SAJE South African Journal of Economics

ESSA The Economic Society of South Africa (Est. 1925)

South African Journal of Economics Vol. 85:1 March 2017

ASSESSING NONLINEAR DYNAMICS OF CENTRAL BANK REACTION FUNCTION: THE CASE OF MOZAMBIQUE

GERSON NHAPULO[†] AND JOÃO NICOLAU[*‡]

Abstract

This paper sheds some light on the elements governing monetary policy-making during the period 2000Q1–2015Q1 in Mozambique. We estimate a time-varying Taylor-type rule for the BM, using a Markov-switching (MS) model and a Threshold model. The general finding is that the behaviour of the BM can be characterised by two regimes. In regime 1, only changes in inflation trigger a reaction by the monetary authority. This behaviour is prominent after the establishment of the monetary policy committee in 2007 (CPMO). In regime 2, the BM reacts aggressively both to cool off the economic activity and to curb inflationary pressures. Regime 2 occurred most frequently during 2000–2006, when the fiscal policy might have played an important role in output stabilization. After the establishment of the CPMO, regime 2 occurred in the context of a steep rise in fuel and food prices in 2007–2008 and in 2010. Both the MS model and the Threshold model show similar asymmetric effects. We find evidence that inflation is viewed more seriously by the monetary authorities when it is accompanied by a high output-gap in the previous period, which triggers a more aggressive response from the monetary authorities.

JEL Classification: E58, E52, C54

Keywords: Taylor rule, Bank of Mozambique, Markov-Switching model, threshold autoregressive model

1. INTRODUCTION

Since the early 90s, the economic literature in the realm of monetary policy actions in terms of reaction function has been gaining momentum and leading economists use monetary aggregates and short-term interest rates as policy instruments (see Aragón and Portugal, 2010; Hutchison *et al.*, 2013). Nevertheless, the question on whether rules or discretion should be used to conduct the monetary policy is still unresolved. In practice, modern policy rules, such as the McCallum rule and Taylor rule (McCallum, 1987; Taylor, 1993), represent a constrained monetary authority's discretion as long as they have some flexibility in emphasizing alternative short-run inflation stabilization objectives (see, for instance, Patra and Kapur, 2012).

McCallum (1987) suggested a rule whereby the monetary authority targets a nominal income, using a monetary base as the main policy instrument. However, the ascendancy

* Corresponding author: ISEG Mathematics Rua do Quelhas, 6 Lisbon 1200-781. E-mail: nicolau@iseg.ulisboa.pt

† Bank of Mozambique, Research and Statistics Department, Central Bank of Mozambique.

‡ ISEG (Lisbon School of Economics & Management), Universidade de Lisboa and CEMAPRE.

João Nicolau was partially supported by the Project CEMAPRE - UID/MULTI/00491/2013 financed by FCT/MEC through national funds.

 doi: 10.1111/saje.12149

of the new Keynesian framework from the late 90s, *inter alia*, has implied a downgrading of monetary aggregates and an upgrading of the Taylor rule in explaining the operational conduct of monetary policy. Taylor (1993) proposed a rule in which the monetary authority adjusts its policy instrument interest rate in reaction to deviations of output and inflation in relation to their targets (see Chen and Werner, 2011; Hutchison *et al*., 2013).

Since 2000, the monetary authority of Mozambique, the Bank of Mozambique (BM), has *de jure* adopted monetary targeting but, from 2011 it started to *de facto* switch to *inflation targeting lite* (ITL) (this term was coined by Stone, 2003, and it is presented in section (iv) in "Literature Review"). In this circumstance, Fernandes (2011) assessed the interest rate transmission mechanism covering the sample period 1993M1–2009M4. Using the marginal lending facility as a proxy of the policy interest rate, Fernandes found that deviations in inflation and output gap take 2 and 4 months, respectively to bring about changes in policy rate. Based on the Johansen cointegration test, Fernandes (2011) also estimated the implied interest rate reaction function of the BM, and found evidence of more sensitivity of the policy rate to inflation deviations than to the output gap and a high degree of smoothing rate. That kind of monetary policy reaction function (MPRF), which we address in more detail in section (i) of "Literature Review", is referred to as a linear function given that it assumes constant and evenly weighted coefficients of target variables (*i.e.* equal weights to deviations below and above the target). This approach, however, is often criticised on the grounds that the monetary authorities may have asymmetric responses to output stimulus and inflation stabilisation, thus, giving rise to a nonlinear monetary policy reaction (see for instance, Aragón and Portugal, 2010; Sznajderska, 2014).

In view of this criticism, our analysis aims to provide an empirical assessment of the nonlinear dynamics of the implied interest rate reaction function of the BM during the sample period (2000Q1–2015Q1). Dynamic MPRFs can shed some light on the elements governing monetary policy-making over time, such as, whether inflation is given more emphasis or not.

The paper is organised as follows. The next section provides the theoretical framework and literature review. Section 3 describes the evolution of the monetary framework and the main reforms in the financial sector in Mozambique in the post-independence period. Section 4 outlines the estimation strategy and specifies the data and the variables used. Section 5 describes the methodology and presents the main results. Finally, section 6 provides the concluding remarks.

2. THE MONETARY POLICY-MAKING

Central banks usually perceive price stability as the main goal of monetary policy, but the mandates of the monetary authorities may comprise other objectives such as economic growth and financial stability.

2.1 Theoretical Framework

One way to assess short to medium-run risks to price stability is to use the New Keynesian Model (NKM) instead of the New Classical Model in which monetary policy is essentially neutral to the real activity (Goodfriend and King, 1997; Romer, 2012).

Following Woodford (2007), one can specify the NKM model using three equations:

Aggregate supply (Phillips curve)

$$\pi_t - \pi_t^* = k\log\left(y_t/y_t^n\right) + \beta\ \mathrm{E}\left(\pi_{t+1} - \pi_{t+1}^* \middle| \mathcal{F}_t\right) \tag{1}$$

where $\mathcal{F}_t$ is the information available up to time t; π_t represents the rate of inflation in period t; π_t^* is the perceived rate of "trend inflation" at date t; y_t is the aggregate output; y_t^n is the "natural rate of output"; and μ_t is the additional exogenous "cost push" disturbance and the coefficients satisfy $k > 0$ and $0 < \beta < 1$.

Aggregate expenditure

$$\log\left(y_t/y_t^n\right) = \mathrm{E}\left(\log\left(y_{t+1}/y_{t+1}^n\right) \middle| \mathcal{F}_t\right) - \sigma\left(i_t - \mathrm{E}(\pi_{t+1}|\mathcal{F}_t) - r_t^n\right) \tag{2}$$

where i_t represents the short-term nominal interest rate and r_t^n is the natural interest rate.

A monetary policy rule

$$i_t = r_t^* + \pi_t^* + \phi_\pi\left(\pi_t - \pi_t^*\right) + \phi_y \log\left(y_t/y_t^n\right) \tag{3}$$

where π_t^* represents the central bank's inflation target at any point in time; r_t^* is the natural interest rate; ϕ_π and ϕ_y are coefficients indicating the degree to which the central bank responds to the observed deviations of inflation from the target rate or of output from the natural rate, respectively.

Moreover, Woodford (2007) assumes that both r_t^* and π_t^* are exogenous processes and which evolution represents shifts in attitudes within the central bank and are taken to be independent of what is happening to the evolution of inflation or real activity. For simplicity, Clarida *et al.* (1999), assumes that the natural real rate and inflation target are constant over time. Therefore, equation (3) is usually estimated as:

$$i_t = c + \phi_\pi \pi_t + \phi_y \log\left(y_t/y_t^n\right) \tag{4}$$

where $c = r_t^* + (1 - \phi_\pi)\pi_t^*$.

In practice, however, monetary policy-making is complex and MPRFs are starting points for describing central banks' behaviour. As Rudebusch and Svensson (1999) and Svensson (1998) outlined, "central banks use more information than the MPRFs are based on, and at best, reaction functions provide a baseline for a comparison to the policy actually followed". Therefore, Patra and Kapur (2012) recommended that policy-makers should use a more pragmatic approach of rules with discretion, especially in the face of unforeseen contingencies that are potentially destabilizing.

2.2 Literature Review

(i) Monetary Policy Reaction Functions Monetary authorities reset their policy instrument such as short-term interest rate or a monetary aggregate in order to affect the economy through several transmission mechanisms[1] to the ultimate policy goal. A MPRF or monetary police rule represents the response of the central bank to deviations in macroeconomic variables in order to achieve its paramount goal (Svensson, 1998).

[1] The literature identifies several channels of transmission mechanism, such as, interest rate, expectations, credit channel and so forth.

A well-known example of a monetary policy rule is the Taylor (1993) rule, defined in equation (3). According to Hutchison *et al.* (2013) this rule described the U.S. Federal Reserve (the Fed) policy performance from 1987 to 1992, to which the Fed adjusts its policy interest, the Federal Reserve funds rate, in response to any deviation of inflation rate from a desired target value and to the output gap. Thus, Taylor recommended how the Fed should manage the policy interest rate to attain both its short-run objective of stabilizing the economy and its long-run goal for inflation.

