

Estimating SARB's Policy Reaction Rule

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Abstract

This paper uses a general equilibrium DSGE model to estimate the SARB's 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, a significant body of literature has framed the debate over monetary policy as that of choosing the appropriate nominal anchor, motivated in part by the concepts of time inconsistency and inflation bias¹. Monetary policy has therefore been discussed as a tension between the credibility

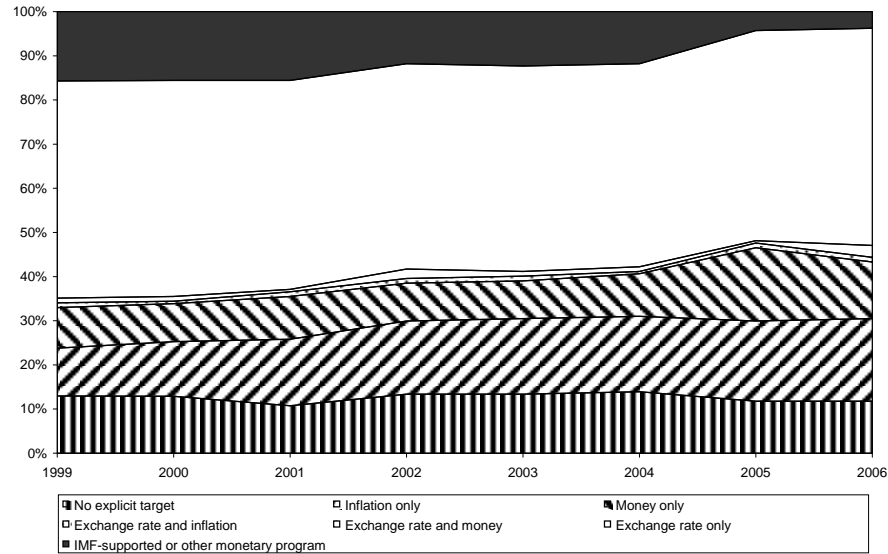
¹The seminal contribution was Kydland and Prescott (1977) for which they obtained the Nobel price in 2005. Calvo (1978) provided an alternative modelization, focusing on the time inconsistency problem of domestically denominated debt. The setup achieved textbook status with Barro and Gordon (1983). In 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 Driffil (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.

provided by an anchor, and the costs of the anchor in terms of a smaller degree of flexibility to respond to shocks. On occasions the anchor becomes 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. In fact this has been the main dilemma that monetary policy has had to deal with.

The issue of describing monetary, i.e. identifying how policy makers choose those anchors and measuring how much flexibility they retain in their policy choices, can be addressed by classifying countries according to their stated anchors, typically, the exchange rate, monetary aggregates or the inflation rate, the 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, some of these targets show some overlaps, others have no explicit target and yet others have IMF supported programs with other objectives. One quick way to assess this is to review the monetary framework classification of the IMF. Figure 1 shows the results. 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

Anchors of Monetary Policy



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 classifications², 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,

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

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 overshoot their targets without reversing the overshoot later and often obscured the reasons why deviations from the monetary targets occurred.”

And 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 the 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 IT gradually proceed from the soft version (which in the early years usually coexists with a dirty exchange rate regimes, see Schmidt-Hebbel and Tapia 2002 for Chile; Armas et al. 2006 for Peru; Fraga et al. 2005 for Brazil, and Mishkin (2006) for everything else) to the more canonical version.

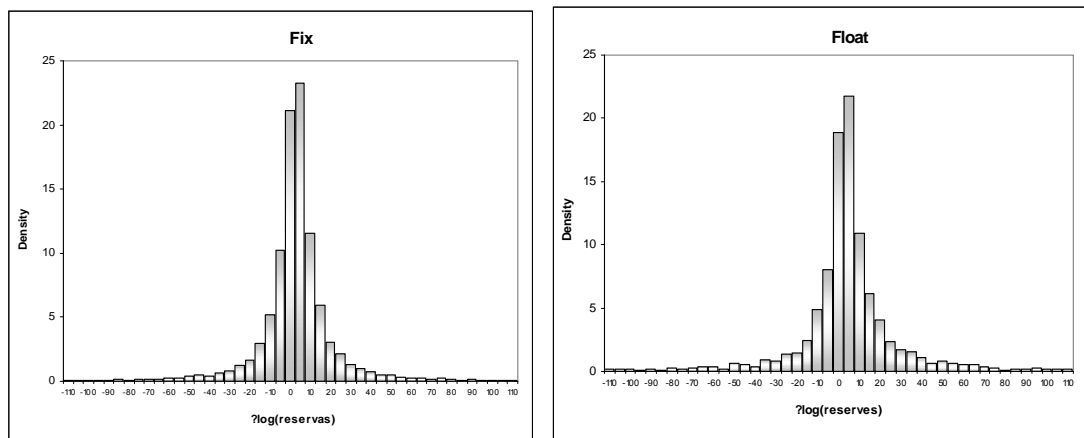
This caveat is more generally related with a definitional problem that plagues inflation targeting as a distinct policy: if by inflation targeting one means an explicit commitment with low and stable inflation, then most central banks in mature economies (and most in high-middle income ones) are in fact 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 IT 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 shown in figure 2 which compares it with the interventions of the group that allegedly focuses on the exchange rate.

