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Exchange Rate Determination Under Monetary Policy Rules in a Financially Underdeveloped Economy: A Simple Model and Application to Mozambique*

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Abstract

Microstructure aspects of nominal exchange rate determination are less relevant in countries with embryonic financial markets. In less-developed economies, trade in goods and services is a more significant driver of currency demand than financial market speculation or hedging; and central banks actively set monetary variables. We develop a simple variation of the standard monetary model of exchange rate determination, incorporating interest rate rules but not relying on interest rate parity; and study the effect of monetary fundamentals on the Mozambican exchange rate. We find a long-run relationship between fundamentals and exchange rates, with coefficient signs in regression equations consistent with theoretic predictions. Moreover, the monetary model outperforms a random walk in predicting metical exchange rates out-of-sample at the four-quarter horizon.

1 Introduction

1.1 Motivation

Standard models of exchange rate determination based on macroeconomic variables, such as price levels, aggregate output, money supply, etc., and henceforth referred to as monetary models, perform worse than a simple martingale in forecasting developed countries’ exchange rates out-of-sample, over short and medium-term horizons (Meese and Rogoff (1983), Frankel and Rose (1995), Lyons (2001)). The evidence on the ability of standard monetary models to explain and forecast exchange rates over very long horizons (about sixteen quarters ahead) is better, but mixed and inconclusive (Nelson (1995), Chen and Chou (2008)).¹

The existing evidence is overwhelmingly based on the analysis of heavily traded currencies from either advanced or emerging economies with developed financial systems. For such currencies, the large volume of currency trading – an average of over three trillion dollars traded per day in the global currency markets by 2007 (Bank of International Settlements (2007)) – can only be explained by micro-structure effects (currency market participants’ trading behaviour due to speculative and hedging demand), and it seems unlikely that simple monetary models can fully explain exchange rate oscillation. (See Lyons (2001).) Less-developed economies are characterised by embryonic financial

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¹Note that the empirical evidence against monetary models relies heavily on the models’ ability to perform better than a random walk in forecasting the exchange rate. Alternative model evaluation criteria can lead to more encouraging results. See Engel, Mark and West (2007).
markets which are only partly integrated with international financial markets. Demand for currency is driven largely by trade in goods and services, rather than currency speculation and hedging. This setting leads to comparatively infrequent currency movements (though the magnitude of movements can be large due to the high price impact of trades), so macroeconomic fundamentals may play a more significant role in the determination of exchange rates — provided we do not rely on the interest parity conditions ubiquitous in the literature.

Moreover, developing-country central banks are responsible for achieving and maintaining macroeconomic stability, leading to an active role in setting monetary variables, analogous to the Taylor rule-following central banks in more advanced economies. Recent research points to an improvement in the performance of macroeconomic exchange rate models when central banks are assumed to set the interest rate in response to the inflation and output gaps (plus, in some cases, the real exchange rate) — rather than treating money supply as an exogenous variable, as is typically done in monetary models. (Engel and West (2006); Engel, Mark and West (2007); and Mark (2009).) So far, this promising research produced models only of the real exchange rate, relies centrally on uncovered interest parity, and has not been applied to a developing-country setting.

1.2 Background: assumptions of the standard monetary model

The standard monetary model consists of three relationships: money market equilibrium; purchasing power parity (PPP, henceforth); and uncovered interest parity (UIP, henceforth). The first is a basic domestic equilibrium relationship. The open-economy element comes from the second and third relationships. The second, PPP, postulates the exchange rate to be such that the prices of homogeneous goods in the domestic and foreign market are equalised when expressed in a common currency and subject to transaction costs. The third relationship, UIP, equates the interest differential to the expected depreciation of the domestic currency over the term of the bonds or deposits to which the interest rates apply. Under perfect foresight it is an arbitrage relationship, such that if it fails there would be unexploited profits in the international bond markets. (Obstfeld and Rogoff (1996).)

The evidence on PPP is mixed. Although strongly rejected as a continuously holding relationship, it is generally regarded as a valid long-term indication of central tendency for the exchange rate. (See for example Sarno and Taylor (2002), chapter 3.) Since goods prices take longer to adjust than securities prices, in principle, PPP should not be expected to hold in the short term. For Mozambique, PPP is supported by existing evidence on the extent and speed of exchange rate pass-through (to domestic prices). (Vicente (2007), Cirera and Nhate (2009).) These findings are consistent with existing studies supporting PPP in less-developed countries, especially in high-inflation economies (Holmes (2000)); and with Mozambique’s large share of imported goods in domestic demand.

