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Martha López P.

Efficient policy rule for inflation targeting in Colombia

1. INTRODUCTION

Around the world monetary authorities meet periodically to determine whether the monetary policy stance is consistent with their short and mid term targets. Those meetings revolve around the change in the tactics or strategies in order to meet the targets. In the early nineties central bankers of many countries like New Zealand, Canada, the United Kingdom, among others, adopted the inflation targeting strategy as one of the means to control inflation. In recent years, many other countries such as Colombia

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and Chile have also adopted the inflation targeting strategy. Within this context, monetary authorities need tools and some criteria to gauge the efficiency of macroeconomic policy.

Bernanke and Mishkin (1997) characterized inflation targeting as "constraint discretion" where there is ample scope for discretionary input into any rule. However, in order to evaluate the efficacy of the policy, the inflation targeting strategy should amount to a well-defined monetary policy-rule. Based on previous research on monetary policy rules, that have demonstrated the efficacy of simple rules, in this paper I explore the characteristics that a well-defined simple policy rule should have for inflation targeting in Colombia. I generate the inflation-output variability frontiers as introduced in Taylor (1979), to investigate what kind of reaction function is more efficient in terms of minimization of output gap, inflation and instrument variability.

The reminder of the paper is as follows. In section 2 a brief description of the output-variability trade-off is given. In section 3 the concepts of optimal-state contingent policy rules and simple policy rules, like the Taylor rule, are discussed briefly. A discussion about the lags in the monetary policy and the ability of Inflation Forecast Based (IFB) rules to embrace the forward looking dimension that the monetary policy should have is presented in section 4. Some other advantages of IFB simple rules are also given. In sections 5 and 6 I describe two basic ingredients needed to evaluate the performance of any simple policy rule; the objective function of the monetary authorities and the model that describes de economy. In section 7, policy frontiers based on Taylor rules and Inflation Forecast Based rules are computed. The most efficient simple policy rule for the Colombian economy is presented in section 8. Section 9 contains a brief summary and conclusion.

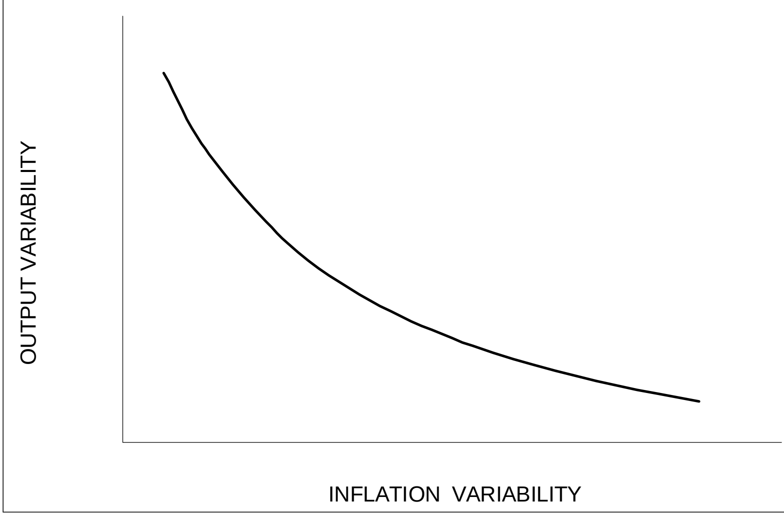
2. THE OUTPUT-INFLATION VARIABILITY TRADE-OFF

In the economics literature it has been argued that there exists a trade-off between the size of the fluctuations in inflation and the size of the fluctuations in real output. In the context of the evaluation of the efficiency of the macroeconomic policies, this means that in the conduction of monetary policy it is useful to construct and estimate a variability trade-off between inflation and unemployment in terms of their fluctuations over time rather than in terms of a single decision made at a single point in time.

Focusing on the long-term, which consist of many short-runs, results in a better evaluation of monetary policy.

The idea of the output-inflation variability trade-off is shown in chart 1. Inefficient macroeconomic policies would lead to outcomes above the curve with both inflation fluctuations and unemployment fluctuations higher than what could be achieved with better policies. Hence points moving to the south-west in Figure 1 signal an improvement in policy performance and conversely, points to the north east signal a worsening policy performance. The efficient frontiers, defined in Taylor (1979), are the locus of the lowest achievable combination of inflation and output variability. In addition, on the frontier, one must view reduced output stability as the opportunity cost of improved inflation stability.

Chart 1
Output/inflation variability trade-off



The response of monetary policy to macroeconomic shocks helps determine how large effects on real output or inflation will be. For example, suppose that the economy is in a state where real output equals potential output and inflation is steady, and suppose that there is an upward demand shock. It causes real output to rise above potential and there will be inflationary pressures. The monetary authority could respond in two ways. The first response could be to tighten policy sharply in order to control the inflation rate, but it might cause a slow down in the real activity. In this case the response results in more inflation stability and less real output stability. The second response could be to use a more cautious monetary policy that might have less effect in controlling the rise in inflation, but it will have a smaller negative effect on real output. Depending on what the monetary authority decides, its monetary policy helps determine the inflation and output stability.

3. THE EFFICIENT FRONTIERS, OPTIMAL STATE-CONTINGENT AND SIMPLE POLICY RULES

3.1 Optimal state-contingent rules

Following Taylor (1994), the optimal State-contingent policy rule is defined as the one that minimizes a weighted sum of output variance and inflation variance (sometimes the variability of the interest rates is also taken into account). The weights are determined by the policy makers tastes.

From optimal control theory it is well known that optimal State-contingent policy rules respond to all variables that offer useful information on the target variables of policy.[1] Optimal state-contingent rules may respond for example not only to the deviation of inflation from target and the output gap, but also to variables such as the real exchange rate, foreign output gap, and foreign inflation.[2] Because of their complexity, optimal state-contingent policy rules might be very impractical to implement.

Some other simple policy rules, although not as efficient as the state-contingent rules, may approximate them reasonably well and have some additional advantages.

3.2 Efficient simple policy rules

Efficient simple policy rules were introduced by Taylor (1979). He proposed an explicit instrument rule for policy that today is known as the Taylor rule. Under such a reaction function, the nominal level of the interest rate is determined by the current level of two variables, the deviation of inflation from a target and, the deviation of actual output from potential, so:

[1] Rudebush and Svensson (1998).
[2] Dennis (2000).

$$i_t^p = (r_t^* + \pi_t) + \alpha_\pi(\pi_t - \pi_t^*) + \delta(y_t - y^*) \quad (1)$$

where r^* is the equilibrium or long-run real interest rate. Efficient simple policy rules for the conduction of monetary policies are defined as those that deliver the lowest achievable combination of inflation and output variability (or some other variable in the objective function of the central bank) given the structure of the model under consideration.

Taylor (1993) suggested a weight of 0.5 on the output gap and on the inflation deviation from target. However, virtually all attempts to estimate the Taylor rule empirically require the addition of a lagged dependent variable in order to fit well. This means that central banks have tried historically to smooth interest rates changes. Thus the common practice among central banks is to make long series of small steps in the same direction. This behavioral pattern is partly picked up in the econometrics for the Taylor rule, in the guise of the near-unity value of the lagged dependent variable. Taylor (1998) studied the comparative virtues of rules of that include the lagged dependent variable. He concludes that it is alright for the authorities to act slowly in a series of cautious steps, just as long as a forward-looking public can effectively undo such cautious lags by immediate anticipation. Interest rate rules which respond with a lag assume that people will expect later increases in interest rates if such increases are needed to reduce inflation. Later, I will introduce a smoothing parameter of the interest rate in the setting for the simple policy rule for Colombia.

One important aspect about simple rules is that they have some advantages over optimal state-contingent policy rules. Some of this advantages are that their implementation is much easier; that it is easy for private agents to understand policy, and that they can verify the Central Bank behavior. However, the efficiency of this kind of rules seems to be limited due to the fact that they respond to only a subset of the available information set. According to studies by Rudebusch and Svensson (1998) and others, the most efficient simple rules are rules called Inflation Forecast Based rules (IFB). I devote the next section to this kind of simple policy rules.

4. LAGS IN THE MONETARY TRANSMISSION MECHANISM AND INFLATION FORECAST BASED RULES

It has long been recognized that monetary policy needs a forward-looking dimension. As Milton Friedman noted, the monetary policy transmission mechanism has "long and variable lags." The Taylor rule sets an interest rate path on the basis of current or lagged values of output and inflation. By contrast, inflation-targeting central banks focus on inflation forecasts rather than in their actual values. In these central banks, forecasts of future inflation and output play a key role in the monetary policy decision-making process.

Inflation Forecasts Based rules (IFB rules) are rules with response to a rule-consistent inflation forecast. The result is an inflation forecast always returning to the target. Consider the following forecast-based rule

$$i_t^p = (r_t^* + \pi_t) + \alpha_\pi (E_t \pi_{t+k} - \pi_t^*) \tag{2}$$

where $E_t(\bullet) = E_t(\bullet \mid \Phi_t)$, where Φ_t is the information set available at time t and E is the mathematical expectations operator. According to the rule, the monetary authorities control deterministically nominal interest rates (i_t) so as to hit a path for the short-term real interest rate. This kind of policy rule is a useful prescriptive tool because deviations of *expected* inflation (the feedback variable) from the inflation target (the policy goal) prescribe remedial policy actions. The rule implies that if new information makes the inflation forecast at horizon *k* increase, the interest rate should be increased, and vice versa.

Besides allowing the policy-maker the control lag for monetary policy, there are good reasons for believing that forecast-based policy rules, although simple, may not be as restrictive as the Taylor rule. Given that an inflation forecast is formed using all information that is useful for predicting future inflation, (i.e. exchange rate, foreign output, foreign interest rates, import prices, etc.) a simple IFB rule is implicitly responding to a wide array of macroeconomic variables. It is for this reason that IFB rules, although not as efficient as the state-contingent policy rule, may tend to be more efficient than other types of simple, backward-looking rule.

In the next section, I will consider the performance of simple Taylor rules and IFB rules in an inflation targeting framework for Colombia. This is made by embedding the various rules in a small macro model, *Model of Transmission Mechanism (MMT)* and, after performing some stochastic simulations, evaluating the resulting (unconditional) moments of the arguments typically thought to enter the central banks' loss function (output, inflation and the policy instrument).

5. THE MONETARY AUTHORITY'S OBJECTIVE FUNCTION

As in Batini and Nelson (2000), we will interpret "inflation targeting" as having a loss function for monetary policy where deviations of inflation from an explicit inflation target are always given some weight, λ_π, but not necessarily all the weight. Strict inflation targeting refers to the situation where only inflation enters the loss function, while "flexible" inflation targeting allows other goal variables.

