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MODELLING AND FORECASTING THE METICAL-RAND EXCHANGE RATE

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ABSTRACT

This paper investigates the ability of the Dornbusch (1976) sticky-price model for the nominal metical-rand exchange rate, over the period 1994:1-2005:4 in explaining the exchange rate movements of Mozambique. Based on the model, we find that there is a stable relationship between the exchange rate and the fundamentals. Gross domestic product and inflation differentials between Mozambique and South Africa play the major roles in explaining the metical-rand exchange rate. However, when the Dornbusch (1976) model is re-estimated over the period of 1994:1-2003:4, and the out-of-sample forecast errors are compared with the atheoretical, Classical and Bayesian variants, of the Vector Autoregressive (VAR) and Vector Error Correction (VEC) models, and models capturing alternative forms of the Efficient Market Hypothesis (EMH) of exchange rates, the sticky-price model performs way poorer. Overall, the Bayesian VEC models (BVECMs), with relatively tight priors, are best suited for forecasting the metical-rand exchange rate.

Keywords: Forecast Accuracy; Metical-Rand Exchange Rate; Random Walk; Sticky-Price Model; VAR Forecasts; VECM Forecasts.

JEL Classification: B23, C22, F31, E17, E27, E37, E47.

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I. INTRODUCTION

Under an environment of free flows of capital and goods worldwide, exchange rate is an indispensable instrument in facilitating trade and investment among different economies. In an open economy, different economic agents buy and sell goods and assets overseas. These transactions require the exchange of one currency for another, whose exchange rate is determined by the market forces in the foreign exchange (forex) market. Recent trade data from the IMF (2005) shows that South Africa is the main trading partner of Mozambique in the Southern African Development Community (SADC) region.

There is an extensive literature, both theoretical and empirical, regarding the determination of exchange rates (bilateral or effective), mostly for the developed economies and to a lesser extent for developing economies. In case of Mozambique, however, there is a clear dearth of studies. From the few publicly available studies on exchange rate determination in Mozambique it is worth mentioning at least those of Drine and Rault (2005) and Kargbo (2006). Drine and Rault (2005) use panel data integration tests as well as panel data cointegration framework in order to find the determinants of the equilibrium real exchange rate of 45 developing economies (including 21 from Africa) where Mozambique is part of the sample, using annual data for the 1980-1996 period and it is found that the degree of openness and development of the economy influence the equilibrium real exchange rate. Note that Mozambique is taken as part of the African economy as a whole. Moreover, Kargbo (2006), tests whether the Purchasing Power Parity (PPP) holds in African economies, including Mozambique. Based on GDP deflators covering the 1958-2003 period he finds that the PPP holds and it is a reliable guide for exchange rate determination.

Although these studies are relevant they have some drawbacks, especially for Mozambique because of the following reasons: (i) the sample periods may suffer from the problem of data inconsistency due to the fact that all the prices (exchange rates) prior to 1994 in Mozambique were not determined by the market forces but rather fixed by the monetary authorities, (ii) with the civil war that affected Mozambique over the 1976-1992 period the fundamentals might may not be very good suits to explain exchange rate fluctuations.

In this study, the sample range runs from 1994:1 to 2005:4, which is a period where the *metical*, the currency of Mozambique, is entirely allowed to fluctuate relative to other major

currencies. Besides modelling the metical-rand exchange rate¹, this study assumes that the PPP holds, among other assumptions. Furthermore, it forecasts the exchange rate. All these factors seem to lack in the existing studies.

The main aim of the proposed study is to find the medium to long-term driving forces of the nominal metical-rand exchange rate in the period 1994:1 to 2005:4 and, hence, discuss their policy implications. More specifically, the study evaluates the impact of the fundamentals (nominal income, money supply, interest rate, and inflation) in the determination process of the metical-rand exchange rate and, therefore, discusses the role of policies in the process. Furthermore, a comparison of out-of-sample forecasting performance, over the period of 2004:1 to 2005:4 of the Dornbusch (1976) model is made with the atheoretical, Classical and Bayesian variants, of the Vector Autoregressive (VAR) and Vector Error Correction (VEC) models and also alternative versions of the Efficient Market Hypothesis (EMH). Although, exchange rates in Mozambique started to be determined by market forces in the period after 1987 with the adoption of Structural Adjustment Programmes (SAP) and macroeconomic stabilization policies the above-mentioned period is chosen mainly due to data availability.

Even though one can also explain exchange rate movements based on the portfolio balance approach, this study is essentially based on the monetary model of nominal exchange rate determination. This is because of at least three reasons: Firstly, Mozambique, compared with other economies, such as South Africa, is a country whose financial market is less developed (deep) and integrated with the rest of international financial markets worldwide. Secondly, there is limited data availability of disaggregated data on non-monetary assets. Thirdly, and related to the first factor, the Mozambican currency, the *metical*, is an exotic currency (it is exclusively used at the domestic level).

The paper is organised in four sections, besides the introduction. In the first section we present an elaborate literature review, by discussing the theories of exchange rate determination and confronting the same with empirical evidence. The second section discusses the data (sources and transformations) as well as the methodology (instruments and techniques) adopted in the analysis. The third section shows the estimated results along with

¹ The exchange rate is defined as units of *metical* per units of rand

their discussions, while, the last section presents the conclusions, policy implications and the possible extensions of the analysis.

II. THEORETICAL FRAMEWORK AND RELEVANCE OF THE STUDY

1. Exchange Rate Determination

There is a wide set of studies that investigate the determinants of real and nominal exchange rates, either bilateral or effective. They can be divided into two main groups. The first group belongs to the chartists and the second, to the fundamentalists. Argy (1994:345) states that the chartists consist of those studies whose models base their expectations of exchange rate fluctuations on its past movements while the fundamentalists consist of those studies whose models are based on the fundamentals, so that when the exchange rate is driven away from fundamentals they form expectations that it will return in due course to the levels projected by fundamentals. Most of the studies that have already been conducted up to this stage regarding floating exchange rates tend to concentrate more on the fundamentals. Floating exchange rate models based on the fundamentals are classified into two categories, namely, monetary exchange rate models and portfolio balance models. As from Neely and Sarno (2002:2-8), the monetary models of exchange rates can also be subdivided into two groups: the flexible-price model, due originally to Frankel (1976) and Mussa (1976, 1979) and the sticky-price model, due originally to Dornbusch (1976), which allows the overshooting of the nominal and real exchange rates above their long-run equilibrium levels.²

One of the critical problems of the flexible-price model of exchange rate is that it assumes continuous Purchasing Power Parity (PPP)³. Under continuous PPP, the real exchange rate cannot vary, by definition. Nonetheless, most recent experience with floating exchange rates

² In this study we concentrate on the Dornbusch (1976) model

³ Under the flexible-price model, an increase of the domestic GDP relative to the foreign GDP, raises the GDP differential. In the domestic market there is an increase in the money demand stock, which in turn, creates imbalances in the money market equilibrium. In order to restore the equilibrium domestic economic agents try to raise their real balances by reducing their spending and prices must fall. Given PPP, falling domestic prices mean an appreciation of the domestic currency relative to the foreign currency (Taylor, 1995:21-22). This interpretation is similar in the Dornbusch model.

between many of the major currencies has been the wide variations in the real exchange rates. This resulted in flexible-price models not being able to fit the observable facts (MacDonald and Taylor, 1992), which in turn has led to the establishment of the sticky-price model of exchange rates.

