

Estimating an Econometric Model of the Rand-USD Nominal Exchange Rate

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Abstract

Modeling the nominal exchange rate has been one of the most difficult exercises in economics. This paper attempts to estimate the nominal Rand-USD exchange rate under the Dornbusch overshooting exchange rate theory using the Johansen cointegration technique. The coefficients of all the variables estimated in the model are statistically significant and consistent with Dornbusch's exchange rate overshooting theory. The movement of the nominal Rand-USD exchange rate during the post-Apartheid period appears to follow the Dornbusch exchange rate overshooting theory. This shows that any monetary policy strategy to strengthen or weaken the Rand by means of raising or cutting interest rate will not be destined to deliver the intended outcome in both the short and long term.

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1. INTRODUCTION

South Africa has adopted various exchange rate regimes spanning over the fixed system to dual and then to single exchange rate regime of the present day. The value of the Rand has been volatile since the country's latest measure to abolish the dual exchange rate system in its entirety in the wake of the country's new political dispensation. The stability of the nominal exchange rate of the Rand plays significant role in the successful performance of the country's economy. The nominal exchange rate also is more visible than the real exchange rate to the ordinary public. Despite these compelling facts, little has been done to understand the dynamism and identify those major economic fundamentals that drive the movement of the Rand. This paper attempts to estimate the Rand-USD exchange rate model using the Johansen (1988) cointegration technique. The Dornbusch overshooting theory forms the principal theoretical foundation of the model estimated in this paper.

The floating exchange rate models that have been developed since the 1970s assumes either flexible or sticky prices in the short run. Taylor (1995) argues that the flexible-price monetary model is, implicitly, a market clearing general equilibrium model in which continuous purchasing power parity among national price levels is assumed. Besides the classification of the various exchange rate models along the line of the degree of flexibility of prices, Frankel (1979) categorizes the various floating exchange rate models under the monetary or asset view. The two different approaches he identified under the asset view have conflicting implications in particular for the relationship between the exchange rate and the interest rate.

Frankel (1979) named the first approach the "Chicago" theory because it assumes that prices are perfectly flexible. Pursuant to the flexible-price assumption, changes in the nominal interest rate reflect changes in the expected inflation rate. The purchasing power parity and the International Fisher Effect appear to reflect the Chicago theory, though the length of time during which they are examined matters significantly. When the domestic interest rate rises relative to the foreign interest rate, the domestic currency is expected to lose value through inflation and depreciation. He argues that the Chicago theory is a realistic description when variation in the inflation differential is large, as in the German hyperinflation. The second approach can be referred to as the Keynesian theory because it assumes that prices are sticky, at least in the short run. According to the sticky price assumption, changes in the nominal interest rate

reflect changes in the tightness of monetary policy. When the domestic interest rate rises relative to the foreign rate it is because there has been a contraction in the domestic money supply relative to the domestic money demand without a matching fall in prices. The higher interest rate at home than abroad attracts a capital inflow, which causes the domestic currency to appreciate instantly. The Keynesian theory is a realistic description when variation in the inflation differential is small, as in the Canadian float against the United States in the 1950s.

There are a number of empirical studies that proved the failure of the purchasing power parity to hold continuously in practice. Thus, the flexible-price monetarist model is of no use in explaining the observed prolonged departures from PPP since the adoption of floating exchange rates. The Dornbusch's sticky price monetarist model is believed to explain large and prolonged departures of the exchange rate from PPP. The basis underlying the model is that prices in the goods market and wages in the labour market are determined in sticky-price markets, and they only tend to change slowly over time in response to various shocks such as changes in the money supply. Prices and wages are especially resistant to downward pressure. However, the exchange rate is determined in a flexible-price market, it can immediately appreciate or depreciate in response to new developments and shocks. In such circumstances, exchange rate changes are not matched by corresponding price movements and there can be persistent and prolonged departures from PPP.

The sticky-price and overshooting model of exchange rate allow short-term overshooting of the nominal and real exchange rates above their long-run equilibrium levels. Taylor (1995) said that this results as the "jump variables" in the system – exchange rates and interest rates – compensate for stickiness in other variables, notably goods prices. Therefore, the principal assumption that forms the basis of overshooting is that the domestic price level does not move instantaneously in response to unanticipated monetary disturbances, but adjusts only slowly over time. Output is considered exogenous to the model (it moves sluggishly in response to monetary shocks). The assumptions also include that money is neutral in the long run, so that a permanent rise in money supply leads to a proportionate rise in exchange rate and domestic price level in the long run.

