Estimating SARB's Policy Reaction Rule

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Estimating SARB´s Policy Reaction Rule

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November 22, 2007

Abstract

This paper uses a Dynamic Stochastic General Equilibrium (DSGE) model to estimate the South African Reserve Bank's (SARB) policy reaction rule. We find that the SARB has a stable rule very much in line with those estimated for Canada, UK, Australia and New Zealand. Relative to other emerging economies the policy reaction function of the SARB appears to be much more stable with a consistent antiinflation bias, a somewhat larger weight on output and a very low weight on the exchange rate.

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1 Introduction and Motivation

Since the early 1970s when the rise of inflation led to increased skepticism on the role of monetary policy, motivated in part by the concepts of time inconsistency and inflation bias[1], a significant body of literature has framed the debate over appropriate nominal anchor in which monetary policy has been discussed as a tension between the credibility provided by an anchor,

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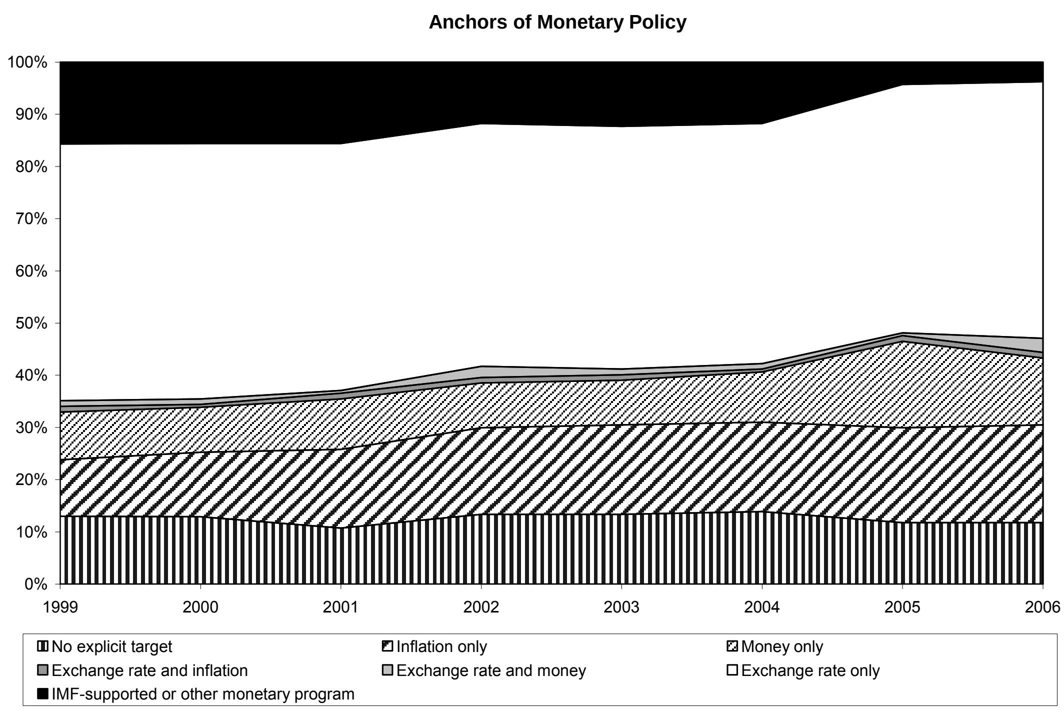
[1] The seminal contribution was Kydland and Prescott (1977) for which they obtained the Nobel price in 2005. Calvo (1978) provided an alternative modelization, focusing on the time inconsistency problem of domestically denominated debt. The setup achieved textbook status with Barro and Gordon (1983). In later years the problem of time inconsistency led to an explosion of work, in particular on ways to deal with it. See Rogoff (1985) on appointing conservative central bankers, Backus and Driffill (1985) or Cukierman and Meltzer (1986) on reputation models, Alesina (1988) and Alesina and Summers (1993) on the independence of the Central Bank, validated in Grilli, Masciandaro and Tabellini (1991) and Cukierman, Webb and Neyapti (1992). The time inconsistency debate has been and is still a key feature of monetary policy debates, all the way through the current debate on inflation targeting.

and the costs of the anchor in terms of a smaller degree of flexibility to respond to shocks. On occasions anchors become too rigid, so that the key problem of monetary policy becomes one of finding a credible anchor that does not jeopardize the ability to react to shocks.

Describing monetary policy, i.e. identifying how policy makers choose those anchors and measuring how much flexibility they retain in their policy choices, the first step in an analysis of monetary policy, can be addressed by classifying countries according to their stated anchors, typically, the exchange rate, monetary aggregates or the inflation rate, the three standard anchors used by the IMF´s exchange rate and monetary framework classification. But such a classification misses most of the complexities of actual policy. For one, in some countries some of these targets show overlaps, others have no explicit target and others have IMF supported programs with other objectives. Figure 1 shows if this is the case by reviewing the monetary framework classification of the IMF. It shows the very few countries do not have explicit targets, and that exchange rate, inflation and money are the main reference points. Among these the exchange rate remains the most common while inflation targeting seems to be gaining ground relative to monetary targets. The figure also shows that Central Banks tend to shy away from combining targets, something that may have to do with the credibility loss associated to providing a weak signal on the intentions and instruments of monetary policy. This figure complements a similar analysis in Sterne (1999) that analyzes the trend in monetary regimes during the 1990s. He concludes that most countries have embraced the use of explicit targets, with a reduction in the use of monetary targets during that period.

Figure 1. De jure policy rules



But even when this classification allows to assess the possibility of multiple anchors or the lack of explicit targets, these are just de jure statements on the objective of monetary policy.

As much as in the large literature on de facto exchange rate classifications[2], there is the question of how relevant these anchors are, as opposed to other variables that central bankers may be concerned about and that may be the real determinants of policy. In other words are stated intentions for real? For example, the SARB has repeatedly claimed that it does not care about the movements in the exchange rate. Do its actions respond to this statement? The Federal Reserve, in the US, has no explicit target, but does this prove that it does not focus on inflation or output to determine policy?

It is very common that countries claim to use the exchange rate as an anchor but then let the exchange rate move regularly so that in practice the stated anchor stops being a relevant anchor. A similar problem arises with monetary targeting. Mishkin (2007) describes the difficulties with measuring monetary aggregates that make it almost impossible to assess if the anchor is binding or not:

> "Why did monetary targeting in the United States, Canada and the United Kingdom during the late 1970s and the 1980s not prove successful in controlling inflation? There are two interpretations . . .
> One is that monetary targeting was not pursued seriously, so it never had a chance to succeed. The Federal Reserve, Bank of Canada, and particularly the Bank of England, engaged in substantial game playing in which they targeted multiple aggregates, allowed base drift (the initial starting point for the monetary target was allowed to shift up and down with realizations of the monetary aggregate), did not announce targets on a regular schedule, used artificial means to bring down the growth of a targeted aggregate, often overshot their targets without reversing the overshoot later and often obscured the reasons why deviations from the monetary targets occurred."

The same ambiguity applies (and is seldom acknowledged) with inflation targeting regimes. Mishkin and Schmidt Hebbel (2001) mention that

> "Classifying country cases into inflation targeting and other monetary regimes involves subjective choices for two reasons. First, there is lack of full agreement on the main conditions and features of inflation targeting and how they apply during transition to low inflation . . . Second, some countries have used simultaneously inflation targets and other nominal anchors (the exchange rate and/or a monetary aggregate), particularly at their early years of inflation targeting."

In addition inflation targeters differ significantly on many dimensions: target price index, target width, target horizon, escape clauses, accountability of target misses, goal independence, and overall transparency and accountability regarding the conduct of monetary policy under inflation targeting. Inflation targeting is in practice a broad category that includes a large array of alternative varieties, going from soft numerical inflation target (in the form of a wide inflation band) to a more sophisticated system that includes, additionally: (i) a legal commitment to price stability as the primary goal of monetary policy, (ii) a dissemination strategy that allows agents to replicate and anticipate the policy decision context (if not the actual policy decision); (iii) direct accountability of the central bank management for attaining the targets. Historically, middle income developing countries adopting inflation targeting gradually proceed from the soft version

[2] For a survey of this literature see Levy Yeyati and Sturzenegger (2007).