Theoretically, uncovered interest parity ought to apply in the short as well as long term. Indeed, it should hold continuously. In practice, it does not. There is some evidence supporting UIP over very long (ten-year) horizons and between currencies and long-term bonds traded in deep and fluid internationally integrated financial markets. (Chinn and Meredith (2004).) But the overwhelming evidence on UIP as a short to medium-term relationship firmly rejects the hypothesis. (Flood and Rose (2002), Chinn (2006), Bergman and Hassan (2008).) More recent studies turn to

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2 This is the case in most of Africa, and the less-developed economies in Latin America, Asia and Eastern Europe. Average monthly turnover in Mozambique’s interbank foreign exchange market is less than 100 million US dollars (Banco de Moçambique, Boletim Mensal de Conjuntura, 2009).

3 The standard monetary model was introduced by Frenkel (1976) and Mussa (1976). Standard textbook treatments include Frankel and Rose (1995), and Obstfeld and Rogoff (1996), chapter 8.

4 According to UIP, currency depreciation is expected if the domestic interest rate exceeds the foreign interest rate; and appreciation is expected if the differential is negative.

5 To illustrate the extent of the failure, consider the evidence in Flood and Rose (2002), who look at short-horizon UIP using high-frequency data from 21 countries during the main crisis episodes of the 1990s. The slope coefficient
the profitability of trading strategies designed to exploit deviations from UIP. These strategies yield particularly attractive returns when applied to emerging markets – compared to industrialised countries. (Burnside, Eichenbaum, and Rebelo (2007); Hassan and Smith (2009).)

That PPP enjoys some support in less-developed economies, while UIP is only supported (for sufficiently long horizons) among higher-income economies, should not be surprising. UIP is an asset market (quasi-) arbitrage relationship, relying on fluid and deep financial markets. PPP is driven by trade in goods. The latter can be the main driver of currency transactions in less-developed countries, but accounts for only a very small share of currency trading in developed markets. (See Lyons (2001).)

1.3 Contribution

In the case of financially under-developed low-income economies, interest parity is neither an empirical fact nor a realistic assumption from a theoretic viewpoint. (See Aron and Ayogu (1997).) Domestic and foreign assets are nowhere near perfect substitutability; currency and fixed-income markets are illiquid. The financial markets are rudimentary and largely isolated from international portfolio investment flows; and the arbitrage-based theoretic motivation for interest parity conditions is inapplicable. Hence, from the standard monetary model (Frenkel (1976), Mussa (1976), Frankel and Rose (1995)), we assume only money market equilibrium and PPP.

In the standard model, monetary policy is exogenous – interest rates adjust to equate money supply to money demand. In reality, central banks worldwide respond to the evolution of macroeconomic fundamentals when, and by, setting the short-term rate – especially in response to deviations of inflation and output growth from targets (or target bands). (Clarida, Gali and Gertler (1998).)

This paper adds to the recent literature linking interest rate rules to exchange rate determination in three ways. First, we develop a simple theoretical model of the nominal exchange rate, with symmetric interest rate rules. Second, we do not assume UIP. Given the low-income developing-country focus of the paper, we consider instead PPP as the international parity condition. Lastly, we examine empirical exchange rate behaviour in a financially underdeveloped economy, namely Mozambique.

The remainder of the paper is organised as follows. Section 2 presents the theoretical model. Section 3 presents the analysis and implications of the model, leading to an equation for the nominal exchange rate. Section 4 begins the empirical analysis, describing the data and performing stationarity tests. Section 5 presents regression results. Section 6 examines the forecasting performance of the model. Section 7 concludes. The appendix contains further graphs and details on the data.

2 Setting

Assume money market equilibrium and inflation targeting, in both the domestic and foreign economies; and PPP as the international parity relationship.

2.1 Money Market Equilibrium in Domestic and Foreign Economy

From the conventional LM curve (Keynes-Hicks) we have

\[ \frac{M_t}{P_t} = L(Y_t, I_t), \]

where \( M_t, P_t, Y_t, \) and \( I_t \) denote the domestic levels of nominal money supply, the price level, real output and nominal interest rates, all at \( t \); and \( L \) is a demand for real money function. Assume (in regressions of the interest differential on exchange rate depreciation, which is equal to 1 if UIP holds) is negative in twelve cases, essentially zero in two cases, and positive in seven cases. Of the seven positive coefficients, three are statistically significant. None of these three is meaningfully close to 1.
log-linear Cagan-type money demand
\[
\log M_t - \log P_t = \phi \log Y_t - \eta \log I_t, \tag{2}
\]
where $\phi$ and $\eta$ are positive parameters (elasticity of demand for real money balances with respect to output and interest rates respectively). Let $m \equiv \log M$, $p \equiv \log P$, $y \equiv \log Y$ and $I = (1 + i)$. Then:
\[
m_t - p_t = \phi y_t - \eta i_t. \tag{3}
\]
Assume the same relationship to hold in the foreign market, with identical money demand elasticity parameters. Letting * represent foreign quantities, we have
\[
m^*_t - p^*_t = \phi y^*_t - \eta i^*_t, \tag{4}
\]
describing money market equilibrium in the foreign economy.