Rogoff (2002) in his Mundell-Fleming Lecture at the IMF's Second Annual Research Conference highlighted what he believes the true strength of the Dornbusch's

exchange rate overshooting model. In his own words, "... the true strength of the model lies in that it highlights how, in today's modern-economies, one needs to think about the interaction of sluggishly adjusting goods markets and hyperactive asset markets." He further indicated that one has to realize that at the time Dornbusch was writing, the world had just made the transition from fixed to flexible exchange rates.

In spite of the theoretical nicety of the Dornbusch's overshooting theory, empirical testing does not appear to support the theory in quite a number of studies. Rogoff (2002), despite its appreciation of the overshooting theoretical foundations, agrees that the model does not seem to capture all big exchange rate swings that regularly take place except the few instances (e.g., the Volker deflation of the early 1980s in the US and the Thatcher deflation of the late 1970s in Britain) when it seems to capture major turning points in monetary policy quite well. Particularly, at horizons of up to one year, Rogoff (1999) argues that using rolling regressions to estimate a variety of state-of-the-art monetary exchange rate models, none could outperform the predictions of a simple random walk model.

The number of studies that have been done in line with either of the Dornbusch's or Frankel's approach are very limited in South Africa. Brink and Koekemoer (2000) estimated the Dornbusch's version of the monetary model for South Africa using the three-step Engle and Yoo cointegration procedure. Their model employed nominal money supply, real GDP, and inflation rate of South Africa relative to those of the US. The long run coefficients are consistent with the Dornbusch's sticky price theory and statistically significant.

The remaining of the paper is structured as follows. Section three attempts to shed some light on the general framework and identify the similarities and differences that exist between the Dornbusch sticky-price overshooting theoretical model and the one developed later by Frankel (1980). The main assumptions underlying the Dornbusch model will also be briefly discussed. The specific model that will be estimated and the data that will be used in the study are explained in this same section. Important tests of seasonal unit root, granger causality, diagnostic tests on the VAR model and the cointegration tests will be separately discussed in the third section. Section four discusses in detail the estimation output from the vector error correction model and examines the statistical and economic significance of the coefficients estimated for

each of the variables and cointegrating vectors included in the model. Section five concludes by highlighting the major findings of the study.

2. METHODOLOGY

2.1 Theoretical framework

The empirical model estimated by Dornbusch (1980) and the model later estimated by Frankel (1979) build on the real money demand function. The models begin with expressing the function of real money demand in logarithmic notation.

$$\text{Home country: } p = m - \beta y + \delta i \dots\dots\dots [1]$$

$$\text{Foreign country: } p^* = m^* - \beta y^* + \delta i^* \dots\dots\dots [2]$$

Combining equation 1 and 2 and assuming that the purchasing power parity condition holds in the long run give us:

$$e = p - p^* = (m - m^*) - \beta(y - y^*) + \delta(i - i^*) \dots\dots\dots [3]$$

In this paper, equation 3 is estimated to see whether the Rand-USD exchange rate follows the Dornbusch's overshooting model since the abolition of the dual exchange rate system in South Africa. Equation 3 establishes that relative changes in money supply, interest rate, and real income affect the exchange rate.

However, the model that was estimated by Frankel (1979) is different to some extent from equation 3 because of introducing two additional assumptions. The first, interest rate parity, is associated with efficient markets in which the bonds of different countries are perfect substitutes:

$$d = i - i^* \dots\dots\dots [4]$$

The second fundamental assumption is that the expected rate of depreciation is a function of the gap between the current spot rate and an equilibrium rate, and of the expected long-run inflation differential between the domestic and foreign countries:

$$d = -\theta(e - \bar{e}) + \pi - \pi^* \dots\dots\dots [5]$$

where e is the log of the spot rate; π and π^* are the current rates of expected long-run inflation at home and abroad, respectively.