Figure 2. Interventions in exchange rate markets



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". Another way of making the point is using a de facto classification of exchange rate regimes (Levy Yeyati and Sturzenegger 2005, 2007). 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.

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

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 the simple equation

$$i - \pi = r^* + 0.5(\pi - \pi^*) + 0.5(Y - \bar{Y})$$

represented US policy fairly well. 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 a rule based on information available at the time. Clarida, Gali and Gertler (2000) suggest that the Taylor rule has more to do with expectations of inflation and the output gap, and use an IV 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 IT, based on the backward-looking framework in Ball (1999):

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

$$\pi_t = \pi_{t-1} + \alpha y_{t-1} + \gamma(s_{t-1} - s_{t-2}) + \mu_t, \quad (2)$$

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

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

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

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

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

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):

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

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 IT 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, $E_t (s_{t+1} - s_t) = r_t - r_t^f$ (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 (IT) becomes:

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

where

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

which for very low pass-throughs ($\omega = \delta/\beta$) 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 dilucidate 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 through 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 Engel and Devereux (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 Devereux 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 their reaction function.

With this as background we can ask the main question that this paper will try to address in the context of South Africa: how can the presence of the exchange rate be identified in the reaction function of the Central Bank? One alternative is to extend the methodology of Clarida, Gali and Gertler (2000) and estimate a univariate model. An alternative is to estimate a structural model. Lubik and

Shorfheide (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 Shorfheide (2007) estimate it for four countries: the UK, Australia, 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. This 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 Shorfheide (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 structure 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 Shorfheide (2007) estimate a version of a model initially developed by Gali and Monacelli (2005) which in log-linearized 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 share³, 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:

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

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

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

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

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

where s_t denotes the nominal effective exchange rate, 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.

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:

$$\Delta q_t = \rho_q \Delta q_{t-1} + \varepsilon_{q,t}. \quad (10)$$

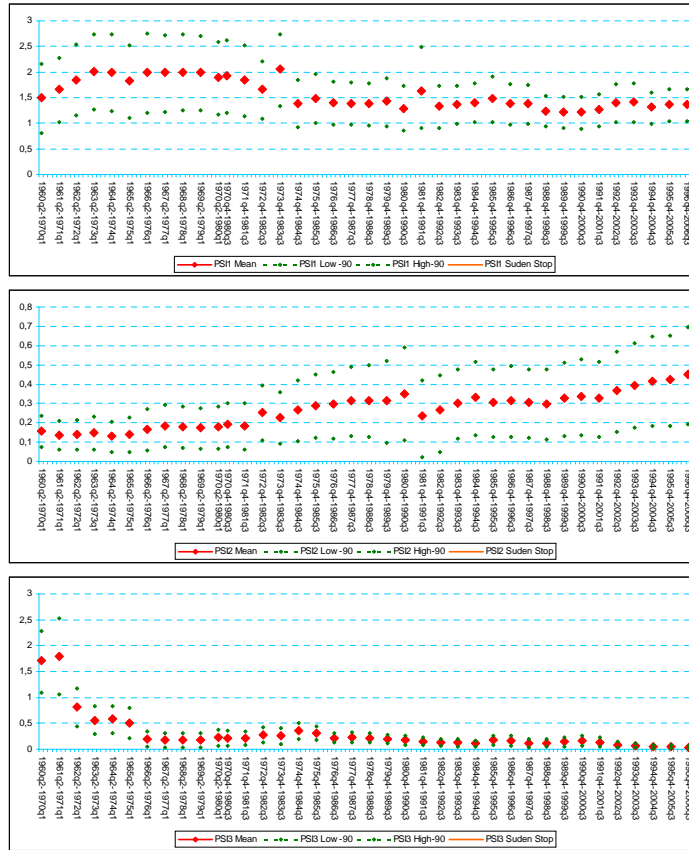
Equations (6) - (10) form a linear rational expectations model. It is assumed that y_t^* and π_t^* evolve according to univariate AR(1) processes with autoregressive coefficients ρ_{y^*} and ρ_{π^*} , respectively. The innovations of the AR(1) processes are denoted by $\varepsilon_{y^*,t}$ and $\varepsilon_{\pi^*,t}$. 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