### 2.2 Purchasing Power Parity

Let $P^*_t$ and $\varepsilon_t$ denote, respectively, foreign country prices and the nominal exchange rate, all at $t$, with the exchange rate expressed in units of domestic currency per unit of foreign currency. With flexible real-sector prices, ignoring transaction costs, international quasi-arbitrage in goods markets requires the cost of an identical basket of goods to command the same price in both countries, when expressed in the same currency:
\[
P_t = \varepsilon_t P^*_t. \tag{5}
\]
Taking logs gives:
\[
p_t = \varepsilon_t + p^*_t, \tag{6}
\]
where and $e \equiv \log \varepsilon$. Note that we do not assume uncovered interest parity. International parity stems from trade in goods alone.

### 2.3 Monetary Policy Rules

Instead of letting the interest rate change to equate money supply and money demand, we assume that both central banks determine the benchmark short-term interest rate depending on macro-economic fundamentals. Specifically, the central bank sets the benchmark nominal interest rate in response to the deviation of the price level from a target, $\rho$, and the deviation of output from a target $\gamma$. (Taylor (1993).) For simplicity, the targets are assumed constant and the central bank reacts to current data. The central bank’s interest rate reaction function is summarised by a standard Taylor rule (Taylor (1993), Woodford (2003), Engel and West (2006)),
\[
i_t = \alpha + \xi (p_t - \rho) + \delta (y_t - \gamma), \tag{7}
\]
where $\xi$ and $\delta$ are positive parameters. The foreign central bank follows the analogous rule
\[
i^*_t = \alpha^* + \xi^* (p^*_t - \rho^*) + \delta^* (y^*_t - \gamma^*), \tag{8}
\]
where for convenience we assume equal monetary policy responsiveness parameters $\xi$ and $\delta$ (Engel and West (2006)).

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6 See Obstfeld and Rogoff (1996, chapter 10) for the development of the micro-foundations for the standard money demand model used here.
2.4 Remarks

In the empirical section we will examine the metical-rand and metical-dollar exchange rates. Empirical research shows that the postulated interest rate rules are valid (implicit) summarised descriptions of interest rate policy in the United States (Taylor (1993)) and South Africa (Woglom (2003)).

It may be argued the Mozambican monetary authorities only target price stability, not the output gap.\(^7\) In that case, the parameter $\delta$ is zero, so the interest rate rule changes to the Wicksellian form used in Calvo (2007) (Wicksell (1907), Woodford (2003)): 

$$i_t = \alpha + \xi(p_t - \rho).$$

As we will see, this change affects a coefficient in the exchange rate equation, but not its form nor the right-hand side variables.

3 Analysis and results

3.1 Standard monetary model without UIP

Assumptions A1 and A2 constitute the standard monetary model without UIP. The first part of our analysis is therefore standard, and included here for completeness. (See Obstfeld and Rogoff (1996), chapter 8.) Subtract (4), the condition for money market equilibrium in the foreign economy, from (3), the equation for domestic money market equilibrium, to find

$$(m_t - m_t^*) - (p_t - p_t^*) = \phi(y_t - y_t^*) - \eta(i_t - i_t^*).$$

(10)

Re-arrange to obtain

$$(p_t - p_t^*) = (m_t - m_t^*) - \phi(y_t - y_t^*) + \eta(i_t - i_t^*).$$

(11)

Use equation (6), PPP, for $(p_t - p_t^*)$ and let $f_t \equiv (m_t - m_t^*) - \phi(y_t - y_t^*)$. This gives the exchange rate as a function of two macro “fundamentals”, money and output, and the interest differential:

$$e_t = f_t + \eta(i_t - i_t^*).$$

(12)

The implications are well-known. An increase in money supply leads to a higher price level, through money market equilibrium; through PPP the exchange rate depreciates. An increase in real output raises money demand. Money market equilibrium then requires a decrease in the domestic price level, causing appreciation through PPP. Finally, an increase in domestic interest rates reduces money demand, requiring either a reduction in money supply or an increase in the price level, or both. The increase in domestic prices leads to an increase the exchange rate, through PPP.