Combining equations 4 and 5 yields:

$$e - \bar{e} = -\frac{1}{\theta} [(i - \pi) - (i^* - \pi^*)] \dots\dots\dots [6]$$

Frankel (1979) argues that the expression in brackets can be described as the real interest differential. Using bars to denote equilibrium values, Frankel (1979) further argues that when $e = \bar{e}$, $\bar{i} - \bar{i}^* = \pi - \pi^*$ in the long run and expressed equation 3 as follows.

$$\bar{e} = \bar{p} - \bar{p}^* = \bar{m} - \bar{m}^* - \beta(\bar{y} - \bar{y}^*) + \delta(\pi - \pi^*) \dots\dots\dots [7]$$

Further more, substituting equation 7 into equation 6 and assuming that the current equilibrium money supplies and income levels are given by their current actual levels, we obtain a complete equation of spot rate determination given below.

$$e = m - m^* - \beta(y - y^*) - \frac{1}{\theta}(i - i^*) + \left(\frac{1}{\theta} + \delta\right)(\pi - \pi^*) \dots\dots\dots [8]$$

Equation 8 can simply be expressed with an error term as follows.

$$e = m - m^* - \beta(y - y^*) + \alpha(i - i^*) + \varphi(\pi - \pi^*) + u \dots\dots\dots [9]$$

where $\alpha (= -1/\theta)$ is hypothesized negative and $\varphi (= 1/\theta + \delta)$ is hypothesized positive and greater than α in absolute value. The innovation that was introduced by Frankel (1979) aims at combining the Keynesian assumption of sticky price with the Chicago assumption that there are secular rates of inflation. Unlike the original hypothesis concerning the relationship between the exchange rate and the nominal interest rate differential, it then turns out that the exchange rate is negatively related to the nominal interest differential, but positively related to the expected long run-inflation differential.

The main difference between the models of Dornbusch and Frankel lie in the hypothesised sign of the coefficient of the nominal interest rate in their equations. Unlike the hypothesized negative sign in the Frankel model, Dornbusch argues that relatively higher domestic interest rates reduce the demand for real balances, raise prices, and therefore bring about an exchange depreciation, i.e., positive coefficient of the interest rate.

2.2 The model

As clearly indicated above, the Dornbusch version of sticky price monetary model will be estimated using the Johansen (1988) technique to model the nominal Rand-USD exchange rate. We would like to make it clear that our use of this specific model should not in any way be understood that it is the best of all the models out there. As we made it clear earlier that our main objectives in this paper are modelling the nominal Rand-USD exchange rate while we would also like to test whether the South African economy works according to the overshooting and sticky price theory of Dornbusch (1980).

The model that is estimated in this study involves a VAR setting including the Rand-USD nominal exchange rate, the natural log of the ratio of South African nominal money supply to the US money supply, the ratio of South African real GDP to US real GDP, the ratio of South African nominal TB rate to the US TB rate and ratio of consumer price index of South Africa relative to the US. The model that we will estimate in this paper is given below with the expected sign of the coefficients hypothesized by Dornbusch (1980).

$$\ln_XR = f\left(\begin{matrix} (+) & & (-) & & (+) \\ \ln\left[\frac{M3_SA}{M3_US}\right]; & \ln\left[\frac{rGDP_SA}{rGDP_US}\right]; & \ln\left[\frac{TBR_SA}{TBR_US}\right] \end{matrix} \right) \dots\dots\dots [10]$$

As can be clear from equation 3, the money supply is restricted to be one in our model since an increase in the relative money supply at home is hypothesized to lead to an equiproportionate depreciation (Dornbusch, 1980; Frankel, 1979). Consistent with the monetary approach, we expect negative sign of the coefficient for the real GDP differential. A negative sign is expected on the difference of nominal interest rate differential expressed in natural log.

To operationalize the Johansen (1988) procedure, we estimated an unrestricted VAR as follows:

$$X_t = \beta_0 + \beta_1 X_{t-1} + \dots + \beta_j X_{t-j} + \Omega D + \varepsilon_t \dots\dots\dots [11]$$

Where

$$X'_t = [\ln_XR \text{ Dif_ln_M3 } \text{ Dif_ln_rGDP } \text{ Dif_ln_TBR } \text{ Dif_ln_CPI}]$$

XR is the exchange rate expressed as the amount of Rand per unit of US dollar;

R_M3 is the ratio of South African nominal money supply to US money supply;

R_rGDP stands for the ratio of South African real GDP to US real GDP;

R_TBR is the ratio of nominal TB rate of South Africa to that of the U.S.; and

R_CPI is the ratio of consumer price index in South Africa relative to the US.