The results of the estimate for South Africa are shown in Figure 3. The model is estimated in a rolling fashion including data from 1960 and using 10 years of quarterly data at a time. The graphs show the coefficients 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" and ψ_3 could be called the "fear of floating bias".

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. Tangent to this process there has been an increase in the output objective. Throughout the SARB has been concerned about inflation as shown, critically, by the coefficient of the inflation rate which 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.

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



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 not 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 Shorfheide (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		Mean	90% Interval	
Australia	Psi1	1,41	1,04	1,77
	Psi2	0,24	0,09	0,39
	Psi3	0,07	0,03	0,12
	Rhor	0,76	0,69	0,83
New Zealand	Psi1	1,69	1,24	2,13
	Psi2	0,25	0,13	0,37
	Psi3	0,04	0,01	0,08
	Rhor	0,63	0,53	0,72
United Kingdom	Psi1	1,30	0,96	1,62
	Psi2	0,20	0,07	0,32
	Psi3	0,13	0,07	0,19
	Rhor	0,74	0,66	0,81
Canada	Psi1	1,30	0,98	1,6
	Psi2	0,23	0,09	0,36
	Psi3	0,14	0,06	0,21
	Rhor	0,69	0,61	0,77
South Africa	Psi1	1,11	0,89	1,33
	Psi2	0,27	0,11	0,43
	Psi3	0,11	0,06	0,16
	Rhor	0,73	0,66	0,79

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 Shorfheide 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 as well as appreciating 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

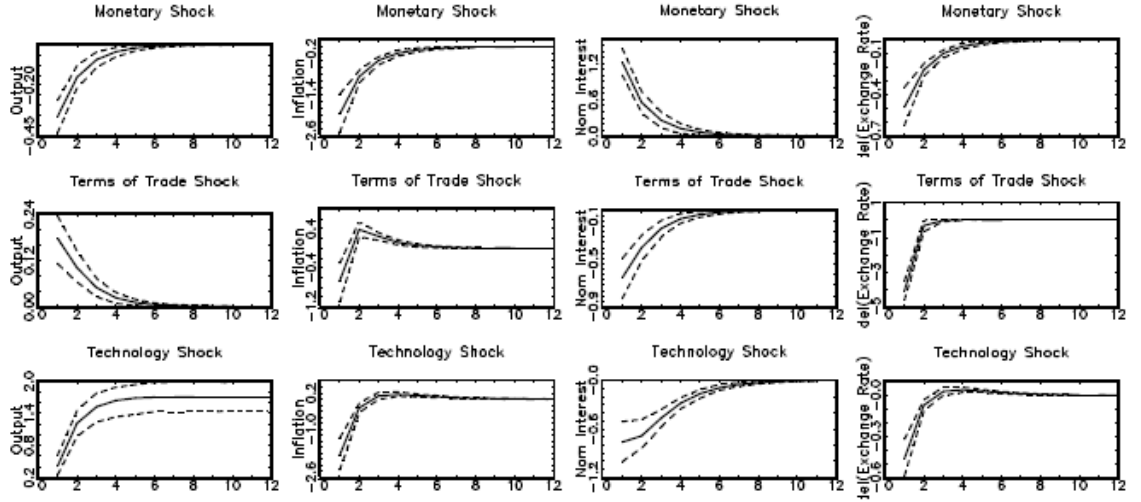


Figure depicts posterior means (solid lines) and pointwise 90% posterior probability intervals (dashed lines) for impulse responses of output, inflation, and exchange rates to one-standard deviation structural shocks.

