarterly): Gross public debt as % of GDP, Datastream code: USEBQDGD%
Euro area proxied by Germany (monthly): Datastream code: BDL99B.CB)
United Kingdom (quarterly): Public sector net debt as % of GDP, Datastream, code: UKRUTOQ.
Japan (monthly): Datastream code: JPDBTGOVA

*Nominal GDP* (quarterly), if needed interpolated linearly from quarterly to monthly frequency

South Africa: IFS/IMF (via Datastream, code: SAI99B.CB)
US economy: IFS/IMF (via Datastream, code: USI99B.CB)
Euro area proxied by Germany: IFS/IMF (via Datastream, code: BDL99B.CB)
United Kingdom: IFS/IMF (via Datastream, code: UKI99B.CB)
Japan: IFS/IMF (via Datastream, code: JPI99B.CB)

# *Monetary model*

**Nominal exchange rates** (monthly data) see real exchange rate model
**Real GDP**, see real exchange rate model, relative to trading partners
**Money supply (M3)** (monthly), relative to trading partners:

South Africa: Main Economic Indicators/OECD (via Datastream, code: SAOMA013B)
US economy: Main Economic Indicators/OECD (via Datastream, code: USOMA013B)
Euro area proxied by Germany: Deutsche Bundesbank (via Datastream, code: BDM3....B)
United Kingdom: M4, Main Economic Indicators/OECD (via Datastream, code: UKOMA019B) (interpolated linearly from quarterly to monthly from 1970 to 1979)
Japan: M3+, Bank of Japan (via Datastream, code: JPM3CDF.A)

**Long-term nominal interest rate** (monthly)**:** see real exchange rate model
**Real commodity prices** (monthly)**:** see real exchange rate model
**Stock market indices** (monthly), relative to trading partners (monthly)

South Africa: Datastream total market stock price, code: SASHRPRCF
US economy: New York Stock Exchange Composite Index, Financial Times (via Datastream, code: USNYSCOM)
Euro area proxied by Germany: CDAX, Main Economic Indicators/OECD (via Datastream, code: BDOSP001F)
United Kingdom: FTSE 100 Share Price Index, Main Economic Indicators/OECD (via Datastream, code: UKOSP001F)
Japan: Tokyo Stock Exchange TOPIX (via Datastream, code: JPOSP001F)

**Risk premium** (monthly)

Relative government debt until normalised by its standard deviation until 2000:1, linked to JP Morgan EMBI index (emerging market bond index) for South Africa (USD-denominated South African government bond yield relative to the yield of US government bond) also normalised by its standard deviation.

**Productivity differential (Balassa-Samuelson effect):** Industrial production in manufacturing divided by employment in manufacturing. As data is not available for services, productivity in this sector is assumed to be equal to 0 in all five economies. If productivity gains are comparable in the four economies, this zero growth assumption has little effect on the variable.

Industrial production in manufacturing (monthly data)

(except UK: industrial production in industry)

South Africa: Main Economic Indicators/OECD (via Datastream, code: SAOL1105G)

US economy: Main Economic Indicators/OECD (via Datastream, code: USOPRI38G)

Euro area proxied by Germany: Main Economic Indicators/OECD (via Datastream, code: BDOCIPIGG)

United Kingdom: IFS/IMF (via Datastream, code: UKI66..IG)

Japan: Main Economic Indicators/OECD (via Datastream, code: JPOPRI38G)

Employment in manufacturing (monthly and quarterly)

(except UK: employment in industry, data for South Africa and UK are interpolated linearly from quarterly to monthly frequency)

South Africa (quarterly): Datastream code: SAEMPTMUG

US economy (monthly): Main Economic Indicators/OECD (via Datastream, code: USOEM006O)

Euro area proxied by Germany (monthly): Main Economic Indicators/OECD (via Datastream, code: BDOEM006P) (the data are adjusted for the observed jump in 1991 of around 20 million due to data reclassification)

United Kingdom (quarterly): IFS/IMF (via Datastream, code: UKOEM026H)

Japan (monthly): Main Economic Indicators/OECD (via Datastream, code: JPOEM006G)

The effective variables are computed as the weighted average of the four foreign economies (US, euro area, UK, Japan). The weights are obtained from the South African Reserve Bank's website. Normalised weights (original weights) Euro area: 46.9% (36.38%), US: 19.9% (15.47), UK: 19.8% (15.37), Japan: 13.4% (10.43). The SARB revised the weights in 2005 by increasing the weight in China from 3.14% to 12.49%. We decided to use the weights prior to the revision mostly because of the problems related to obtain the Chinese data series necessary for our empirical analysis.

# Appendix B. – Fit of the monetary model, 1980-2009