All the variables are expressed in natural log form.

Along with the long-term relationship that is captured by the Dornbusch model specified in equation 3, a VECM (Vector Error Correction Model) of the following form will be estimated to see the short run exchange rate dynamics.

$$\Delta X_t = \pi X_{t-1} + \sum_{i=1}^{p-1} \pi_i \Delta X_{t-i} + \varepsilon_t \dots\dots\dots[12]$$

2.3 Data

Quarterly data is collected for all the variables from IMF's international financial statistics, the South African Reserve Bank, and Bureau of Economic Analysis of the U.S. Department of Commerce. We used seasonally adjusted data on all the variables. We managed to get seasonally adjusted nominal money supply and real GDP data from the IMF international financial statistics. Because of the unavailability of seasonally adjusted data on the other variables included in our model, we adjusted these variables for seasonality using moving average technique. We limited our study to the period covering 1994Q1 to 2004Q4 since variability in the exchange rate of the Rand was restricted via the dual exchange rate regime and strict exchange control regulations being adopted prior to 1994. South Africa maintained some form of fixed exchange rate system until the year 1979 since the collapse of the Bretton Woods arrangement. Later, the dual exchange rate system had been conceived as a transitory measure to a unitary exchange rate regime. As a result, the country had been subscribing to the dual exchange rate regime during the majority of the years of the 1980s and first half of the 1990s. Even though it is not purely floating, it is only after 1994 that the Rand was allowed to fluctuate according to the demand and supply in the foreign exchange market. It is also after 1994 that the country has started to open itself to international scrutiny and extensive economic transactions.

3. RESULTS OF RELEVANT TESTS ON THE VAR AND COINTEGRATION

3.1 Tests for unit root

All the variables included in the model are tested for unit root. One can easily see from the following graphical representations that most of the variables appear to be non-stationary. Given the limited number of observations examined in the paper, it would be difficult to determine the level of integration of each of the variables from the graphical representation.