How do these results fare relative to other emerging economies? Ortiz, Talvi and Sturzenegger (2007) run similar exercises to the ones done here for South Africa for a larger group of emerging economies. We refer the reader to this work for the estimation details, sample periods and data sources. Their results are summarized in Table 3. In this table we also look at comparable periods so that these results can be more easily compared with those of South Africa.⁴

⁴For 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	Sample		Mean	90% Interval		Country	Sample		Mean	90% Interval	
Argentina	95q4-05q3	Psi1	0,83	0,68	0,98	Mexico	95q1-04q4	Psi1	1,75	1,35	2,13
		Psi2	1,22	0,70	1,71			Psi2	0,52	0,26	0,77
		Psi3	0,18	0,10	0,27			Psi3	0,39	0,24	0,54
		Rhor	0,34	0,18	0,51			Rhor	0,30	0,06	0,51
Brazil	95q1-04q4	Psi1	0,70	0,50	0,90	Peru	95q1-04q4	Psi1	2,88	1,91	3,84
		Psi2	0,24	0,07	0,40			Psi2	0,19	0,10	0,27
		Psi3	0,08	0,02	0,15			Psi3	0,69	0,39	0,99
		Rhor	0,87	0,79	0,96			Rhor	0,55	0,42	0,69
Chile	95q1-04q4	Psi1	2,46	1,74	3,17	Phillipines	95q1-04q4	Psi1	1,63	0,91	2,31
		Psi2	0,22	0,10	0,34			Psi2	0,36	0,13	0,59
		Psi3	0,08	0,02	0,13			Psi3	0,23	0,11	0,35
		Rhor	0,48	0,33	0,63			Rhor	0,63	0,48	0,78
Colombia	95q3-05q2	Psi1	1,34	0,94	1,72	Poland	95q2-05q1	Psi1	2,47	1,66	3,25
		Psi2	0,30	0,12	0,47			Psi2	0,39	0,19	0,59
		Psi3	0,21	0,08	0,33			Psi3	0,20	0,03	0,45
		Rhor	0,69	0,59	0,79			Rhor	0,79	0,70	0,88
Croatia	95q1-04q4	Psi1	1,00	0,59	1,38	Russia	95q2-04q4	Psi1	1,10	0,77	1,52
		Psi2	0,27	0,12	0,42			Psi2	1,39	0,68	2,09
		Psi3	1,52	0,99	2,02			Psi3	0,29	0,17	0,40
		Rhor	0,58	0,42	0,76			Rhor	0,14	0,00	0,29
Ecuador	95q4-05q3	Psi1	1,06	0,74	1,37	South Africa	95q2-05q1	Psi1	1,35	1,02	1,65
		Psi2	0,24	0,08	0,38			Psi2	0,42	0,18	0,65
		Psi3	0,27	0,08	0,44			Psi3	0,05	0,02	0,08
		Rhor	0,33	0,15	0,51			Rhor	0,67	0,58	0,76
Indonesia	95q2-05q1	Psi1	1,36	1,00	1,71	Thailand	95q1-04q4	Psi1	2,31	1,51	3,11
		Psi2	0,55	0,27	0,83			Psi2	0,39	0,16	0,62
		Psi3	0,11	0,05	0,17			Psi3	0,10	0,03	0,16
		Rhor	0,53	0,41	0,66			Rhor	0,69	0,57	0,81
Korea	95q1-04q4	Psi1	2,46	1,57	3,30	Turkey	95q4-05q3	Psi1	1,13	0,05	2,60
		Psi2	0,48	0,22	0,73			Psi2	0,33	0,00	0,80
		Psi3	0,18	0,07	0,29			Psi3	0,22	0,00	0,42
		Rhor	0,78	0,70	0,86			Rhor	0,31	0,02	0,59
Malaysia	95q1-04q4	Psi1	3,12	1,94	4,28	Uruguay	95q1-04q4	Psi1	1,02	0,51	1,51
		Psi2	0,28	0,12	0,43			Psi2	0,51	0,24	0,76
		Psi3	0,11	0,03	0,19			Psi3	0,55	0,33	0,77
		Rhor	0,83	0,75	0,91			Rhor	0,36	0,19	0,54

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 unattentive 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 their interest instrument is 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.

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.