In the optimization exercises used to derive the optimal policy rule, this is the function that is being minimized. And when comparing the performance of rules like (1) or (2), this loss function is used to compute welfare losses in all experiments. In particular for a discount factor β, $0<\beta<1$, we consider the loss function given by:

$$L_t = E_t \sum_{j=0}^{\infty} \beta^j \{ \lambda_\pi (\pi_{t+j} - \pi^*_{t+j})^2 + \lambda_y (y_{t+j} - y^*_{t+j})^2 + \lambda_{\Delta i} (\Delta i_{t+j})^2 \} \quad (3)$$

We use standard weights used in the inflation targeting literature, with $\beta=0.99$, $\lambda_\pi = 1$, $\lambda_y=1$ and $\lambda_{\Delta i} = 0.5$. It means that loss is calculated under the assumption that output and inflation variability are equally distasteful and variations in the costs of variability of interest-rate changes receives a penalty half that of the other terms.

6. A SMALL OPEN ECONOMY MODEL

6.1 Description of the model

In this section it is presented a latest version of a *Small Macro Model of Transmission Mechanism (SMMT)* developed at the Bank by Gómez, Uribe and Vargas (2002)[3] for the description of the Colombian economy. This model is a small, dynamic open economy representation of the Colombian economy. It follows the

[3] The main features and econometric estimations of the model are presented in Gómez, J Uribe, J D, and Vargas, H (2002) "The implementation of Inflation Targeting in Colombia" *Borradores Semanales de Economía* no. 202. The main difference of the version presented here is that static homogeneity is not imposed in the model, therefore the long-run restrictions on the levels of the variables are not present. However, dynamic homogeneity is tested and still present in the model, allowing the model to be superneutral.

models developed by Rotemberg and Woodford´s (1997), McCallum and Nelson (1999), Svensson (1998), and Fuhrer and Moore (1995), that are derived from representative agent micro-foundations. The model is explicitly foreward-looking in financial markets and, potentially, in the goods market.[4]

The model is based on the following equations:

$$\hat{y}_t = \beta_1 \hat{y}_{t-1} + \beta_2 \hat{y}_{t+1} - \beta_3 \hat{r}_t + \beta_4 \hat{y}_t^{usa} + \beta_5 \hat{q}_{t-1} + \varepsilon_t^y \tag{4}$$

$$\pi_t^c = (1-\eta_1-\eta_2)\pi_{t-1}^c + \eta_1 E_{t-1}\pi_{t+1}^c + \eta_2 \pi_{t-1}^m + \eta_3 \hat{y}_{t-1} + \varepsilon_t^\pi \tag{5}$$

$$\pi_t^f = \theta_1 \pi_{t-1}^c + (1-\theta_1)\pi_{t-1}^f + \theta_2 \varphi_{t-1} + \theta_3 \varphi_{t-2} + \theta_4 \varphi_{t-5} + \theta_5 \varphi_{t-6} + \varepsilon_t^{f\pi} \tag{6}$$

$$\pi_t^T \equiv 0.3\pi_t^f + 0.7\pi_t^c \tag{7}$$

$$\pi_t^m \equiv \pi_t^{int} + \Delta e_t^{usa} \tag{8}$$

$$\hat{q}_t = E_{t-1}\hat{q}_{t+1} - (\hat{r}_t - \hat{r}_t^{usa} - \psi_t) \tag{9}$$

$$\Delta i_t = \omega_1 \Delta i_{t-1} + \omega_2 \Delta i_t^p + (1-\omega_1-\omega_2)\Delta i_{t-1}^p + \omega_3 z_{t-4} + \varepsilon_t^i \tag{10}$$

Where according to the rational expectations hypothesis of Muth (1961), expectations should satisfy

$$x_{t+k} = E_{t-1}x_{t+k} + \eta_{t+k}$$

and $E(\eta_{t+k}) = 0$

All variables in the economy are defined as deviations from equilibrium values. Equation (4) is similar to the aggregate demand equation that Svensson (1998), and Rotemberg and Woodford (1997) derive from representative agent microfoundations. Svensson derives a structure in which aggregate demand is a function of foreign demand, current and expected real interest rates, and the real exchange rate. As in Svensson partial adjust-

[4] It is important to notice, however, that in the calibration of the model not all the equations have been parameterized based on structural parameters and therefore the Lucas critique is not overcame completely.

ment is imposed (i.e. the lag of the left hand side variable is put on the right hand side assuming habit persistence). Finally, ε^y represents an aggregate demand shock.

Equations (5), (6) and (7) define the models' supply side. Equation (5) is an open-economy Phillips curve expressed in terms of core inflation. Core inflation depends on the mixed backward-forward looking term, the lagged change in the imported goods price, π^m, lag of the output gap, and a supply shock. In Svensson (1997), a similar Phillips curve is derived using an open-economy extension of Rotemberg and Woodford´s (1997) representative consumer/producer model. In his derived Phillips curve, prices are determined by the (model-consistent) expectation of future prices, aggregate demand, and the real exchange rate (which impacts through the cost of imported intermediate goods). Based on the over-lapping relative real wage contracting model by Fuhrer and Moore (1995), partial adjustment is imposed to avoid that domestic inflation behave like a jump variable, making it difficult to replicate the persistence found in actual inflation series. The difference between Svensson´s specification and (5) is that the price of imports is used to capture intermediate input effects according to a cost push theory of inflation in the long run.[5]

The Phillips curve is superneutral because the sum of the coefficients on the nominal variables in the curve is one. This property is also known as dynamic homogeneity and makes the long-run trade-off between output and inflation disappears, that is in the long run the Phillps curve is vertical. There is a trade off between economic activity and inflation but this trade-off takes place in the short run. Any attempt to stimulate output is not lasting in the long run; it only results in higher inflation.

Equation (6) describes food inflation. The equation comes from a model developed by Avella (2001). In Colombia supply shocks related to the weather phenomenon, El Niño, drives food price inflation. At the same time, total inflation in Colombia is mainly determined by output gap and supply shocks in the agricultural sector. Equation (6) tells us that food inflation is determined by core inflation, lags of food inflation and the rainfall deficit, φ.

In equation (7), CPI inflation is expressed as a convex combination of core inflation and food inflation. Equation (8) is the identity that defines price of imports as the sum of foreign inflation and nominal depreciation.

[5] The growth of total cost is estimated as a weighted average of unit labor cost and the price of imports.

Equation (9) posits a link between the differential of domestic and foreign real interest rate and the real exchange rate. This is simply an uncovered interest parity (UIP) condition, written in real terms to reduce the dimension of the system. This UIP condition simply states that the expected change in the exchange rate fully offsets the foreign-domestic nominal interest rate differential. The shock ψ_t captures other influences on the exchange rate, such as investors' confidence. The real exchange rate is a bilateral rate with the United States, defined in terms of consumer prices.

Finally, equation (10) is the transmission between the market nominal interest rates,[6] i_t , and the central banks' policy nominal interest rate, i_t^p , and z_t is the spread between the market nominal interest rate and the policy interest rate and a long-run constant.

6.2 Data, econometric estimation, and calibration

Once the structure discussed above was specified, the model needs to be parameterized. There is a growing literature on the methodology of model calibration. Much of the recent literature on calibration has sought to compare, and perhaps ultimately reconcile, the calibration methodology with more traditional estimation methods. For example King (1995) and Sargent (1998) note that system-based estimation techniques such as the Hansen-Sargent procedure provide an alternative to both calibration and equation by equation model estimation. However, King expresses some skepticism about this approach because the full system estimation generally gives unreasonable results for a portion of model parameters, and recommends generalized methods of moment analysis (GMM), which is similar in spirit to calibration, but provides a variance-covariance matrix for the parameters in the model, which gives the researcher information on the extent of parameter uncertainty.

Using Hansen's (1982) Generalized Method of Moments, GMM, the system of equations (4) (5) and (10), which corresponds to Aggregate demand, Phillips curve and transmission between interest rates, respectively, was estimated. There are eleven parameters to be estimated, named $\sigma = (\beta_1\ \beta_2\ \beta_3\ \beta_4\ \beta_5\ \eta_1\ \eta_2\ \eta_3\ \omega_1\ \omega_2\ \omega_3)$. The vector of instruments used to conform the orthogonality conditions is $\{1,\ y_{t-2},\ y_{t-3},\ q,\ q_{t-1},\ q_{t-2},\ r_{t-2},\ tt,\ tt_{t-4},\ y_{t-2}^{usa},\ \Delta i_{t-4},\ \Delta i^p_{t-1},\ z_{t-5}\}$, where tt represents terms of trade. Equation (6), on the other

[6] The market nominal interest rate is the 90 days CD's.

hand, it was estimated using ordinary least squares given that food inflation depends on core inflation with a lag and core inflation is independent on food inflation, which means that there is not a simultaneity bias. In a subsequent step, some of the parameters were adjusted in order to obtain some reasonable impulse response functions and reasonable forecast out of sample for some of the key variables in the economy, such as inflation and output.

For the empirical analysis, the sample period is 1980:1 through 2002:4 for the system of equations (4), (5) and (10) and 1990.1 thorough 2002.4 for equation (6). Core inflation is calculated as the annual difference in the log of the monthly geometric average of the nonfood component of CPI, $\pi_t^c = log\ P_t^c - log\ P_{t-4}^c$. Similarly, inflation of the price of imports calculated with the imported component of the PPI. $\pi_t^m = log\ P_t^m - log\ P_{t-4}^m$. Output gap, y_t, is the difference of output from potential, and potential output it was calculated based on the Neoclassical Growth Model.[7] Real interest rate, $(1+r)$, is the ratio between one plus the market passive interest rate and one plus the core inflation rate. Real exchange rate, q, is a bilateral rate with the United States, and its equilibrium value is calculated from a Hoddrick-Presscot filter. Terms of trade, tt, are calculated as the ratio between export goods index and import goods index in the Total PPI price index. The policy interest rate, i^p, corresponds to the rate that the Central bank charges to the financial intermediaries, called the TIB rate. Droughts, φ, are measured as the seasonally adjusted amount of rain that is 20% below the average.