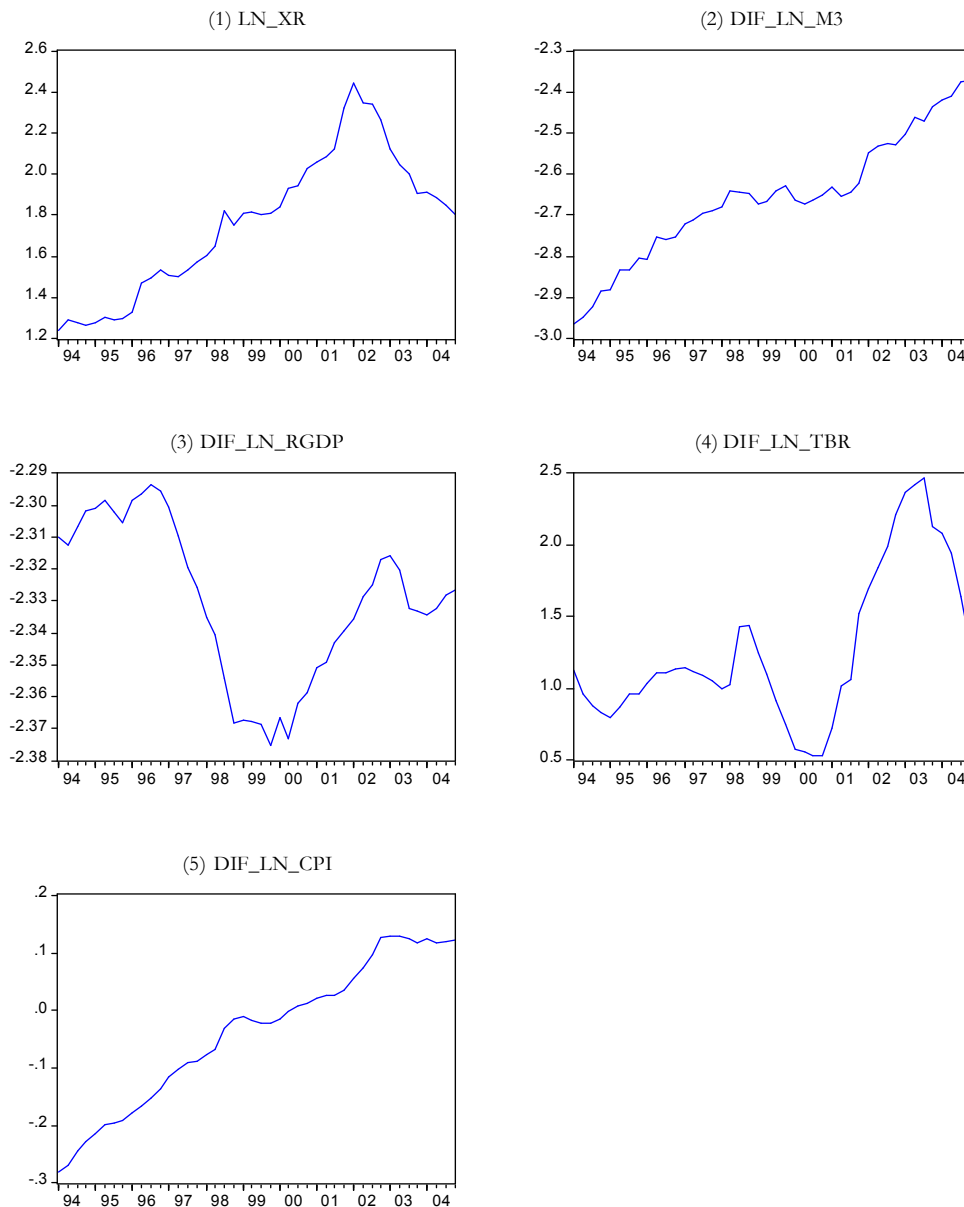


Figure 1: Graphical representation of all the variables

The Augmented Dickey Fuller test of unit root is done on each of the variables and the results are reported in Table 1.

Table 1: The ADF test for unit root

Variable	Model spec.	ADF-stat.	CV at 5%	Prob.	Conclusion
LN_XR	Intercept & Trend	0.311	-3.518	0.9981	Fail to reject H_0 .
	Intercept	-1.575	-2.931	0.4864	Fail to reject H_0 .
	None	0.436	-1.948	0.8038	Fail to reject H_0 .
DIF_LN_M3	Intercept & Trend	-1.877	-3.518	0.6486	Fail to reject H_0 .
	Intercept	-0.729	-2.931	0.8282	Fail to reject H_0 .
	None	-4.416	-1.948	0.0000	Reject H_0 of unit root.
DIF_LN_RGDP	Intercept & Trend	-1.853	-3.518	0.6600	Fail to reject H_0 .
	Intercept	-2.076	-2.931	0.2549	Fail to reject H_0 .
	None	0.192	-1.948	0.7370	Fail to reject H_0 .
DIF_LN_TBR	Intercept & Trend	-3.082	-3.518	0.1243	Fail to reject H_0 .
	Intercept	-2.027	-2.931	0.2743	Fail to reject H_0 .
	None	-0.731	-1.948	0.3937	Fail to reject H_0 .
DIF_LN_CPI	Intercept & Trend	-2.406	-3.518	0.3710	Fail to reject H_0 .
	Intercept	-1.873	-2.931	0.3414	Fail to reject H_0 .
	None	-1.789	-1.948	0.0701	Fail to reject H_0 .

Almost all the variables are found to be non-stationary in their level form in two or all the three models used in the ADF test procedure.

Nevertheless, we managed to reject the null hypothesis of unit root for all variables after first differencing.

3.2 Diagnostics on the reduced form VAR

The VAR that is estimated using the five variables indicated in equation 10 satisfies the stability condition. All the roots have modulus less than one and lie inside the unit circle. We used a lag length of four based on the number of observations and sequential modified LR test for determining the appropriate lag length for the VAR¹.

All important diagnostics tests have been conducted on the VAR. The results of the relevant tests are given in Table 2.