(which in the early years usually coexists with a heavily managed exchange rate regime, see Schmidt-Hebbel and Tapia (2002) for Chile; Armas and Grippa (2006) for Peru; Fraga et al. (2003) for Brazil, and Mishkin (2006) for everything else) to the more canonical version.

This caveat is more generally related with a definitional problem that plagues inflation targeting as a distinct policy: if by inflation targeting one means an explicit commitment with low and stable inflation, then most central banks in mature economies (and most in high-middle income ones) are in fact inflation targeters. If, as it appears, the empirical characterization of inflation targeting, in practice hinges on the two other pillars mentioned above, namely, dissemination and accountability, the boundaries of what constitutes inflation targeting and what not appears to be rather fussy.

In particular, in a context of inflation inertia due to (implicit or explicit) backward indexation, and high pass-through due to dollar pricing, the exchange rate is a natural candidate to anchor inflation expectations, so that even when monetary aggregates are supposed to be the target exchange rate may play a role. With such a large dimensionality it is difficult to provide a clean description of what policies really are.

To see this consider countries that are categorized by the IMF as floaters, a group that includes the typical inflation targeter. Yet when looking at the degree of intervention in exchange rate markets one obtains the distribution of interventions which in Figure 2 is compared with the interventions of the group that allegedly focuses on the exchange rate. The two are virtually indistinguishable and show that interventions in exchange rate markets are pervasive even among the so called floaters, a point that had been raised early on by Calvo and Reinhart (2002) and referred to as "fear of floating".

Figure 2. Interventions in exchange rate markets

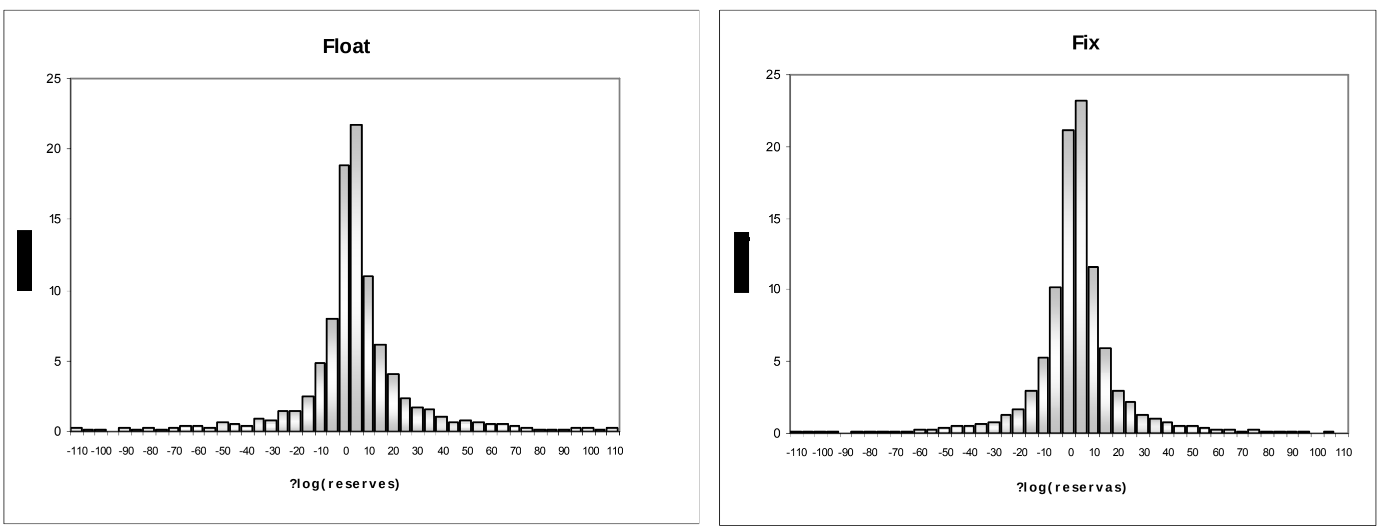


Figure 2: source Levy Yeyati and Sturzenegger (2007a). Percentage changes in international reserves are reported.

Another way of making the point is using a de facto classification of exchange rate regimes as in Levy Yeyati and Sturzenegger (2005), (2007b). Take for example Mexico, Brazil, Argentina, Korea, Malaysia and Thailand in the aftermath of their currency crises. During this period all these countries appear in the IMF classification as pure floaters or managed floating regimes. The shaded area in Table 1 indicates the periods in which actual policies differ from stated policies. The table shows that after crises countries opted away from a full float in spite of allegedly embracing exchange rate flexibility de jure.

Table 1. De facto exchange rate regimes

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
México	Fix	Intermed	Float	Float	Float	Float	Float	Float	Float	Float	Float
Brazil	Intermed	Float	Intermed	Intermed	Fix	Intermed	Fix	Intermed	Intermed	Float	Float
Argentina	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Intermed	Float	Float
Korea	Fix	Intermed	Fix	Intermed	Intermed	Fix	Fix	Fix	Fix	Fix	Fix
Malaysia	Fix	Float	Intermed	Float	Intermed	Fix	Fix	Fix	Fix	Fix	Fix
Thailand	Intermed	Intermed		Intermed	Intermed	Float	Float	Float	Float	Float	Float

Table 1: source Levy Yeyati and Sturzenegger (2005)

2 Measuring monetary policy

As a result of these difficulties we plan to measure monetary policy in this paper, not on the basis of surveying what countries report to have done but on estimating the reaction function of the Central Bank directly. The literature has addressed this in several ways. In recent years there has been an active literature trying to estimate the policy reaction function of Central Banks, following Taylor's innovative (1993) description of a simple rule by which interest rates were adjusted in response to inflation changes and the output gap. Taylor suggested that a simple equation represented US policy fairly well, namely

$$i_t = \pi_t + 0.5\left(100\left(\frac{Y_t - Y_t^*}{Y_t^*}\right)\right) + 0.5(\pi_t - 2) + 2$$

where i_t is the federal funds rate, π_t is the rate of inflation over the previous four quarters, Y_t is real GDP and Y_t^* is trend real GDP (which equals 2.2 percent per year from 1984.1 through 1992.3) in period t. Orphanides (2001a, 2001b) criticizes this rule on the basis that the information used by it is unavailable to policy makers at the time of the decision, and thus impossible as a description of actual policies, and suggests an alternative rule based on information available at the time. Clarida, Galí and Gertler (2000) suggest that the Taylor rule has more to do with expectations of inflation and the output gap, and use an instrumental variables (IV) Generalized Method of Moments (GMM) procedure to estimate it, instrumenting future values of inflation and output on current and lagged information.

But do these Taylor rules depend exclusively on the inflation rate and the output gap as suggested by Taylor or do they take into consideration other variables? As we mentioned above, and in developing countries in particular, it is likely that the exchange rate plays an important role as well. In fact, a simple model can show how, in a typical developing economy with inflation inertia, financial dollarization and high pass through, the exchange rate naturally belongs into the inflation targeting rule. To see this consider the following reduced model of a small open economy under inflation targeting, based on the backward-looking framework in Ball (1999):

$$y_t = -\beta r_{t-1} + \delta s_{t-1} + \lambda y_{t-1} + \upsilon_t \qquad (1)$$

$$\pi_t = \pi_{t-1} + \alpha y_{t-1} + \gamma\left(s_{t-1} - s_{t-2}\right) + \mu_t \qquad (2)$$

where r is the real interest rate, s the (log) real exchange rate, y the (log) output gap, π inflation, and μ and υ are shocks.

To solve the model, we update (2) two periods and impose an inflation target (which, without loss of generality, we can assume equal to zero), to obtain

$$0 = E_t\pi_{t+1} + \alpha E_t y_{t+1} + \gamma E_t\left(s_{t+1} - s_t\right) \quad (3)$$

Next, we update (1) and (2) one period and take expectations:

$$E_t y_{t+1} = -\beta r_t + \delta s_t + \lambda y_t \quad (4)$$

$$E_t\pi_{t+1} = \pi_t + \alpha y_t + \gamma\left(s_t - s_{t-1}\right) \quad (5)$$

Finally, substituting (4) and (5) into (3) and rearranging, we have the following equation (where the left hand side is referred to as the Monetary Conditions Indicator, or MCI):

$$\alpha\beta r_t - \left(\gamma + \alpha\delta\right)s_t - \gamma E_t\left(s_{t+1} - s_t\right) = \left[\pi_t + \alpha\left(1+\lambda\right)y_t - \gamma s_{t-1}\right]$$

The first, trivial thing to note here is that a change in the nominal exchange rate s_t demands a compensating change in r_t. In other words, monetary policy under inflation targeting cannot neglect exchange rate fluctuations. The reaction function and the direction of the policy response, however, would depend on a number of factors: the interest rate effect through domestic absorption $(\alpha\beta)$, the pass-through of the exchange rate change to domestic prices γ , the effect of a depreciation on domestic demand, δ; and the link between the interest rate and the exchange rate, the equation needed to close the model.