3.2 Exchange rate model with an interest rate rule but no UIP

The interest rate rules in the domestic and foreign economies determine the interest differential. Thus, if central banks target the inflation deviation and the output gap, we have, using (7) and (8), and letting $\alpha = \alpha^*$,

$$(i_t - i_t^*) = \xi((p_t - p_t^*) + (\rho - \rho^*)) + \delta((y_t - y_t^*) - (\gamma - \gamma^*)).$$

(13)

For simplicity, equate domestic and foreign target price and output levels, i.e. $\rho = \rho^*$ and $\gamma = \gamma^*$. Then,

$$(i_t - i_t^*) = \xi(p_t - p_t^*) + \delta(y_t - y_t^*).$$

(14)

\(^7\)The primary objective of Mozambique’s central bank is the “preservation of the value of the national currency/money.” (Authors’ translation of Article 3 of the central bank’s mandate, published in Assembleia da República, Lei n°. 01/92 de 03 de Janeiro.) Since the exchange rate is officially flexible, we take this to mean the maintenance of domestic purchasing power.
Now substitute into the exchange rate equation (12) to obtain
\[ e_t = (m_t - m^*_t) - (\phi + \eta \delta)(y_t - y^*_t) + \eta \xi (p_t - p^*_t). \]  
(15)

Equation (15) describes the monetary determinants of the nominal exchange rate when both central banks pursue an interest rate rule (Taylor (1993)), and two building blocks of the standard monetary model apply, namely, money market equilibrium and PPP. It is, by construction, a model for the medium to long-term value of the currency, since each assumption can only realistically describe low-frequency behaviour. It differs from the standard monetary model in two ways. (See Frankel and Rose (1995), p. 1692.) First, the price differential is retained as an exchange rate determinant. Second, the coefficients of the output and price differentials in the exchange rate equation are driven by interest rate rule parameters, in addition to the usual elasticity parameters from the money demand equation.

Ceteris paribus, the exchange rate appreciates if domestic money supply reduces relative to foreign money supply; if domestic output growth exceeds foreign output growth; and/or if domestic inflation reduces relative to foreign inflation. It is interesting to determine how quickly Mozambican exchange rates react to deviations from their long-run equilibrium implied in (15). In order to do so, following the Engle-Granger methodology, we developed a short-run version of (15) by using the rate of change of the variables and the error-correction mechanism (ECM) underlying (15). Coefficients of ECM terms are expected to provide information regarding the speed of adjustment to the equilibrium. The ECM version of (15) is given by
\[ \Delta e_t = \theta_1 \Delta(m_t - m^*_t) + \theta_2 \Delta(y_t - y^*_t) + \theta_3 \Delta(p_t - p^*_t) + \theta_4 v_{t-1} + x_t, \]  
(16)

where $\Delta$ denotes the first-difference operator, $x_t$ is a random error term and $v_{t-1}$ is the one-period lagged value of the error from the equilibrium regression (15). ECM equation (16) states that the rate of change of the ratio of domestic-to-foreign fundamentals and also on the equilibrium error term. If the equilibrium error term $v_{t-1}$ is nonzero, then the model is out of equilibrium, which is likely to happen in the short-run. Equation (16) is thus a short-run representation of our macro model (15). Coefficients $\theta_1$, $\theta_2$ and $\theta_3$ measure the impact of short-run changes of our macro fundamentals on the exchange rate. Since $\theta_4$ is expected to be negative, the term $\theta_4 v_{t-1}$ will be positive (negative) if $v_{t-1}$ is below (above) its equilibrium value (zero). Thus, the absolute value of $\theta_4$ decides how quickly the long-run equilibrium is restored.

4 Data and Stationarity Tests

We now turn to an empirical examination of (15), with a focus on coefficient signs of the explanatory variables, and predictive content relative to a naïve random walk. The data are quarterly observations for Mozambique (Moz), South Africa (SA), and the United States (US). The sample consists of 56 observations, extending from the first quarter of 1994 (coinciding with the liberalisation of Mozambique’s currency market) to the fourth quarter of 2007. We consider South African and US data because the rand and the dollar are the most important exchange rates in Mozambique. (The rand due to close trade links with South Africa, which is the origin of approximately 30 percent of Mozambique’s imports; and the dollar is the main reference currency for most currency transactions.) Exchange rates are in units of metical per unit of foreign currency. The monetary variable is M2. Price levels are measured by Consumer Price Indices (CPI). Output is measured by real Gross Domestic Product (GDP). Following Meese and Rogoff (1983), the data are not adjusted for

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8In comparison, Portugal (the former colony) and China account for approximately 4 and 3 percent, respectively, of Mozambique’s imports. (Instituto Nacional de Estatística.)