Table 4. Taylor function stability

Country	Sample		Variance	Obs.	Country	Sample		Variance	Obs.
Argentina	90q2-93q3 to 96q4-06q3	Psi1	0,0833	47	Mexico	83q1-92q4 to 97q1-06q4	Psi1	0,1086	256
		Psi2	0,0759				Psi2	0,0040	
		Psi3	4,4400				Psi3	0,0020	
		Rhor	0,0281				Rhor	0,0296	
Brazil	94q4-97q3 to 96q4-06q3	Psi1	0,1286	22	Peru	87q1-96q4 to 97q1-06q4	Psi1	0,7262	31
		Psi2	0,0006				Psi2	0,0033	
		Psi3	0,0158				Psi3	0,0912	
		Rhor	0,0307				Rhor	0,0296	
Chile	87q1-96q4 to 97q1-06q4	Psi1	0,1878	23	Phillipines	84q3-94q2 to 96q4-06q3	Psi1	0,1238	52
		Psi2	0,0009				Psi2	0,0015	
		Psi3	0,0016				Psi3	0,0077	
		Rhor	0,0150				Rhor	0,0043	
Colombia	94q2-97q2 to 96q4-06q3	Psi1	0,1126	21	Poland	95q2-98q1 to 96q2-06q1	Psi1	0,6039	37
		Psi2	0,0117				Psi2	0,0287	
		Psi3	0,0392				Psi3	0,0284	
		Rhor	0,0058				Rhor	0,0081	
Croatia	94q3-97q2 to 97q1-06q4	Psi1	0,0676	23	Russia	95q2-97q4 to 96q1-05q4	Psi1	0,0453	22
		Psi2	0,0101				Psi2	0,0682	
		Psi3	0,0234				Psi3	0,0457	
		Rhor	0,0042				Rhor	0,0102	
Ecuador	90q2-97q3 to 96q4-06q3	Psi1	0,0120	21	South Africa	84q4-94q3 to 97q1-06q4	Psi1	0,0047	20
		Psi2	0,0016				Psi2	0,0036	
		Psi3	0,0038				Psi3	0,1091	
		Rhor	0,0009				Rhor	0,0092	
Indonesia	94q2-97q1 to 97q1-06q4	Psi1	0,0540	40	Thailand	93q2-96q1 to 97q1-06q4	Psi1	5,3423	22
		Psi2	0,0512				Psi2	0,0179	
		Psi3	0,0490				Psi3	0,1506	
		Rhor	0,0190				Rhor	0,0495	
Korea	84q1-93q4 to 97q1-06q4	Psi1	0,2695	31	Turkey	89q2-93q1 to 96q3-06q2	Psi1	0,1530	33
		Psi2	0,0062				Psi2	0,0170	
		Psi3	0,1004				Psi3	0,0086	
		Rhor	0,0015				Rhor	0,0109	
Malayasia	89q1-93q4 to 97q1-06q4	Psi1	0,0034	32	Uruguay	94q1-98q1 to 94q1-03q4	Psi1	0,1026	29
		Psi2	0,0033				Psi2	0,0077	
		Psi3	0,0092				Psi3	0,0143	
		Rhor	0,0012				Rhor	0,0195	

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 estimated the policy reaction function of the SARB. We found 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 1. Description of the model and estimation

5.1 A simple structural open economy model

The description of the small open economy model follows Gali and Monacelli (2005) and it is mainly presented to make the paper self-contained. The model economy incorporates the basic microfoundations 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: (i) a forward-looking open economy IS-equation, (ii) an open economy Phillips curve, (iii) monetary policy described by an interest rate rule, (iv) an equilibrium condition describing the evolution of the nominal exchange rate⁵, and (v) an equilibrium relation describing the evolution of the terms of trade.

5.1.1 Households

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

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

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

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

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 $E_t \{ \phi_{t,t+1} \}$, 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

$$P_{H,t} C_{H,t} + P_{F,t} C_{F,t} + E_t \{ \phi_{t,t+1} D_{t+1} \} \leq D_t + W_t N_t + T_t. \quad (13)$$

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

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

⁵In 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).

where $P_t = \left[(1 - \alpha) (P_{H,t})^{1-\eta} + \alpha (P_{F,t})^{1-\eta} \right]^{\frac{1}{1-\eta}}$ 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 Gali 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

$$C_t^\sigma N_t^\varphi = \frac{W_t}{P_t} \quad (15)$$

and

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

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

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

where $R_t = \frac{1}{E_t \{ \phi_{t,t+1} \}}$ is the gross return on the riskless one-period discount bond, with price $E_t \{ \phi_{t,t+1} \}$, 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 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 $\bar{P}_{H,t}(j)$ 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

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

subject to the sequence of demand constraints

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

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

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

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

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

or, in terms of stationary variables,

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

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

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

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

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

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

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

5.1.3 Inflation, terms of trade and exchange rate

Inversely to Gali 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

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

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 and P_t^* is the world price index. Combining the previous result with the definition of the terms of trade yields

$$Q_t = \frac{P_{H,t}}{S_t P_t^*}. \quad (24)$$

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

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

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.