The results from estimating the system of equations (4), (5) and (10) are displayed in Table 1. All the parameter estimates have the expected sign. The first row of table 1 contains the results of the GMM estimation of η_1, that tell us how much of the core inflation is explained by agents that form their expectations in a rational way, which seems to be quite significant. Import goods inflation did not result significant in the estimation but the value of the coefficient seems to be quite reasonable according to other studies that use kalman filter technique to estimate changing parameters over time. Estimates of η_3 tells us that the effect of the output gap results significant in the explanation of core inflation in Colombia. This finding is very interesting because as Clarida, Gali, and Gertler (2000) point out, in many countries is not possible to find a direct relationship between output gap and inflation

[7] Gómez, Uribe and Vargas (2002).

TABLE 1. SYSTEM OF EQUATIONS FOR PHILLIPS CURVE, AGGREGATE DEMAND AND TRANSMISSION BETWEEN INTEREST RATES

Parameter	*Coefficient*	*t-statistic*	*P-value*
η_1	0.352	4.438	0.000
η_2	0.026	1.504	0.134
η_3	0.106	2.999	0.003
β_1	0.891	21.459	0.000
β_3	-0.167	-5.468	0.000
β_4	0.092	0.936	0.351
β_5	0.002	0.038	0.970
ω_1	0.248	3.203	0.002
ω_2	0.440	3.544	0.001
ω_3	-0.036	-0.142	0.887
$J_{(T)}$ =	8.411		

NOTES: Sample = 1980:1-2002:4; estimation technique: Generalized Method of Moments; Newey-West HAC Standard Errors & Covariance; Bandwidth: Fixed (3); Kernel: Bartlett; $J_{(T)}$ (5% significancia) = 11.524.

rate but it is necessary introduce a marginal cost equation in order to find the expected relationship.

The parameters *β's*, of the aggregate demand equations present the correct signs. However it was not possible to find a set of instruments that allow the inclusion of the forward looking output gap variable in the equation because when it is introduced, the sign of the real interest rate gap it was incorrect or the variable was not significant. Output gap seems to be very persistent as the parameter β_1 indicates. Interest rate changes have also significant effects on output gap. The effect of real exchange rate gap and the output gap of the United States did not appear to be significant but the sign seems to be right. The effect of real exchange rate depreciation could be positive or negative depending of the degree of financial vulnerability in the economy.[8] In a recent study on balance sheet effects in Latin America, Morón and Winkelried (2001)[9] show that in Colombia the potential contractionary effects of a depreciation rate are not very high given that the economy does not present a high level of liability dollarization during the period 1991-2000. Therefore in their econometric estimations, the Colombian economy did not result to be classified

[8] Woon Gyu Choi, "*Liability Dollarization and Balance Sheet effects Channel*", IMF nov 2002.

[9] E. Morón y D. Winkelried, "*Monetary Policy rules for Financially Vulnerable Economies*" IMF nov 2001.

as a financially vulnerable economy where the negative wealth effect of a real exchange rate depreciation is higher that the positive substitution effect.

The parameter estimates for the equation that explains the transmission between the policy and the market interest rate are significant except the parameter that corresponds to the long run relation between the series, z_t.

In addition to the parameter estimates and their respective *t*-values, the Hansen (1982) statistic for testing the validity of the over-identifying restrictions implied by the model is reported. This test is the J(σ) statistic and it is equal to 8.41. The null hypothesis is that the model is correctly specified. J(σ) converges in distribution to a χ^2_{q-p}, where q is the number of population momoment conditions and p is the number of parameter to be estimated. In this case, the critical χ^2_{16-10} is 11.52 at a five percent significance level. So we do not reject the null hypothesis and assume that the model is correctly specified.

The estimates for the food inflation equation are shown in table 2. As Avella (2001) described, the rainfall variable enters with a negative sign at short lags because of the effect of the weather of food supply and with positive sign by the fifth quarter because, as in the cobwed effect, farmers respond to high relative prices with an increase in supply.

TABLE 2. FOOD INFLATION EQUATION

Parameter	*Coefficient*	*t-statistic*	*P-value*
θ_1	0.484	6.706	0.000
θ_2	-0.136	-4.065	0.000
θ_3	-0.104	-2.781	0.008
θ_4	0.144	4.265	0.000
θ_5	0.164	4.563	0.000

NOTES: Sample = 1990:1-2002:4; Estimation Tecnique: Ordinary Least Squares; Adjusted R-squared = 0.938; Durdin-Watson stat. = 1.994.

In a final step, the some of the parameter values were adjusted considering some properties of the model such as the impulse response functions and the root of mean squared error of the forecast for some key variables such as the output gap, inflation rate and interest rates.[10] The parameter values that needed to be ad-

[10] "Meta de Inflación" 2003 – 2004 mimeo, SEE - Banco de la República.

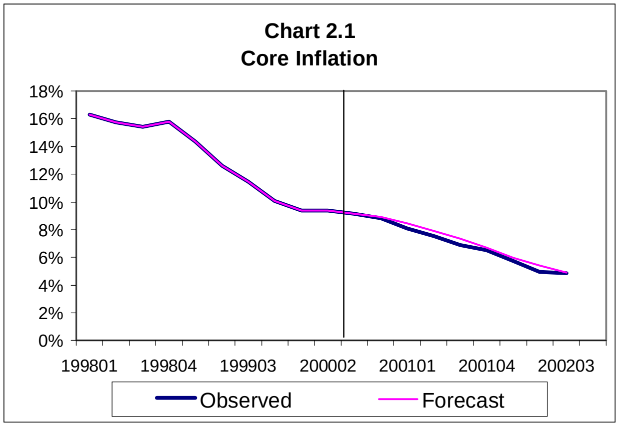


Chart 2.1
Core Inflation
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
199801
199804
199903
200002
200101
200104
200203
Observed
Forecast

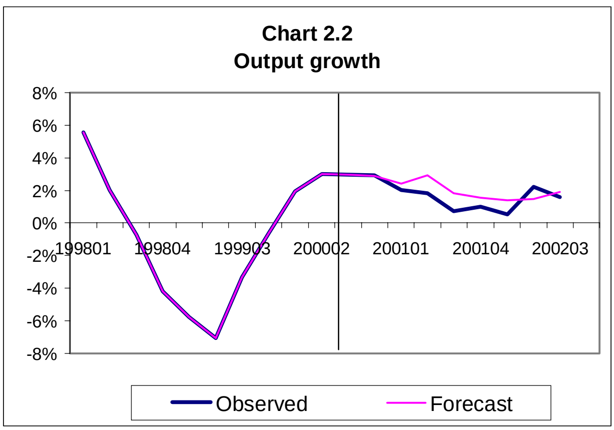


Chart 2.2
Output growth
8%
6%
4%
2%
0%
-2%
-4%
-6%
-8%
199801
199804
199903
200002
200101
200104
200203
Observed
Forecast

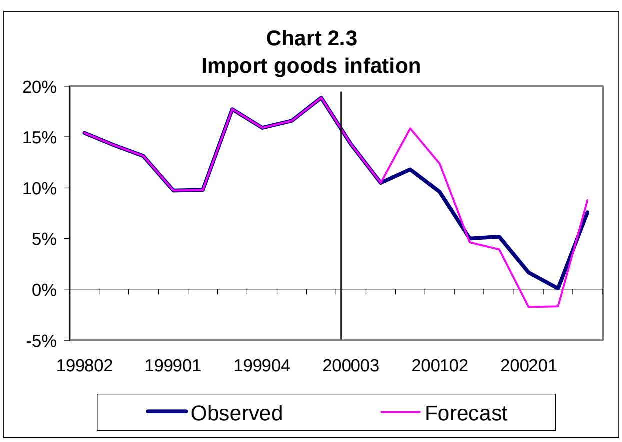


Chart 2.3
Import goods infation
20%
15%
10%
5%
0%
-5%
199802
199901
199904
200003
200102
200201
Observed
Forecast

justed were: the parameter on inflation expectations, η_1, from 0.35 to 0.47, the response of core inflation to output gap, η_3 , from 0.106 to 0.047; and the parameter that measures the response of aggregate demand to real exchange rate, β_5, from 0.002 to 0.01. The value of 0.47 for the inflation expectations parameter is more in line with the estimation of the structural parameters in a Phillips curve estimated by Bejarano (2003).[11] The choice of the parameter values it was made with the goal of been able to make a reasonably good dynamic forecast[12] of the core inflation, output gap and import goods inflation for the years 2001 and 2002. The dynamic forecast for core inflation, output growth, and imported goods inflation resulting from the calibration is presented in Chart 2, and the corresponding root of mean squared error of the forecast of the inflation rate for different horizons is presented in table 3.

Finally, some impulse response functions of the model are presented in chart 3. These correspond to the response to a shock of one percent increase in the policy rate during four quarters.

TABLE 3

RMSE 2000:3-2002:3							
1 quarter	*2 quarter*	*3 quarter*	*4 quarter*	*5 quarter*	*6 quarter*	*7 quarter*	*8 quarter*
0.2175	0.3316	0.3668	0.4194	0.3959	0.4652	0.4987	0.4309

7. PERFORMANCE OF SIMPLE TAYLOR AND IFB RULES

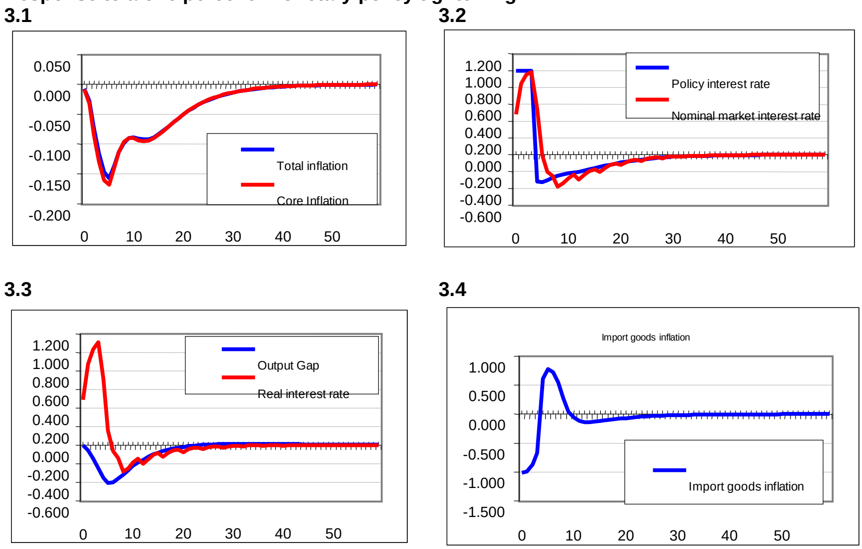
The model is to be closed with a policy rule that should be chosen in such a way that it will minimize the loss function of the monetary authority represented in equation (3). In this section, I compare the performance of some rules and choose the most efficient simple feedback rule. The method used to solve this model with forward expectations was the *Staked Newton* method described by Pierse (1999).[13]

[11] Bejarano (2003) found that in Colombia the structural parameter that, according to Calvo (1982), measures the probablility of adjustment of prices by firms is about 0.65, which implies a parameter for inflation expectations of 0.57.