For example, assuming uncovered interest rate parity, $E_t\left(s_{t+1} - s_t\right) = r_t - r_t^f$ (where r^f the international interest rate) implies that, in general, exchange rate changes would elicit a countervailing interest rate move in the opposite direction, as inflation targeting becomes:

$$r_t - \omega s_t = \left[\pi_t + \alpha\left(1+\lambda\right)y_t - \gamma s_{t-1} - \gamma r_t^f\right] / \left(\alpha\beta - \gamma\right)$$

where

$$\omega = \frac{\gamma + \alpha\delta}{\alpha\beta - \gamma}$$

which for very low pass-through $\omega = \dfrac{\delta}{\beta}$ would be roughly equal to the tradables share of GDP. However, the relation between the variables is complex. Interest rate increases that raise the exchange rate may be "inflationary" if the pass-through coefficient is large $(\gamma > \alpha\beta)$. Similarly, contractionary devaluations $(\delta < 0)$ that may arise, for example, due to balance sheet effects in financially dollarized economies, may call for lower interest rates if $\delta < -\gamma/\alpha$. Finally, when the foreign exchange market is under speculative pressure, lowering interest rates would reduce the cost of shorting the domestic currency and fuel a run. In those cases, the authorities may choose to intervene directly in the forex market.

This simple example helps to clarify the distinction between foreign exchange intervention and exchange rate targeting, and illustrates the severe identification problems associated with it. In developing economies with large pass-through or balance sheet concerns, one would expect that the central bank reacts to exchange rate fluctuations (either though interest rates adjustments or outright forex intervention) even in the absence of an exchange rate target. Moreover, in some cases, two regimes coexist: a floating cum inflation targeting (or, more generally, a flexible regime with autonomous monetary policy) that tolerates moderate exchange rate movements, together with a de facto peg activated by substantial exchange rate realignments.

An alternative story for including the exchange rate in the Taylor rule is provided in a recent paper by Devereux and Engel (2007) who explore the implications of the fact that exchange rates respond primarily to news about future fundamentals. The main lesson from the new Keynesian models is that monetary policy should aim - to the extent it can - to eliminate the distortions introduced by sticky nominal prices. Ideally, monetary policy should try to reproduce the outcome that would be achieved if nominal prices were flexible. In open economies with price stickiness, relative prices change when the nominal exchange rate changes. If the exchange rate drives the change in relative prices there is a problem when those relative prices change as a result of news about future fundamentals (monetary and real) potentially moving the economy away from its short run equilibrium. If goods prices were flexible, then relative goods prices would not be influenced by news about the future that is driving the nominal exchange rate, but if prices are rigid there is a distortion in relative prices caused by nominal price stickiness. Since most of the variation in exchange rates comes from news about these future fundamentals, most exchange rate variation generates inefficient relative price movements in the short run. Engel and Deveraux argue that this provides a case for monetary policy to target unexpected changes in nominal exchange rates in addition to targeting inflation. This idea is further reinforced In developing countries for which Hausmann, Panizza and Rigobon (2006) argue that exchange rate volatility is significant larger than in industrial countries in a way that cannot be explained by fundamentals, providing an additional justification for including the exchange rate in the reaction function of the Central Bank.

With this as background we can ask how to estimate the actual Taylor rule used by Central Bankers. First it is important to note that monetary policy rules cannot be consistently estimated by ordinary least squares because regressors are endogenous. One alternative is to extend the IV GMM methodology of Clarida, Galí and Gertler (2000) and estimate a univariate model. We found these estimates to be widely unstable, even when applied to the US. An alternative is to estimate a structural model. Lubik and Schorfheide (2007) use a Dynamic Stochastic General Equilibrium (DSGE) model and Bayesian techniques to estimate a Taylor rule for a small open economy that includes the exchange rate. Lubik and Schorfheide (2007) estimate it for four countries: the United Kingdom (UK), Australia, New Zealand (NZ), and Canada, countries that share some of characteristics with the South African economy, both institutionally as well as the fact of being small open economies with a large dependency on natural resources. They find that only UK and Canadian monetary authorities care about nominal exchange rates, which is not contradictory with inflation targeting per se, but it signals how complex the measurement of monetary policy is. This is the route we have followed in this paper where we estimate a fully fledged DSGE model following Lubik and Schorfheide (2007) for South Africa and compare this with the estimates for other countries from related work.

2.1 Dynamic Stochastic General Equilibrium models

The appendix provides a description of the model. In a nutshell the new Keynesian models in international finance typically boil down to three equations, a dynamics IS curve, a Philips curve and a policy reaction function. The IS curve is derived from the Euler equation of consumer maximization and aggregate demand matters because the models assume monopolistic competition. The Philips curve originates in the assumption of price rigidities. A very popular choice to model this price rigidity is Calvo's (1983) price staggering mechanism. In Calvo's model firms are allowed to change prices randomly, but once they can, they do so rationally anticipating the conditions of the economy during the period they thought the price would be relevant. This set up leads to a very elegant structure. Because change opportunities appear stochastically and independently across firms, it means that a constant fraction of firms adjust their prices making the price level a smooth variable that changes only over time. Finally, because these models have well defined objective functions they allow for precise statements on welfare, a key step to evaluate policy. Monetary policy, in turn, can be described by an interest rule. With these models, the literature has come full circle, recovering the main tenets of the Mundellian approach, but now derived in coherent fully specified general equilibrium models.

Specifically, Lubik and Schorfheide (2007) estimate a version of a model initially developed by Galí and Monacelli (2005) which in loglinearized form can be described by three main equations an open economy IS-curve:

$$y_t = E_t y_{t+1} - [\tau + \alpha(2-\alpha)(1-\tau)](R_t - E_t \pi_{t+1}) - \rho_z z_t - \alpha[\tau + \alpha(2-\alpha)(1-\tau)]E_t \Delta q_{t+1} + \alpha(2-\alpha)\frac{1-\tau}{\tau} E_t \Delta y^*_{t+1} \quad (6)$$

where y_t denotes aggregate output, R_t nominal interest rate, π_t is CPI inflation, z_t is the growth rate of an underlying non-stationary world technology process Z_t, q_t is the terms of trade (as well as the real exchange rate as explained below), defined as the relative price of exports in terms of imports, and y_t^* is exogenous world output. The parameter τ represents the elasticity of intertemporal substitution, α is the import share[3], and ρ_z is the AR coefficient of the world technology. In order to guarantee stationarity of the model, all real variables are expressed in terms of percentage deviations from Z_t.

An open economy Phillips curve:

$$\pi_t = \beta E_t \pi_{t+1} + \alpha\beta E_t \Delta q_{t+1} - \alpha \Delta q_t + \frac{\kappa}{\tau + \alpha(2-\alpha)(1-\tau)}\left(y_t - \overline{y_t}\right) \quad (7)$$

where $\overline{y_t} = -\alpha(2-\alpha)\frac{1-\tau}{\tau} y_t^*$ is potential output in the absence of nominal rigidities. β represents the discount factor while is κ the structural parameter that gives the slope of the Phillips curve.

Monetary policy is described by a Taylor-type interest rate rule. We assume that the central bank adjusts the nominal interest rate in response to deviations of inflation, output and depreciation from their respective steady-states:

$$R_t = \rho_R R_{t-1} + (1-\rho_R)\left[\psi_1 \pi_t + \psi_2 y_t + \psi_3 \Delta s_t\right] + \varepsilon_t^R \quad (8)$$

where s_t denotes the nominal effective exchange rate, defined as the price of domestic currency in terms of foreign currency, ρ_R captures the partial adjustment of the interest rate to target, while ψ_1, ψ_2 and ψ_3 captures the monetary authorities reaction to inflation, output and exchange rate fluctuations.