9Mozambican data were obtained from Banco de Moçambique (Mozambique’s central bank) and Instituto Nacional de Estatística; South African data from the South African Reserve Bank and Statistics South Africa; US data from the Federal Reserve System (esp., Federal Reserve Bank of St. Louis), the Bureau of Economic Analysis, and the Bureau for Labor Statistics.
seasonality.

The data series are non-stationary (i.e. either the mean or the auto-covariances depend on the date – see Hamilton (1994, chapter 3)). This is immediately apparent from visual examination of the graphs in Appendix A, particularly for exchange rates, and the differences between domestic and foreign money, and prices (all in natural log form). Tables 1 and 2 show the results of the Dickey-Fuller unit root test for stationarity (Dickey and Fuller (1979), Harvey (1993), p. 130-131, Hamilton (1994) chapter 17.)\textsuperscript{10}

The levels test shows that, for all variables, the computed statistics are not more negative than the critical values. They are, however, when in first-difference form. We observe the same general result when analysing the metical-dollar rate and associated explanatory variables.

The statistical tests confirm that all series are I(1) – i.e. they are non-stationary, and become stationary on first differencing.

\section{5 Regression results}

Table 3 reports the cointegration and error correction regression results for our macro model with monetary policy rules. Specifically, the table presents OLS estimates of the regressions

\begin{equation}
\begin{aligned}
e_t &= \alpha + \beta_1(m_t - m_t^*) + \beta_2(y_t - y_t^*) + \beta_3(p_t - p_t^*) + v_t, \\
\Delta e_t &= \phi + \theta_1 \Delta(m_t - m_t^*) + \theta_2 \Delta(y_t - y_t^*) + \theta_3 \Delta(p_t - p_t^*) + \theta_4 v_{t-1} + x_t,
\end{aligned}
\end{equation}

where \( \Delta \) denotes the first difference operator, \( x_t \) is a random error term and \( v_{t-1} \) is the one-period lagged value of the error from the equilibrium regression (E17). For evaluation of our model’s predictive performance, we also estimate a driftless random walk

\begin{equation}
e_t = e_{t-1} + u_t,
\end{equation}

where \( v \) and \( u \) are random disturbances (irregular components or measurement error). Regression results for the random walk model are presented in Appendix D.

The dependent and explanatory variables are cointegrated if the residuals from these regressions (which form a linear combination of the dependant and explanatory variables) are stationary, or I(0). We can then conclude that there is a long-term relationship between the exchange rate and macro fundamentals (rather than spurious correlations).

We test the residuals for stationarity using the augmented Dickey-Fuller test (Dickey and Fuller (1979), Harvey (1993), p. 132, Hamilton (1994) chapter 17, p. 501-502). Table 4 shows the results.

We conclude that the exchange rate and the macro fundamentals are cointegrated; thus the regression coefficients are statistically consistent. Notice that the coefficient signs are consistent with our expectations from theory. In the long run, faster economic growth in the domestic economy generates an appreciation of the domestic currency; but faster increases in domestic money supply or prices depreciate the currency. The in-sample fit of the model is illustrated in Figure 1. Blue lines (darker) are actual exchange rates; red lines (lighter) are model-estimated exchange rates.

Considering that we do not use the lagged exchange rate as an explanatory variable, the in-sample fit is very high. (For comparison, see for example Frankel (2007).) Notice that the actual metical-dollar exchange rate is smoother than the rate given by the estimated regression parameters. This is somewhat unusual. Typically, exchange rates are more volatile than macroeconomic fundamentals, which helps explain the poor empirical performance of macroeconomic models of exchange rate determination.

\textsuperscript{10}The statistical procedures employed here are standard, but note that there are fundamental difficulties to establishing whether a time series has a unit root on the basis of a finite sample of observations. (See Hamilton (1994), p. 444-445.)
Table 3 also presents regression results for the ECM model. The results suggest that, for both metical-dollar and metical-rand rates, the elasticity of exchange rate to macro-fundamentals is higher in the long run (cointegrating regression) than in the short run (ECM), except for money supply differentials (indeed, the coefficients of the rate of change of money supply differentials have the wrong sign). The ECM term, which is the key element in ECM models, behaves as expected and is significant at the 1% level for both the metical-dollar and metical-rand rates. According to the estimated ECM coefficients, if the metical-dollar rate deviates from its equilibrium level in a given quarter, 18% of such deviation would be corrected in the following quarter. In the case of the metical-rand rate the adjustment would be smaller (13%), as implied by its ECM coefficient.