[12] In a dynamic forecast, the last forecast of the variable is used as an observed value in the forecast for the next quarter and so on.

[13] Following Blanchard and Kahn (1980), in the solution of linear difference models under rational expectations it is necessary to meet a stability condition,

Chart 3.
Response to a one percent monetary policy tightening



In this section, we start by comparing the performance of Taylor rules and inflation-forecast-based rules by generating the inflation-output variability frontiers to investigate the general properties of each of this kind of rules.

The frontiers are traced out for what might be termed "reasonable" preferences over inflation and output variability as described in the quadratic loss function in equation (3). Stochastic simulations of the model and a grid search technique over policy rule coefficient are employed to trace out the efficient frontier,[14] For each rule considered, the resulting moments are calculated by averaging the results from 100 draws, each of which is simulated over a 25-year horizon. The measures of variability used are

---

the saddle-path condition. The model must have a number of eigenvalues inside the unit circle exactly equal to the number of predetermined variables in the model and a number of eigenvalues outside the unit circle exactly equal to the number of unpredetermined variables in the model in order to have a unique stable solution. The model represented by equations 4 – 10 closed by the different policy rules presented in section 7 satisfy the saddle-path condition.

[14] The model and the policy rule are subject to a sequence of macroeconomic shocks. Here we consider simultaneous shocks to the aggregate demand, aggregate supply and interest rate transmission.

the root mean squared deviation (RMSD) of inflation from its target and output from potential output.

7.1 Performance of Taylor rules

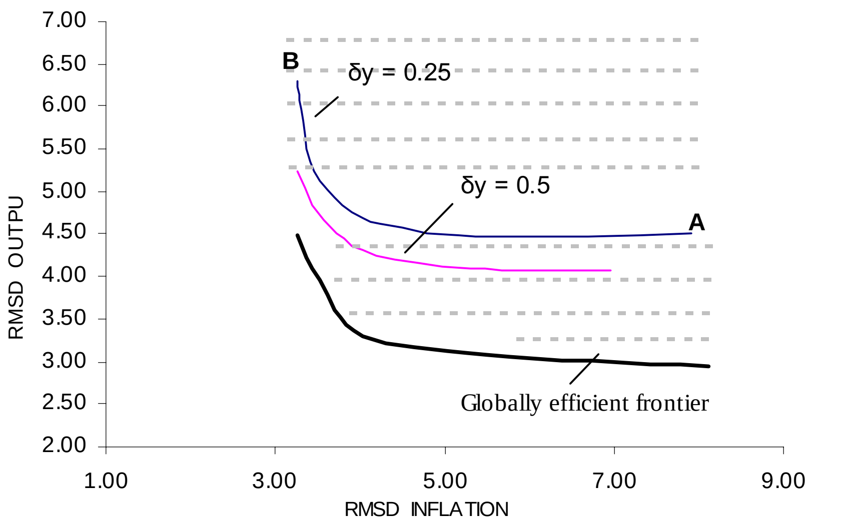
Here we close the *SMMT* described in section six with a variety of Taylor rules that are characterized by any policy rule where the central banks' policy nominal interest rate responds to the contemporaneous deviation of output from potential and non-food inflation from target.

$$i_t^p = (r_t^* + \pi_t) + \alpha_\pi(\pi_t - \pi_t^*) + \delta_y(y_t - y_t^*)$$

Similarly to Drew and Hunt (1999), I examined 9 combinations on the contemporaneous output gap ranging from 0.25 to 3, with 7 weights on the contemporaneous deviation of inflation from target, ranging from 0.25 to 3, in order to trace out the efficient frontier under Taylor rules.

The output-inflation variability pairs achieved are graphed in chart 4. The thin line with label δ_y = 0.25 corresponds to the inflation-output variability achieved by holding the weight on the output gap fixed at 0.25 and increasing the weight on the inflation

Chart 4
Taylor Rules



gap from 0.25 (point A) to 3 (point B). Increasing δ_y to 0.5 shifts the trade-off curve towards the origin, as illustrated in chart 2. Increasing δ_y up to 3 continues to shift the trade-off curve towards the origin. No appreciable shifts occur with δ_y values larger than 6. The thick line trace out the corresponding globally efficient frontier for the Taylor rules.

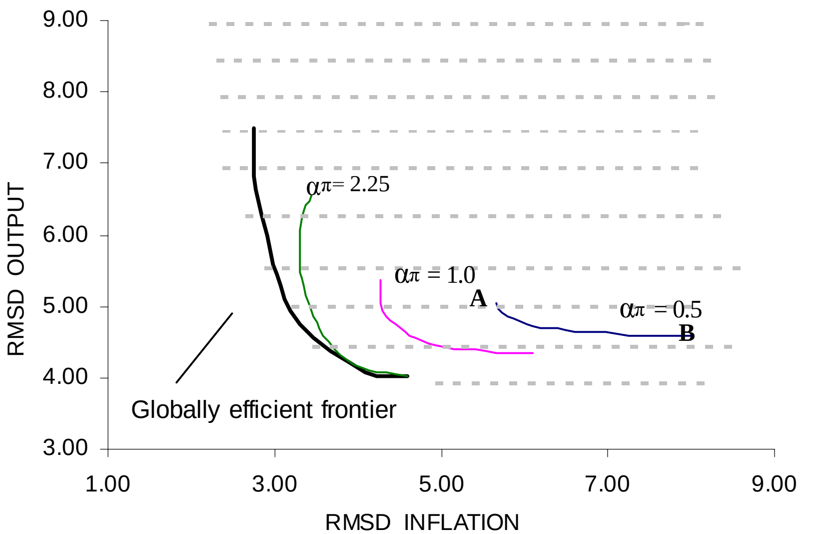
7.2 Performance of IFB rules

As explained before, these rules adjust to the policy instrument in response to a model-consistent projection of the deviation of inflation from its target rate:

$$i_t^p = (r_t^* + \pi_t) + \alpha_\pi (E_t \pi_{t+k} - \pi_t^*)$$

The parameters $\{\alpha_\pi$ and $k\}$ are a calibration choice in this stage of the study. The targeting horizon, k, goes from 2 to 12. The weights, α_π, range in value from 0.25 to 3. In chart 5, the thin line with $\alpha_\pi = 0.5$ is derived using a weight of 0.5 on the projected deviation of inflation from its target and varying the forward-looking targeting horizon. The line AB joins these simulation points. Moving along the locus of points from A to B, the simula-

Chart 5
IFB Rules



tions use a policy rule with a progressively more distant inflation forecast horizon.

The thin line where $\alpha_\pi = 1.0$ shows the results of the simulations when the weight on the projected inflation gap is increased to 1.0. Increasing the weight reduces inflation and output variability for targeting horizons that start at $k=6$ and beyond. Once the weights reach a level of 2.25, reduced inflation variability can only be achieved at the expenses of increased output variability at all targeting horizons examined. At this point, the thick line starts to trace out the globally efficient frontier for IFB rules.

7.3 Comparing Taylor and IFB rules

Here, efficient frontiers under inflation-forecast-based and Taylor rules are compared. Policy rules that respond to forecasts of future inflation seem to perform well in quantitative simulations. Taylor rules are able to achieve lower output variability than IFB rules, but inflation and interest rate variability are larger.

The results for different policy rules specifications are as follows. Table 4 contains the volatility of the goal variables (measured as the unconditional standard deviations),[15] and the stochastic welfare loss, L. Looking at the performance of the Taylor rules, it is clear that placing a higher weight on output than on inflation yields welfare improvements only until certain point but with higher weights the welfare loss starts increasing again. Second, simple forecast-based rules perform favorably compared with sim-

TABLE 4. COMPARING INFLATION FORECAST BASED RULES AND TAYLOR RULES

	Standard deviation of			*Welfare loss*
	output	*inflation*	*interest rates*	L
Inflation forecast bases rules				
$k = 6, \alpha_\pi = 1.0$	4.42	5.18	5.67	62.39
$k = 6, \alpha_\pi = 2.5$	4.51	3.46	7.10	57.50
$k = 6, \alpha_\pi = 2.0$	4.38	3.96	6.38	55.22
Taylor-type rules				
$\alpha_\pi = .\,, \delta_y = 0.5$	4.09	5.30	6.19	64.00
$\alpha_\pi = .\,, \delta_y = 1.0$	3.58	4.55	6.97	57.85
$\alpha_\pi = .\,, \delta_y = 2.0$	3.09	4.27	9.66	74.37

[15] Here considered the resulting moments are also calculated by averaging the results from 100 draws, each of which is simulated over a 25-year horizon.

ple Taylor rules. For example, the best-performing Taylor rule delivers a welfare loss higher than the welfare loss coming from a forecast-based rule with parameters $\{k=6,\ \alpha_\pi=2.0\}$.

This is evidence of the information-encompasing nature of inflation-forecast-based rules. An inflation forecast is formed conditioned on all variables that affect future inflation and output dynamics, not just output and inflation themselves. Even an apparently simple, forecast-based rule is implicitly responding to a wide and complex set of macroeconomic variables. This is a property of forecast-based rules broadly documented since Svensson and Rudebusch (1998).

7.4 The efficient simple feedback rule for a model of the Colombian economy

In the previous section it was shown that inflation forecast-based-rules are more efficient than Taylor rules in the context of inflation targeting. This is a familiar result found also in other countries targeting inflation directly. Now the exploration has to do with the features of an efficient simple inflation-forecast-based rule for the Colombian economy given the *SMMT* described in section six. In addition to the parameters α_π and k, I also will investigate if a smoothing parameter, ρ, should be taken into account in the policy rule. The goal is to find the combination of parameters $\{\alpha_\pi, k, \rho\}$ that will provide the lowest welfare loss. Our baseline rule now takes the modified form:

$$i_t^p = (r_t^* + \pi_t) + \alpha_\pi (E_t \pi_{t+k} - \pi_t^*) + \rho * i_{t-1}^p$$

The volatility of the goal variables (measured as the unconditional standard deviations), and the stochastic welfare loss (L), are reported in table 6. There, it is provided the results for various combinations of the parameters α_π, and ρ. In terms of welfare loss, the policy rules with a smoothing parameter, ρ, lower than 0.25 and feedback parameter, α_π, between 1.75 and 2.25 perform better in general. This is mainly due to a lower output and instrument variability. According to these results, the most efficient combination of parameters $\{\alpha_\pi, \rho\}$ is $\alpha_\pi = 2.0$ and $\rho = 0.0$.