[3] The equation reduces to the closed economy variant when $\alpha = 0$

The exchange rate is introduced via CPI inflation according to:

$$\pi_t = \Delta s_t + (1-\alpha)\Delta q_t + \pi_t^* \quad (9)$$

where π_t^* is a world inflation shock which is treated as an unobservable.

Terms of trade, in turn, are assumed to follow a law of motion for their growth rate:

$$\Delta q_t = \rho_q \Delta q_t + \varepsilon_{q,t} \quad (10)$$

Equations (6) - (10) form a linear rational expectations model. It is assumed that y_t^* and π_t^* evolve according to univariate AR(1) processes with autoregressive coefficients ρ_{y^*} and ρ_{π^*}, respectively. The innovations of the AR(1) processes are denoted by $\varepsilon_{y^*,t}$ and $\varepsilon_{\pi^*,t}$. The model is solved using the method described in Sims (2002). The solved model is estimated using Bayesian methods. Details on estimation methods, data, and choice of prior are described in the appendix.

3 Results

To analyze the evolution of monetary policy in South Africa the model is estimated in a rolling fashion including data from 1960 and using 10 years of quarterly data at a time[4]. This means that starting from the subsample 1960q2 - 1970q1 we repeated the estimation moving the starting date by one year keeping the size of the sample constant to 10 years up to the last estimate which covers the period 1997q1 - 2006q4 for a total of 38 estimations. By keeping the size of the subsample constant we minimize differences produced by different precision of the estimates. The results of these estimations are presented in Figure 3.

The graphs show the estimated coefficients and 90% confidence intervals of ψ_1, ψ_2, ψ_3 and ρ_R allowing to see the evolution of the three coefficients of the reaction function and how they have changed over time. ψ_1 could be interpreted as the "anti-inflation bias" in monetary policy, ψ_2 represents the "output bias", ψ_3 could be called the "fear of floating bias", and ρ_R reflects the interest rate smoothing.

It is clear that monetary policy has been fairly stable. In the 70s, the SARB showed some concern over the exchange rate that has declined over time. Tantamount with this process there has been an increase in the output objective. Throughout the SARB has been concerned about inflation as shown, primarily, because the coefficient of the inflation rate is always larger than one. The results show a slightly strengthening of the output motive in the reaction function of the SARB in recent years and a slight weakening of the already low weight of the exchange rate. These results appear to be fairly consistent with the explicit views of the SARB, i.e. a staunchly anti inflation bias and low preference for exchange rate fluctuations.

[4] Canova (2005) does a similar analysis for the US since 1950 and concludes that monetary policy has been remarkably stable.

Figure 3. The Taylor rule in South Africa since the 1970s

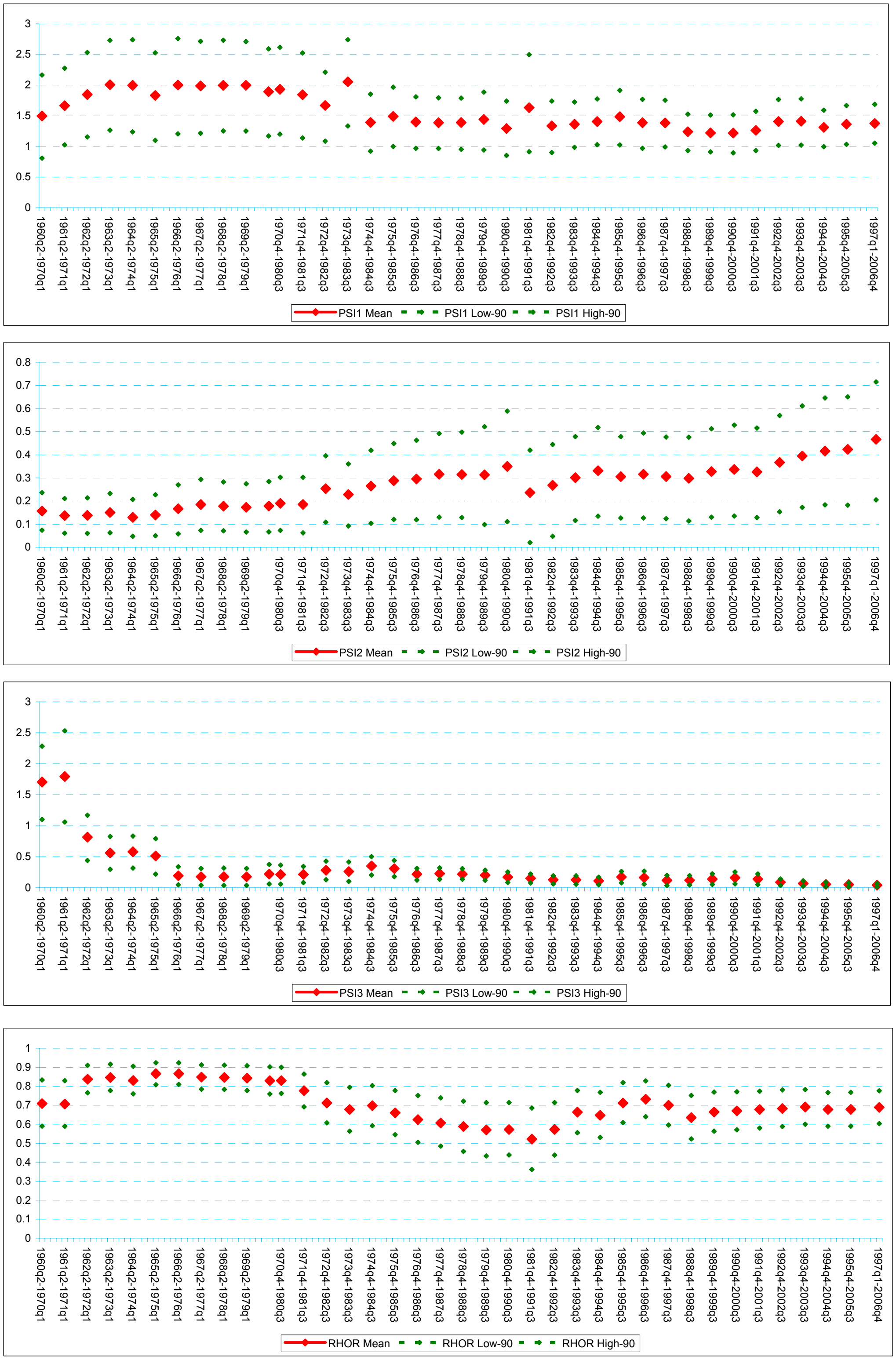


Figure 3: rolling estimations for a 10-year window. Estimated parameters and 90% confidence intervals are reported.

In the case of the SARB, however, one word of caution is required before proceeding. The model, as stated, captures the changes in the policy instrument of the Reserve Bank in response to inflation, output and exchange rate dynamics. This means that the model will miss interventions geared to control the exchange rate that do no occur through this channel. The use of capital controls or interventions in the forward market, two practices that have been common in South Africa, would imply that our estimates probably underestimate the relevance of the exchange rate objective.

With this caveat in mind, how do these results compare with what Lubik and Schorfheide (2007) estimated for other former UK colonies as well as for the UK itself? Table 2 shows the results.

Table 2. SARB vs. Commonwealth countries

Country	ψ_1	ψ_2	ψ_3	ρ_R
Australia	1.41	0.24	0.07	0.76
	(1.04 , 1.77)	(0.09 , 0.39)	(0.03 , 0.12)	(0.69 , 0.83)
Canada	1.30	0.23	0.14	0.69
	(0.98 , 1.60)	(0.09 , 0.36)	(0.06 , 0.21)	(0.61 , 0.77)
New Zealand	1.69	0.25	0.04	0.63
	(1.24 , 2.13)	(0.13 , 0.37)	(0.01 , 0.08)	(0.53 , 0.72)
South Africa	1.11	0.27	0.11	0.73
	(0.89 , 1.33)	(0.11 , 0.43)	(0.06 , 0.16)	(0.66 , 0.79)
United Kingdom	1.30	0.20	0.13	0.74
	(0.96 , 1.62)	(0.07 , 0.32)	(0.07 , 0.19)	(0.66 , 0.81)

Table 2: 90% confidence intervals are reported in parenthesis.