6 Forecasting performance

Since Meese and Rogoff (1983), forecasting ability has been the most common test of the performance of an exchange rate model (Engel, Mark and West (2007)). We evaluate out-of-sample forecast accuracy using the minimum mean square error criterion, and contrast the regression forecast root mean square error (RMSE, henceforth) to that of the driftless random walk (Harvey (1993), p.33-34, Nelson (1995). As a simple additional statistic, we also report the mean absolute percentage error (MAPE).

The original regressions were estimated excluding the four last quarters in the data set. The least-squares coefficients were then used to obtain the exchange rate forecast for the next quarter, using the actual values of the explanatory variable for this quarter (a la Meese and Rogoff (1983)). The exchange rate forecast is then added to the exchange rate series, and the procedure is repeated for the each of the remaining out-of-sample quarters. The results are reported in Table 5.

The model’s forecast of the metical-rand exchange rate becomes more accurate than that of a simple random walk at the four-quarter forecast horizon. That is, the ratio of the regression forecast RMSE to the random walk RMSE goes from around 1.7 (one to three-quarter forecast) to 0.17 (four quarters horizon). Figure 2a illustrates our findings for the metical-rand rate.

The same pattern is observed for the metical-dollar exchange rate, where we see that the forecasting accuracy of the regression model is poorer (in the sense of a larger RMSEs) than that of the simple random walk at horizons from one to three quarters; but this is reversed at the fourth-quarter horizon, where the model forecast has a lower MPSE than the random walk. See Figure 2b for an illustration.

Our results indicate that macroeconomic fundamentals play a greater role in forecasting the metical-rand and metical-dollar rates at medium-term to long horizons, rather than at short horizons. Longer samples may permit further research and insights in the future.

Note that in most of the international literature on advanced economies, evidence of predictive performance using monetary models requires substantially longer horizons. Nelson (1995) for example, finds comparable improvements in forecasting accuracy (to a ratio of model forecast MPSE to random walk forecast MPSE, of circa 0.50), only at the 16-quarter horizon.

7 Concluding remarks

Mozambique adopted a flexible exchange rate regime in 1994. This paper develops and tests empirically an analytic model for understanding the influence of macroeconomic (monetary) variables on the free-floating value of the Mozambican currency. The model consists of a simple extension of a standard monetary model of exchange rate determination, adapted to reflect salient features of a financially under-developed economy. Trade in goods is assumed to be a more significant driver of currency transactions than international capital market flows; and the central bank, both domestically and in the foreign economy, are assumed to play an active role in setting benchmark interest rates. Specifically, central banks follow interest rate rules, increasing (respectively, decreasing) the
interest rate when the growth in domestic prices exceeds (is lower than) an inflation target; and decreasing (increasing) the interest rate when economic growth is lower (higher) than desired.

Our results indicate a long-run relationship between metical exchange rates and the standard monetary fundamentals (money and output), plus inflation. Specifically, faster economic growth strengthens the value of the metical; but high inflation and/or monetary expansion weaken the metical. Our empirical analysis confirms these effects for the two main exchange rate pairs for Mozambique: the metical-dollar and metical-rand rates. In the medium to long-term, the positive effect of economic growth, and the negative effect of inflation are particularly strong. Hence, policy decisions which contribute to economic growth, while keeping inflation low, will have a positive medium to long-term impact on the value of the currency.

Internationally, similar models of exchange rate determination typically perform worse than a naïve “random walk” in predicting short-term (less than one year) and medium-term exchange rate fluctuations in rich economies and emerging markets. We examine an out-of-sample forecast horizon of one to four quarters. We find that the model predicts the metical-rand and metical-dollar rates better than a random walk at the fourth-quarter horizon, but not at shorter horizons. We also find that the metical-dollar rate seems less variable than its fundamentals (as implied by the regression model). One possible interpretation for this finding on the metical-dollar rate is that the metical-dollar rate is better modelled as fluctuating within an implicit (possibly varying) range, rather than floating free of any official intervention. This issue may be worth further investigation.

Lastly, note that previous research shows that inflation in Mozambique is affected not only by monetary aggregates, but also by climatic conditions affecting agricultural output (Ubide (1997)). Similarly, there will be factors beyond the control of economic policy makers which affect the country’s rate of growth. This paper shows that these factors, through their effects on output and inflation, eventually contribute to movements in Mozambican exchange rates. Conversely, policy decisions which contribute to economic growth, while keeping inflation low, will have a positive medium to long-term impact on the value of the currency.