The results are very robust to changes in the weights that are assigned to the three goal variables on the monetary authorities' objective function. In table 7, it was set the same weight on each of the goal variables and the resulting efficient combination of parameters is $\alpha_\pi = 1.5$ and $\rho = 0.0$. This combination is very similar

Chart 6
Variability frontier

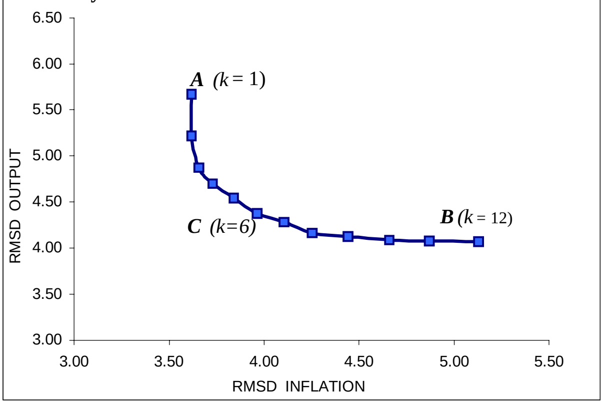


Table 5
Efficient forecast horizon

k	Welfare Loss *L*
1	81.83
2	69.05
3	61.30
4	57.86
5	56.29
6	55.22
7	55.64
8	55.65
9	56.28
10	57.37
11	58.78
12	61.20

to the one from the baseline case chosen before. In table 8, more weight on inflation stability is put, there, the first best is the combination of parameters $\alpha_\pi = 1.75\ \rho = 0.25$, and the second best is again the combination $\alpha_\pi = 2.0$ and $\rho = 0.0$. In table 9, it is assigned more weight to output stabilization than to the other two variables. In that case, the smoothing parameter is still zero and the feedback parameter is a little lower than 2.0 (1.5).

Finally I explore the optimal forecast horizon parameter, k. Chart 6 plots the locus of output-inflation variability points delivered by the IFB rule given the efficient parameters $\{\alpha_\pi, \rho\}$. The values of k that are used are 0, 1,…, 12. Moving along the locus of points from A to B, the simulations use a policy rule with a progressively more distant inflation forecast horizon. So, point A shows the pair of inflation/output variability associated with the policy rule when $k=1$, and point B gives the pair of inflation/output variability associated with a policy rule that responds to expected inflation three years ahead.

The most efficient inflation forecast horizon is also found by minimizing the loss function. In table 4 it is reported the welfare loss for each forecast horizon. In the model, the most efficient forecast horizon lies somewhere in between, at around six to eight quarters.

8. CONCLUSIONS

In this paper it was used the technique of stochastic simulations to select an efficient policy rule in the implementation of inflation targeting in Colombia. This methodology allows the researchers and the monetary authority to take into account the minimization of output, inflation and interest rates variability in the economy. This technique can be used in many other research fields, for example, measuring the impact of output gap uncertainty in the performance of economic models.

Using stochastic simulations of a small macroeconomic model of the Colombian economy, *SMMT*, we examined the relative performance of two classes of simple policy rules. For this purpose, I used as evaluation criteria the unconditional standard deviations of the goal variables, and a standard stochastic welfare loss function from a monetary authority that undertakes flexible inflation targeting.

The results are it is better to choose an Inflation Forecast Based rule than a Taylor rule for inflation targeting in Colombia. Taylor rules can achieve lower output variability than IFB rules, but the inflation and instrument variability are too high. In terms of welfare loss, IFB rules perform better than Taylor rules. Consequently, a well-defined monetary policy-rule for the Colombian economy should incorporate a forward looking dimension. It is important to keep in mind that even though in the IFB rules the current period output gap does not enter explicitly, its endogenous solution is an important part of the information set that is taken into account in the inflation forecast.

The results from the stochastic simulations are that the most efficient combination of parameters in the IFB rule for this small macroeconomic model is an inflation feedback parameter of between 1.5 and 2.0, a smoothing parameter between 0.0 and 0.25 and an optimal forecast horizon between six and eight quarters. This policy horizon supports the view that inflation targeting in practice should be designed so that the target is achieved over the medium term. Finally, this parameter values are robust to reasonable changes in the weights given to output gap, inflation or interest rates stabilization in the objective function of the monetary authority.

Given that the results presented here depend on how well the small macro model describes the Colombian economy, for future research some other characteristics of the economy should try to be incorporated in the model. Even though this is a model used by the central bank for the prescription of monetary policy because it captures the main characteristics of the Colombian economy, it is still very simple. For example the wealth effects of the monetary policy on the economy are left aside. Another extension could be to use the technique presented here in order to calibrate a simple policy rule in a dynamic stochastic general equilibrium model of the Colombian economy. These models have the advantage that they have strong microfoundations even though they are not as tractable as the small macro model presented here.

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Adriana Arreaza
Enid Blanco
Miguel Dorta

A small scale macroeconomic model for Venezuela

1. INTRODUCTION

Throughout most of the 1990´s the exchange rate was the nominal anchor in the Venezuelan economy. In February 2002, the narrow exchange rate band regime was abandoned and a flotation regime adopted. This new framework brings challenges for the monetary authority in its role of controlling inflation, which requires, among other things, the development of models and indicators that help the decision making process of the monetary authority.

Among the variety of models employed in inflation targeting regimes to carry out policy analysis, small-scale macroeconomic models are widely used, since they allow a straightforward understanding of the transmission mechanisms of policy actions to vari-

Paper prepared by A. Arreaza, analista, E. Blanco, jefe del departamento de Análisis Económico and M. Dorta, especialista II de la Oficina Técnica de la Consultoría Económica, Vicepresidencia de Estudios, Banco Central de Venezuela, and presented at the VIII Meeting of the Network of America Central Bank Researchers, hosted by the Banco Central de Venezuela, in Caracas, November 12-14, 2003. The author wants to thank Oswaldo Rodríguez, José Guerra and Víctor Olivo, for their comments.

ables of interest, such as inflation, output or the real exchange rate. Typically, these are stylized aggregate models that encompass an important degree of economic theory within a reduced number of equations. Their simplicity facilitates experiments with different assumptions regarding agents or policy makers preferences, represented by certain parameters in the model.

In this paper we build a model for the Venezuelan economy, in the spirit of Batini and Haldane (1999), Svensson (2000), Gómez (2002), and Martínez, Messmacher and Werner (2002). The model consists of four building blocks: a price equation, an aggregate demand equation (IS curve), an exchange rate equation (UIP) and a policy rule. The first two equations are estimated using quarterly data for the period 1989-2001. The exchange rate is determined as an asset price by the uncovered interest rate parity condition and the policy rule is calibrated for alternative preferences of the central bank authorities. All the equations in the model are forward looking, which is an innovation for the Venezuelan case that allows us to include the effect of agent's expectations.

We conduct simulation experiments to analyze the effect of different shocks on inflation, output, exchange rate and interest rates. First, we examine the impact of a permanent reduction of the inflation target with different degrees of credibility for the central bank, and alternative specifications for the interest rate rule. Then we look at the effect of a temporary public expenditure shock, and a temporary increase in the policy rate.

The paper is organized as follows: The next section contains the description of the model. Then, in the third section we discuss the transmission mechanisms implied by the model. In the fourth section we show the results of simulation exercises, and the last section has the final comments.

2. THE MODEL

The model is set for a small open economy and consists of four building blocks: a price equation (Phillips curve), an aggregate demand equation (IS curve), an exchange rate equation (UIP) and a policy rule. For estimation purposes, we use quarterly data for the period 1989-2001. All variables are expressed in logs, except for the interest rates.

The model is forward-looking in all markets, including features from the New-Keynesian framework based on dynamic optimization models with nominal rigidities and imperfect competition in the spirit of Rotemberg and Woodford (1997), McCallum and Nelson (1999b), Clarida, Gali and Gertler (1999) among others. This may provide a richer analysis---compared to the traditional backward-looking IS-LM-AS specification---since aggregate behavioral equations are derived from intertemporal optimization by households and firms, incorporating expectations. Although we do not estimate the LM curve in the model, it does not affect our results. This is mainly because the LM curve would only give us the path of money, presumably determined by output, prices, interest rates and the exchange rate, which are derived from the other equations in the model where money does not intervene.[1]

The model is solved simultaneously, allowing for more interactions among the variables, instead of solving it sequentially by blocks.

2.1 The price equation

We estimated the following inflation equation:[2]

$$\pi_t = \alpha_0 E_t \pi_{t+1} + (1-\alpha_0)\pi_{t-1} + \alpha_1 (y_{t-j} - y^*_{t-j}) + \psi \Delta q_{t-j} \quad (1)$$

where π is the inflation rate, $E_t\pi_{t+1}$ represents expected inflation, y denotes output, y^* stands for potential output and q is the real exchange rate. Output is detrended with the Hodrick-Prescott filter. The real exchange rate is given by $q_t = \log(Q_t) + \log(P^*_t) - \log(P_t)$, i.e., the ratio of foreign prices in domestic currency and domestic prices, where P is CPI, P^* is US CPI, and the nominal exchange rate is Q_t. Equation (1) expresses that inflation dynamics are influenced by past inflation,[3] by inflation expectations, by demand

[1] To derive the money equation, McCallum and Nelson (1999b) assume money enters in the consumer's utility function, but it is separable from consumption. Thus, it is not present in the Euler equation for consumption and hence money is not a determinant of aggregate demand. By the same token, the marginal conditions for money do not depend on consumption. Considering similar assumptions, this would be the case in our model.

[2] Within the New-Keynesian framework the price equation is derived from a log-linear approximation of the aggregation of firms decisions, that is, the relation between price and marginal cost. Output gap is included establishing a proportional relation between output gap and marginal cost. See Nelson and MacCallum (1999b) or Clarida, Gali and Gertler (1999).

[3] The inclusion of lagged inflation is justified on empirical grounds, see Fuhrer (1996).

pressures, and by external supply shocks captured by the real exchange rate.

Inflation expectations are given by:

$$E_t\pi_{t+1} = \mu\pi_{t+1} + (1-\mu)\pi^{tar} \tag{2}$$

where π^{tar} represents the inflation target the central bank sets, and $0 \le \mu \le 1$. What we pursue with this formulation is to include the effect of credibility of the central bank. The parameter μ can be thought as a measure of the credibility of the monetary policy: as μ tends to 1, the policy is less credible. As μ approaches 0, the target becomes more credible, so expected inflation looks more like the target.