In the table we show an estimate for South Africa for the period 1983-2002 which matches the data for the other countries in the Lubik and Schorfheide study. While all countries in this group show strong anti inflation credentials, and the output objectives appears to be relatively homogenous among them, the relative importance of the exchange rate appears to be different. Canada and the UK, on the one hand, appear to give some weight to avoiding exchange rate fluctuations whereas Australia and New Zealand appear to do this less so. South Africa's monetary policy appears very much in line with that of Canada and the UK, in terms of its weight on the exchange rate, though shares with the other four its strong anti-inflation stance.

Figure 4 shows the impulse responses of the main variables to monetary, terms of trade and technology shocks. The results are fairly predictable. An increase in the nominal interest rate reduces output and inflation, while it strengthens domestic currency and leads to an appreciation of the exchange rate. A positive terms of trade shock increases output, decreases inflation and appreciates the exchange rate. Monetary policy responds with a loosening in response to the decline in the inflation rate. A technology shock has a permanent and positive effect on output, decreases inflation in the short run, appreciates the exchange rate which also induces a loosening of monetary policy.

Figure 4. Impulse responses

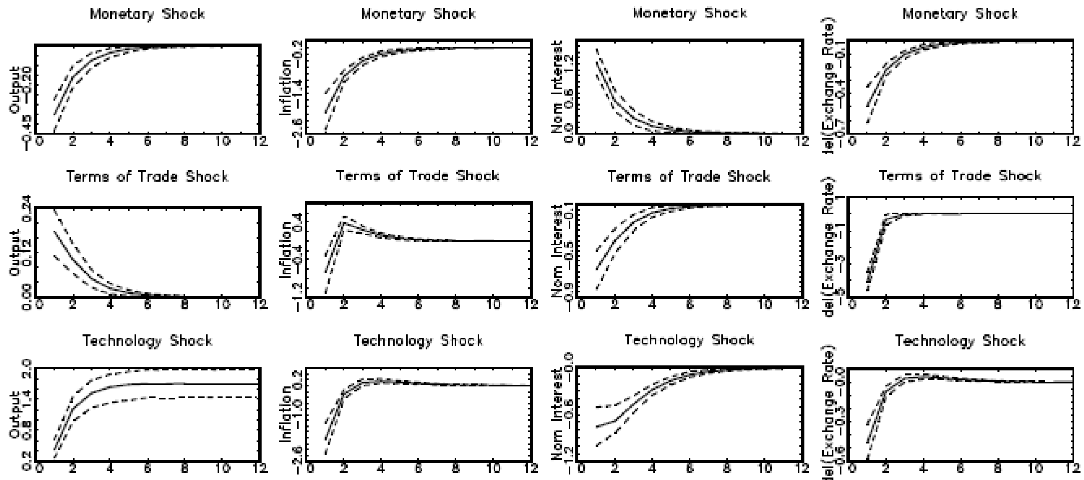


Figure 4: Posterior means (solid lines) and pointwise 90% posterior probability intervals (dashed lines) for impulse responses of output, inflation, and exchange rates to one-standard deviation structural shocks.

How do these results fare relative to other emerging economies? Ortiz, Ottonello, Sturzenegger, and Talvi (2007) run similar exercises to the ones done here for South Africa for a larger group of emerging economies that suffered systemic sudden stops in capital flows during the last two decades. We refer the reader to this work for the estimation details, sample periods and data sources. The results are summarized in Table 3 where we look at comparable 10-year periods with samples starting in 1995.[5]

The comparison with these other countries is interesting. On the one hand, the SARB appears to be on the low side in terms of its concerns for the exchange rate. This is not surprising as the South African economy is well known for having avoided the "original sin" that precludes it from issuing debt in its own currency. As a result the SARB appears to be, among emerging countries, distinctively inattentive to what happens with its exchange rate. On the other hand, many countries in the list appear to have stronger weights on inflation, much higher than that of the SARB. This allows two interpretations. One is that they are more concerned with inflation as an objective. The other is that they need to respond more dramatically to the inflation rate in order to reign in the inflationary process. This, potentially, indicates that interest instruments are less effective elsewhere than in South Africa. Finally, the SARB appears to be on the higher end of interest in terms of its concern on output. This naturally follows from its lower weights on the other variables.

One could argue that these sharp differences are in part due to the fact that all the other emerging market countries suffered sudden stops in capital flows and financial instability during the estimated sample. We are more inclined to think that these differences partially explain why South Africa has not faced a systemic sudden stop in capital flows since 1978. By keeping low levels of foreign denominated debt and low levels of inflation, South Africa was able to build and retain a substantial degree of flexibility for its monetary policy which allowed it to face periods of global financial instability.

[5] For some of these countries terms of trade series were not available. In these cases we used the real exchange rate, $rer_t = p_t - s_t - p_t^*$, which in this model is related to the terms of trade according to $rer_t = (1-\alpha)q_t$.

Table 3. Taylor rules for other emerging economies

Country	Estimation Period		ψ_1	ψ_2	ψ_3	ρ_R
Argentina	1995:Q4	2005:Q3	0.83 (0.68 , 0.98)	1.22 (0.70 , 1.71)	0.18 (0.10 , 0.27)	0.34 (0.18 , 0.51)
Brazil	1995:Q1	2004:Q4	0.70 (0.50 , 0.90)	0.24 (0.07 , 0.40)	0.08 (0.02 , 0.15)	0.87 (0.79 , 0.96)
Chile	1995:Q1	2004:Q4	2.46 (1.74 , 3.17)	0.22 (0.10 , 0.34)	0.08 (0.02 , 0.13)	0.48 (0.33 , 0.63)
Colombia	1995:Q3	2005:Q2	1.34 (0.94 , 1.72)	0.30 (0.12 , 0.47)	0.21 (0.08 , 0.33)	0.69 (0.59 , 0.79)
Croatia	1995:Q1	2004:Q4	1.00 (0.59 , 1.38)	0.27 (0.12 , 0.42)	1.52 (0.99 , 2.02)	0.58 (0.42 , 0.76)
Dominican Republic	1996:Q1	2005:Q4	1.21 (0.83 , 1.60)	0.75 (0.40 , 1.09)	0.20 (0.08 , 0.32)	0.65 (0.56 , 0.76)
Ecuador	1995:Q4	2005:Q3	1.06 (0.74 , 1.37)	0.24 (0.08 , 0.38)	0.27 (0.08 , 0.44)	0.33 (0.15 , 0.51)
Indonesia	1995:Q2	2005:Q1	1.36 (1.00 , 1.71)	0.55 (0.27 , 0.83)	0.11 (0.05 , 0.17)	0.53 (0.41 , 0.66)
Korea	1995:Q1	2004:Q4	2.46 (1.75. , 3.30)	0.48 (0.22 , 0.73)	0.18 (0.07 , 0.29)	0.78 (0.70 , 0.86)
Malaysia	1995:Q1	2004:Q4	3.12 (1.94 , 4.28)	0.28 (0.12 , 0.43)	0.11 (0.03 , 0.19)	0.83 (0.75 , 0.91)
Mexico	1995:Q1	2004:Q4	1.75 (1.35 , 2.13)	0.52 (0.26 , 0.77)	0.39 (0.24 , 0.54)	0.30 (0.06 , 0.51)
Peru	1995:Q1	2004:Q4	2.64 (1.79 , 3.47)	0.49 (0.28. , 0.69)	0.77 (0.47 , 1.07)	0.44 (0.29 , 0.60)
Phillipines	1995:Q1	2004:Q4	1.63 (0.91 , 2.31)	0.36 (0.13 , 0.59)	0.23 (0.11 , 0.35)	0.63 (0.48 , 0.78)
Poland	1995:Q2	2005:Q1	2.47 (1.66 , 3.25)	0.39 (0.19 , 0.59)	0.20 (0.03 , 0.45)	0.79 (0.70 , 0.88)
Russia	1995:Q2	2004:Q4	1.10 (0.77 , 1.52)	1.39 (0.68 , 2.09)	0.29 (0.17 , 0.40)	0.14 (0.00 , 0.29)
South Africa	1995:Q4	2005:Q3	1.36 (1.02 , 1.67)	0.42 (0.18 , 0.65)	0.05 (0.02 , 0.08)	0.68 (0.59 , 0.77)
Thailand	1995:Q1	2004:Q4	2.31 (1.51 , 3.11)	0.39 (0.16 , 0.62)	0.10 (0.03 , 0.16)	0.69 (0.57 , 0.81)
Turkey	1995:Q4	2005:Q3	1.13 (0.05 , 2.60)	0.33 (0.00 , 0.80)	0.22 (0.00 , 0.42)	0.31 (0.02 , 0.59)
Uruguay	1995:Q1	2004:Q4	1.02 (0.51 , 1.51)	0.51 (0.24 , 0.76)	0.55 (0.33 , 0.77)	0.36 (0.19 , 0.54)

Table 3: 90% confidence intervals are reported in parenthesis.