Sticky-Price Monetary Model of Exchange Rates

Dornbusch (1976) established the sticky-price monetary model, which allows for substantial overshooting of both the nominal and the real exchange rates beyond their long-run PPP levels because exchange rates and interest rates compensate for the sluggishness in the goods prices. After a cut in the domestic money supply, given sticky prices in the short-run, a fall in the real money supply occurs and a subsequent increase in interest rates in order to clear the money market. This in turn leads to a capital inflow and an appreciation of the nominal exchange rate, which, given sticky prices, also implies an appreciation of the real exchange rate. Foreign investors are conscious of the fact that they are contributing to take the exchange rate up and that they may suffer a foreign exchange loss when the proceeds are converted into their local currency. However, as stated by MacDonald and Taylor (1992:7), so long as the expected foreign exchange loss is less than the known interest rate differential, risk-neutral investors will continue to buy domestic assets. A short-run equilibrium is achieved when the expected rate of depreciation is just equal to the interest rate differential (uncovered interest rate parity holds). Because the expected rate of depreciation must be non-zero for a non-zero interest rate differential, the exchange rate must have overshoot its long-run equilibrium level. In the medium term, domestic prices begin to fall in response to the fall in money supply. The real money supply rises and the domestic interest rates begin to decline. The exchange rate depreciates slowly in order to converge at the long-run PPP level. From this model countries with relatively high interest rates tend to have currencies whose exchange rate is expected to depreciate. Equation (1) is the representation of the Dornbusch sticky-price model.

$$e_t = (m - m^*)_t + k(y - y^*)_t + \psi(i - i^*)_t \quad (1)$$

Despite its usefulness the Dornbusch model was criticized. Frankel (1979a) argued that the Dornbusch model did not allow a role for the differences in the inflation rates. Therefore, he

included the inflation rate differential as an explanatory variable for the exchange rate equation, as shown by equation (2). Overall, the sticky-price monetary model is an advance over the flexible-price monetary model.

$$e_t = (m - m^*)_t + k(y - y^*)_t + \psi(i - i^*)_t + \delta(\pi - \pi^*)_t \quad (2)$$

Where π and π^* are domestic and foreign inflation rates, respectively.

In terms of empirical evidence the results are not very strong when the data period is extended beyond the late 1970s as shown by the studies of Driskell (1981), Backus (1984), Meese and Rogoff (1988). More recently, MacDonald and Taylor (1993), applying multivariate cointegration analysis to a number of exchange rates, find some evidence to support the monetary model as a long-run equilibrium toward which the exchange rate converges, while allowing for short-run dynamics. Sichei *et al.*, (2005), use the Johansen cointegration procedure for the rand-dollar nominal exchange rate during the period 1994-2004 and also find signs and magnitudes that are conformable with the sticky-price monetary model.

New attempts of modelling exchange rates combine both monetary models and portfolio balance models into a reduced-form equation. Examples of such studies are those of Hooper and Morton (1982), Frankel (1983 and 1984) Rogoff (1984), Fisher *et al.*, (1990). Because of this apparent deviation from the fundamentals some authors concentrate their analysis of exchange rates based on the influence of exchange rate analysts who base their predictions not on economic theory but on the identification of the patterns of exchange rate movements, that is, technical or chart analysis. For example, Frankel and Froot (1986, 1990), suggested a model of foreign exchange market in which traders based their expectations partly on the advice of fundamentalists and partly on the advice of chartists. Furthermore, Masson and Knight (1986, 1990) and Frenkel and Razin (1987) analysed the role of shifts in fiscal policy stance among the major Organisation for Economic Cooperation and Development (OECD) countries as important determinants of exchange rate behaviour. Large autonomous changes in national savings and investment balances must exert a very strong influence on current account positions, real interest rates, and, hence, exchange rates. On the other hand, Moosa (2004: 102-3) states that the government can affect the supply of and demand for foreign exchange by imposing or abolishing trade barriers (such as tariffs and quotas) and taxes. The effect arises because tariffs and taxes change goods prices and the rates of return on financial assets.

Also, one must take into account the fact that the models are not able to capture all the dynamics of exchange rate markets. Indeed, aspects influencing exchange rates such as lag structures, real disturbances, among other factors, tend to be disregarded. The main implication of all this discussion is that new models of exchange rates must not be based solely on the fundamentals but rather on the combination of fundamentals, the chartist view and possibly some form of government policies (or socio-economic factors) with a potential impact on exchange rates. This is the bulk of this study.

2. Relevance of the Study

Neely and Sarno (2002) argue that despite the models' differences on the price stickiness or flexibility in the assumptions, they imply the same fundamental equation for the bilateral exchange rate, that is, equation (2). There is a dearth of studies regarding exchange rate determination for Mozambique and South Africa, that is, for the metical-rand exchange rate. The analysis is based on the sticky-price monetary model of exchange rates, which is reflected by equation (2). Note in order to evaluate the performance of the Dornbusch (1976) model, we require to analyse how well or worse the same performs relative to alternative models of exchange rate determination. One such method of evaluation is by looking at the out-of-sample forecasting performance of the sticky-price model with the alternative specifications. In this regard, the alternative models used, besides models capturing the EMH, are the atheoretical, Classical and Bayesian variants of the Vector Autoregressive (VAR) and Vector Error Correction (VEC) models.

III. DATA AND METHODOLOGY

1. Data

Quarterly data from the first quarter of 1994 to the fourth quarter of 2005 is used, which translates into 48 observations. All the South African data, the Mozambican money supply (M2) and interest rates are obtained from the International Monetary Fund's *International Financial Statistics*. The Mozambican Gross Domestic Product (GDP), which is obtained from the World Bank's *World Development Indicators* in annual dollar terms, is transformed into average quarterly rand terms based on quarterly *metical-rand* exchange rate, which is

obtained from the *Statistical Yearbook of National Institute of Statistics* of Mozambique (issues from 1995 up to 2005). For the last two quarters of 2005 the *International Financial Statistics Handbook* (August 2006) is used. With regards to interest rates, the discount rate is used for both South Africa and Mozambique due to unavailability of Treasury bill data for Mozambique.

The Mozambican and South African real GDP and M2 differentials are seasonally adjusted whereas interest rate and inflation rate differentials are in levels. In addition, the first two differentials and the nominal *metical-rand* exchange rate are converted to natural logarithms to smooth the data and to interpret their estimated coefficients in terms of elasticities. Inflation and interest rate differentials are in percentage terms and hence, readily interpreted in terms of elasticities. The data used are described in Table 1 in the Appendix. Also, the graphs of all the variables used are in Figures 1 and 2 in the Appendix.

The formal unit root tests of Augmented Dickey-Fuller (ADF) (1979) and Phillips Peron (PP) (1988) show that all the variables (nominal metical-rand exchange rate, nominal and real GDP differential, the differentials of money supply, inflation and nominal interest rate) do not seem to exhibit stationary (Table B in the Appendix). Hence, those series are non-stationary. However, after differencing the variables once they all seem to be stationary, that is, integrated of order one, I (1) (Table C in the Appendix).

2. Methodology

Due to the fact that the exchange rate differentials are I (1) as shown by the formal ADF and PP tests, a Vector Error Correction Methodology (VECM) is used. Thereafter, the Johansen (1988) cointegration procedure is conducted to estimate an exchange rate equation. The Johansen (1988) method allows one to estimate multiple long-run relationships between a set of non-stationary variables, through cointegrating vectors, as well as any short-run dynamics in these variables, in the VECM.

Given a vector X_t of n variables, which can then be expressed as:

$$X_T = \sum_{l=1}^p A_l X_{T-l} + \varepsilon_T \text{ where } \varepsilon_t \sim iid (0, \Omega). \quad (3)$$

Therefore, the VECM representation of X_t is: $\Delta X_T = \pi x_{t-1} + \sum_{l=1}^{\rho-1} A_l \Delta X_{T-l} + \varepsilon_T$ (4)

Where $\pi = -(I - \sum_{l=1}^{\rho} A_l) + \varepsilon_T$ and $\pi_i = - \sum_{l=1+j}^{\rho} A_l$

The Engle-Granger (1987) Representation Theorem asserts that if the coefficient matrix π (the cointegrating space) has reduced rank $r < n$, then there exist matrices α and β each with rank r such that $\pi = \alpha\beta'$ and $\beta'y_t$ is $I(0)$. Note r is the number of cointegrating relations (the cointegrating rank) and each column of β is the cointegrating vector, and the elements of α are known as the adjustment parameters in the VECM. α is also known as the loading matrix and has a dimension $n \times r$. Since it is not possible to use conventional OLS to estimate α and β , Johansen's (1988) full information maximum likelihood estimation is used to determine the cointegrating rank of π , and use the r most significant cointegrating vectors to form β , from which a corresponding α is derived. Note that the specification in (4) is in line with the Engle and Granger (1987) Representation Theorem.