Table 2: Diagnostics on the reduced form VAR

	H_0	Test	Statistic	Prob.
Serial correlation	No serial correlation	LM-Test - χ^2 (lag, 12)	23.43	0.55
Normality	Normally distributed error terms	JB - Joint	41.89	0.00
		Kurtosis - Joint	41.03	0.00
		Skewness - Joint	0.86	0.97
Heteroscedasticity	No heteroscedasticity	χ^2	603.64	0.45

¹ The five possible lag selection criteria provide different appropriate lag length. The appropriate lag length is indicated to be 4 and 6 with the sequential modified LR test statistic and the Akaike information criteria, respectively. On the other extreme, all the Final prediction error, Schwarz and Hannan-Quinn information criteria indicate that the appropriate lag length is one. We, however, preferred a lag length of four as suggested by the Sequential modified LR test statistic and the lag exclusion criteria to take the middle ground.

The VAR model specified in equation 10 passes all the important diagnostic tests given in Table 2. In other words, the error term is white noise despite the lack of normality of the distribution of the error terms. However, the results of the Johansen (1988) tests will not be affected because of the lack of normality as long as the skewness of the distribution of the error terms is fine (Paruolo, 1997).

3.3 Granger causality test

We have tested whether the variables included in the Dornbusch model granger causes the Rand-USD nominal exchange rate.

Since the variables included in our model are not all stationary, we used the granger causality test under the non-stationary VAR setting. This is done first by imposing zero restrictions on the adjustment coefficients. In the two cointegrating vectors, the adjustment coefficients related to CPI in the exchange rate equation, real GDP in the exchange rate and money demand equation, TBR in the money demand equation are found to be weakly exogenous.

We further imposed zero restrictions on the short run coefficients. We used Wald test to determine granger causality among the variables in the short run. The results of the test are given in the following Table 3.

Table 3: Wald test of granger causality

Cointegrating vector	Null Hypothesis	Wald Test Stat.	Prob.	Conclusion
<i>Exchange rate</i>	Dif_ln_M3 does not GC	2.59	0.6278	No granger causality
	ln_XR			
	Dif_ln_rGDP does not GC	13.22	0.0102	There is granger causality
	ln_XR			
<i>Money demand</i>	Dif_ln_TBR does not GC	15.77	0.0033	There is granger causality
	ln_XR			
	Dif_ln_CPI does not GC	20.9	0.0003	There is granger causality
	ln_XR			
<i>Money demand</i>	ln_XR does not GC	2.77	0.5964	No granger causality
	Dif_ln_M3			
	Dif_ln_rGDP does not GC	4.45	0.3479	No granger causality
	Dif_ln_M3			
	Dif_ln_TBR does not GC	1.008	0.9085	No granger causality
	Dif_ln_M3			
<i>Money demand</i>	Dif_ln_CPI does not GC	0.672	0.9546	No granger causality
	Dif ln_M3			

The test of granger causality shows that the null hypothesis of no granger causality is rejected in all except one case in the exchange rate function. Money supply does not

granger cause the Rand-USD exchange rate in the short run. On the other hand, it is found that real GDP granger causes the exchange rate of the Rand in the short run. The same is true with the Treasury bill rate and consumer price index.

In the money demand equation all the other four variables – i.e., Rand-USD exchange rate, real GDP, Treasury bill rate, and CPI – do not granger cause the money demand in the short run.

3.4 Cointegration test results

The appropriate model is selected on the basis of the nature of the DGP of all the five variables, the original Dornbusch (1980) model and the results of the trace and maximum eigenvalue tests.

The trace and maximum eigenvalue tests enabled us to identify three cointegrating vectors using a model that has no intercept or trend in the cointegrating equation (CE) or test VAR. Despite the tendency of most economic variables to include the intercept term, the use of this model is dictated by the specification of the original Dornbusch model and the use of the other possible models are found to adversely affect the robustness of the results by inflating the size of the cointegrating parameters.

The cointegration test results obtained using this model are given in Table 4. The five characteristics roots (or eigenvalues) estimated using the Johansen (1988) procedure are 0.63583, 0.501616, 0.362872, 0.193515 and 0.025359.

Both the trace and the maximum eigenvalue tests of cointegration indicate that there are three cointegrating vectors among the variables included in our model. Both the tests are conducted at 5 percent significance level.