The Taylor rule is prominent in countries where there have been reforms such as financial innovation and deregulation, which, in turn, led to both the instability of money demand and a less reliable connection between monetary aggregates and output,[2] hence inflation (Chen and Werner, 2011; Romer, 2012). Apart from that, Xiong (2012) finds policy interest rate [when compared to monetary growth] as a more informative variable with respect to future real economic variables such as income, consumption, and employment.

A fundamental aspect in the Taylor rule is the assumption that the central bank should increase the nominal policy interest rate more than one-for-one with inflation, *i.e.* the increase in nominal interest rate must be more than inflation in order to bring about a rise in real rates in response to an increase in inflation.

In the context of the NKM, this stability condition is given by[3]:

$$\phi_\pi + \frac{(1-\beta)}{k} > 1. \tag{5}$$

Given the assumption that $\beta \simeq 1$ then it turns out that $\phi_\pi > 1$, which is denominated the Taylor principle (Davig and Leeper, 2007; Cochrane, 2011).

In addition, ϕ_y is expected to be positive, indicating that the central bank increases the interest rate if actual output is above its potential. Taylor (1993) assumed specific values for the coefficients, $\phi_\pi = 1.5$ and $\phi_y = 0.5$.

A possible explanation of the Taylor Principle is suggested by Ncube and Tshuma (2010): "… [if], for instance, the federal funds rate [the policy instrument rate] is raised by 1.5% points for each 1% point increase in inflation… an increase in the interest rate of that magnitude would raise real interest rates and help cool off the economy, thus reducing inflationary pressures … [and] the rule also assumes that the interest rates are reduced by 0.5% point for each percentage point decline in real gross domestic product (GDP) below its potential. Such a reduction in the interest rate helps to mitigate a recession and maintain price stability" (Ncube and Tshuma, 2010: 2)

[2] Sánchez-Fung (2011) finds that in some countries, such as China, the monetary target framework, *e.g.* McCallum (1987), can be useful as a benchmark for understanding monetary policy behaviour. However, one may arguably point out that changes in the monetary aggregates reflect not only the China's monetary authority policy stance but also demand shocks.

[3] To obtain this condition one uses equation (4) to eliminate *it* in equation (2). This reduces equations (2), (3) and (4) to a system of two equations. Let z_t be a vector with elements π_t and $\log y_t$. The system can be written in the form of $\mathrm{E}(z_{t+1}|\mathcal{F}_t) = Az_t + e_t$ where A is a matrix of constant coefficients and e_t is a vector collecting all the remaining terms other than π_t, $\log y_t$. The system is stable, *i.e.* it converges to a unique solution as $t \to \infty$, regardless of the initial conditions, if and only if the two eigenvalues of A lie outside the unit circle. If we restrict attention to policy rules with $\phi_\pi, \phi_y \geq 0$, this condition can be shown to be true if and only if equation (5) holds.

Davig and Leeper (2007) proposed a generalisation of the Taylor principle to an environment in which reaction coefficients in the monetary policy rule change across time as a function of a Markov chain process. They developed a solution method which obtains determinacy conditions and solutions for rational expectations equilibrium, and they argued that "this method can be applied to a broad class of purely forward-looking rational expectations models with exogenous Markov switching (MS) in parameters and many discrete regimes."

When central banks follow interest rate rules, as Svensson (1998) points out, in the underlying transmission mechanism, money demand becomes endogenous and the focus is on: short-term nominal interest rate, the resulting short-term real interest rate and exchange rate, and the effects on expectations, aggregate demand, and inflation.

(ii) Taylor-Type Rules The Taylor rule defined in equation (3) links the policy interest rate to the contemporaneous output gap and inflation. The literature on monetary policy interest has proposed several modifications to this Taylor rule.

The Taylor rule can be expressed in a way that the policy interest rate is adjusted based on the leading path of non-predetermined variables (Clarida *et al.*, 1999), or the policy rate is adjusted taking into account the lagged information, given that policy decisions are usually responses to data, which is not available in real time (McCallum, 1999).

Another feature of the modified Taylor rule is the inclusion of indicators that may play an important role in the economy such as changes in the equity price, changes in the housing price, changes in the exchange rate, the growth rate of the monetary aggregate, and changes in the oil price (Jawadi *et al.*, 2011). In this regard, Taylor (2001), for instance, proposed a small open economy Taylor's rule where the policy interest rate is a function of the inflation target, the output gap, real effective exchange rate and lagged real effective exchange rate. Nevertheless, Taylor (2001) suggests that more research is needed to establish the advantage of an interest reaction to the exchange rate, as – he argues – "what might appear to be a closed-economy policy rule is actually just as much an open-economy rule, as if the exchange rate appeared directly."

Mohanty and Klau (2004) expanded the Taylor (2001) rule also taking into consideration the interest rate smoothing. Then, the rule becomes:

$$i_t = \delta_0 + \delta_1 Infl_t + \delta_2 ygap_t + \delta_3 reer_t + \delta_4 reer_{t-1} + \delta_5 i_{t-1} + \varepsilon_t \tag{6}$$

where i_t is the short-run nominal interest rate, or the policy rate of the central bank, $Infl_t$ is the year-on-year inflation, $ygap_t$ is the output gap and $reer_t$ denotes the change of log of real effective exchange rate (in this formulation, an increase in $reer_t$ means an appreciation and vice versa).

Following Mohanty and Klau (2004), the expected signs of the parameters in equation (6) are:

$$\delta_0, \delta_2, \delta_5 > 0; \frac{\delta_1}{1-\delta_5} > 1; \delta_3 < 0; \delta_4 \neq 0. \tag{6a}$$

Additionally, the exchange rate is expected to have only marginal significance in equation (6), with δ_4 approximately equal to $-\delta_3$. Hutchison *et al.* (2013), assume that the constant term, δ_0, in this specification, captures the deviation of the baseline interest rate from the target values of inflation rate and output gap, each weighted by the response coefficients embodied in the monetary policy rule and it is not economically meaningful.

Typically, the literature on the central bank reaction functions with smoothing variables examines long-run coefficients (Mohanty and Klau, 2004; Altavilla and Landolfo, 2007). These coefficients, with respect to equation (6), can be obtained as follows:

$$\delta_{1l} = \frac{\delta_1}{1-\delta_5}, \delta_{2l} = \frac{\delta_2}{1-\delta_5}, \text{ and } \delta_{3l} = \frac{\delta_3 + \delta_4}{1-\delta_5}. \tag{6b}$$

Long-run coefficients of the monetary policy rules show the expected full impact of the changes in policy rules in the long run.

(iii) Nonlinear MPRFs Monetary policy rules, as defined in equations (3) and (6), assume a linear and symmetric response by central banks to inflation and output disturbances, *i.e.* the coefficients imply that central banks give similar weights to positive and negative price pressures as well as the economic upswings and downswings and that their reaction coefficients do not vary with the size of the shocks (see, for instance, Mohanty and Klau, 2004; Sznajderska, 2014).

However, nonlinear policy rules may emerge when there is a nonlinear relationship between inflation and output in the presence of significant price and wage rigidities, producing a non-linear (convex) Phillips curve (see, for instance, Aksoy *et al.*, 2006; Jawadi *et al.*, 2011; Sánchez-Fung, 2011). There are also nonlinearities stemming from nonlinear central banks' loss function with respect to the size of inflation and output deviations or when the central bank follows the opportunistic approach to disinflation.

Linear functions are mathematically tractable but from an economic point of view, may not be realistic. Therefore, assessing nonlinear dynamics of the Taylor-type rule can be more appropriate to ascertain whether the behaviour of monetary policy changes over time or not.

There are several approaches to assess nonlinearities in MPRFs (see, for example, Mohanty and Klau, 2004; Petersen, 2007). However, there is little evidence concerning the relative strengths and weaknesses of these approaches. Therefore, they might be valuable and we do not take a stand concerning whether one or the other is more appropriate.

The first approach, applied in Mohanty and Klau (2004) estimations, augments variables to the baseline model and then tests the significance of the augmented variables to come up with findings on nonlinearities.

The second one is based on MS model.[4] Following Petersen (2007), the MS model provides a plausible explanation of nonlinearities as it gives some structural explanation for the data assuming that the regime switches are exogenous and driven by an unobservable process. However, the smoothed probability that data at any given time are associated with each respective state is evaluated from the estimated model and the observed data. Therefore, it is possible to evaluate the points of regime switches from this smoothed probability.

[4] See the seminal paper on Markov Switching Model by Hamilton (1989). Usually, as an alternative, researchers use smooth transition (STR) models or Threshold autoregressive models (see, for instance, Petersen, 2007; Bunzel and Enders, 2010).