Along the lines of the Dornbusch (1976) model, a five variable regression is estimated, based on the Johansen (1988) procedure, in order to establish the determinants of the metical-rand exchange rate for the period of 1994-2005⁴. In addition, an extension of the Dornbusch (1976) model is made by testing the market efficiency hypothesis of exchange rate. The ultimate goal is to see which model best explains the behaviour of the metical-rand exchange rate over the sample period.

IV. EMPIRICAL RESULTS

The estimated Vector Autoregressive model (VAR) is stable, since no roots lie outside the unit root circle (see Table E in the Appendix). Table 1, below, shows the outcomes of both the *trace* and the *maximum eigenvalue* tests. Based on both the *trace* and the *maximum eigenvalue* statistics there are two cointegrating equations (CEs). Therefore, the rank of the system is equal to 2. Two CEs are obtained based on a model with a linear trend in the data,

⁴ See Table D in the Appendix for tests determining the choice of lag lengths.

an intercept and no trend. The unrestricted cointegrating coefficients estimated according to the Johansen cointegration procedure are in Table 2.

Table 1: *Johansen cointegration test*

Test	Statistic	p-value*	Number of CEs
Trace	25.0143	0.1609	2
Maximum Eigen value	14.1459	0.3532	2

*the tests are performed at the five per cent level.

Table 2: *Unrestricted cointegrating vectors*

Exchange rate	GDP differential	Money supply differential	Inflation differential	Interest rate differential
1.198298	0.989519	2.235335	-0.738771	0.062344
-16.08079	-4.610465	-0.136046	-0.151587	0.017862
9.186162	1.086935	7.703415	0.366118	-0.095322
-10.59140	-2.314250	-15.47127	0.162343	-0.107184
-8.970832	2.427812	-14.55871	1.277281	-0.398723

A VECM is estimated in order to account for short-run variations in the cointegrating relationship. The hypothesized unrestricted VECM with at most two cointegrating vectors is written as follows:

$$\begin{bmatrix} \Delta le_t \\ \Delta lgdpr_t \\ \Delta lm2r_t \\ \Delta infd_t \\ \Delta intd_t \end{bmatrix} = \begin{bmatrix} \delta_{11} & \delta_{12} & \delta_{13} & \delta_{14} & \delta_{15} \\ \delta_{21} & \delta_{22} & \delta_{23} & \delta_{24} & \delta_{25} \\ \delta_{31} & \delta_{32} & \delta_{33} & \delta_{34} & \delta_{35} \\ \delta_{41} & \delta_{42} & \delta_{43} & \delta_{44} & \delta_{45} \\ \delta_{51} & \delta_{52} & \delta_{53} & \delta_{54} & \delta_{55} \end{bmatrix} \begin{bmatrix} \Delta le_{t-1} \\ \Delta lgdpr_{t-1} \\ \Delta lm2r_{t-1} \\ \Delta infd_{t-1} \\ \Delta intd_{t-1} \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \\ \alpha_{31} & \alpha_{32} \\ \alpha_{41} & \alpha_{42} \\ \alpha_{51} & \alpha_{52} \end{bmatrix} \begin{bmatrix} le_{t-1} \\ lgdpr_{t-1} \\ lm2r_{t-1} \\ infd_{t-1} \\ intd_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \end{bmatrix} \quad (5)$$

The expected signs of the nominal exchange rate model to be estimated are as hypothesized by Dornbusch (1976) and Frankel (1979a).

$$e_t = \begin{bmatrix} \overset{(+)}{m} \\ \overset{(-)}{m^*} \end{bmatrix}_t, \begin{bmatrix} \overset{(-)}{y} \\ \overset{(+)}{y^*} \end{bmatrix}_t, \overset{(+)}{(i-i^*)}_t, \overset{(+)}{(\pi-\pi^*)}_t \quad (6)$$

with $e_t, \frac{m}{m^*}$ and $\frac{y}{y^*}$ in logarithmic terms.

Since the aim is to estimate an exchange rate equation, long-run restrictions are imposed such that cointegrating equation I (CE I) is normalised with respect to exchange rate, i.e. $\beta_{11} = 1$, and the estimated long-run nominal exchange rate equation is shown by equation (7) as follows (t-values in brackets):

$$Le_t = -2.1015lgdpr_t + 1.0323infd_t + lm2r_t + 0.0037intd_t + 0.12 \quad (7)$$

(-4.7555)
(6.07)
(1.4753)

From the above cointegrating equation, all the coefficients are statistically significant⁵ in explaining the long-run behaviour of the metical-rand exchange rate. *Ceteris paribus*, following the model predicted in equation (2), an increase in the Mozambican GDP relative to the South African GDP, which raises the GDP differential, creates an excess demand for

⁵ The interest rate differential is only significant at the 10 percent level.

money stock in Mozambique. Mozambican residents try to raise their real money balances by reducing their expenditure and prices fall until money market equilibrium is achieved. Based on purchasing power parity condition, falling prices in Mozambique, given South African prices, mean an appreciation of the *metical* relative to the rand, which is reflected by the negative sign in the coefficient of GDP differential in equation (7). Likewise, the sign of GDP differential coefficient also makes economic sense if one considers the fact that economic growth is related to booming sectors of an economy. Sectors such as transport, manufacturing, financial and infrastructure has grown in Mozambique over the past decade. Although one can argue that a relatively higher growth rate implies an increase in the propensity to import especially from South Africa (thus depreciating the metical), this effect is to some extent offset by capital inflows in terms of Foreign Direct Investment (FDI) made by South African firms in the Mozambican growing sectors.

On the other hand, all the things being equal, an increase in the inflation differential, which is represented by the Mozambican prices relative to the South African ones, makes Mozambican goods and services relatively expensive and hence, more South African goods and services are demanded relative to domestic goods (the Mozambican current account is put under pressure). By doing so, Mozambicans are willing to sacrifice more *meticals* in favour of the rand and the *metical* depreciates against the rand.

Note to be consistent with the theoretical model, the coefficient of money supply is restricted to unity. We also observe that the interest rate differential plays a very small role (it is not significant at a one per cent and ten per cent, respectively) in explaining the long-run behaviour of the exchange rate. However, its effect means that an increase in Mozambique's interest rate relative to South Africa's leads to small a very small depreciation rate of the metical in the long run. This should not be the case because relatively higher interest rates in Mozambique should attract more capital from abroad that in the end would imply an appreciation of the *metical* against the rand. Possible reasons include the following. Firstly, the referred capital inflows predicted by the sticky-price model are supposed to be portfolio flows and not private foreign direct investment (neither Brownfield investment nor green field investment) as is the case with most capital inflows in Mozambique. Secondly, the financial market in Mozambique is very small, not deep and less integrated with the major financial markets worldwide including the South African one. Thirdly, the sticky-price monetary model assumes that domestic and foreign assets are perfect substitutes, which is not

always necessarily true. Even with relatively higher interest rates in Mozambique in the period after 1994, portfolio investment from South African investors is not flowing to Mozambique enough to have a significant impact on the exchange rate. This may partially be explained by the perceived high economic and political risks associated with the *metical*-denominated assets especially in the after-war period in Mozambique and also with the fact that in the years following 1994 South African investors had also to make important domestic investment decisions that were associated with the political and economic changes resulting from the end of the Apartheid regime. Furthermore, even if South African investors had profitable portfolio investment opportunities in Mozambique they would still have very few options in terms of corporate bonds or shares to invest on and also they would be faced by exchange rate risks associated with exchange rate fluctuations. For example, the Mozambique Stock Exchange, the only stock exchange in Mozambique, which started its operations in October 1999, currently has less than ten firms listed on it. Additionally, there is a problem of the losses incurred when the proceeds in *meticals* are converted into Rands due to relatively high depreciation rates of the metical. Over the sample period of this study, on average, the metical relative to the rand has observed quarterly depreciation rates that reached about 20 per cent in mid-90s and 12 per cent in early 2005. Consequently, private portfolio preferences are diverted to other financial markets that are well organised, deep and internationally integrated with other markets, such as the New York Stock Exchange, the London Stock Exchange, among others.