Table 4: Cointegration test results

Trace Test				Maximum Eigenvalue Tests			
H_0	H_1	λ -Trace Stat.	5% CV	H_0	H_1	λ -max	5% CV
$r = 0$	$r \geq 1$	105.5	60.06	$r = 0$	$r = 1$	44.44	30.43
$r \leq 1$	$r \geq 2$	61.06	40.17	$r = 1$	$r = 2$	30.64	24.15
$r \leq 2$	$r \geq 3$	30.42	24.27	$r = 2$	$r = 3$	19.83	17.79
$r \leq 3$	$r \geq 4$	10.59	12.32	$r = 3$	$r = 4$	9.46	11.22
$r \leq 4$	$r \geq 5$	1.13	4.12	$r = 4$	$r = 5$	1.13	4.12

We normalized on the nominal exchange rate and checked for the significance and consistency of the coefficients with economic theory, particularly with the theory

hypothesized by Dornbusch. The parameterized restrictions are shown clearly in the following Π -matrix.

$$\Pi = \alpha\beta'$$

$$\alpha = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \\ \alpha_{31} & \alpha_{32} \\ \alpha_{41} & \alpha_{42} \\ \alpha_{51} & \alpha_{52} \end{bmatrix}, \quad \beta' = \begin{bmatrix} 1 & -1 & \beta_{31} & \beta_{41} & 0 \\ 0 & 1 & \beta_{32} & \beta_{42} & \beta_{52} \end{bmatrix}$$

Additionally, we imposed a value of one on the coefficient of the relative money supply as appeared on the original model of Dornbusch (1980). The number of variables to be included and restrictions to be imposed on the system takes into account the number of total observations and the specific theory that hypothesizes the relationship between the variables. In the exchange rate cointegrating vector, we excluded the relative consumer price index by imposing zero restriction, as instantaneous inflation is not one of the variables included in the original Dornbusch model. It is possible to identify the second cointegrating vector using the money demand equation. Instantaneous consumer price index is included in our VAR since the nominal money demand function cannot be identified without price index. In total, we are supposed to impose four restrictions (2 zeros and 2 normalizing restrictions) on the β -matrix since we identified two cointegrating vectors in the system, one for the exchange rate and the other for the money demand function. As indicated above, one more restriction is imposed to take account of the hypothesized money supply elasticity of one of the exchange rate. Four more restrictions are placed on the adjustment coefficients based on the weak exogeneity of some of the variables in the long run to the exchange rate and the money demand functions.

The adjustment coefficients (α) associated with all the variables are tested for weak exogeneity. In spite of its effect on the entire system through the other cointegrating vector and the short run dynamics as reflected in the VECM, relative consumer price index is exogenous to the vector representing the exchange rate function. Real GDP is found to be weakly exogenous in the long run in both cointegrating vectors. Relative interest rate also is weakly exogenous in the money demand function in the long run.

4. DISCUSSION OF IMPORTANT FINDINGS OF THE STUDY

The complete result from the cointegration test could not be captured in a single cointegrating vector. Identification of the two cointegrating vectors is possible through a system of two equations. The first establishes the relationship between the nominal exchange rate, the relative money supply, the relative real GDP and the short run interest rate. The second cointegrating vector identifies the money demand function, expressed in terms of relative money supply, which establishes the relationship between South African nominal money supply, real GDP, interest rate and consumer price index relative to the United States.

Table 5: Selected results from the VECM

Variables	Cointegrating Eq. 1	Cointegrating Eq. 2
Panel A: Estimates of the cointegrating vectors' β-values		
LN_XR (-1)	1.0000	0.0000
DIF_LN_M3 (-1)	-1.0000	1.0000
DIF_LN_RGDP (-1)	1.094231 [6.65077]	-0.967854 [-31.5608]
DIF_LN_TBR (-1)	-1.406377 [-5.39513]	0.191484 [3.61922]
DIF_LN_CPI (-1)	0.0000	-1.093457 [-9.55059]
Panel B: Estimates of the cointegrating vectors' α-values		
Δ (LN_XR)	-0.093876 [-2.13714]	-1.078966 [-5.20497]
Δ (DIF_LN_M3)	-0.059175 [-2.64403]	-0.269722 [-2.47654]
Δ (DIF_LN_RGDP)	0.0000	0.0000
Δ (DIF_LN_TBR)	0.292693 [4.12914]	0.0000
Δ (DIF_LN_CPI)	0.0000	-0.047025 [-2.12265]

Note: *t*-statistics are given in square brackets.