References


### Table 1: Stationarity Test: Natural Log of MT/ZAR Rate

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<th>Variable (Log of)</th>
<th>DF statistic</th>
<th>Critical Values</th>
<th>p-value</th>
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</thead>
<tbody>
<tr>
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### First Differences Test

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<th>Variable (Log of)</th>
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<th>Critical Values</th>
<th>p-value</th>
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<tbody>
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### Table 2: Stationarity Test: Natural Log of MT/USD Rate

<table>
<thead>
<tr>
<th>Variable (Log of)</th>
<th>DF statistic</th>
<th>Critical Values</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange rate (MT/USD)</td>
<td>-2.998</td>
<td>-3.555 -2.916 -2.596</td>
<td>0.04</td>
</tr>
<tr>
<td>Domestic-Foreign M2 Ratio</td>
<td>0.452</td>
<td>-3.555 -2.916 -2.596</td>
<td>0.98</td>
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<tr>
<td>Domestic-Foreign GDP Ratio</td>
<td>-3.128</td>
<td>-3.555 -2.916 -2.596</td>
<td>0.03</td>
</tr>
<tr>
<td>Domestic-Foreign CPI Ratio</td>
<td>-0.598</td>
<td>-3.573 -2.916 -2.598</td>
<td>0.86</td>
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</table>

### First Differences Test

<table>
<thead>
<tr>
<th>Variable (Log of)</th>
<th>DF statistic</th>
<th>Critical Values</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange Rate (MT/USD)</td>
<td>-5.026</td>
<td>-3.557 -2.916 -2.596</td>
<td>0.00</td>
</tr>
<tr>
<td>Domestic-Foreign M2 Ratio</td>
<td>-7.012</td>
<td>-3.557 -2.916 -2.596</td>
<td>0.00</td>
</tr>
<tr>
<td>Domestic-Foreign GDP Ratio</td>
<td>-6.029</td>
<td>-3.557 -2.917 -2.596</td>
<td>0.00</td>
</tr>
<tr>
<td>Domestic-Foreign CPI Ratio</td>
<td>-5.872</td>
<td>-3.557 -2.917 -2.596</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Table 3: Cointegration and Error Correction Model - Regression Results

<table>
<thead>
<tr>
<th></th>
<th>Cointegrating Regression</th>
<th>Error Correction Regression 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>et=MT/USD</td>
<td>et=MT/USD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>et=MT/ZAR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>et=MT/ZAR</td>
</tr>
<tr>
<td>coef.</td>
<td>p-value</td>
<td>coef.</td>
</tr>
<tr>
<td>$y_t - y_t^*$</td>
<td>**-1.14 ** 0.000</td>
<td>**-0.78 ** 0.000</td>
</tr>
<tr>
<td>$m_t - m_t^*$</td>
<td>**0.32 ** 0.001</td>
<td>**0.17 ** 0.028</td>
</tr>
<tr>
<td>$p_t - p_t^*$</td>
<td>**0.19 ** 0.062</td>
<td>**0.58 ** 0.000</td>
</tr>
<tr>
<td>$v_{t-1}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>**-3.94 ** 0.014</td>
<td>**0.66 ** 0.266</td>
</tr>
<tr>
<td>Adj-R²</td>
<td>0.98</td>
<td>0.92</td>
</tr>
<tr>
<td>F Test</td>
<td>**973 ** 0.000</td>
<td>**217 ** 0.000</td>
</tr>
<tr>
<td>Observations</td>
<td>56</td>
<td>56</td>
</tr>
</tbody>
</table>

1 - Variables from the cointegrating regression enter in first differences and cointegrating residuals enter with one lag. ***, ** and * denote statistical significance at 1, 5% and 10%, respectively.

Table 4: Stationarity Test on Residuals

<table>
<thead>
<tr>
<th></th>
<th>Augmented Dickey-Fuller test with Intercept</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Critical Values</td>
</tr>
<tr>
<td></td>
<td>Model</td>
</tr>
<tr>
<td>MT/USD</td>
<td></td>
</tr>
<tr>
<td>MT/ZAR</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Forecast Evaluation

<table>
<thead>
<tr>
<th></th>
<th>Forecasting Horizon</th>
<th>IRR Monetary Model</th>
<th>Random walk 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RMSE</td>
<td>MT/USD</td>
<td>MT/ZAR</td>
</tr>
<tr>
<td></td>
<td>In-Sample (RMSE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 quarter</td>
<td>0.059</td>
<td>0.064</td>
</tr>
<tr>
<td></td>
<td>2 quarters</td>
<td>0.078</td>
<td>0.057</td>
</tr>
<tr>
<td></td>
<td>3 quarters</td>
<td>0.121</td>
<td>0.051</td>
</tr>
<tr>
<td></td>
<td>4 quarters</td>
<td>0.127</td>
<td>0.020</td>
</tr>
<tr>
<td></td>
<td>MAPE</td>
<td>1 quarter</td>
<td>0.510</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 quarters</td>
<td>0.763</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 quarters</td>
<td>1.191</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 quarters</td>
<td>1.261</td>
</tr>
</tbody>
</table>