For estimation purposes we assumed $\mu = 1$, so that $E_t\pi_{t+1}$ is proxied by π_{t+1}. We then estimated equation (1) by a two step procedure, following Galí (2000).[4] First, we obtained estimates for α_0 by GMM, using contemporary and lagged values of the output gap and first differences of the real exchange rate as instruments. Then we imposed this estimate in an OLS estimation of (1) to obtain the coefficients of the output gap and the real exchange rate. We used two dummies to capture the effect of capital controls: one in 1994, at the beginning of the regime, and one in 1996, when it was abandoned. We also imposed dynamic homogeneity, which implies that there is no long run relationship between the output gap and inflation.[5] The results of the estimations are displayed in Table 1.

The first row of Table 1 contains the results of the GMM[6] estimation of α_0. The rest of the rows correspond to the OLS estimation of (1) imposing $\alpha_0 = 0.587197$. The estimation results of (1) suggest that inflation is more influenced by expectations of future inflation than by past inflation. This may be a feature in high and moderate inflation countries, such as Venezuela. Inflation is also positively affected by the output gap with a lag of four quarters, and by the real exchange rate with two lags and three lags.

[4] Galí (2000) establishes that by estimating inflation equations with forward looking terms by a two step procedure, first obtaining the inflation lags and leads coefficients by GMM and then imposing those estimates in an OLS regression to get the coefficients of the rest of the variables, we avoid biased results.

[5] A Wald test for the null of the sum of the coefficients of π_{t-1} and π_{t+1} is equal to one could not be rejected. Thus, imposing the homogeneity restriction seems valid.

[6] We used a HAC weighting matrix with Bartlett Kernel, Newey-West fixed bandwith and prewhitening.

We also attempted to estimate an equation including an error correction term to account for a long run relationship between domestic prices and import prices in domestic currency. The error correction term was never significant, and the specification was not structurally stable. When we solved the full model imposing the long run relationship it presented convergence problems, so although it would be theoretically more appealing to include a price equation that contains a long run adjustment, it did not seem empirically appropriate to do so.

TABLE 1. PRICE EQUATION

Variable	*Coefficient*	*t-Statistic**	*P-value*
π_{t+1}	0.587197	3.933598	0.0003
$(y-y^*)_{t-4}$	0.084993	2.167576	0.0358
Δq_{t-2}	0.052559	2.572602	0.0136
Δq_{t-3}	-0.039067	-2.332028	0.0245

Sample Adjusted 1989:04-2001:03
*Newey-West HAC Standard Errors & Covariance
Adjusted R-squared 0.662320
Serial Correlation LM Test: F= 0.508775 p-value=0.604977
Jarque-Bera Normality Test: 24.158 p-value 0.0005
White Heteroskedasticity Test: F=0.167835 p-value=0.993968
The CUSUM and CUSUM of squares tests suggest parameter stability

In future developments of this model, we would like to include a long run relationship, and possibly the effect of wage dynamics on prices, as long as restrictions with the data allow it.

2.2 Aggregate demand

We estimated the following forward-looking version of the aggregate demand, loosely based on the log-linearization of the Euler equation of consumption, imposing the equilibrium condition that consumption equals output minus government expenditure and exports.

$$y_t - y_t^* = \beta_0 r_{t-j} + \beta_1 e_{t-j} + \beta_2 (y_{t+1} - y_{t+1}^*) + \beta_3 (y_j - y_{t-j}^*) + \beta_4 g_{t-j} + \beta_5 X_{t-j} \quad (3)$$

where $y - y^*$ is the output gap, r is the real interest rate, e is the deviation of real exchange rate from its trend, g is detrended public expenditure and X is a vector of variables intended to control for oil wealth. The variable g is assumed as an exogenous process. Output and the real exchange rate are detrended by the Hodrick-Prescott filter. The real interest rate is derived by the Fisher equation using future inflation, $1+r_t=(1+i_t)/(1+\pi_{t+1})$, where i is the nominal loan rate.[7] The vector X includes variables such as oil prices, oil exports or oil exports income. Public expenditure is the sum of central government plus PDVSA (the state owned oil company) expenditure. Equation (3) was estimated by GMM and OLS---as Equation (1)---and controlling for seasonal effects. Results are displayed in Table 2.

TABLE 2. AGGREGATE DEMAND

Variable	*Coefficient*	*t-Statistic**	*P-value*
$(y-y^*)_{t-1}$	0.262117	3.125420	0.0037
$(y-y^*)_{t+1}$	0.538591	7.033464	0.0000
r_{t-1}	0.060319	2.612958	0.0129
r_{t-2}	-0.060415	-2.928250	0.0058
e_{t-2}	-0.060080	-1.455021	0.1541
e_{t-3}	0.079474	1.484504	0.1461
g_t	0.027851	2.006482	0.0522

Sample Adjusted 1990:04-2001:03
*Newey-West HAC Standard Errors & Covariance
Adjusted R-squared 0.846544
Arch LM Test: F= 0.152176 p-value=0.698347
White Heteroskedasticity Test: 0.454959 p-value 0.957480
Jarque-Bera Normality Test: F=0.041596 p-value=0.979451
The CUSUM and CUSUM of squares tests suggest parameter stability

Output gap is then influenced by a lag and a lead of itself, that is, policy actions that affect the expected output gap, also have an impact on current output gap. Interest rates have a lagged negative effect on the output gap. Misalignments of the real exchange rate from its equilibrium value (proxied in this simple version by its HP trend) also affect output gap, i.e., a real depreciation increases the output gap. When we included public expenditure, none of the wealth variables were significant. This may be because oil wealth is canalized to the rest of the economy through public expenditure. It is also worth noticing that the impact of the exchange rate is more significant than the effect of the interest rates.

[7] The nominal loan rate is an average of the different credit operations that banks perform, published by the central bank.

Under this specification the exchange rate is the adjustment variable that guarantees that in the long term the output-gap, is equal to zero for a given level of the public expenditure. It is worth noticing that the aggregate effect of the interest rate is very small in magnitude.

2.3 The exchange rate: UIP

The short run dynamics of the nominal exchange rate are determined by forward looking and risk-adjusted uncovered interest rate parity

$$i_t = i_t^f + E_t(\Delta \log(Q_{t+1})) + \varphi_t \tag{4}$$

This equation links the domestic nominal interest rates, i , to the foreign interest rate, i^f , the expected variation of the nominal exchange rate, $E_t(\Delta \log(Q_{t+1}))$, and the country risk premium, φ, so that risk-adjusted returns from holding assets in different currencies should be equal in expectations. For a given interest rate path, the nominal exchange rate can be solved as

$$\log(Q_t) = E_t \log(Q_{t+1}) - i_t + i_t^f + \varphi_t \tag{5}$$

In this model the domestic interest rate path is endogenously determined following a forecast based policy rule that will be explained in more detail in the next section. This specification implies that if the domestic interest rate is higher than the foreign interest rate in period t, the currency will appreciate today, which leads to an expected depreciation in t+1. We assume that the risk premium is exogenous, but it can also be endogenized in future works by relating it, for example, to the degree of indebtedness of the public sector.

2.4 The policy rule

We used the following forecast-based policy rule:

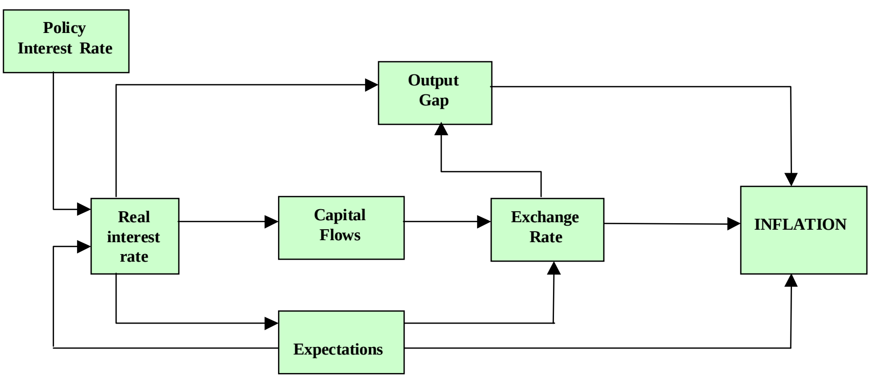
$$i_t = \theta\, i_{t-1} + (1-\theta)\left[(\pi_t + r^*) + \lambda_0\left(E_t y_{t+j} - y^*_{t+j}\right) + \lambda_1\left(E_t \pi_{t+j} - \pi^{tar}\right)\right] \tag{6}$$

Where θ is a smoothing parameter, r^* is the steady state real interest rate, and λ_0 and λ_1 are feedback parameters with respect of expected output gaps and expected deviations of inflation from the target. For simulation purposes we take r^* as a constant. The parameters θ, λ_0 and λ_1 are calibrated, allowing for alternative preferences of the central bank authority. For simplicity, we also assume that any changes in the policy rate are transferred on a one to one basis to the market rate. Unfortunately, we do not have enough data to estimate a yield curve, since we started to use interest rates as policy instruments barely since May 2002. As we gain more information in time, we should include a yield curve in the model.

3. TRANSMISSION MECHANISMS

There are several channels of transmission for monetary policy actions in this model. This model incorporates three channels: aggregate demand, exchange rate and expectations. These are depicted in Figure 1.

FIGURE 1. TRANSMISSION MECHANISMS



3.1 The aggregate demand channel

This channel reflects the traditional interest rate mechanism. Essentially, the policy rate affects the real interest rate, thereby affecting inter-temporal consumption and investment decisions. Changes in consumption and/or investment alter the output gap, which then affects inflation via the price equation. According to our estimates, an increase of the real interest rate negatively affects the output gap with a lag of two (2) quarters. A positive output gap has a positive effect on inflation after four (4) quarters.

3.2 The exchange rate channel

In open economies, the exchange rate affects inflation directly and indirectly. The exchange rate has a direct effect on inflation through the price of imports in domestic currency that, according to our estimates, takes place after 2 quarters. It also has an indirect effect through the aggregate demand: an increase of the exchange rate widens the output gap with 3 lags, implying pressures on inflation. An increase in the policy rate today increases capital flows, which tends to appreciate the real exchange rate, but as the economy returns to equilibrium--- in a flexible regime---agents expect the exchange rate to depreciate (UIP).