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

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

$$R_t = R_{t-1}^{\rho_R} \left[r \pi^* \left(\frac{\pi_t}{\pi^*} \right)^{\psi_1} \left(\frac{Y_t}{Y_t^*} \right)^{\psi_2} \left(\frac{S_t}{S_{t-1}} \right)^{\psi_3} \right]^{(1-\rho_R)} e^{\varepsilon_t^R} \quad (26)$$

where r is the steady-state real interest rate, π^* is the target inflation rate, which in equilibrium coincides with the steady-state inflation rate, Y_t^* is the level of output that would prevail in the absence of nominal rigidities, 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^*

$$C_t^* = Y_t^*. \quad (27)$$

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

$$C_{H,t} + C_{H,t}^* = Y_t. \quad (28)$$

Domestic economy asset accumulation follows

$$E_t \{ \phi_{t,t+1} D_{t+1} \} - D_t = Y_t - C_{H,t} - \frac{S_t P_t^*}{P_t} C_{F,t} + C_{H,t}^*. \quad (29)$$

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

$$D_t + D_t^* = 0. \quad (30)$$

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

$$[\tau + \alpha(2 - \alpha)(1 - \tau)] q_t = y_t^* - y_t \quad (31)$$

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, $E \{ \varepsilon_t^R \mid \pi_t, y_t, \Delta e_t \} \neq 0$. 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:

$$R_t = E \{ \varepsilon_t^R \mid \pi_t, y_t, \Delta e_t \} + \rho_R R_{t-1} + (1 - \rho_R) [\psi_1 \pi_t + \psi_2 y_t + \psi_3 \Delta e_t] + (\varepsilon_t^R - E \{ \varepsilon_t^R \mid \pi_t, y_t, \Delta e_t \}). \quad (32)$$

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

The DSGE model presented above is estimated using Bayesian methods⁶. The object of interest is the vector of parameters

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

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

$$p(\theta \mid Y^T) = \frac{L(\theta \mid Y^T) p(\theta)}{\int L(\theta \mid Y^T) p(\theta) d\theta}$$

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

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. Af-

ter 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 mean and 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

⁶A detailed description of the methods is found in An and Schorfheide (2007). Textbook treatments are available in Canova (2007) and Dejong and Dave (2007).

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.

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.

Symbol	Domain	Prior Mean	Prior Std. Dev.	Distribution	Description
ψ_1	\mathbb{R}^+	1.50	0.50	Gamma	Taylor rule coefficient on inflation
ψ_2	\mathbb{R}^+	0.25	0.125	Gamma	Taylor rule coefficient on output
ψ_3	\mathbb{R}^+	0.90	0.50	Gamma	Taylor rule coefficient on currency depreciation
ρ_R	$[0, 1)$	0.50	0.20	Uniform	degree of interest rate smoothing
α	$[0, 1)$	0.30	0.05	Beta	import share
r	\mathbb{R}^+	2.50	1.50	Gamma	real interest rate
κ	\mathbb{R}^+	0.80	0.30	Gamma	structural parameter, slope of Phillips curve
τ	$[0, 1)$	0.50	0.20	Beta	elasticity of inter-temporal substitution
ρ_q	$[0, 1)$	0.60	0.20	Beta	AR coefficient of the terms of trade
ρ_z	$[0, 1)$	0.30	0.07	Beta	AR coefficient of the world technology
ρ_{y^*}	$[0, 1)$	0.90	0.05	Beta	AR coefficient of the world output
ρ_{π^*}	$[0, 1)$	0.40	0.10	Beta	AR coefficient of the world inflation shock
σ_R	\mathbb{R}^+	0.50	4.00	InvGamma	
σ_q	\mathbb{R}^+	4.50	4.00	InvGamma	
σ_z	\mathbb{R}^+	1.00	4.00	InvGamma	
σ_{y^*}	\mathbb{R}^+	1.50	4.00	InvGamma	
σ_{π^*}	\mathbb{R}^+	2.50	4.00	InvGamma	

The graph shows rolling estimations of the policy parameters for a 10-year window. The graphs report the estimated parameter and a 90% confidence interval.

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