A third approach is followed, for example, by Bunzel and Enders (2010) who formulated a threshold process to model the Taylor rule which is consistent with an opportunistic monetary policy. Their version of the opportunistic model allows the monetary authorities to be policy active when the inflation is high in relation to the interim threshold and when the output gap is negative.

(iv) Monetary Policy Instruments and Frameworks According to Baliño *et al.* (1995), over the last decades, central banks have used indirect instruments instead of direct instruments to conduct monetary policy. Direct instruments of monetary policy operate by setting or limiting either prices (interest rates) or quantities (amounts of credit outstanding) through regulations, such as credit limits and interest rate controls. In contrast, indirect instruments act through the market by, in the first instance, adjusting the underlying demand for, and supply of, bank reserves, which include open market operations (OMOs), reserve requirements, marginal facilities, foreign exchange operations with repos and outright sales and purchases of government securities.

Several contexts, such as financial innovations, have led monetary authorities, both in advanced and emerging market economies, to switch, explicitly or implicitly, from monetary to inflation targeting (IT) frameworks (Mehrotra and Sánchez-Fung, 2009; Heintz and Ndikumana, 2010; Shirai, 2014).

Monetary targeting involves using monetary aggregates as an intermediate target to achieve an ultimate goal such as price stability (Stone, 2003). It relies on the stability of the demand for money or a gradual change in monetary aggregate velocity and requires a strong and predictable relationship between growth of monetary aggregates and inflation over the medium term (Xiong, 2012). Therefore, if that relationship does not hold, then the monetary aggregate will no longer provide adequate signals about the stance of monetary policy.

IT involves a declaration of an inflation target by the central bank and it then uses monetary tools, such as a short-term interest rate regarded as policy interest rate and OMOs, in an attempt to steer forecasted inflation to the inflation target (Heintz and Ndikumana, 2010). Usually, IT countries have financial markets developed enough to allow the use of OMOs and a short-term interest rate operating target.

According to Shirai (2014), in advanced economies, during the global financial crisis, although the monetary authorities continued adopting the IT regime, they took several unconventional monetary policy measures aimed at restoring the functioning of financial markets and intermediation and to provide further monetary policy accommodation at the zero lower bound, as well as putting an emphasis on financial stability and its relation to monetary and macro prudential policies.

Andrle *et al.* (2013), surveyed central banks of sub-Saharan African (SSA) countries, and found that in the context of fiscal-based stabilization efforts, between 2000 and 2006, many SSA countries adopted policy regimes centred on monetary targeting and considerably managed the exchange rate. They also found that, although the monetary targets were frequently missed in either direction, these central banks succeeded in re-anchoring inflationary expectations. However, the steep rise in global fuel and food prices in 2007–2008, followed by the spillovers from the global financial crisis in 2008–2009, among other reasons, resulted in large swings in inflation.

The challenges posed to monetary targeting lead emerging market economies to reveal preferences for transitional regimes, such as ITL.

According to Stone (2003), ITL can be seen as a transitional regime, not a monetary framework along with IT or monetary targeting regimes, because they are essentially eclectic and incorporate some of the key features of IT. Furthermore, ITL, the operating targets of which comprise short-term interest rates, the exchange rate, and quantity targets, is a flexible IT framework aimed at buying time for the implementation of the structural reforms in support of a single credible nominal anchor, given that usually in emerging market countries the financial system elements needed for OMOs instruments are lacking, such as a deep and liquid interbank market, deep and liquid securities markets and a number of healthy commercial banks.

According to Shirai (2014), within the ITL framework, emerging market economies put a growing emphasis on price stability, allow greater movements in the exchange rates, reduce the policy interest rate and extensively use Macro-prudential Policy to maintain financial stability.

(v) Modeling Nonlinear MPRFs The general finding of the empirical literature investigating nonlinearities in MPRFs, both in advanced and emerging market economies is that nonlinear MPRFs might be appropriate to depict the behaviour of central banks.[5]

Mohanty and Klau (2004) estimated Taylor-type rule for 13 emerging market economies for the sample period 1980Q1–2002Q4, and found evidence that in some of them, such as Brazil, the Czech Republic, Hungary, Korea, and Thailand, monetary authorities might have responded more aggressively to positive inflation swings than to negative inflation swings, but little evidence was found on the interest rate responsiveness related to the size of inflation or output shocks.

Based on the MS regression model or the Smooth Transition Regression (STR) model, nonlinear modeling of central banks' behaviour across emerging market economies is mostly focused on BRICS (Brazil, Russia, India, China, and South Africa).

Ncube and Tshuma (2010) examined the applicability of a nonlinear Taylor rule for the South African Reserve Bank, using a STR approach. Covering the sample period 1976Q1–2008Q4, they evaluated the movement of the nominal short term interest rate for the South African Reserve Bank, and found that a nonlinear Taylor rule holds in stark contrast to some studies, but only – they argue – because those studies removed the structural break which coincided with the Asian crises and estimated two different Taylor rules.

Hutchison *et al.* (2013) assessed monetary policy change in India using a univariate MS model to estimate a time-varying Taylor-type rule for the Reserve Bank of India (RBI) covering 1987Q1–2008Q2 sample period. They estimated the Woodford (2001)[6] version of the Taylor rule and found that the way monetary policy was conducted over that sample period can be characterised by two regimes, which they term "Hawk" and "Dove" regimes. In the hawkish regime, the central bank reveals a greater relative weight in controlling inflation vis-à-vis narrowing the output gap. On the basis of this analysis, they argue that the RBI was found to be dovish about half of the sample period, focusing

[5] Clearly, this is not a comprehensive survey on this topic, because the literature is ever growing and country-specific.

[6] Compared to Mohanty and Klau (2004), this specification excludes the lagged real interest rate.

more on the output gap and exchange rate targets to stimulate exports, rather than moderating inflation.

More recently, Jawadi *et al.* (2014) estimated monetary policy rules for Brazil and China using quarterly data from the sample period 1990–2008. They assessed whether the monetary authorities react to changes in economic activity, financial markets, monetary conditions, the foreign exchange market, and the commodity price. They assessed the importance of nonlinearity using a STR model. The estimation result they found provided evidence that considerations about the output gap and the real effective exchange rate (in the case of Brazil), and inflation rate (for China) explain the nonlinear adjustment of the central bank rate. In addition, the results suggest that central banks pursue a target range for the threshold variable rather than a specific point target. In the case of China, the McCallum rule shows that the GDP growth, the interest rate and the commodity price drive the response of the growth rate of the relevant monetary aggregate.

Some contributions to research into nonlinear MPRFs in developed countries include Altavilla and Landolfo (2007), Assenmacher-Wesche (2006), Cukierman and Muscatelli (2008), Bunzel and Enders (2010), among others. For instance, Altavilla and Landolfo (2007), assessed nonlinearities in MPRF in order to ascertain whether the European Central Bank (ECB) and the Bank of England have a different behaviour during recession and expansion. First, they estimated Taylor-type rules by means of a multivariate MS model in order to capture the systematic behaviour of those central banks. They then analysed impulse response functions that account for the different phases of the business cycle. Finally, they implemented a comparative analysis concerning the estimated rules as well as the different reactions of the real economy to monetary shocks and found evidence that the business cycle phase is an important matter in monetary policy-making. Bunzel and Enders (2010) investigated the possibility that the Taylor rule should be formulated as a threshold process which makes the Federal Reserve acts more aggressively in some circumstances than in others. They found that a modified threshold model that is consistent with “opportunistic” monetary policy makes significant progress towards explaining Federal Reserve behaviour.

Assenmacher-Wesche (2006), estimated MPRFs for the United States, the United Kingdom, and Germany, using a MS model that allows for shifts in the coefficients of the central bank’s reaction function as well as for independent shifts in the error variance. The model estimates cover different sample periods for each country. For the United States and the United Kingdom’s central banks, the Fed and the Bank of England, respectively, the sample period is 1973Q1–2004Q2, whereas for the German Central Bank, the Bundesbank, the sample period starts in 1973Q1 but runs until 1998Q4, because from 1999 the monetary policy was transferred to the ECB. On one hand, the empirical evidence suggests central bank monetary policy regime switching from a low-inflation and a high-inflation regime, which is reflected in the central banks changing weights to inflation and the output gap over time. On the other hand, switching in the error variance was found to be important in terms of the model specification. Finally, in comparing the three central banks’ preferences, Assenmacher-Wesche concluded that the Bundesbank had placed a relatively higher weight on inflation than the Fed. In contrast, the Bank of England showed a markedly reduced weight on output in the later part of the sample period. Moreover, for the Bundesbank and the Fed the differences between both regimes seem to derive mainly from a changing preference for interest rate smoothing.