3.3 The expectations channel

The model incorporates agents' expectations via forward-looking terms in all equations. Current inflation in the price equation is affected by expected inflation, which has a larger weight on inflation today than past inflation as suggested by our estimates. Future inflation also affects the determination of the real interest rate, and expected nominal exchange rate is a determinant of the exchange rate today. The expected output gap affects the output gap today, which implies that policy actions that impact the output gap tomorrow also alter the output gap today.

For simplicity, the credit channel is not incorporated in this framework. In future developments, we may include the effect of changes in the credit supply following Nelson (2001), for example, by incorporating a money aggregate in the aggregate demand function to include effects that, due to market imperfections, are not captured by short term interest rate.

4. SIMULATION EXERCISES

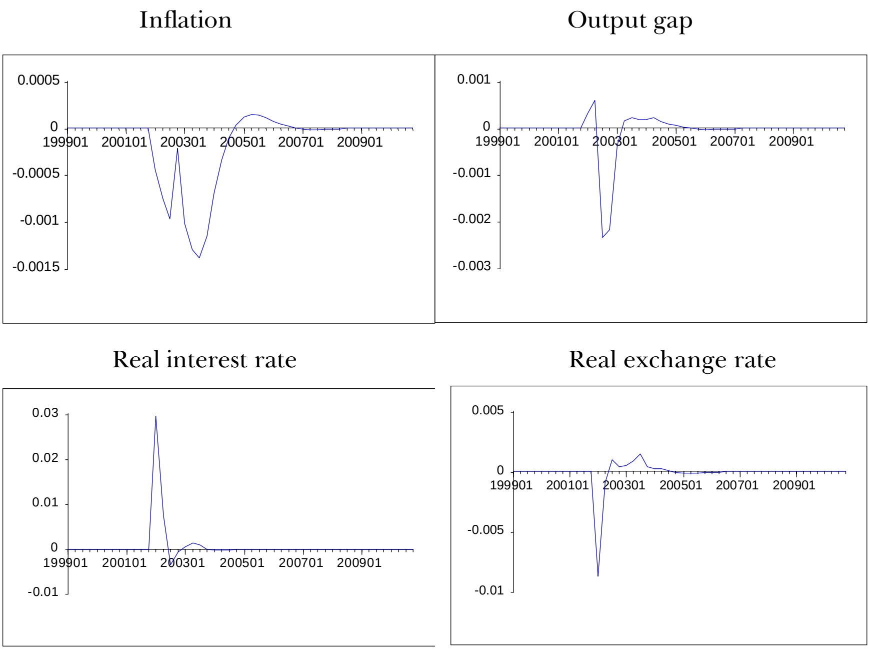
In this section we examine the response of the main variables in the model to alternative shocks. We consider the following shocks: a transitory increase in the policy rate, a transitory increment of public expenditure, and the effect of lowering the inflation target under different preferences of the central bank authority and degrees of credibility.

Our benchmark simulations use the following values for the policy rule: $\theta = 0.6$, $\lambda_0 = 0.5$, $\lambda_1 = 1.5$, $j=2$ for output and $j=6$ for inflation. This implies that the rule is a forecast-based flexible inflation targeting. We also take $\mu = 1$ in the expectations equation, which implies no credibility, that is, the target does not affect inflation expectations at all.

4.1 A shock in the policy rate

Here we consider an increase of 100 bp in the policy rate for one quarter, letting the policy rule operate thereafter. The results are displayed in Figure 2.

FIGURE 2. A 100BP INCREASE IN THE POLICY RATE



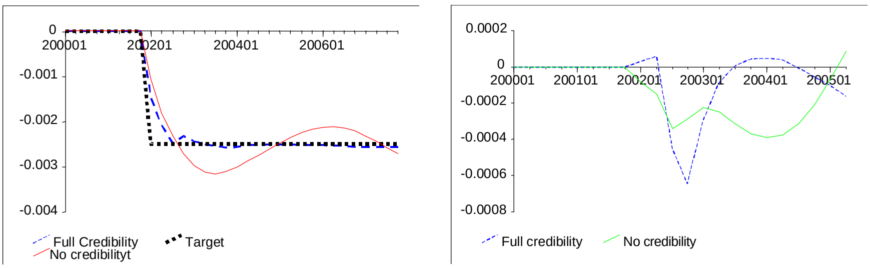
An increase in the policy rate rises the real interest rate, which reduces output (negative output gap), thereby contributing to diminish inflation. The increase in the nominal interest rate also generates an initial appreciation of the exchange rate that reduces the domestic currency price of imports and also net exports, which further shrinks output and inflation. The decrease of inflation reaches its maximum effect after 5 quarters and the largest drop in the output-gap is observed after 3 quarters. The effect in inflation lasts longer than the effects on output. Notice though, that both effects are rather small in magnitude.

4.2 Change in the inflation target

In Figure 3 we consider a permanent reduction of 1% in the inflation target with no credibility $\mu = 1$ and with full credibility $\mu = 0$.

FIGURE 3. A REDUCTION OF THE INFLATION TARGET UNDER DIFFERENT DEGREES OF CREDIBILITY

Inflation Output gap



We observe from the simulation results that as the central bank gains more credibility, inflation reaches the target faster and with no overshooting. The cost in terms of output of reducing inflation is also smaller with more credibility. With no credibility, the sacrifice ratio (the sum of the output losses) is -0,0024 whereas with full credibility, it falls to -0,0015. Therefore, we may expect that as the central bank increases its credibility the cost of disinflation will fall in time.

In Figure 4 we show the path of inflation and output gap under a forecast based rule vs. a rule using observed data. For the alternative rule we use j=0 for inflation and j=-2 for the output gap.

This exercise confirms that using future information for the policy rule, i.e. making policy decisions based on forecasts or lead indicators, produces more stable paths for inflation and output than using current or past data on inflation and output.

In Figure 5 we consider alternative preferences for the central bank authority: $\lambda_0 = 0$ and $\lambda_1 = 2.5$, i.e. a strict inflation targeting.

FIGURE 4. A REDUCTION OF THE INFLATION TARGET UNDER A FORECAST-BASED RULE AND A BACKWARD-LOOKING RULE

Inflation Output gap

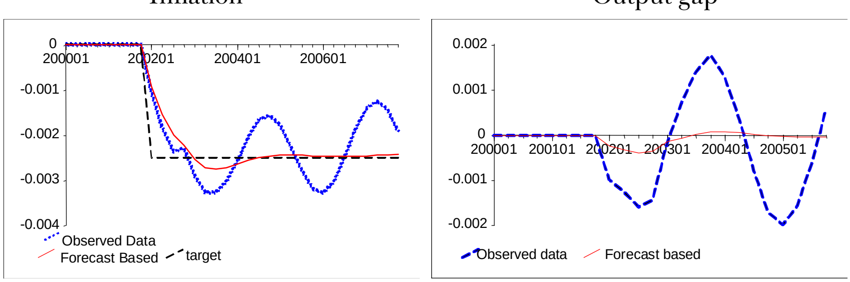
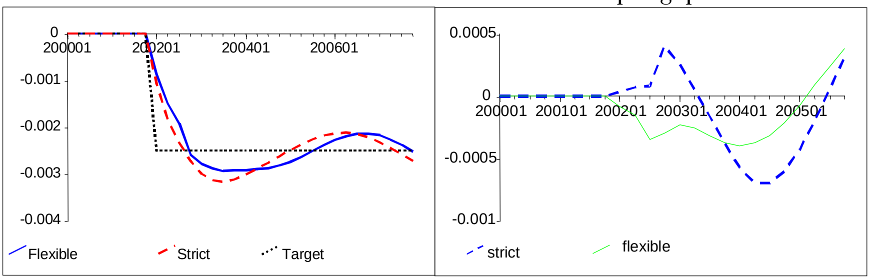


FIGURE 5. A REDUCTION OF THE INFLATION TARGET UNDER STRICT OR FLEXIBLE INFLATION TARGETING

Inflation | Output gap



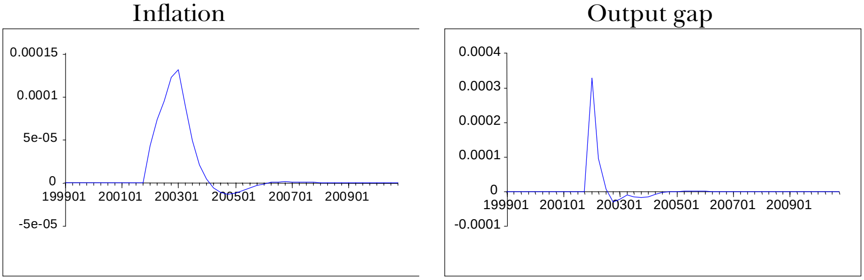
There does not seem to be much difference in the paths of inflation or output whether we set the interest rate rule based on inflation only (strict targeting), or if we set the rule to respond to inflation and output gap (flexible targeting). It only seems that the sacrifice ratio may be marginally lower with the flexible targeting.

4.3 A shock in public expenditure

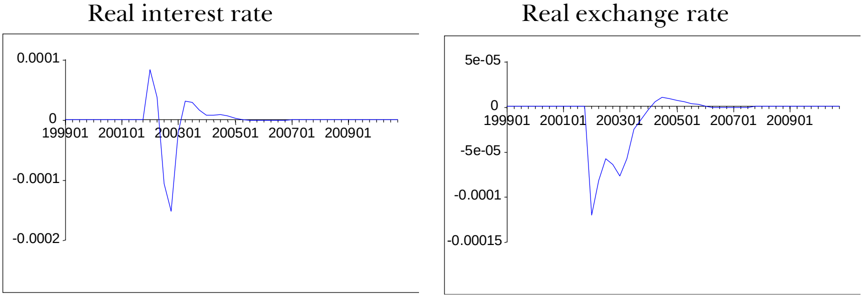
Since oil wealth is canalized to the rest of the economy through public expenditure, it is important to analyze its impact. In the fol-

FIGURE 6. AN INCREASE IN PUBLIC EXPENDITURE

Inflation | Output gap



Real interest rate | Real exchange rate



lowing figure we consider a shock of 1% increase in public expenditure that lasts for one quarter.

The increase in public expenditure generates a positive output gap the quarter after the shock. Inflation increases, reaching a maximum with a lag of 4 quarters. Note that since this model does not capture any effect of public finances on interest rates, the increase in interest rates is a response derived from the policy rule to expected larger inflation rates and future positive output gaps. The rise in interest rates will eventually bring down both, output and inflation. The increase in the interest rates also appreciates the real exchange rate, which further helps to reduce the output gap and thus inflation. The effect of a public expenditure shock on output dies out rather fast, whereas its effects on inflation persist for about 8 quarters. This suggests that the real effects of public expenditure are small and short-lived.