The estimated second cointegrating vector captures the relationship between the interest rate differential with the inflation differential and the exchange rate, and is given as follows (t-values in brackets):

$$intd_t = -1781.164 + 218.723le_t + 33.52inf_d_t \quad (8)$$

(5.4) (6.94)

The t-statistics suggest that the estimated coefficients are statistically significant. *Ceteris paribus*, a depreciation of the metical relative to the rand leads to an increase in the interest rate differential. This can be explained by the fact that continuous depreciation of the metical relative to the rand exert inflationary pressures in Mozambique that in turn force monetary authorities to raise interest rates in order to curb inflation. On the other hand, *ceteris paribus*,

an increase in the inflation differential leads to an increase in interest rate differential due to the fact that Mozambique would increase interest rates to contain the inflation pressures.

Weak exogeneity tests are performed on the elements of the loading matrices of CE I and CE II. Positive and negative loading factors imply pushing the system away from equilibrium and back to equilibrium, respectively. Those variables with 0 speed of adjustment mean that the cointegrating vector does not enter into the short-run determination for the variable. For example, inflation differential is weakly exogenous in the exchange rate equation whereas the exchange rate is weakly exogenous in the interest rate differential equation. Hence, if there is an economic shock that pushes exchange rate away from the equilibrium in equation (7), inflation differential would not adjust immediately to correct the discrepancy. For the same equation, the exchange rate and GDP differential adjustment coefficients, although negative (between 0 and -2 range), are not significant, which means that, if there is a shock that pushes exchange rate away from the equilibrium in equation (7), exchange rate and GDP differential cannot correct the discrepancy. In addition, both money supply and interest rate differentials push the system away from its long-run equilibrium because their adjustment coefficients lie outside the 0 and -2 range. However, in the case of the CE II, money supply differential is capable of bringing interest rate differential back to its long-run equilibrium whereas the interest rate differential does not play a pivotal role in bringing itself back to its long-run equilibrium. Thus, money supply differential is weakly exogenous in CE I and interest rate differential, although significant, is weakly exogenous in both CE I and CE II (see Table 3).

Table 3: *loading matrix of VECM (t-values in brackets)*

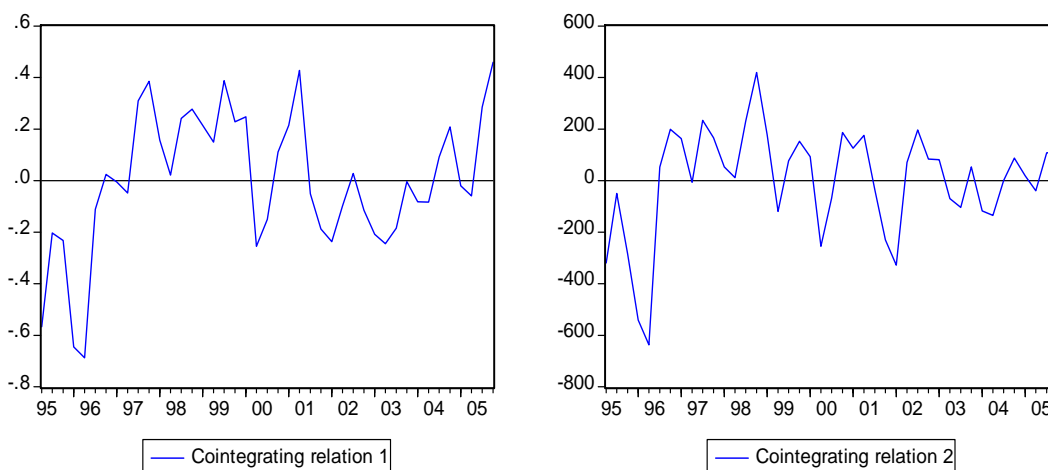
	Δle_t	$\Delta lgdpr_t$	$\Delta lm2r_t$	$\Delta infd_t$	$\Delta intd_t$
<i>CEI</i>	-0.0295 (-1.25)	-0.0163 (-0.2748)	0.1476 (3.1458)	0.0000	2.208 (2.075)
<i>CEII</i>	0.0000	0.0000	-0.0047 (-3.2566)	0.0000	0.0771 (2.3586)

The residuals of the two cointegrating equations are mean-reverting around zero and are stationary (see Figure 1), which implies that the estimated cointegrating relations are appropriate. Moreover, based on Table 4, the estimated VECM satisfactorily passes the residual tests with the null hypothesis of normal residuals, no autocorrelation and no heteroscedasticity, respectively, at the one per cent level of significance.

Table 4: *Diagnostic tests*

	Test	Statistic	p-value	Conclusion
Normality	Skewness (joint)	4.8589	0.4333	Residuals are normally distributed
Autocorrelation	LM(5)	16.8115	0.8885	no autocorrelation
Heteroscedasticity	X ² (360)	349.1172	0.6498	no heteroscedasticity

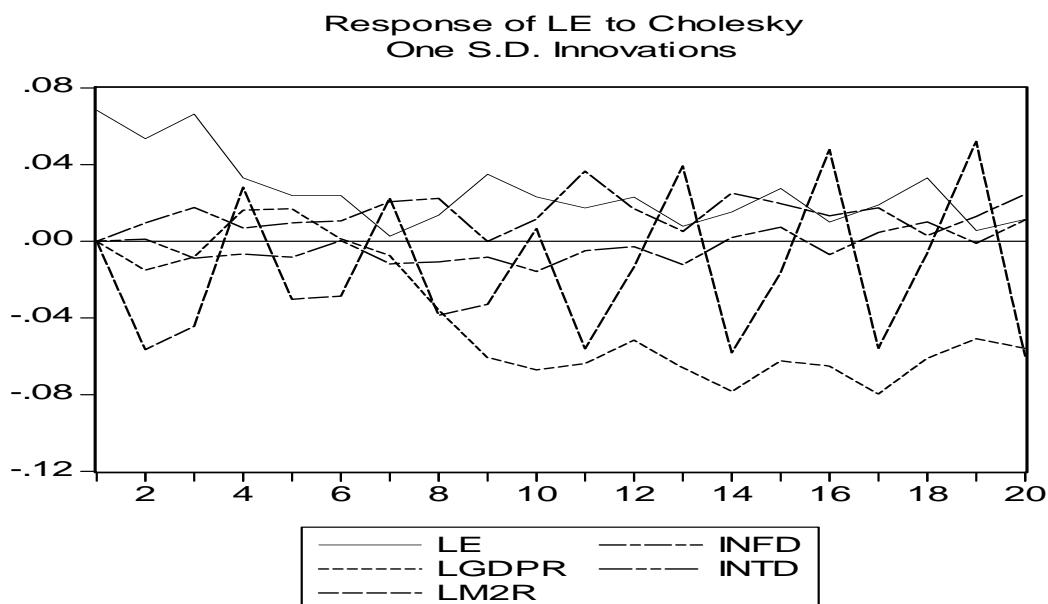
Figure 1: *Residuals of the cointegrating equations 1 and 2 (CE I and CE II)*



Impulse response functions of the estimated VECM

The VECM is used to evaluate impulse responses of the variables in the VAR. Figure 2 shows the impulse response functions over twenty quarters, the perceived expected time necessary for changes in GDP, interest and inflation rates and money supply to have an impact on the metical-rand exchange rate. The figures show the effects of increases on the explanatory variables of CE I on exchange rate.

Figure 2: *Impulse response functions of estimated VECM*



As predicted by equation (7), an increase in the GDP differential results in an appreciation of the metical-rand exchange rate over the entire period; increases in money supply and inflation differentials lead to the metical depreciation relative to the rand; although the effect of interest rate differential on exchange rate is relatively small, the final impact is positive, as predicted by the Dornbusch model (1976). When compared to the effect of other explanatory variables the exchange rate responds relatively slowly to interest rate differential changes, which makes sense if one considers the fact that the Mozambican financial market is relatively small and less integrated with other international financial markets such as the Johannesburg Stock Exchange. Hence, its assets are not necessarily perfect substitutes to those assets from other markets. Consequently, the variables included in the VECM are important in explaining the movement of nominal metical-rand exchange rate over the period 1994:1 – 2005:4.

Variance Decomposition

A variance decomposition analysis is used to identify the relative importance of the random innovation of each variable on the VECM on the exchange rate. The variance in exchange rate is mostly accounted for by itself until the twelfth quarter when GDP and money supply

differential account for about 33 and 27 per cent, respectively, of the variation in exchange rate (see Table 5).