It is interesting to notice that the "output motive" coefficient, ψ_2, is negatively related to the slope of the Phillips curve, the κ parameter on equation (7). This implies that that the larger the possibilities of exploiting the output-inflation trade-off, the larger the Central Bank reaction to the output gap[6]. This relationship is depicted in Figure 5.

Figure 5. Output motive ψ_2 and sensitivity of inflation to output deviations κ

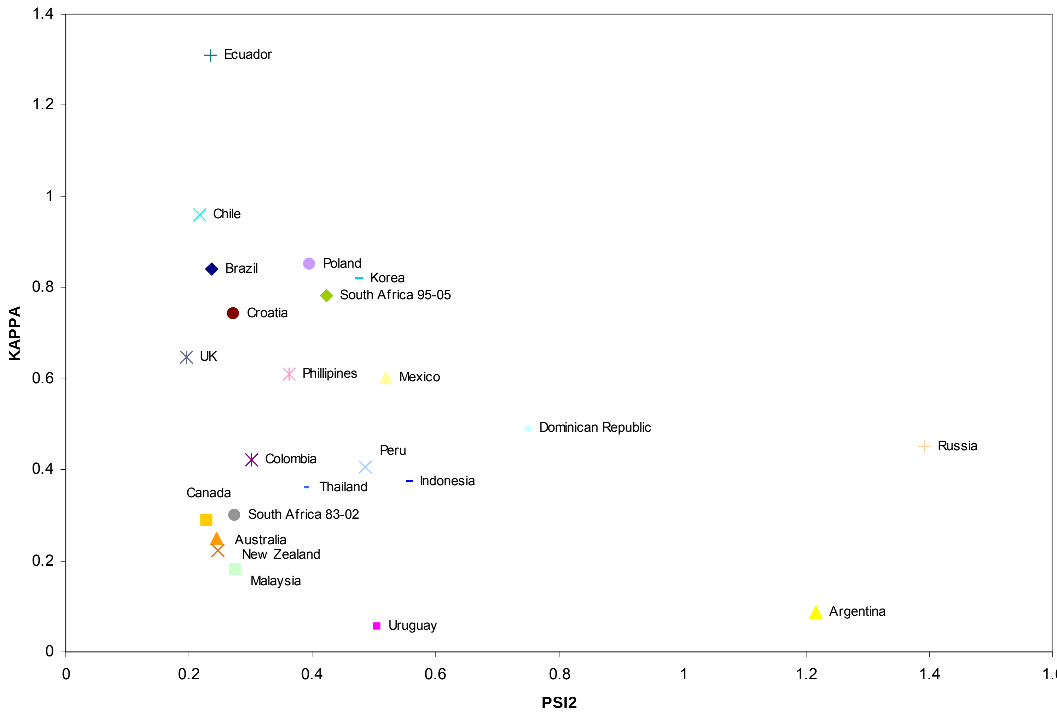


Figure 5: Turkey is excluded from the graph because the estimate that we get for κ is to high (4.81)

Finally, Table 4 compares the stability of the reaction functions across time by showing the volatility of the parameters of the Taylor function over time sorted in descending order by the standard deviation of the estimated "anti-inflation bias" (ψ_1) coefficients.

[6] Adrian Verdelhan suggested that a natural extension is to investigate if the observed conduct of monetary policy is optimal using the structural parameters estimated.

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Table 4. Taylor function stability

Country	Observations	Estimation Period	ψ_1	ψ_2	ψ_3	ρ_R
Malaysia	32	89Q1-93Q4 to 97Q1-06Q4	0.06	0.06	0.10	0.03
South Africa	20	84Q4-94Q3 to 97Q1-06Q4	0.07	0.06	0.33	0.10
Ecuador	21	90Q2-97Q3 to 96Q4-06Q3	0.11	0.04	0.06	0.03
Russia	22	95Q2-97Q4 to 96Q1-05Q4	0.21	0.26	0.21	0.10
Indonesia	40	94Q2-97Q1 to 97Q1-06Q4	0.23	0.23	0.22	0.14
Croatia	23	94Q3-97Q2 to 97Q1-06Q4	0.26	0.10	0.15	0.07
Argentina	47	90Q2-93Q3 to 96Q4-06Q3	0.29	0.28	2.11	0.17
Uruguay	29	94Q1-98Q1 to 94Q1-03Q4	0.32	0.09	0.12	0.14
Mexico	57	83Q1-92Q4 to 97Q1-06Q4	0.33	0.06	0.06	0.17
Colombia	21	94Q2-97Q2 to 96Q4-06Q3	0.34	0.11	0.20	0.08
Phillipines	52	84Q3-94Q2 to 96Q4-06Q3	0.35	0.04	0.09	0.07
Brazil	22	94Q4-97Q3 to 96Q4-06Q3	0.36	0.03	0.13	0.18
Turkey	33	89Q2-93Q1 to 96Q3-06Q2	0.39	0.13	0.09	0.10
Chile	23	87Q1-96Q4 to 97Q1-06Q4	0.43	0.03	0.04	0.12
Korea	31	84Q1-93Q4 to 97Q1-06Q4	0.52	0.08	0.32	0.04
Poland	37	95Q2-98Q1 to 96Q2-06Q1	0.78	0.17	0.17	0.09
Peru	31	87Q1-96Q4 to 97Q1-06Q4	0.85	0.06	0.30	0.17
Thailand	22	93Q2-96Q1 to 97Q1-06Q4	2.31	0.13	0.39	0.22

Table 4: standard deviations of the rolling estimations described in the estimation period.

Again the results suggest the SARB has been able to build a tradition of a stable policy reaction function. In particular its antinflation bias has been among the steadiest (together with Malaysia´s).

4 Conclusions

This paper estimates the policy reaction function of the SARB. We find monetary policy to be quite similar to that of Canada and the UK, and close to that of Australia and New Zealand. Relative to other emerging countries, it stands out for its stability and its relative stronger weight on output and lower relative weight on the exchange rate. It also shows a strong antinflation bias that appears to be among the steadiest among all emerging economies.

5 Appendix: Description of the model and estimation

5.1 A simple structural open economy model

The description of the small open economy model follows Galí and Monacelli (2005) and it is mainly presented to make the paper self-contained. The model economy incorporates the basic microfundations standard in the New Keynesian framework. The model is presented in detail first and then the economy is reduced to the system of 5 equations used for estimation consisting on: a forward-looking open economy IS-equation (6), an open economy Phillips curve (7), monetary policy described by an interest rate rule (8), an equilibrium condition describing the evolution of the nominal exchange rate[7] (9), and an equilibrium relation describing the evolution of the terms of trade (10).

5.1.1 Households

A representative household chooses a sequence of consumption, C_t, and labor, N_t, to maximize expected lifetime utility

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, N_t\right) \tag{11}$$

where $\beta \in (0,1)$ is the discount factor. Consumption is divided between domestic goods, $C_{H,t}$, and foreign goods, $C_{F,t}$, according to

$$C_t = \left[(1-\alpha)^{\frac{1}{\eta}} \left(C_{H,t}\right)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} \left(C_{F,t}\right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{12}$$

where $(1-\alpha) \in [0,1]$ is associated to the degree of home bias in preferences, while $\eta > 0$ measures the substitutability between domestic and foreign goods.