Cukierman and Muscatelli (2008) theoretically and empirically explored the view that Taylor rules are often nonlinear due to asymmetric central bank preferences, and that the nature of these asymmetries changes across different policy regimes. The theoretical model uses a standard new Keynesian framework to establish equivalence relations between the shape of nonlinearities in Taylor rules and asymmetries in monetary policy objectives. These relations were estimated and tested for the United Kingdom (UK) and the United States (US) over various sub periods by means of STR. Findings from both countries support the view that reaction functions and the asymmetry properties of the underlying loss functions change in line with the regime and the main macroeconomic problem of the day.

3. MONETARY FRAMEWORK AND FINANCIAL SECTOR REFORMS IN MOZAMBIQUE

During the post-independence history, from 1975 to 1992, the BM – the central bank of Mozambique – simultaneously took on the functions of central bank and commercial bank in the context of a centrally planned economy characterised by administrative price setting and credit ceilings, fixed exchange, and interest rates (BM, 2007a).

The Organic Law of the BM, Law no. 1/92, which allowed the institutional separation of the functions of central bank and commercial bank, sets out the preservation of the value of the national currency as the main objective of monetary policy, which can be understood as low and stable inflation. The medium-term target for inflation, which is measured as a year per year change of the Consumer Price Index (CPI) of Maputo City, is 5–6% (BM, 2007a; IMF, 2014).

Financial reforms in Mozambique began in the late 80s. However, several segments of domestic financial markets, such as the money market, debt market, and foreign exchange market have undergone significant shifts mainly from the 90s.

According to the BM (2007a) and Baptista (2011), from 1987 to 1999, the BM employed direct instruments to monitor monetary aggregates. In 1987, the Mozambican Government started to implement a stabilization programme supported by the International Monetary Fund (IMF) aimed at generating a relatively robust fiscal stance. among other objectives. In 1992, the BM introduced the free floating exchange rate regime and liberalised the interest rates in 1994, followed by the establishment of the domestic interbank foreign exchange market and interbank money market in 1996 and 1997, respectively. The stock market was introduced in October 1999.

The working of the prevailing framework continued to be hindered by structural rigidities, such as administrative setting of credit ceilings. The framework failed to deliver price stability, given that from March 1994 to November 1996, price instability, measured by standard deviation of inflation rate, was relatively high, that is, 9% points. The average inflation rate was persistently high at approximately 41% (See the Fig. 1).

During the 1997–1999 period, the BM replaced the administrative setting of credit ceilings with net domestic assets (NDA) of the commercial banks, in order to keep the monetary aggregates on track but the NDA were frequently missed. From early 2000 until early 2006, the BM decided to target its own NDA. Then, in 2007, the BM created the monetary policy committee (CPMO) and moved formally towards monetary

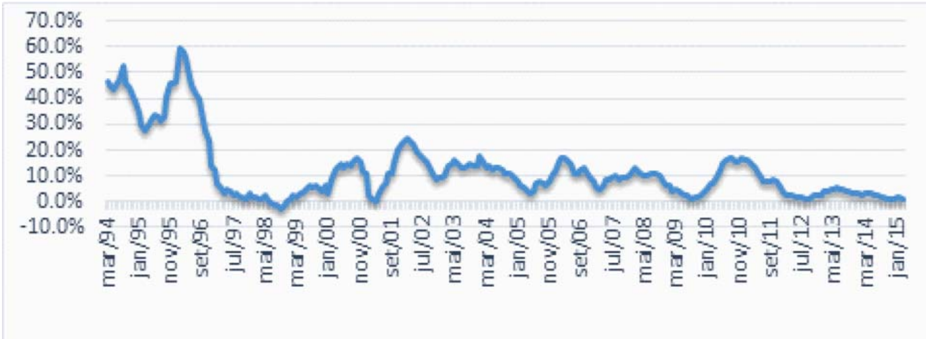

Figure 1. Inflation rate (%) [Colour figure can be viewed at wileyonlinelibrary.com]

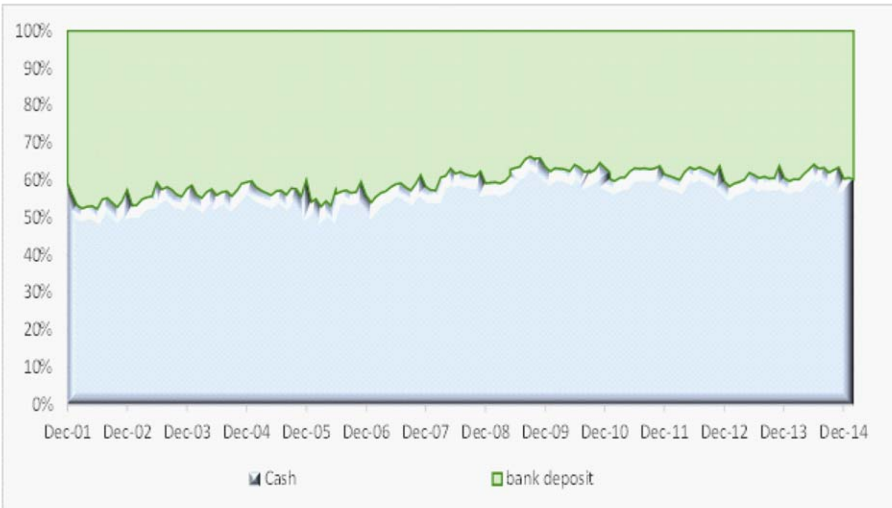

Figure 2. Cash and bank-deposit ratio (%) [Colour figure can be viewed at wileyonlinelibrary.com]

targeting, where the monetary base (MB) and the broad money aggregate (M3) are the operational and intermediate targets, respectively (BM, 2007a; Baptista, 2011).

In spite of the development of the settlement system in Mozambique, such as the use of cheques, credit and debit cards, automatic teller machines and the emergence of mobile-phone-based cash transfer services, the demand for money is still dominated by the demand for cash (average weight, 59%) rather than bank-based deposits (see the Fig. 2).

This circumstances has created difficulties for the BM to control its operational variable and, as a result, the monetary base target has been missed in either direction (see the Fig. 3).

Even so, since 2000, the BM succeeded in anchoring inflationary expectations,[7] given rise to lower average inflation (9.1%) and less volatility (5.6% points) compared to the

[7] Inflation expectations are survey-based and cover households, economists and other professionals. These expectations are essentially backward-looking.

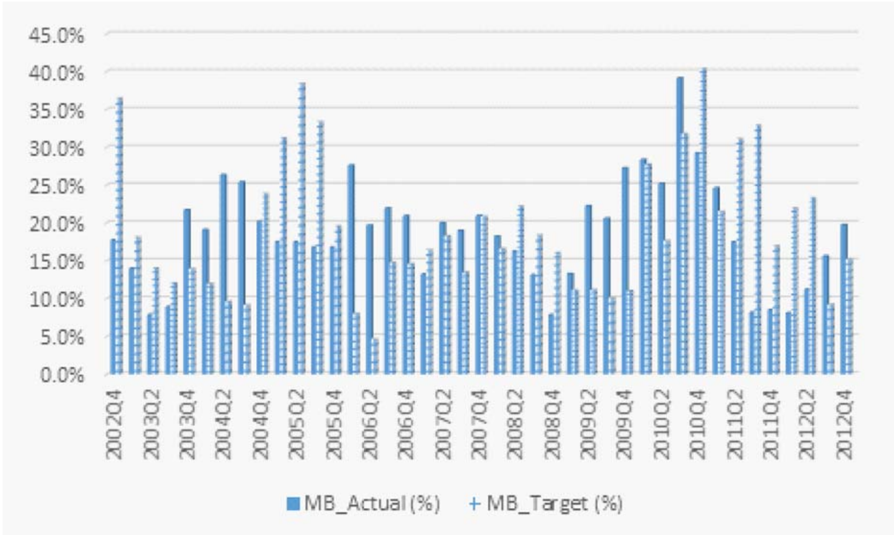

Figure 3. Actual and targeted monetary base (%) [Colour figure can be viewed at wileyonlinelibrary.com]

previous period. This performance was even better after the creation of the CPMO in 2007. Although there was no significant difference in terms of price stability (the standard deviation changed from 5.1 pp. during 2000Q1–2006Q4, to 4.6 pp. from 2007Q1–2015Q1), in the latter sub-period inflation averaged 6.5% against 12.1% in the former sub-period.

Since 2000, the monetary base has been managed using indirect instruments, which include reserve requirements and a gradual reliance on repos/reverse repos, sales/purchases of Treasury bills and marginal facilities. These can be seen as a way of enhancing price signals in the economy given that the increasing implementation of money market rates allowed their use as benchmarks for pricing of loans and other financial products. During this period, apart from the transactions through marginal facilities, namely, marginal lending facility (area A) and marginal deposit facility (area B), the commercial banks operated more regularly through refinancing operations, that is, uncollateralised interbank lending transactions (C) (see the Fig. 4).

During the sampling period, the money market was structurally in surplus liquidity, which was reinforced by limited availability of alternative financial instruments. Consequently, the commercial banks have deposited their cash in the central bank, by doing so earning the lowest interest rate in the money market.