Table 5: *Variance Decomposition analysis of the estimated VECM*

Quarter	S.E.	LE	LGDP	LM2R	INFD
1	0.068361	100.0000	0.000000	0.000000	0.000000
2	0.105100	68.24507	2.039748	28.88273	0.822066
3	0.133656	66.83255	1.641266	28.83607	2.249134
4	0.141789	64.82017	2.763392	29.57046	2.230355
5	0.148434	61.72522	3.818234	31.12886	2.449677
6	0.153426	60.19966	3.580065	32.62445	2.773557
7	0.157103	57.44522	3.642687	33.18916	4.371960
8	0.168088	50.83312	7.701331	34.28829	5.586585
9	0.185200	45.43052	17.06233	31.39483	4.601953
10	0.199417	40.52664	26.04931	27.18698	4.309800
11	0.220530	33.75806	29.66496	28.68530	6.265437
12	0.228672	32.41270	32.66120	27.02270	6.376270
13	0.241686	29.12112	36.67042	26.82967	5.753162
14	0.262290	25.06521	40.06148	27.69611	5.791912
15	0.272344	24.27391	42.41511	26.06094	5.891099
16	0.284634	22.34591	44.06311	26.67877	5.608757
17	0.301920	20.25258	46.11982	27.12822	5.318186
18	0.310042	20.34200	47.61445	25.76475	5.052441
19	0.318781	19.27239	47.58291	27.03854	4.944964
20	0.330450	18.05548	47.14722	28.45064	5.151928

Forecasting

Under a system of floating exchange rates, forecasting exchange rate is a crucial element in the decision-making process of firms that conduct cross-border trade and investment operations. Generally, economy-wide forecasting models are in the form of simultaneous-equations structural models. However, two problems, often, encountered with such models

are as follows: (i) correct number of variables needs to be excluded, for proper identification of individual equations in the system, which are, however, often based on little theoretical justification (Cooley and LeRoy (1985)), and, (ii) given that, projected future values are required for the exogenous variables in the system, structural models are poorly suited to forecasting.

The Vector Autoregressive (VAR) model, though ‘atheoretical’ is particularly useful for forecasting purposes. Moreover, as shown by Zellner (1979) and Zellner and Palm (1974) any structural linear model can be expressed as a VAR moving average (VARMA) model, with the coefficients of the VARMA model being combinations of the structural coefficients. Under certain conditions, a VARMA model can be expressed as a VAR and a VMA model. Thus, a VAR model can be visualized as an approximation of the reduced-form simultaneous equation structural model.

Note an unrestricted VAR model, as suggested by Sims (1980), can be written as follows:

$$X_t = C + A(L)X_t + \varepsilon_t \quad (10)$$

where X : ($n \times 1$) vector of variables being forecasted; $A(L)$: ($n \times n$) polynomial matrix in the backshift operator L with lag length p , i.e., $A(L) = A_1L + A_2L^2 + \dots + A_pL^p$; C : ($n \times 1$) vector of constant terms, and; ε : ($n \times 1$) vector of white-noise error terms. The VAR model, thus, posits a set of relationships between the past lagged values of all variables and the current value of each variable in the model. Focusing on the practical case, of X_t being a vector of n time series that are integrated⁶ to the order of 1 ($I(1)$)⁷, the ECM counterpart of the VAR, given by (10), is captured by a VECM, as described in (3), as follows:

$$\Delta X_t = \pi X_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-1} + \varepsilon_t \quad (11)$$

where $\pi = -[I - \sum_{i=1}^p A_i]$ and $\Gamma_i = -\sum_{j=i+1}^p A_j$.

⁶ A series is said to be integrated of order q , if it requires q differencing to transform it to a zero-mean, purely non-deterministic stationary process.

⁷ LeSage (1990) and references cited therein for further details regarding most macroeconomic time series being $I(1)$.

Thus, a VECM is a restricted VAR designed for use with non-stationary series that are known to be cointegrated. While allowing for short-run adjustment dynamics, the VECM has cointegration relations built into the specification so that it restricts the long-run behavior of the endogenous variables to converge to their cointegrating relationships. The cointegration term is known as the error correction term because the deviation from long-run equilibrium is corrected through a series of partial short-run adjustments, gradually.

Note the VAR model, generally, uses equal lag length for all the variables of the model. One drawback of VARs model is that many parameters are needed to be estimated, some of which may be insignificant. This problem of overparameterization, resulting in multicollinearity and loss of degrees of freedom leads to inefficient estimates and possibly large out-of-sample forecasting errors. Given that in the VECMs, besides the parameters corresponding to the lagged values of the variables, the parameters corresponding to the error correction terms are also estimated. So the problem of overparameterization, in this case, might be acute enough to outweigh the advantages, in terms of smaller forecast errors, emanating from the use of long-run equilibrium relationships from economic theory to explain short-run dynamics of data. One solution, often adapted, is simply to exclude the insignificant lags based on statistical tests. Another approach is to use near VAR, which specifies unequal number of lags for the different equations.

However, an alternative approach to overcome this overparameterization, as described in Littermann (1981), Doan *et al.*, (1984), Todd (1984), Littermann (1986), and Spencer (1993), is to use a Bayesian VAR (BVAR) model. Instead of eliminating longer lags, the Bayesian method imposes restrictions on these coefficients by assuming that these are more likely to be near zero than the coefficient on shorter lags. However, if there are strong effects from less important variables, the data can override this assumption. The restrictions are imposed by specifying normal prior distributions with zero means and small standard deviations for all coefficients with the standard deviation decreasing as the lags increases. The exception to this is, however, the coefficient on the first own lag of a variable, which has a mean of unity. Note Litterman (1981) used a diffuse prior for the constant. This is popularly referred to as the ‘Minnesota prior’ due to its development at the University of Minnesota and the Federal Reserve Bank at Minneapolis. Note, as described in (11), an identical approach can be taken to implement a Bayesian variant of the Classical VECM based on the Minnesota prior.

Formally, as discussed above, the Minnesota, prior means and variances take the following form:

$$\beta_i \sim N(1, \sigma_{\beta_i}^2) \text{ and } \beta_j \sim N(1, \sigma_{\beta_j}^2) \quad (12)$$

where, β_i denotes the coefficients associated with the lagged dependent variables in each equation of the VAR, while, β_j represents any other coefficient. In the belief that lagged dependent variables are important explanatory variables, the prior means corresponding to them are set to unity. However, for all the other coefficients, β_j 's, in a particular equation of the VAR, a prior mean of zero is assigned, to suggest that these variables are less important to the model.

The prior variances $\sigma_{\beta_i}^2$ and $\sigma_{\beta_j}^2$, specify uncertainty about the prior means $\bar{\beta}_i = 1$, and $\bar{\beta}_j = 0$, respectively. Because of the overparameterization of the VAR, Doan *et al.*, (1984) suggested a formula to generate standard deviations as a function of small number of hyperparameters: w , d , and a weighing matrix $f(i, j)$. This approach allows the forecaster to specify individual prior variances for a large number of coefficients based on only a few hyperparameters. The specification of the standard deviation of the distribution of the prior imposed on variable j in equation i at lag m , for all i, j and m , defined as $S(i, j, m)$, can be specified as follows:

$$S(i, j, m) = [w \times g(m) \times f(i, j)] \frac{\hat{\sigma}_j}{\hat{\sigma}_i} \quad (13)$$

with $f(i, j) = 1$, if $i = j$ and k_{ij} otherwise, with $(0 \leq k_{ij} \leq 1)$, $g(m) = m^{-d}$, $d > 0$. Note $\hat{\sigma}_i$ is the estimated standard error of the univariate autoregression for variable i . The ratio $\hat{\sigma}_i / \hat{\sigma}_j$ scales the variables so as to account for differences in the units of measurement and, hence, causes specification of the prior without consideration of the magnitudes of the variables. The term w indicates the overall tightness and is also the standard deviation on the first own lag, with the prior getting tighter as we reduce the value. The parameter $g(m)$ measures the tightness on lag m with respect to lag 1, and is assumed to have a harmonic shape with a decay factor of d , increasing which tightens the prior on increasing lags. The parameter $f(i, j)$ represents the tightness of variable j in equation i relative to variable i , and by increasing the interaction, i.e., the value of k_{ij} we can loosen the prior.⁸

⁸ For an illustration, see Dua and Ray (1995).