Household resources are composed of a portfolio of bonds holdings, D_t, labor income with nominal wage, W_t, and lump-sum transfers, T_t. These resources are divided between one-period discount bonds with unit price $E_t\left\{\phi_{t,t+1}\right\}$ and domestic and foreign goods with prices $P_{H,t}$ and $P_{F,t}$, respectively. Therefore, each period's maximization problem (11) is subject to the sequence of budget constraints

$$P_{H,t} C_{H,t} + P_{F,t} C_{F,t} + E_t\left\{\phi_{t,t+1} D_{t+1}\right\} \le D_t + W_t N_t + T_t \tag{13}$$

Optimal allocation of expenditures between domestic and imported goods is given by

[7] In the description below the exchange rate is introduced via the definition of the consumer price index (CPI) under the assumption of purchasing power parity (PPP). An alternative would be to use the uncovered interest parity condition (UIP).

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \quad , \quad C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t \tag{14}$$

where $P_t = \left[(1-\alpha)\left(P_{H,t}\right)^{1-\eta} + \alpha\left(P_{F,t}\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}$ is the consumer price index (CPI). Total consumption expenditure by domestic households is given by $P_t C_t = P_{H,t} C_{H,t} + P_{F,t} C_{F,t}$.

Following Galí and Monacelli, we specialize the period utility function to take the form

$$U(C,N) = \frac{C^{1-\sigma}}{1-\sigma} - \frac{N^{1+\varphi}}{1+\varphi}$$

where $\tau \equiv \frac{1}{\sigma} > 0$ represents the intertemporal elasticity of substitution in consumption and $\frac{1}{\varphi} > 0$ is elasticity of labor supply with respect to real wages. Then household's labor, consumption and bond holdings optimality conditions imply

$$C_t^{\sigma} N_t^{\varphi} = \frac{W_t}{P_t} \tag{15}$$

and

$$\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\frac{P_t}{P_{t+1}}\right) = \phi_{t,t+1} \tag{16}$$

Taking conditional expectations on both sides of (16) and rearranging we get the Euler condition

$$\beta R_t E_t\left\{\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\frac{P_t}{P_{t+1}}\right)\right\} = 1 \tag{17}$$

where $R_t = \frac{1}{E_t\left\{\phi_{t,t+1}\right\}}$ is the gross return on the riskless one-period discount bond, with price $E_t\left\{\phi_{t,t+1}\right\}$, paying off one unit of domestic currency in $t+1$.

Under the assumption of complete securities markets, a first-order condition analogous to (16) must also hold for the representative household in any country.

5.1.2 Firms

The small open economy is inhabited by a continuum of monopolistic competitive firms indexed by $j \in [0,1]$ that operate a constant returns to scale (CRS) technology $Y_{H,t}(j) = Z_t N_t(j)$, where Z is a total factor productivity shifter following the AR(1) process (in logs) $z_t = \rho_z z_{t-1} + \varepsilon_t$. The nominal marginal cost is given by $MC_t^n = \frac{W_t}{Z_t}$, while the real marginal cost is given by $MC_t = \frac{W_t}{P_{H,t} Z_t}$.

To introduce nominal rigidities assume that firms face an à la Calvo (1983) price stickiness with a probability θ of not being able to adjust its price in any given period. Let $\overline{P}_{H,t}(j)$ denote the price set by firm j adjusting its price in time t. When setting a new price in period t firm j seeks to maximize expected profits taking into account that this price will remain unchanged for k periods with probability θ^k, and taking as given the household discount factor $\phi_{t,t+k}$. In a symmetric equilibrium all firms adjusting its price in any given period make the same decision, so we can drop the j subscript. The firm's problem is

$$\max_{\overline{P}_{H,t}} \sum_{k=0}^{\infty} \theta^k E_t \left\{ \phi_{t,t+k} \left[\left(\overline{P}_{H,t} - MC_{t+k}^n \right) Y_{t+k} \right] \right\}$$

subject to the sequence of demand constraints

$$Y_{t+k} \leq \left(\frac{\overline{P}_{H,t}}{P_{H,t+k}} \right)^{-\varepsilon} \left[C_{H,t+k} + C_{H,t+k}^* \right] \equiv Y_{t+k}^d \left(\overline{P}_{H,t} \right)$$

Thus, $\overline{P}_{H,t}$, must satisfy the first order condition

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \phi_{t,t+k} \left[\left(\overline{P}_{H,t} - \frac{\varepsilon}{\varepsilon - 1} MC_{t+k}^n \right) Y_{t+k} \right] \right\} = 0 \qquad (18)$$

Using (16) that implies $\phi_{t,t+k} = \beta^k \left(\frac{C_{t+k}}{C_t} \right)^{-\sigma} \left(\frac{P_t}{P_{t+k}} \right)$, we can rewrite the previous condition as

$$\sum_{k=0}^{\infty} (\beta\theta)^k E_t \left\{ (C_{t+k})^{-\sigma} \frac{1}{P_{t+k}} \left[\left(\overline{P}_{H,t} - \frac{\varepsilon}{\varepsilon - 1} MC_{t+k}^n \right) Y_{t+k} \right] \right\} = 0$$

or, in terms of stationary variables,

$$\sum_{k=0}^{\infty} (\beta\theta)^k E_t \left\{ (C_{t+k})^{-\sigma} \left(\frac{P_{H,t-1}}{P_{t+k}} \right) \left[\left(\frac{\overline{P}_{H,t}}{P_{H,t-1}} - \frac{\varepsilon}{\varepsilon - 1} \Pi_{t-1,t+k}^H MC_{t+k} \right) Y_{t+k} \right] \right\} = 0 \qquad (19)$$

where $\Pi_{t-1,t+k}^H = \frac{P_{H,t+k}}{P_{H,t-1}}$, and $MC_{t+k} = \frac{MC_{t+k}^n}{P_{H,t+k}}$. Under the assumed price-setting structure, the dynamic of the domestic price index is described by

$$P_{H,t} = \left[\theta \left(P_{H,t-1} \right)^{1-\varepsilon} + \left(1 - \theta \right) \left(\overline{P}_{H,t} \right)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \tag{20}$$

Combining equations (19) and (20) yields an expression for gross inflation rate for domestically produced goods:

$$\pi_{H,t} = \frac{P_{H,t}}{P_{H,t-1}} = \left(\frac{\varepsilon}{\varepsilon - 1} \frac{MC_t^n}{P_{H,t}} \right)^{\frac{(1-\theta)(1-\beta\theta)}{\theta}} E_t \left\{ \frac{P_{H,t+1}}{P_{H,t}} \right\}^{\beta} \tag{21}$$

Equation (21) is the optimization-based Phillips curve arising from this environment of time-dependent staggered price setting.

CPI inflation is a composite of domestic and foreign good price inflation. Within a local region of the steady state, CPI inflation, π_t, may be expressed as

$$\pi_t = \frac{P_t}{P_{t-1}} = \left(\frac{P_{H,t}}{P_{H,t-1}} \right)^{(1-\alpha)} \left(\frac{P_{F,t}}{P_{F,t-1}} \right)^{\alpha} \tag{22}$$

5.1.3 Inflation, terms of trade and exchange rate

Inversely to Galí and Monacelli, we define the effective terms of trade as the relative price of exports in terms of imports $Q_t \equiv \frac{P_{H,t}}{P_{F,t}}$. Replacing this in (22) domestic inflation, and CPI inflation are related by

$$\pi_t = \pi_{H,t} \left(\frac{Q_t}{Q_{t-1}} \right)^{-\alpha} \tag{23}$$

Assume that the law of one price holds at all times both for import and export prices, which implies that

$$P_{F,t} = S_t P_t^*$$

where S_t is the nominal effective exchange rate, defined as the price of domestic currency in terms of foreign currency, and P_t^* is the world price index.

Combining the previous result with the definition of the terms of trade yields

$$Q_t = \frac{P_{H,t}}{S_t P_t^*} \tag{24}$$

Real exchange rate $RER_t = \frac{P_t}{S_t P_t^*}$ is related to terms of trade by

$$RER_t = \frac{\left(P_{H,t}\right)^{(1-\alpha)}\left(P_{F,t}\right)^{\alpha}}{S_t P_t^*} = \left(\frac{P_{H,t}}{P_{F,t}}\right)^{(1-\alpha)} = Q_t^{(1-\alpha)}$$

Finally, by replacing $P_{H,t}$ from (24) into equation (23) we can get an expression relating CPI inflation with foreign inflation, terms of trade changes and exchange rate changes.

$$\pi_t = \left(\frac{S_t}{S_{t-1}}\right)\left(\frac{Q_t}{Q_{t-1}}\right)^{1-\alpha} \pi_t^* \tag{25}$$

where $\pi_t^* = \frac{P_t^*}{P_{t-1}^*}$ is world inflation.