Clearly, the interbank lending rate tracks the dynamics of the liquidity condition reasonably well, being close to marginal lending/deposit facility when there are deficit/surplus liquidity conditions (see the Fig. 5). The marginal facilities form a corridor to other money market rates.

Since 2011, the BM has taken some steps toward the implementation of Inflation Target Lite (ITL), following the recommendations from the BM strategic plan for the 2008–2010 period (BM, 2007b). Since then, monetary targeting is still in a *de jure* framework but the *de facto* framework is ITL.

In this context, the BM started to put more emphasis on the price channel, so that the changes in the marginal facilities primarily took into account inflation prospects,

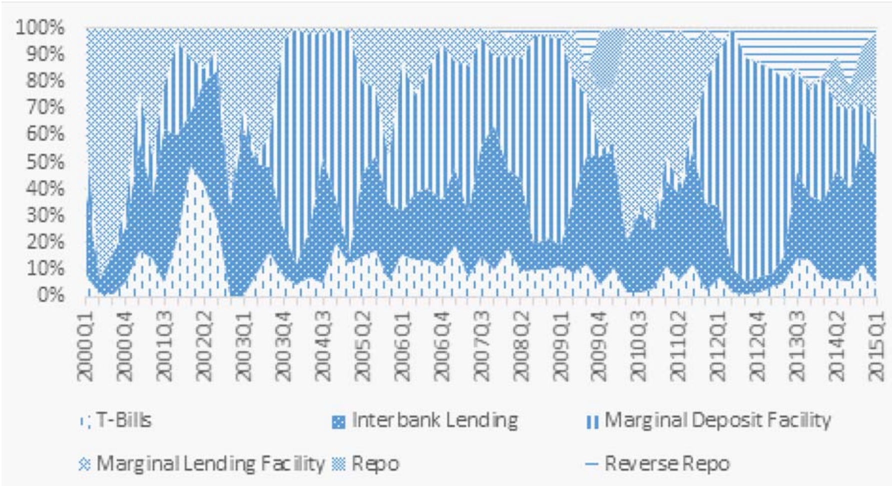

Figure 4. Money market transactions (in million Meticais) [Colour figure can be viewed at wileyonlinelibrary.com]

with the objective of influencing the money market rates and thus signalling the monetary policy stance. In this perspective, the ITL was expected to improve the role of the money market and provide signalling of monetary policy.

Under ITL the BM has taken some policy measures. For instance, in 2011 the CPMO of the BM started to gradually reduce marginal facilities aimed at supporting economic growth while bringing down inflation and strengthening international reserves (BM, 2012a; IMF, 2013). According to the IMF (2014), to promote financial stability, among other measures, the BM reinforced its supervisory and regulatory framework by conducting the first stress test in 2013, starting the risk-based supervision, and the Basel II Capital Accord came into effect in January 2014. Furthermore, the BM's interventions in the foreign exchange market have been to provide foreign currency rather than targeting a particular exchange rate level. For instance, in 2013

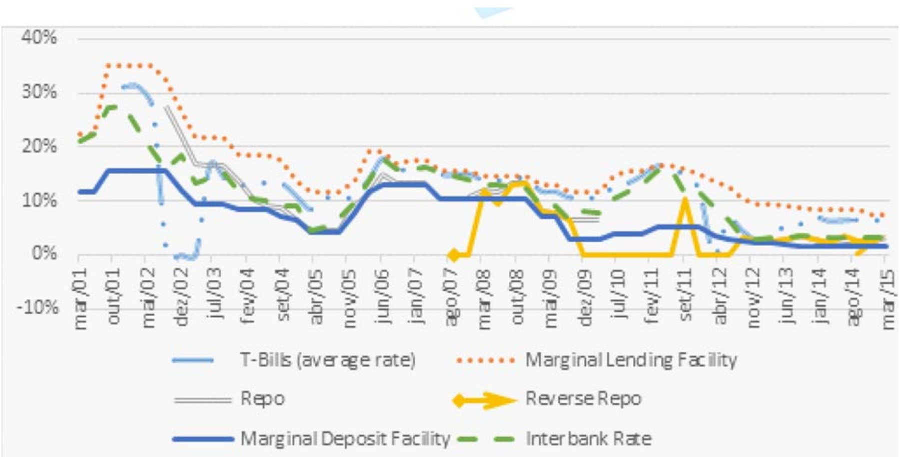

Figure 5. Money market rates [Colour figure can be viewed at wileyonlinelibrary.com]

and 2014, at least 55% of net sales in the foreign exchange market were assigned to cover imports of fuel.

Mozambique is a small economy (the estimated nominal GDP in 2014 is around 16 USD billion)[8] which has been increasingly opening up with the adoption of current account convertibility since 2011. There have been fast growing foreign direct investment inflows, mainly export-oriented (in 2014, it was approximately fivefold higher compared to 2010) and the external trade-to-GDP ratio averaged 2.9 over the last 5 years (BM, 2015).

4. METHODOLOGY AND DATA

4.1 Estimation Strategy

Taking into account the features of the monetary framework and financial reforms in Mozambique since 2000, and the findings on interest rate smoothing, we start by assuming the baseline Taylor-type rule defined in (6):

$$i_t = \delta_0 + \delta_1 Infl_t + \delta_2 ygap_t + \delta_3 reer_t + \delta_4 reer_{t-1} + \delta_5 i_{t-1} + \varepsilon_t$$

where i_t is the quarterly end of period interbank rate, $Infl_t$ is the quarterly annualised percentage change in consumer prices of Maputo, $ygap_t$ is the output gap at time t, and $reer_t$ denotes the quarterly change in the log of real effective exchange rate.

The Taylor rule specified in equation (6) assumes that the policy response to economic variables is stable over time. However, a hypothesis of interest is whether the BM might have behaved differently over time given price pressures and outputs swings, switching between periods when inflation was the primary concern of policy or the other way round. There are several approaches to deal with this issue.

A first approach, in line with Mohanty and Klau (2004), consists of testing the significance of the baseline model's augmented variables:

$$\begin{aligned} i_t = {} & \delta_0 + \delta_1 Infl_t + \delta_2 ygap_t + \delta_3 reer_t + \delta_4 reer_{t-1} + \delta_5 i_{t-1} \\ & + \delta_6 d_{1t} \times Infl_t + \delta_7 d_{2t} \times ygap_t + \varepsilon_t \end{aligned} \tag{7}$$

and

$$\begin{aligned} i_t = {} & \delta_0 + \delta_1 Infl_t + \delta_2 ygap_t + \delta_3 reer_t + \delta_4 reer_{t-1} + \delta_5 i_{t-1} \\ & + \delta_6 \pi_t^2 + \delta_7 ygap_t^2 + \varepsilon_t. \end{aligned} \tag{8}$$

The variables d_{1t} and d_{2t} (in equation (7)) are dummy variables such that $d_{1t} = 1$ and $d_{t_2} = 1$ if inflation and output are, respectively below their respective trend values, and π_t (in equation (8)) is the gap between the actual and the target inflation rate. Equation (7) allow us to test whether the interest rate responses change with the sign of inflation and output deviations. The monetary authority's reaction to inflation and output is given by the combined effect of the usual coefficients and the slope dummy coefficients. Negative and significant dummy coefficients imply a relatively weak response to negative inflation and output deviations, while positive coefficients

[8] Mozambique has been one of the world's 10 fastest-growing economies over the last decade.

indicate the opposite. Equation (8) can test the responsiveness of the short-term interest rate to the size of shocks. This implies testing the parameter constraints $\delta_6 = \delta_7 = 0$. Acceptance of the constraint implies accepting the hypothesis that central banks do not view a larger shock differently from a smaller shock when changing their interest rates, that is, there is only one regime.

Another alternative approach is to consider a MS model as follows:

$$
\begin{aligned}
i_t = & (\alpha_0 + \alpha_1 Infl_t + \alpha_2 ygap_t + \alpha_3 reer_t + \alpha_4 reer_{t-1} + \alpha_5 i_{t-1}) \times \mathcal{I}_t \\
& + (\beta_0 + \beta_1 Infl_t + \beta_2 ygap_t + \beta_3 reer_t + \beta_4 reer_{t-1} + \beta_5 i_{t-1}) \times (1 - \mathcal{I}_t) + \varepsilon_t
\end{aligned} \tag{9}
$$

where $\mathcal{I}_t$ is a variable that takes on the value 1 if $S_t = 1$ and zero if $S_t = 2$. This is a very popular non-linear model due to Hamilton (1989). As the i_t process evolves over time, i_t switches between two reaction functions, given by the first and second equations in (9), according to the unobservable state variable S_t. Hence, a reaction function may prevail for a random period of time, and it will be replaced by another function when a switch takes place. It should be noted that the MS model differs from the models of structural changes. While the former allows for frequent changes at random time points, the latter is usually associated with permanent structural change at given points in time. The MS model is therefore suitable for describing different reaction functions that exhibit recurrent dynamic patterns during different time periods. Technically, $\{S_t\}$ is an hidden first-order Markov chain process with state space {1, 2}. The Markov chain may be homogeneous, in which case the transition probabilities are constants as, for example, in Hutchison *et al.* (2013), or inhomogeneous in which case the transition probabilities evolve over time, based on the previous regime and some predetermined variables. In addition to switching the coefficients, we also allow the variance of the error term to switch between the states,[9] that is $\varepsilon_t \sim N(0, \sigma_1 \mathcal{I}_t + (1 - \mathcal{I}_t)\sigma_2)$. The model is estimated through the maximum likelihood and we use Huber-White robust standard errors. Given that the state S_t is unobserved, we also obtain the smoothed probabilities, $P(S_t = i | \mathcal{F}_T)$, $i = 1, 2$, using all the information from the sample.