The Bayesian variants of the Classical VARs and VECMs are estimated using Theil's (1971) mixed estimation technique, which involves supplementing the data with prior information on the distribution of the coefficients. In an artificial way, the number of observations and degrees of freedom are increased by one, for each restriction imposed on the parameter estimates. The loss of degrees of freedom due to over parameterization associated with a VAR model is, therefore, not a concern in the BVAR model.

Given the structure of the Bayesian prior, we can now discuss the issue of misspecification involved with the BVECMs, as referred to in the introduction, in detail. Lutkepohl (1993: 375), has claimed that the Minnesota prior is not a good choice if the variables in the system are believed to be cointegrated. He makes such an argument based on the interpretation of the prior as to suggesting that the variables are roughly random walks. Moreover, Engle and Yoo (1987) argued that with the Minnesota prior, a BVAR model approaches the classical VAR model with differenced data, and, hence, would be misspecified for cointegrated variables without an error correction term.

But Dua and Ray (1995) indicate that the suggestion of the Minnesota prior being inappropriate, when the variables are cointegrated is incorrect. They point out that the prior sets the mean of the first lag of each variable equal to one in its own equation and sets all the other coefficients to be zero, and hence, this implies, if the prior means were indeed the true parameter values, each variable would be a random walk. But at the same time the prior probability that the coefficients are actually at the prior mean is zero. The Minnesota prior, indeed, places high probability on the class of models that are stationary. Alternatively, if a model is specified in levels is equivalent to one in differences, then the sum of the coefficients on the own lags will equal to one, while, the sum of the coefficients on the other variables exactly equals zero. Though this holds for the mean of the Minnesota prior, used in this paper, the prior actually assigns a probability of zero to the class of parameter vectors that satisfy this restriction. LeSage (1990) and Dua and Ray (1995), however, point out that if a very tight prior is specified, the estimated model will be close to a model showing no cointegration. With the Minnesota priors, chosen in practice, being not so tight to produce the forecasts, concerns of misspecification with cointegrated data are, therefore, misplaced.

Evaluation of forecast accuracy

For a fair comparison, with the sticky-price model, we estimate the VARs and VECMs, both the Classical and the Bayesian variants, with the same variables with one lag, for the period 1994:1 – 2003:4. The variables used are, however, in levels, since as Sims *et al.*, (1990) has indicated that with the Bayesian approach entirely based on the likelihood function, the associated inference does not need to take special account of nonstationarity, since the likelihood function has the same Gaussian shape regardless of the presence of nonstationarity.⁹ In addition, to comparing the forecasting performance VARS and VECMs relative to the Dornbusch model, we also look at the performance of two versions of the EMH. Following Rossi (2005), the weak and semi-strong versions of the EMH used, respectively, in this study, can be formally outlined as follows¹⁰:

$$le_t = \beta le_{t-1} + \varepsilon_t, \varepsilon_t \sim N(0, \sigma_\varepsilon^2) \quad (14)$$

$$\Delta le_t = \beta_0 + \beta_1 \Delta intd_{t-1} + \beta_2 \Delta infd_{t-1} + \varepsilon_t, \varepsilon_t \sim N(0, \sigma_\varepsilon^2) \quad (15)$$

Note, following Doan (2000) and Dua *et al.*, (1999), we choose 0.1 and 0.2 for the overall tightness (w) and 1 and 2 for the harmonic lag decay parameter (d). Moreover, as in Dua and Ray (1995), we also report our results for a combination of w = 0.3 and d = 0.5. Finally, a symmetric interaction function $f(i, j)$ is assumed with $k_{ij} = 0.5$, as in Dua and Smyth (1995) and LeSage (1990).

The forecast accuracy of the Dornbusch model, the random walks, the VAR, the VECM, the BVARs and the BVECMs (for alternative priors) for the metical-rand exchange rate, are compared based on the Mean Absolute Percentage Errors (MAPEs) for the one- to four-quarters-ahead out-of-sample forecast errors over the period of 2004:1 to 2005:4. Note the MAPEs for the dynamic forecasts can be calculated using the following expression:

⁹ However, as shown in Tables B and C all the 5 variables were found to be, first-order difference stationary, i.e., integrated of order 1 (I(1)).

¹⁰ Tests on the coefficients, of the above two equations, and the overall fit revealed that the metical-rand exchange rate movements, over the period in concern, better reflected by the weak version of the EMH. In fact, in terms of the R^2 and the adjusted R^2 , the weak version even outperformed the sticky-price model. The results of the analyses have been suppressed due to issues of space, but can be made available, by the authors, upon request.

$$MAPE = \left(\frac{1}{N} \sum abs\left(\frac{A_{t+n} - F_{t+n}}{A_{t+n}}\right) \right) \times 100 \quad (16)$$

Also note that if A_{t+n} denotes the actual value of a specific variable in period $t + n$ and ${}_tF_{t+n}$ is the forecast made in period t for $t + n$, the MAPE statistic can be defined as:

$$MAPE = \sqrt{\frac{\sum (A_{t+n} - F_{t+n})^2}{\sum (A_{t+n} - A_t)^2}} \quad (17)$$

where *abs* stands for the absolute value. For $n = 1$, the summation runs from 2004:1 to 2005:4, and for $n = 2$, the same covers the period of 2004:2 to 2005:4 and so on.

From the results reported in Table F in the Appendix, we find that on average, between the random walk models and the Dornbusch model, the latter has the highest MAPE, whereas, the weak-form efficiency model has the lowest MAPE for the one- to eight-quarters-ahead forecast. However, the VARs and the VECMs, both Classical and Bayesian in nature, outperform the theoretical models. Amongst the VARs, and unlike in the literature¹¹, the Classical VAR always outperform the BVARs, for all the alternative set of specifications of the prior. Moreover, all the BVARs produce higher average MAPEs when compared to the Classical VECM. But the Classical VAR and VECM, in turn, are outperformed by all the BVECMs and amongst the latter, the BVECMs with relatively tight priors produces the minimum average MAPEs for the forecasting horizon. Thus, the results suggest that the tighter BVECMs, though atheoretical, are the best suited models for forecasting the metical-rand exchange rate.

V. CONCLUSIONS AND POLICY IMPLICATIONS

Three models of exchange rate determination were compared from the point of view of their out-of-sample forecast performances in comparison to VARs and VECMs, both Classical and Bayesian in nature. Based on the Dornbusch (1976), sticky-price model, we found that the metical-rand exchange rate is best explained by changes in GDP and inflation differentials, whereas, the interest rate differential plays a negligible role. In the long-run, while the metical-rand exchange rate is elastic with respect to the GDP differential, it is

¹¹ See Dua and Ray (1995) for a detailed review on the use of BVARs in carrying out economy- and region-wide forecasting. They observe that, generally, the BVARs outperform their Classical counterpart. However, as LeSage (1995) shows the same might not hold with the Classical VECM.

relatively less elastic in relation to the inflation differential, and highly inelastic with respect to the interest rate differential. The estimated Dornbusch model, thus, has two major implications. Firstly, open market operations, conducted by the Bank of Mozambique, in order to influence the discount rate, cannot be expected to exert a significant influence on the metical-rand exchange rate. Rather, other economic policies with a potential impact on GDP and inflation differentials can have a significant impact on the movement of the metical-rand exchange rate. For example, government investment in infrastructure and human capital coupled with supportive programs to Small, Medium and Micro Enterprises (SMMEs), that are not only able to integrate themselves with mega projects associated with Foreign Direct Investment (FDI), but, more importantly, where employment creation is an important element, can have a positive effect on the Mozambican GDP growth rate, and, hence, affect its differential with the South African one. Secondly, in the presence of an economic shock that pushes the exchange rate away from its long-run equilibrium, the money supply differential is not able to adjust the market mechanism in order to bring the metical-rand exchange rate back to its long-run equilibrium.

It should, however, be noted that not all the economic dynamics of both the Mozambican economy and South African economy are captured by the Dornbusch (1976) model adopted here. Aspects such as (i) the distortions imposed by tariffs or quotas on Mozambican imports from South Africa, (ii) inflation and exchange rate expectations, (iii) the degree of openness of the Mozambican economy could eventually play a critical role in the explanation of the metical-rand exchange rate over the period 1994:1 – 2005:4. Inclusion of these factors into the standard sticky-price model could be an area of further research in the explanation of the metical-rand behaviour.