NB: All β -values except those normalized should be interpreted by reversing their sign.

As indicated in Table 5, the results of the exchange rate function displayed in the first column are statistically significant and consistent with what was hypothesized by Dornbusch. The higher the South African money supply relative to the US even though it is restricted to be one, the weaker the Rand would be. The positive coefficient of the relative money supply indicates the higher Rand value of the US dollar, which is depreciation of the Rand. The higher becomes the real GDP of South Africa relative to the US, the stronger the Rand would be. This is shown by the

negative sign of the coefficient of the relative real GDP in the first cointegrating vector. The increase in the short run Treasury bill rate in South Africa is found to depreciate the Rand in the long run as hypothesized by the Dornbusch's exchange rate overshooting model. The policy implication that comes out clearly from this result is that a measure of the Monetary Policy committee to strengthen the Rand by raising interest rate will depreciate the currency in the long term even if the intended outcome could be attained in the short term. The reverse holds true if the aim is to depreciate the currency.

The other cointegrating vector identified in the model relates to the money demand equation. Since the relative money supply variable included in the model is expressed in nominal terms, the money demand function identified in the VAR must incorporate price index to be correctly specified. The coefficients of all the three variables appeared in the money demand function are statistically significant and consistent with economic theory. The increase in real GDP in South Africa relative to the U.S. triggers the transaction demand for money. This is shown by the positive coefficient of real GDP in the second cointegrating vector. The higher consumer price index has similar impact on the demand for money. The speculative demand for money underlies the negative reaction of money demand for increase in the short run interest rate.

A vector error correction model (VECM) is estimated using the five variables explained above. The specification includes only four lags based on the limited number of observations and the number of parameters estimated in the model.

Panel B of Table 5 shows adjustment coefficients [α -values] that play significant role in bringing back the system to equilibrium in case of discrepancy from the long run relationship. The change in the nominal exchange rate plays a pivotal role to bring the exchange rate equation back to equilibrium. The magnitude of the coefficient for the change in the nominal exchange rate shows that about 9% of the deviation from the equilibrium exchange rate is adjusted during the first quarter. Five percent of the deviation from the equilibrium exchange rate is also taken care of by the money supply during the same quarter. While the change in the exchange rate and money supply help in the adjustment process in the exchange rate equation, the change in the

relative short-term interest rate contributes to the discrepancy by pushing the system away from equilibrium.

In the money demand function as displayed in the third column of Table 5, the adjustment role is played by the change in the exchange rate, relative money supply and the relative price level in both countries.

5. CONCLUSION

The Johansen (1988) cointegration test reveals that there is cointegration among the Rand-USD nominal exchange rate, money supply, real income, short run interest rate and consumer price index of South Africa relative to the United States. Two cointegrating vectors are identified in the system and all the coefficients estimated in the system are statistically significant and consistent with economic theory. Given the non-stationarity of most of the variables included in the VAR, a VECM is estimated to examine the short run dynamics that is expected to play important role in determining the equilibrium exchange rate.

The Dornbusch sticky-price overshooting monetary model appears to underlie the movement of the Rand-USD exchange rate since the country's new political dispensation of the 1994. The Rand-Dollar exchange rate movement during the period examined lends support to Dornbusch's hypothesis about the positive relationship between exchange rate and the short-term interest rate differential. The positive relationship between the Rand-USD exchange rate and the ratio of money supply of South Africa and the US is well established in the VECM. Real GDP's impact on the Rand-USD exchange rate is negative as postulated in economic theory.

To sum up, any attempt by the Reserve Bank to influence the Rand's value by manipulating interest rate will have opposing outcome in the short and the long term. According to the results, any attempt to depreciate the Rand by cutting the interest rate will deliver the intended outcome in the short run, but the measure is found to appreciate the currency in the long run and thus bring the exchange rate back to equilibrium.

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