Finally, we consider the threshold autoregressive (TAR) model, which extends and refines the method explored in the first approach (equation (7)). Contrarily to the MS, where the regimes are hidden, the TAR model separates the regimes based on threshold variables, which are observable variables by nature. This strategy is followed, for example, by Bunzel and Enders (2010) who formulated a threshold process to model the Taylor rule that is consistent with an opportunistic monetary policy. Their version of the opportunistic model allows the monetary authorities to be policy active when the inflation is high relative to the interim threshold and when the output gap is negative. The TAR model with two regimes is defined essentially as the MS model:

[9] Switching in the error variance is found to be important for the fit of the model (see Assenmacher-Wesche, 2006).

$$i_t = (\alpha_0 + \alpha_1 Infl_t + \alpha_2 ygap_t + \alpha_3 reer_t + \alpha_4 reer_{t-1} + \alpha_5 i_{t-1}) \times \mathcal{I}_t + (\beta_0 + \beta_1 Infl_t + \beta_2 ygap_t + \beta_3 reer_t + \beta_4 reer_{t-1} + \beta_5 i_{t-1}) \times (1 - \mathcal{I}_t) + \varepsilon_t. \quad (10)$$

As in the MS model the process i_t switches between two reaction functions, given by the first and second equations in (10) according to whether "$\mathcal{I}_t = 1$" or "$\mathcal{I}_t = 0$". The main difference between the TAR and the MS model, lies in the way $\mathcal{I}_t$ is defined. In the TAR model this variable takes on the value 1 if some threshold variable, say q, is such that $q_{t-d} < \gamma$, and zero otherwise, where d is the delay parameter and γ is the threshold parameter.

Testing linearity is a crucial step to discuss whether the non-linear specification is superior to a linear model and, to be more specific, whether the BM might have behaved differently over time given price pressures and output swings.

In both models, the MS and TAR models, the test of linearity involves the null

$$H_0 : \alpha_i = \beta_i, \quad i = 0, 1, \ldots, 5.$$

However, the testing problem is non-regular and outside the domain of standard asymptotic results (see, for instance, Davies, 1987; Hansen, 1996). Under the null (one regime) several parameters are not identified, that is, the likelihood function does not depend on those parameters and the asymptotic information matrix is singular. In the case of the MS model, the parameters associated with the transition probabilities are unidentified under the null, and in the case of the TAR model, the threshold is not identified under the null. To perform the test, we consider bootstrap resampling schemes in both cases (MS and TAR) to approximate the distribution of the test statistic of interest under the null of linearity. Further details are presented in sections 5.2.2 and 5.2.3 of "Empirical Assessment".

4.2 Data Description

The data consists of marginal lending rate, inflation rate, output gap and real effective exchange rate.[10] The overall sample period is from 2000Q1 to 2015Q1. We start our sample at 2000Q1 because indirect instruments of monetary policy to target monetary base started to be employed from that time onwards.

The inflation rate (Infl) is measured by using the annual percentage change in the monthly end-of-quarter CPI of Maputo. The CPI is the price level employed by the BM to generate "headline" inflation. Simple rules, such as the one defined in (6), typically perform better when responding to a 1-year inflation rate than those that respond to the one-quarter inflation rate, even though the objective is to stabilise the one-quarter rate (see Taylor and William, 2010). We derive the output gap (Ygap) using the Hodrick-Prescott (HP) filter for measuring trend output and taking the residual of the HP filter. To measure output, we use the de-seasonalised quarterly real GDP.

[10] Source: Consumer Price Index of Maputo City (CPI), [2010 = 100]: National Bureau of Statistics; Real Effective Exchange Rate Index, [2010 = 100]: Central Bank of Mozambique; Real Gross Domestic Product, [2009 = 100]: National Bureau of Statistics; Marginal Lending Facility: Central Bank of Mozambique.

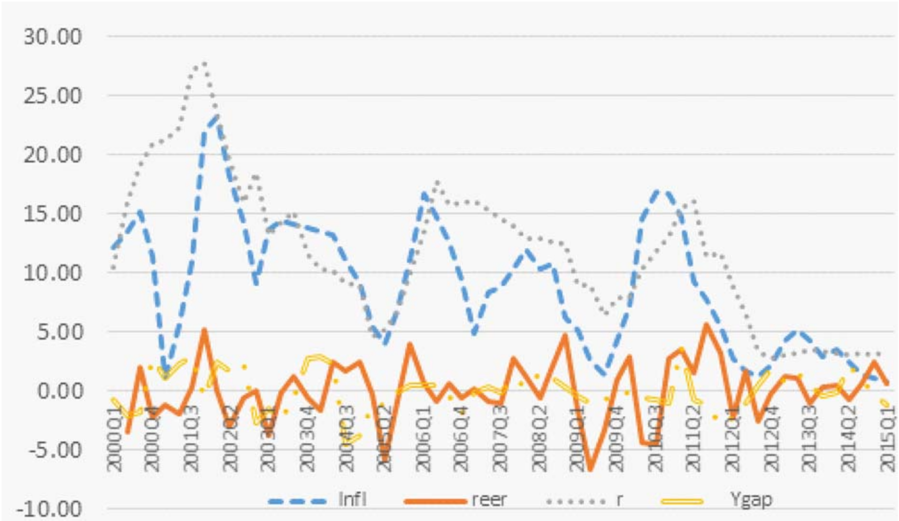

Figure 6. Inflation, real effective exchange rate, interbank rate and output gap [Colour figure can be viewed at wileyonlinelibrary.com]

For the short-term interest rate, we use the monthly end-of-quarter marginal lending rate, i_t. This choice is guided by the fact that the marginal lending facility is perceived as the policy rate (see IMF, 2014).

The BM sees the changes in real effective exchange rate (reer) as a measure of the country's competitiveness, as long as the reer takes into account changes in prices and nominal exchange of the main external trade partner countries (BM, 2012b).

The Kwiatkowski–Phillips–Schmidt–Shin and Ng-Perron unit root tests combined with the graphical analysis (Fig. 6), suggest that all variables, the marginal lending facility, output gap, inflation and change in the real effective exchange rate, are stationary.

5. EMPIRICAL ASSESSMENT

5.1 Linear Estimates

From Table 1 on linear estimates, the coefficients on the inflation, output gap and lagged interest rate have the signs expected in line with the theory and are all significant. The interest rate does not seem to be sensitive to changes in real effective exchange rate. The BM increases the marginal lending rate (its policy rate) by 20 basis points in response to a one unit rise in inflation and by 42 basis points in response to a rise in 100 basis points in output. The long-run coefficient on inflation is slightly greater than one, $0.202/(1-0.830)=1.18$ but it is in line with theory. These findings suggest that the BM has reacted to inflationary pressure to keep the real interest stable over time.

Table 1. Linear model

	δ_0	δ_1	δ_2	δ_5
Estim.$_{(Std.Errors)}$ *logLik* $=-130.15$	0.907 (0.741)	0.202*** (0.065)	0.422** (0.166)	0.830*** (0.053)

Notes: The parameters δ_3 and δ_4 were set to zero as their t-ratios were lower than one. The errors do not exhibit autocorrelation and heteroskedasticity according to standard LM tests. $*, **, ***$, denote significance at the 10%, 5% and 1% level, respectively.

Table 2. Baseline model and augmented variables' model

	δ_0	δ_1	δ_2	δ_5	δ_6	δ_7
Baseline	0.907	0.202***	0.422**	0.830***	–	–
	(0.741)	(0.065)	(0.166)	(0.053)		
Model (7)	0.920	0.190**	0.609*	0.823***	−0.035	−0.361
	(0.948)	(0.077)	(0.342)	(0.055)	(0.192)	(0.581)
Model (8)	1.036	0.176*	0.428**	0.822***	0.002	0.039
	(0.866)	(0.094)	(0.170)	(0.057)	(0.008)	(0.077)

Notes: The parameters δ_3 and δ_4 were set to zero as their t-ratios were lower than one. Errors do not exhibit autocorrelation and heteroskedasticity according to standard LM tests.
$*, **, ***$, denote significance at the 10%, 5% and 1% level, respectively.