Finally, in terms of the forecasting power, the BVECMs, with relatively tight specification of the prior, outperform all the models, whether theoretical or atheoretical. In other words, though the BVECMs are based on no proper theory, they, however, do indicate the role of the fundamentals in exchange rate modelling, unlike the EMH. This, in turn, then emphasizes, that the monetary model cannot be completely discarded. Perhaps, the inclusion of distortions, exchange rate expectations and degree of openness, as suggested above, in the traditional Dornbusch (1976) model, might improve its capabilities to forecast better the movement of the metical-rand exchange rate

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APPENDIX

Table A: *Data Description*

Data Series	Source	Code
Nominal metical-rand exchange rate, E	National Institute of Mozambique, Yearbooks (1995-2005)	N.A.*
Mozambican GDP (constant 2000 prices)	World Bank, <i>World Development Indicators</i>	DI; MOZNYGDPM
Mozambican M2	International Monetary Fund	IFS; 68834...BZF...
Mozambican nominal interest rate (discount rate)	International Monetary Fund	IFS; 68860...ZF...
Mozambican Consumer Price Index (2000=100)	International Monetary Fund	IFS; 68864...ZF...
South African real GDP, millions of Rand (constant 2000 prices)	International Monetary Fund	IFS; 19999B.CZF...
South African M2 (millions of Rand)	International Monetary Fund	IFS; 19959MB.ZF...
South African Consumer Price Index (2000=100)	International Monetary Fund	IFS; 19964...ZF...
South African nominal interest rate (discount rate)	International Monetary Fund	IFS; 19960...ZF...

* *N.A.* = *not available*

Figure 1: Inflation differential (infd), interest rate differential (intd), money supply differential (Lm2r), metical-rand exchange rate (Le) and real GDP differential (Lgdpr).

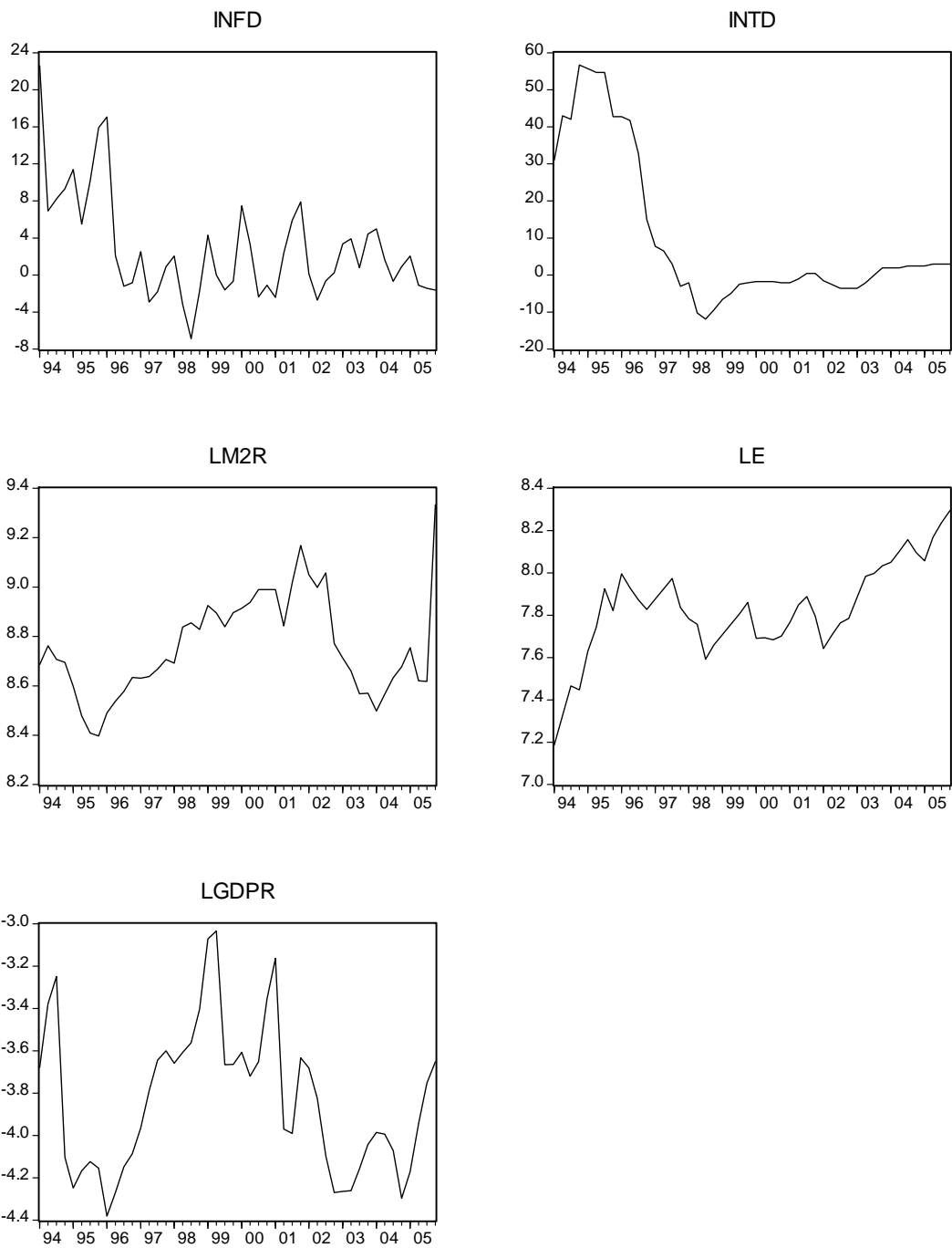


Figure 2: First-order differences of all the variables in Figure 1.