5.1.4 Monetary policy

Monetary policy is described by an interest rate rule of the form

$$R_t = R_{t-1}^{\rho_R}\left[r\hat{\pi}\left(\frac{\pi_t}{\hat{\pi}}\right)^{\psi_1}\left(\frac{Y_t}{\hat{Y}}\right)^{\psi_2}\left(\frac{\frac{S_t}{S_{t-1}}}{\left(\frac{\hat{S}}{S_{-1}}\right)}\right)^{\psi_3}\right]^{(1-\rho_R)} e^{\varepsilon_{R,t}} \tag{26}$$

where r is the steady-state real interest rate, $\hat{\pi}$ is the target inflation rate, which in equilibrium coincides with the steady-state inflation rate, $\hat{Y}$ is the steady-state output level, $\left(\frac{\hat{S}}{S_{-1}}\right) = 1$ is the steady-state depreciation, ρ_R captures the partial adjustment of the interest rate to target, while ψ_1, ψ_2, and ψ_3 captures the monetary authority's reaction to inflation, output and exchange rate fluctuations.

5.1.5 Equilibrium

World's goods market clearing condition requires that world consumption represented by the index C_t^* is equal to the world output index Y_t^*

$$C_t^* = Y_t^* \tag{27}$$

Domestic goods market clearing requires that domestic production meets domestic demand and exports $C^{*}_{H,t}$

$$C_{H,t} + C^{*}_{H,t} = Y_t \tag{28}$$

Domestic economy asset accumulation follows

$$E_t\left\{\phi_{t,t+1} D_{t+1}\right\} - D_t = Y_t - C_{H,t} - \frac{S_t P^{*}_t}{P_t} C_{F,t} + C^{*}_{H,t} \tag{29}$$

Finally, bonds market clearing requires that there is no excess demand for bonds

$$D_t + D^{*}_t = 0 \tag{30}$$

5.1.6 Log-linearization and simplification

The model economy described above can be simplified and log-linearize to yield the system of 5 equations described in the text and that is the basis for estimation. All small letters denote log-deviations from steady-state.

Using the log-linear terms of trade evolution condition

$$\left[\tau + \alpha\left(2-\alpha\right)\left(1-\tau\right)\right] q_t = y^{*}_t - y_t \tag{31}$$

and the goods markets clearing conditions (27) and (28) into the Euler equation (17) we get the open economy IS-curve (6). The open economy Phillips curve (7) is obtained by using the CPI inflation condition (23), and the equilibrium real marginal cost into the Phillips curve (21), and log-linearizing. The log-linear version of the interest rate rule (26) is given by (8). In order to study exchange rate policies we log-linearize equation (25) to obtain (9).

Even when the above conditions make use of the equilibrium condition for the terms of trade (31), estimation of the fully structural model turns out to be problematic because the model is very restricted. Therefore a law of motion for their growth rate as in (10) is used.

5.2 Estimation Strategy and Empirical Implementation

5.2.1 Bayesian estimation of the DSGE model

As noted by Lubik and Schorfheide (2007) the monetary policy rule cannot be consistently estimated by ordinary least squares because the regressors are endogenous, that is, $E_t\left\{\varepsilon^R_t / \pi_t, y_t, \Delta e_t\right\} \neq 0$. System based methods correct for the endogeneity by adjusting the non-zero conditional expectation of the monetary policy shock. The monetary policy rule is implicitly replaced by the following equation:

$$R_t = E_t\left\{\varepsilon^R_t / \pi_t, y_t, \Delta e_t\right\} + \rho_R R_{t-1} + \left(1-\rho_R\right)\left[\psi_1 \pi_t + \psi_2 y_t + \psi_3 \Delta s_t\right] + \left(\varepsilon^R_t - E_t\left\{\varepsilon^R_t / \pi_t, y_t, \Delta e_t\right\}\right) \tag{32}$$

The likelihood function associated with the DSGE model discussed above is used to generate the correction term $E_t\{\varepsilon_t^R / \pi_t, y_t, \Delta e_t\}$. Potential efficiency gains are exploited by imposing all the rational expectations cross-coefficient restrictions.

The DSGE model presented above is estimated using Bayesian methods[8]. The object of interest is the vector of parameters

$$\theta = \left\{\psi_1, \psi_2, \psi_3, \rho_R, \alpha, \beta, \kappa, \tau, \rho_q, \rho_z, \rho_{y^*}, \rho_{\pi^*}, \sigma_R, \sigma_q, \sigma_z, \sigma_{y^*}, \sigma_{\pi^*}\right\}$$

Given a prior $p(\theta)$, the posterior density of the model parameters, θ, is given by

$$p\left(\theta \middle| Y^T\right) = \frac{L\left(\theta \middle| Y^T\right) p(\theta)}{\int L\left(\theta \middle| Y^T\right) p(\theta) d\theta}$$

where $L\left(\theta \middle| Y^T\right)$ is the likelihood conditional on observed data $Y^T = \{Y_1, \ldots, Y_T\}$. In our case $Y_t = \left[\Delta y_t + z_t, 4\pi_t 4R_t, \Delta s_t, \Delta q_t\right]'$.

The likelihood function is computed under the assumption of normally distributed disturbances by combining the state-space representation implied by the solution of the linear rational expectations model and the Kalman filter. Posterior draws are obtained using Markov Chain Monte Carlo methods. After obtaining an approximation to the mode of the posterior, a Random Walk Metropolis algorithm is used to generate posterior draws. Point estimates and measures of uncertainty for θ are obtained from the generated values. In the graphs we have reported the mean and the 90% confidence interval.

Once we have this, inferential exercises are straightforward for example, by studying the propagation and relative importance of structural shocks through impulse response functions and variance decompositions.

5.2.2 Data

The model is estimated using quarterly data on real output growth, inflation, nominal interest rates, exchange rates changes, and terms of trade or real exchange rate changes. For South Africa data is from the SARB. Output growth rates are computed as natural logarithm (ln) differences of the seasonal adjusted real gross domestic product. Inflation rates are log differences of the consumer price indices, multiplied by 4 to annualize. Nominal interest rates are reported in levels and correspond to the best available proxy for each country's monetary policy instrument. Exchange rates changes are ln differences of domestic currency per US dollar. Terms of trade, defined as the relative price of exports in terms of imports, are reported in changes by using the ln differences. When terms of trade data is not available, we use real exchange rate defined as the ratio of domestic price level to foreign prices.

[8] A detailed description of the methods is found in An and Schorfheide (2007). Textbook treatments are available in Canova (2007) and Dejong and Dave (2007).

5.2.3 Choice of prior

Priors were selected on the basis of previous estimations and available information. Here is an example of prior choices for the South African estimation reported in Table 2.

Priors South Africa

Symbol	Mean	Std. Dev.	Distribution	Description
ψ_1	1.50	0.50	Gamma	Taylor rule coefficient on inflation
ψ_2	0.25	0.13	Gamma	Taylor rule coefficient on output
ψ_3	0.90	0.50	Gamma	Taylor rule coefficient on currency depreciation
ρ_R	0.50	0.20	Uniform	degree of interest rate smoothing
α	0.30	0.05	Beta	import share
r	2.50	1.50	Gamma	real interest rate
κ	0.80	0.30	Gamma	structural parameter, slope of Phillips curve
τ	0.50	0.20	Beta	elasticity of inter-temporal substitution
ρ_q	0.60	0.20	Beta	AR coefficient of the terms of trade / real exchange rate
ρ_z	0.30	0.07	Beta	AR coefficient of the world technology
ρ_{y^*}	0.90	0.05	Beta	AR coefficient of the world output
ρ_{π^*}	0.40	0.10	Beta	AR coefficient of the world inflation
σ_R	0.50	4.00	InvGamma	standard deviation of nominal interest rate innovation
σ_q	4.50	4.00	InvGamma	standard deviation of terms of trade
σ_z	1.00	4.00	InvGamma	standard deviation of the world technology innovation
σ_{y^*}	1.50	4.00	InvGamma	standard deviation of the world output innovation
σ_{π^*}	2.50	4.00	InvGamma	standard deviation of the world inflation innovation

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