The nonsignificance of the real effective exchange rate could reinforce the idea that the BM's interventions in the foreign exchange market have been to provide foreign currency, rather than reacting to changes in the real effective exchange rate. Moreover, data does not support the rejection of $\delta_3=\delta_4=0$ (even at 0.10 level of significance), which is in line with Taylor's (2001) argument, advanced before, on interest rate reaction to the exchange rate. The coefficient on the lagged interest rate is 0.83, and it suggests a high inertia in policy such that the initial adjustment in interest rates is only 17% points.

The Breusch–Godfrey serial correlation LM test suggests the absence of serial correlation and the Breusch–Pagan–Godfrey and ARCH test shows that the model is free of heteroskedasticity in error terms.

5.2 Assessing Nonlinearities

(i) Testing for Sign and Size of Shocks The results on whether interest rate responses change with the sign of inflation and output deviations from their respective targets are shown in Table 2.

Both the inflation and the output gap dummies are statistically insignificant. These results indicate (at least using this model) that there is no evidence to suggest that the BM's responses to a negative deviation as against a positive deviation of inflation and output from their target were different.

The findings on testing the dependence of response to the size of inflation and output shocks are reported in Table 2. The p-value of Wald test failed to reject the constraints of zero coefficients on the squared inflation and output gaps. It implies no significant difference in reaction to the size of shocks, that is, there is no statistical evidence, using these models, that the size of inflation deviations matters for monetary authorities in conducting monetary policy. However, this conclusion follows from this particular model, which may be a little rudimentary to capture some more subtle nonlinear relationships, as we will show below.

(ii) MS Model In estimating the MS model, we explored several variants of the baseline specification, because of the complexity of the underlying economic dynamics and of the possible policy rule followed by the monetary authority (See, for instance, Hutchison *et al.* (2013). The variants of the baseline specification are, namely, (i) switching both inflation rate and output gap; (ii) switching only output gap; and (iii) switching only inflation rate.

We also investigated whether the change of regimes is endogenous, *i.e.* whether the transition probabilities depend on the previous state and some other predetermined

Table 3. Markov switching model

Regime 1	α_0	α_1	α_2	α_5	σ
$Estim._{(Std.Errors)}$	1.635***	0.201***	−0.123	0.749***	0.714
	(0.541)	(0.0407)	(0.087)	(0.052)	(0.311)
Regime 2	β_0	β_1	β_2	β_5	σ
Estim.	1.635***	0.304***	1.1552***	0.767***	2.758
$_{(Std.Errors)}$ Transition parameters and expected durations	(0.541)	(0.138)	(0.388)	(0.078)	(0.510)
$\hat{P}(S_t=1 \mid S_{t-1}=1)=0.946$	(Std. Error: 0.287)				
$\hat{P}(S_t=2 \mid S_{t-1}=2)=0.896$	(Std. Error: 0.445)				
Regime 1 Expec. Duration =18.7					
Regime 2 Expec. Duration =9.67					
$logLik=-101.18$					

Note: The variable reer was not included in the model as it is not statistically significant. $*, **, ***$, denote significance at the 10%, 5% and 1% level, respectively.

variables. However, the best model in terms of statistical and economic significance was the one presented in Table 3.

To test linearity against the MS model we follow Sanzo (2009) who proposes a straightforward bootstrap procedure. According to Sanzo (2009), his bootstrap method outperforms the tests of Hansen (1992) in terms of size and power, especially when the sample size is small, the parameter changes are moderate and the Markov chain is not persistent, exactly as happens in our case. The bootstrap algorithm is as follow: (i) estimate the model under the null; (ii) compute the standardised residuals under the null, $\hat{u}_t$:; (iii) Estimate the model under H1 and compute the LR statistic; (iv) Generate the bootstrap errors u_t^* by sampling with replacement from the set of standardised residual $\hat{u}_t$; The bootstrap sample is constructed as follows:

$$i_t^* = \hat{\alpha}_0 + \hat{\alpha}_1 Infl_t + \hat{\alpha}_2 ygap_t + \hat{\alpha}_5 i_{t-1}^* + \hat{\sigma} u_t^*$$

(the estimates $\hat{\alpha}_i, i=0,1,2,5$ are obtained in step 1). (v) Use the bootstrap sample i_t^* to calculate the LR statistic. Call its value LR*. The experiment consists of repeating steps 4 and 5 B times. This provides a distribution of LR*, which is the bootstrap distribution of LR. Using 2500 bootstrap replicas, *i.e.* $B=$ 2500, we have obtained a 5% bootstrap critical value of 16.3 and $LR=21.7$. Therefore there is evidence against the hypothesis of linearity. This result is expected given the large difference between the log-likelihood functions under H0 and H1 (see Tables 1 and 3).

The findings in Table 3 show that the conduct of monetary policy in Mozambique during 2000Q1–2015Q1 was characterised by two regimes. In regime 1, the favourable macroeconomic conditions have allowed the BM to adopt disinflationary process without a strong stabilizing reaction in long-term. However, the coefficient on output gap is not statistically significant in that regime and it shows an odd sign, meaning that only changes in inflation bring about a reaction of the monetary authority. In contrast, in regime 2, the BM reacts aggressively both to cool off the economic activity and to curb inflationary pressures. In both regimes, the coefficient on the lagged interest rate is approximately the same (0.75 and 0.77 in regime 1 and regime 2, respectively), and it suggests a high inertia in policy such that the range of the initial adjustment in interest rates is only between 23 and 25 basis points.

Regime 1 is the most persistent with an expected duration of 18.7 quarters, almost double the expected duration of regime 2. The most prominent prevalence of regime 1

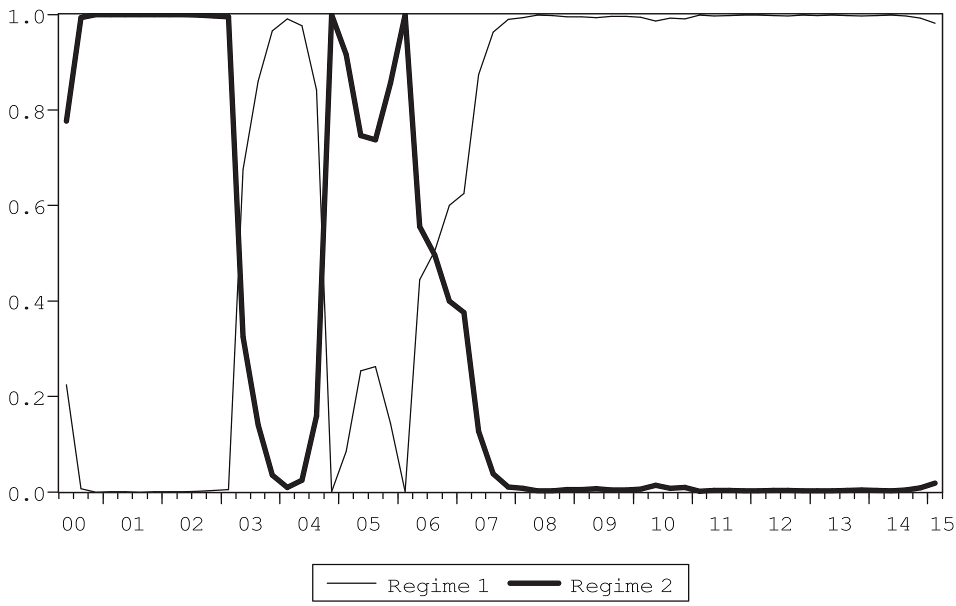

Figure 7. Smoothed regime probabilities

is during the existence the CPMO period, when the monetary authority may have accommodated some of the non-monetary factors of inflation in order to reduce the output costs. As Omar (2012) points out, after 1998, disinflation occurred without incurring costs in terms of the output in Mozambique.

These findings are reasonably depicted in Fig. 7.

Before the establishment of the CPMO – before 2007 – inflation was relatively higher and persistently above the medium-term target (regime 2). The probability of staying in this regime once started is 89.7%. Regime 1 captures the sub-periods when the BM mostly met its medium-term inflation target, with the probability of staying in this regime once started is 94.7%.[11]

(iii) Threshold Model As in the estimation of the MS model, we explored several variants of the baseline model. Given the relatively small sample, we imposed only two regimes, but we allowed several threshold variables with different delay parameters. Interestingly, the best specification in terms of statistical properties and economic interpretation turned out to be the variant in which the threshold variable is $q_t = Infl_{t-1} \times ygap_{t-2}$. Table 4 presents the results.

The parameters were estimated using sequential conditional least squares (see, *e.g.* Hansen, 1997). The minimization problem is $\hat{\gamma} = \arg\min_{\gamma \in \Gamma} \sum_{t=1}^{n} \hat{u}_t^2(\gamma)$ where $\hat{u}_t(\gamma)$, $t = 1, \ldots, n$ are the LS residuals conditional on the threshold γ and Γ denotes a compact subset of the threshold variable sample space (in line with the usual practice, a certain percentage of Γ at both ends was trimmed and not used to avoid having few observations in one of the regimes).