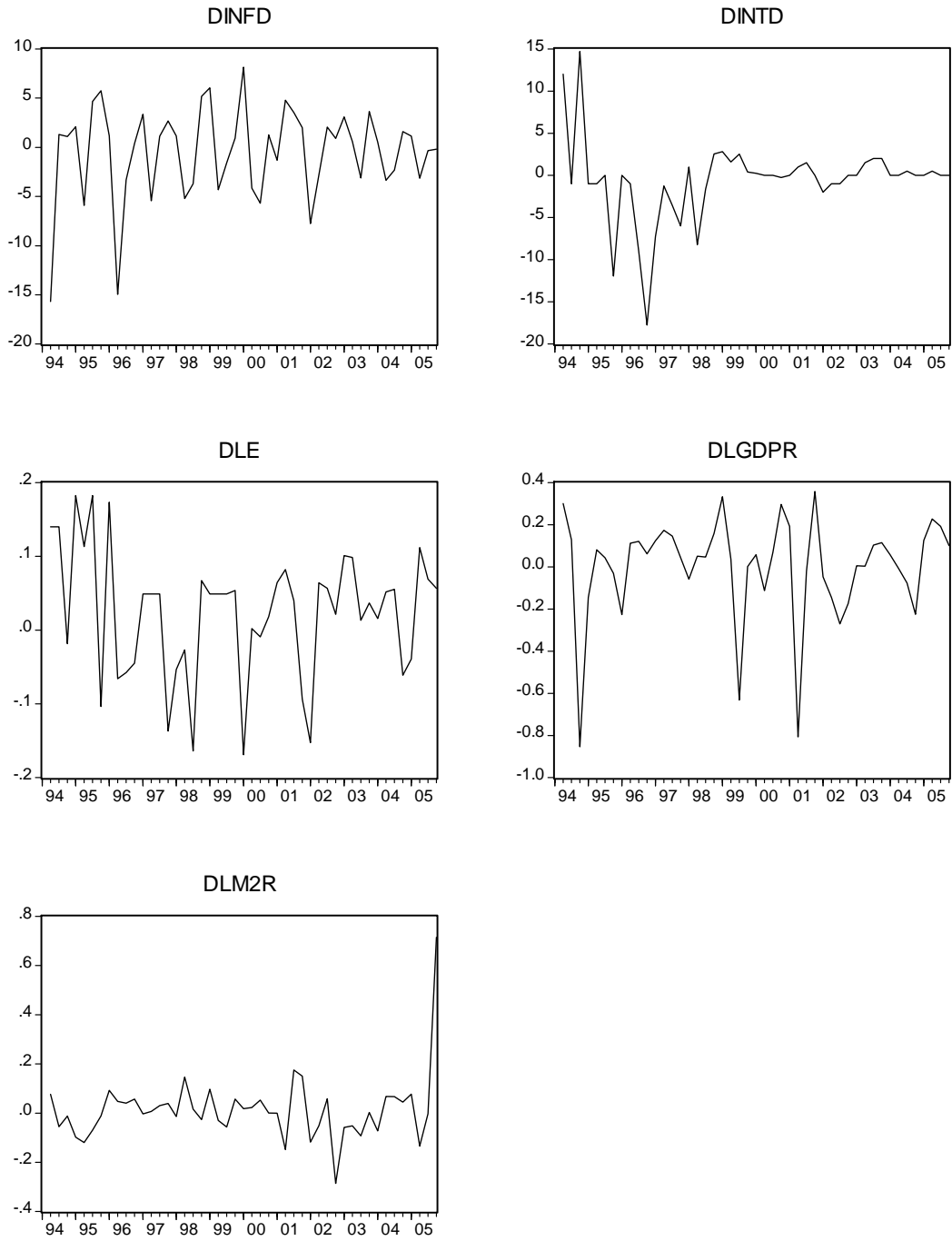


Table B: Univariate characteristics of all the variables (in levels) $H_0: \rho^* = 0$ (non-stationary) $H_1: \rho^* < 0$ (stationary)

series		ADF			PP		Conclusion
		Lags	t _m t _t	f ₃ f ₁	Lags		
<i>le</i>	Trend &						
	Intercept	1	-0.309319	20.07242	3	0.093777	
	Intercept	1	0.535692	27.00586	3	-0.300867	Non
<i>lgdpr</i>	None	1	-0.994884		3	-0.968411	stationary
	Trend &						
	Intercept	1	-0.386382	20.78236	3	-0.249677	
<i>lm2r</i>	Intercept	1	-1.255907	29.74121	3	-1.512244	Non
	None	1	-1.224578		3	-0.920979	stationary
	Trend &						
<i>inf</i>	Intercept	3	-2.221206	2.380476	3	-1.911555	
	Intercept	3	-1.736899	2.144457	3	-1.577699	Non
	None	3	0.5979		3	0.680283	stationary
<i>intd</i>	Trend &						
	Intercept	3	-2.12486	5.084355	3	-4.661304***	
	Intercept	3	-2.248194	6.467015	3	-4.601127***	Non
<i>intd</i>	None	3	-2.427231		3	-4.493452***	stationary
	Trend &						
	Intercept	3	-2.698091	5.071423	3	-1.252604	
<i>intd</i>	Intercept	4	-4.007397***	6.482631	3	-1.300347	Non
	None	3	-4.43161***		3	-1.456554	Stationary

*(**) [***] statistically significant at 10 (5) [1] per cent, respectively.

where:

le = natural logarithm of nominal metical-rand exchange rate*lgdpr* = natural logarithm of real GDP differential*lm2r* = natural logarithm of nominal differential

infd = inflation differential

intd = interest rate differential

Table C: Univariate characteristics of all the variables (in differences)

$H_0: \rho^* = 0$ (non-stationary)

$H_1: \rho^* < 0$ (stationary)

series		ADF			PP		Conclusion
		Lags	t _m t _t	f ₃ f ₁	Lags		
<i>Dlgdpr</i>	Trend & Intercept	1	-6.198561***	14.30124***	3	-5.746690***	stationary
	Intercept	1	-6.025013***	20.28438***	3	-5.655135***	
	None	1	-5.979625		3	-5.669163***	
<i>Dlm2r</i>	Trend & Intercept	2	-1.906827	5.607859	3	-3.878643**	stationary
	Intercept	2	-2.006037	7.127527*	3	-3.947903***	
	None	2	-2.035944		3	-3.990152***	
<i>Dle</i>	Trend & Intercept	0	-6.119227***	18.82094***	3	-6.116120***	stationary
	Intercept	0	-6.203518***	38.48363***	3	-6.200493***	
	None	0	-5.964429***		3	-5.963327***	
<i>Dintd</i>	Trend & Intercept	0	-5.414911***	14.99263***	3	-5.404249***	stationary
	Intercept	0	-5.225780***	27.30878***	3	-5.234573***	
	None	0	-5.103314***		3	-5.132684***	
<i>Dinfd</i>	Trend & Intercept	4	-4.502060***	14.01804***	3	-8.762545***	stationary
	Intercept	4	-4.496312***	17.00013***	3	-8.996579***	
	None	4	-4.426077***		3	-9.110918***	

*(**)[***] statistically significant at 10 (5) [1] per cent, respectively.

where:

Dle = first difference of the natural logarithm of nominal metal-rand exchange rate

Dlgdpr = first difference of the natural logarithm of real GDP differential

Dlm2r = first difference of the natural logarithm of nominal money supply differential

Dinfd = first difference of inflation differential

Dintd = first difference of the interest rate differential

Table D: *lag length*

VAR Lag Order Selection Criteria

Endogenous variables: *le lgdpr lm2r infd intd*

Exogenous variables: C

Sample: 1994Q1 2005Q4

Included observations: 44

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-294.3855	NA	0.559388	13.60843	13.81118	13.68362
1	-102.3378	331.7188*	0.000284*	6.015354*	7.231847*	6.466489*
2	-83.34662	28.48677	0.000391	6.288483	8.518720	7.115562
3	-56.72146	33.88657	0.000410	6.214612	9.458593	7.417636
4	-34.17590	23.57036	0.000586	6.326177	10.58390	7.905147

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Table E: *Stability test of the VECM*

Roots of Characteristic Polynomial

Endogenous variables: *le lgdpr lm2r infd intd*

Exogenous variables:

Lag specification: 1 2

Root	Modulus
1.000000	1.000000
1.000000 - 8.89e-16i	1.000000
1.000000 + 8.89e-16i	1.000000
0.648117 - 0.416235i	0.770265
0.648117 + 0.416235i	0.770265
-0.112260 - 0.663009i	0.672446
-0.112260 + 0.663009i	0.672446
-0.651469	0.651469
0.064636 - 0.633434i	0.636723
0.064636 + 0.633434i	0.636723
0.560219	0.560219
-0.205595 - 0.254376i	0.327073
-0.205595 + 0.254376i	0.327073
0.172039 - 0.085116i	0.191943
0.172039 + 0.085116i	0.191943

VEC specification imposes 3 unit root(s).

Table F: MAPE (2004:1-2005:4): metical-rand exchange rate in logs

					w=0.3, d=0.5		w=0.2, d=1		w=0.2, d=2		w=0.1, d=2		w=0.1, d=1		
QA	model 1	model2	model3	VAR	VECM	BVAR	BVECM	BVAR	BVECM	BVAR	BVECM	BVAR	BVECM	BVAR	BVECM
1	15.3856	1.575558	1.35394	0.0137	0.0000	0.0123	0.0004	0.0107	0.0009	0.0107	0.0009	0.0029	0.0029	0.0029	0.0029
2	17.3413	1.085516	1.5470	0.059	0.0709	0.0605	0.0701	0.0622	0.0692	0.0622	0.0692	0.0712	0.0654	0.0712	0.0654
3	12.5532	0.913986	3.71763	0.1535	0.029	0.1546	0.1378	0.156	0.1367	0.156	0.1367	0.1635	0.1322	0.1635	0.1322
4	23.0863	0.726921	0.02347	0.0806	0.2600	0.0812	0.0279	0.082	0.0266	0.082	0.0266	0.0873	0.0213	0.0873	0.0213
AV	17.0916	1.075495	1.66051	0.0767	0.0596	0.0771	0.0590	0.0777	0.0583	0.0777	0.0583	0.0812	0.0554	0.0812	0.0554

MAPE: mean absolute percentage error; QA: quarter ahead; AV: Average

Model 1: Dornbusch model; model 2: weak-form efficiency of exchange rate; model 3: semi-strong form efficiency of exchange rate