1 - No intercept
Figure 1: In-Sample Fit
Blue lines (darker) are actual exchange rates; red lines (lighter) are model-estimated exchange rates

Actual and Estimated MT/USD Exchange Rate

Actual and Estimated MT/ZAR Exchange Rate
Figure 2a: Out-of-Sample Forecast: Metical-Rand Rate

Figure 2b: Out-of-Sample Forecast: Metical-Dollar Rate
APPENDIX A

A1: Mozambican Metical -South African Rand Data

Figure 1: Natural Log of MT/ZAR Rate 1994I-2007IV

Figure 2: First Differences of Log MT/ZAR Rate 1994I-2007IV

Data Source: Banco de Mocambique

Figure 3: Log of Mozambique/South Africa GDP Ratio 1994I-2007IV

Figure 4: First Differences of Log GDP Ratio Moz-SA 1994I-2007IV

Data Source: Banco de Mocambique

Figure 5: Log of M2 Ratio Moz-SA 1994I-2007IV

Figure 6: First Differences of Log M2 Ratio Moz-SA 1994I-2007IV

Data Source: Banco de Mocambique
A2: Mozambican Metical – US Dollar Data
APPENDIX B: MULTICOLLINEARITY

A variance inflation test shows that none of the explanatory variables in the model has a variance inflation factor larger than 10, except for the ratio of domestic to US price level, which is above 10. (As a common rule of thumb, we regard the model as free of severe multicollinearity when all variance inflation factors are below 10.)

<table>
<thead>
<tr>
<th>Model MT/ZAR</th>
<th>Variable</th>
<th>VIF</th>
<th>1/VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(m/m*)</td>
<td>4.06</td>
<td>0.246108</td>
<td></td>
</tr>
<tr>
<td>ln(y/y*)</td>
<td>2.93</td>
<td>0.340768</td>
<td></td>
</tr>
<tr>
<td>ln(p/p*)</td>
<td>2.70</td>
<td>0.370288</td>
<td></td>
</tr>
<tr>
<td>Mean VIF</td>
<td>3.23</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model MT/USD</th>
<th>Variable</th>
<th>VIF</th>
<th>1/VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(m/m*)</td>
<td>5.46</td>
<td>0.183171</td>
<td></td>
</tr>
<tr>
<td>ln(y/y*)</td>
<td>5.20</td>
<td>0.192247</td>
<td></td>
</tr>
<tr>
<td>ln(p/p*)</td>
<td>12.45</td>
<td>0.080318</td>
<td></td>
</tr>
<tr>
<td>Mean VIF</td>
<td>7.70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

APPENDIX C: FUNDAMENTALS
Figure 18: relationship between MT/USD and Moz to US money supply

Figure 17: relationship between MT/USD and Moz to US GDP

Figure 19: relationship between MT/USD and Moz to US CPI ratio

Figure 20: relationship between MT/USD and interest rate differential

APPENDIX D: COINTEGRATION AND RANDOM WALK MODEL – REGRESSION RESULTS
<table>
<thead>
<tr>
<th></th>
<th>IRR Monetary Model</th>
<th>Random Walk</th>
<th>Random Walk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef.</td>
<td>p-value</td>
<td>Coef.</td>
</tr>
<tr>
<td>$y_t - y_{t-1}$</td>
<td>-1.14*** 0.000</td>
<td>-0.78*** 0.000</td>
<td>------</td>
</tr>
<tr>
<td>$m_t - m_{t-1}$</td>
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<tr>
<td>$p_t - p_{t-1}$</td>
<td>0.19* 0.062</td>
<td>0.58*** 0.000</td>
<td>------</td>
</tr>
<tr>
<td>$e_{t-1}$</td>
<td>------ ------</td>
<td>1.00*** 0.000</td>
<td>1.00*** 0.000</td>
</tr>
<tr>
<td>Constant</td>
<td>-3.94 0.014</td>
<td>0.66 0.266</td>
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<tr>
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</tr>
<tr>
<td>Observations</td>
<td>56 56</td>
<td>55 55</td>
<td>55 55</td>
</tr>
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</table>

***, ** and * denote statistical significance at 1%, 5% and 10%, respectively.