[11] As a reviewer has pointed out, the possibility of a structural break in 2005 cannot be discarded. This line of argument deserves further analysis in future work.

Table 4. Threshold model

Regime 1: If $Infl_{t-1} \times ygap_{t-2} < 7.074$	α_0	α_1	α_2	α_5
$Estim._{(Std.Errors)}$	−0.319 (0.820)	0.173** (0.067)	0.344 (0.337)	0.948*** (0.085)
Regime 2: If $Infl_{t-1} \times ygap_{t-2} \geq 7.074$	β_0	β_1	β_2	β_5
$Estim._{(Std.Errors)}$ $logLik = -124.2613$	−0.398 (0.815)	0.316*** (0.072)	0.336** (0.136)	0.778*** (0.026)

Notes: The standard errors were computed using the estimator Newey–West (Bartlett kernel). The variable reer was not included in the model as it is not statistically significant.
$*, **, ***$, denote significance at the 10%, 5% and 1% level, respectively.

Again, testing the linearity against the TAR model is outside the domain of standard asymptotic results. Hansen (1996, 1997) proposed a bootstrap procedure to test linearity, as follows. Let $x_t = (1 \quad Infl_t \quad ygap_t \quad i_{t-1})$ and $x_t(\gamma) = (x_t \mathcal{I}_t \quad x_t(1-\mathcal{I}_t))$ where $\mathcal{I}_t =$ 1 if $q_t < \gamma$, and $\mathcal{I}_t = 0$ otherwise. 1) Estimate the model under the null, *i.e.* regress i_t on x_t and obtain the residual variance $\hat{\sigma}_n^2$; 2) Estimate the model under the alternative, *i.e.* regress i_t on $x_t(\gamma)$ and obtain the residual variance $\hat{\sigma}_n^2(\gamma)$; 3) Compute the statistics $F_n(\gamma) = n\left(\left(\hat{\sigma}_n^2 - \hat{\sigma}_n^2(\gamma)\right)/\hat{\sigma}_n^2(\gamma)\right)$; 4) Let u_t^* be i.i.d. $N(0,1)$ random draws and set $i_t^* = u_t^*$. Regress i_t^* on x_t to obtain the residual variance $\hat{\sigma}_n^{*2}$ and on $x_t(\gamma)$ to obtain the residual variance $\hat{\sigma}_n^{*2}(\gamma)$. 5) Form $F_n^*(\gamma) = n\left(\left(\hat{\sigma}_n^{*2} - \hat{\sigma}_n^{*2}(\gamma)\right)/\hat{\sigma}_n^{*2}(\gamma)\right)$ and $F_n^* = \sup_{\gamma \in \Gamma} F_n^*(\gamma)$.. (vi) Repeat steps 4 and 5 B times. This provides a distribution of $F_n(\gamma)$. We also carried out a robust test against heteroskedasticity using the robust Wald statistics:

$$W_n(\gamma) = \left(R\hat{\theta}(\gamma)\right)' \left[R\left(M_n(\gamma)^{-1} V_n(\gamma) M_n(\gamma)^{-1}\right)R'\right]^{-1} R\hat{\theta}(\gamma)$$

and

$$W_n = \sup_{\gamma \in \Gamma} W_n(\gamma)$$

where $R = (I \quad -I)$, $\theta(\gamma) = (\alpha_0 \quad \alpha_1 \quad \alpha_2 \quad \alpha_5 \quad \beta_0 \quad \beta_1 \quad \beta_2 \quad \beta_5)'$, $M_n(\gamma) = \sum_t x_t(\gamma) x_t(\gamma)'$, $V_n(\gamma) = x_t(\gamma) x_t(\gamma) \hat{\varepsilon}_t^2$. For the F test and $B = 2500$ we obtained a 5% bootstrap critical value of 7.5 and $F_n = 8.10$. For the Wald test we obtained a 5% bootstrap critical value of 15.3 and $W_n = 17.18$. In both cases we reject the null at 5% level of significance. Therefore, there is evidence against the hypothesis of linearity.

Fig. 8 shows the threshold variable $q_t = Infl_{t-1} \times ygap_{t-2}$ across time. This variable presents high fluctuation at the beginning of the period and low fluctuation after 2006, stabilizing below the threshold value 7.074 (regime 1) and only occasionally changing to regime 2. This suggests that, to a large extent, the CPMO succeeded in anchoring inflationary expectations.

We did not find evidence to support the view that either the output gap or inflation alone acts as the threshold variable. However, when both output and inflation are high, to be more precise, when inflation pressures in the previous quarter are proceeded by a high output gap, such that $q_t = Infl_{t-1} \times ygap_{t-2} > 7.074$, Table 4 does suggest that, in the short run, apart from reacting aggressively to changes in output gap, the BM seems to have a more aggressive reaction to inflationary pressures, as the inflation coefficient almost doubles from regime 1 to regime 2. Regime 2 occurred most frequently during 2000–2006, when the fiscal policy might have played an important role in output

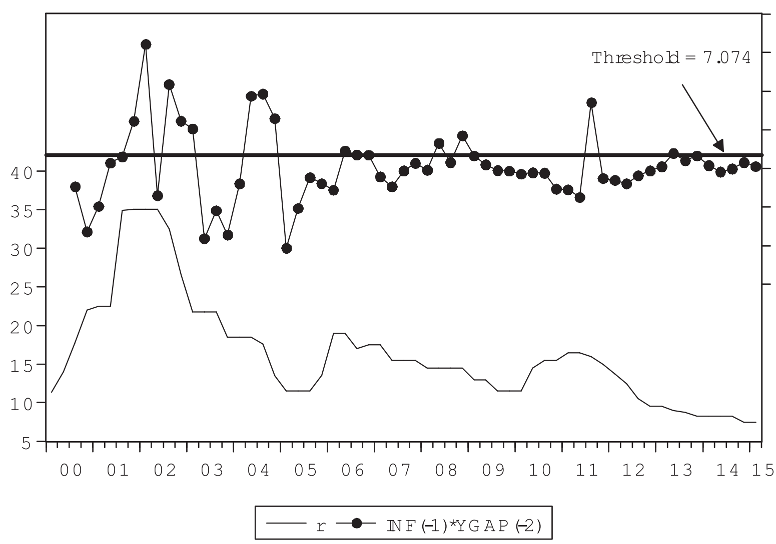

Figure 8. $Infl_{t-1} \times ygap_{t-2}$*, the threshold 7.074 and* r_t

stabilization. After the establishment of the CPMO, regime 2 occurred only in the context of a steep rise in fuel and food prices in 2007–2008 and in 2010.

Figs. 7 and 8 show that regime 1 of the MS model and regime 1 of the TAR model tend to occur about the same periods. In particular, we note that in both processes, regime 1 prevails in the CPMO period (*i.e.* after 2006).

6. CONCLUSIONS

This paper aims to provide an empirical assessment of the elements governing the monetary policy-making in Mozambique during the period 2000Q1–2015Q1. This approach is in stark contrast to a previous study on interest rate policy rule which takes for granted that central banks attribute similar weights to price pressures as well as to output swings, that is, a linear model.

Based on some features of the Mozambican economy during the sample period, we assumed the Mohanty and Klau (2004) Taylor-type rule as the baseline model, regarded as a version of small open economy Taylor-type reaction function.

We examined the baseline model assuming that it is linear and then assessed several variants of nonlinear models following two alternative approaches namely, the threshold model and the MS model.

The general finding is that the behaviour of the BM can be characterised by two regimes. In regime 1, only the changes in inflation bring about a reaction from the monetary authority. This behaviour is prominent after the establishment of the CPMO in 2007. Regime 2 occurred most frequently during 2000–2006, when the fiscal policy might have played an important role in output stabilization. After the establishment of the CPMO, regime 2 occurred only in the context of a steep rise in fuel and food prices in 2007–2008 and in 2010.

Although both nonlinear models basically reach the same conclusion, the TAR model allows us to explicitly relate regime changing to high inflation and high output. The

TAR model highlights the fact that inflation is viewed more seriously by the monetary authorities, when it is accompanied by a high output gap in the previous period, which triggers a more aggressive response from the BM.

Changes in the real effective exchange rate were not found to be statistically significant in the whole sample period, which reinforce the idea that the BM's interventions in the foreign exchange market have been to provide foreign currency rather than targeting a particular exchange rate level. Moreover, as Taylor (2001) suggests, more research is needed to establish the advantage of an interest reaction to the exchange rate.

This approach seems to be heading in the right direction, but future research may assess alternative Taylor-type rules and assess the role of the fiscal policies in output stimulus, as it might have reduced the need for an aggressive monetary policy response stimulate the output.

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