4. FINAL COMMENTS

In this paper we developed a small-scale macroeconomic model for the Venezuelan economy. We used the model to simulate the impact of different shocks on the path of key variables in the model, mainly inflation and output. In spite of its simplicity, the model captures the essential transmission mechanisms of monetary policy, which is a handy tool for policy makers, as it allows to visualize the effect of policy actions.

We may derive several implications from the simulation exercises. First, disinflation is more costly without credibility. Since the central bank is in a transition period, we expect to increase the degree of credibility over time, so that the temporary reduction of output due to the process of disinflation becomes smaller. The model also reflects the fact that a forecast based rule for the interest rate produces less volatility on output and inflation than a rule based on past information. This is an important result that policy makers should take into account. Having a strict targeting policy versus a flexible one does not seem to produce significantly different results in terms of output and inflation.

This model should be updated continuously, as we get more information. In future developments we may incorporate long run relationships in the aggregate demand and aggregate supply equation, a yield curve, endogenize other variables or do stochastic simulations. Our economy has suffered structural changes in the last decade, which may explain the non-significance of long-term relationships in the equations, so far, but we hope that in the future we will be able to include them.

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Wayne Robinson

Real shocks, credibility & stabilization policy in a small open economy

1. INTRODUCTION

Stabilization policies in small developing economies have to varying degrees used the exchange rate as a nominal anchor for prices and expectations with varying success.[1] However, the choice of an exchange rate regime for a small open economy has recently re-emerged in the literature following the financial crises of the 1990s and the debt problem in the currency board regime of Argentina.

One solution, which is to have no exchange rate, has recently emerged as an alternate stabilization option within Latin Amer-

[1] See Kiguel and Liviatan (1992) and Végh (1992).

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ica.[2] This is against a background that dollarization underwrites the credibility of a government's anti-inflationary policy by ensuring monetary discipline. However, a number of studies[3] has pointed to the role of external shocks in explaining aggregate fluctuations in small open developing economies. The inability to adjust to these shocks may result in a situation where the welfare cost of losing monetary policy exceeds the benefits. Schmitt-Grohe and Uribe (2001) argue that given that the shocks affecting the dollarized economy often differ from the host country or have asymmetric effects on the two economies, dollarization can result in higher macroeconomic instability. Further, Edwards and Magendzo (2001) find that although dollarised economies have a lower rate of inflation, economic growth tends to be lower due to the inability of the countries to accommodate external disturbances such as terms of trade shocks and shocks to capital flows.[4]

Following on these conclusions and given the vulnerability of the Jamaican economy to external shocks, this paper evaluates alternate stabilization measures for the economy. Specifically, the paper compares the welfare costs of four policy regimes: *i)* inflation targeting; *ii)* money-based stabilization; *iii)* currency board; and *iv)* a dollarized economy. Given that the economy is open, the policies considered have as their objective some form of inflation/exchange rate stabilization.

Some of the more influential papers that studied the effects of different stabilization policies include Calvo (1986), Calvo and Végh (1994) and Uribe (1999). Calvo (1986) focuses on the commitment and duration of an exchange rate based stabilization programme. He shows that temporary stabilization is pareto inferior to a permanent rate of devaluation, as a temporary policy gives rise to current account deficits and lower consumption relative to that of a permanent monetary policy. Calvo and Végh (1994) extend Calvo's (1986) model to include staggered prices and currency substitution and show that temporary monetary based stabilization programmes generate a contraction in aggregate demand. However, a temporary exchange rate based programme results in an initial expansion followed by a subsequent

[2] Ecuador dollarized in 2001 while Bolivia and Argentina have considered this option.

[3] See for example Calvo, Leiderman and Reinhart (1993), Schmitt-Grohe and Uribe (2001) and Agenor, McDermott and Prasad (1999).

[4] See Robinson (2001) for a discussion on the pros and cons of dollarizing the Jamaican economy.

recession. Uribe (1999) extends this framework to allow for a one-time jump in the money supply. He shows that the welfare gains of a permanent money base policy exceed that of its rivals and that a temporary policy is more costly.

There is a number of recent applied papers that compares various monetary arrangements and stabilization strategies for various emerging market economies subject to exogenous shocks. Schmitt-Grohe and Uribe (2001), show that in the presence of business cycle shocks, a credible exchange rate based stabilization programme is to be preferred to inflation targeting, monetary stabilization and dollarization in the case of Mexico. Mendoza (2001) arrives at the converse conclusion when account is taken of financial market imperfections. Similarly, in the case of Argentina, when account is taken of the shocks to risk premia, Ghironi and Rebucci (2002) argue that dollarization is to be preferred to inflation targeting or a currency board.

The theoretical framework used in this paper is a stochastic discrete time version of the general equilibrium model of Calvo (1986). We extend this framework in two important ways. First, foreign currency balances enter the utility function, similar to Ghironi and Rebucci (2002), which accounts for currency substitution and unofficial dollarization that typify developing economies with a history of high inflation such as Jamaica. Secondly, we introduce a stochastic production function similar to that in Cooley and Hansen (1989), in which output and productivity are subject to exogenous shocks, thereby giving rise to business cycle fluctuations. In this model, exchange rate and monetary policies can have real effects.[5]

The model is calibrated to Jamaican data. To ensure the model's validity, we compare the observed business cycle trends to those predicted by the model. Simulations are then done wherein the welfare cost of various stabilization regimes are evaluated. The results show that policy regimes, which allow for some flexibility in monetary policy, given the vulnerability of the economy to external shocks, are superior in terms of welfare, to the extreme of dollarization. The most optimal policy from the perspective of consumer welfare is monetary stabilization. However, as inflation falls, economic agents become indifferent between a monetary targeting and an inflation-targeting regime. The results, however, rely on the critical assumption that the pol-

[5] See Obstfeld (1981) for a similar model in which monetary policy can have real effects in the long run.

icy regime is credible. Thus whilst dollarization maybe inferior, the Jamaican policy makers are still confronted with the issue of ensuring the credibility of their stabilization policies.

The rest of the paper is organised as follows. Section 2 presents the theoretical model, while section 3 outlines the calibration and the simulated results. Section 4 compares the welfare costs of the different policy options followed by some concluding comments in section 5.

2. MODEL

We consider a small open economy of infinitely lived households that are identical in preferences over consumption and money. In this model the variables are measured in per capita terms. In this economy there is a single consumption good, *c,* which is a traded good.[6] The household's wealth is divided between domestic fiat money, M, that pays no interest, foreign currency M^*, foreign currency and domestic government bonds (net), b^* and b_g, and physical capital k. There are no restrictions to capital and domestic and foreign bonds pay a real rate of return per period of r and r^*,[7] respectively. The economy is small and as such is a price taker and does not influence international interest rates. The domestic price level then follows the *PPP* relation $P_t = S_t P_t^*$, where S is the domestic currency price of one unit of foreign currency and P^* is the foreign price level. Assuming that foreign inflation is negligible the domestic rate of inflation is given by $(P_t - P_{t-1})/P_{t-1} \cong (S_t - S_{t-1})/S_{t-1} = \varepsilon_t$. The government gives a lump-sum transfer to the households, issues domestic currency at the rate of ω per time period (i.e. monetary policy) and sets the exchange rate policy, ε_t. The amount of domestic currency issued is equal to a portion, ψ, of the economy's net foreign assets.

2.1 Households

Households have identical preferences over real consumption and real domestic (M/P) and foreign currency (SM^*/P) holdings. The household maximises its lifetime utility:

[6] See also Backus et al. (1995) for another example in which there is a single traded good.

[7] We assume a positive interest rate, such that money is return dominated by bonds.

$$E_t \sum_{t=0}^{\infty} \beta^t U\left[c_t, m\left(\frac{M_t}{p_t}, \frac{S_t M_t^*}{p_t}\right)\right] \tag{1}$$

Money enters the utility function motivated by the same rationale as in Sidrauski (1967), i.e. the liquidity services provided. *U(.)* is assumed to be strictly concave, continuously differentiable and increasing in *c* and *m*, which are normal goods.

In each time period *t*, the household allocates its income towards current consumption and wealth accumulation. Income is derived from the output of the economy, *y*,[8] government lump-sum transfers (net of taxes and other claims), *g*, and returns on financial assets and capital. Capital accumulation is given by:

$$i_t = k_{t+1} - (1 - \delta - n)k_t \tag{2}$$

The household therefore faces the following inter-temporal budget constraint:

$$S_t b_t^* + b_{gt} + i_t + \frac{M_t}{P_t} + \frac{S_t M_t^*}{P_t} \leq (1 + r_t) b_{gt-1} + \frac{M_{t-1}}{P_t} + (1 + r_t^*) S_t \left(b_{t-1}^* + \frac{M_{t-1}^*}{P_t} \right) \tag{3}$$
$$+ r_t^k k_t + g_t + y_t - c_t$$

and the no-Ponzi –game condition $\lim_{T \to \infty} (1 + r)^{-T} b_{gt+T} = 0$ and $\lim_{T \to \infty} (1 + r^*)^{-T} b_{g_{t+T}}^* = 0$.

The household chooses the paths for *c*, *m*, *k*, b_g and b^* to maximise (1) subject to (2), (3) and the transversality conditions. The first order conditions for the household's maximisation problem are:

$$U_c(c_t, m_t) = \lambda_t \tag{4}$$

$$\lambda_t S_t = \beta^t E_t \lambda_{t+1} S_{t+1} (1 + r_t^*) \tag{5}$$

$$\lambda_t = \beta E_t \lambda_{t+1} (1 + r_t) \tag{6}$$

$$\frac{1}{P_t} U_m(c_t, m_t).m_{m/p}\left(\frac{M_t}{P_t}, \frac{S_t M_t^*}{P_t}\right) + \beta E_t \lambda_{t+1} \frac{1}{P_{t+1}} = \lambda_t \frac{1}{P_t} \tag{7}$$

[8] For simplicity and without loss of generality, we assume that the household owns the firm.

$$\frac{S_t}{P_t}U_m(c_t, m_t).m_{m*/p}\left(\frac{M_t}{P_t}, \frac{S_t M_t^*}{P_t}\right) + \beta E_t \lambda_{t+1} \frac{(1+r_t)S_{t+1}}{P_{t+1}} = \lambda_t \frac{S_t}{P_t} \tag{8}$$

$$\lambda_t = \beta_t E_t \lambda_{t+1}(\square + r_{t+1}^k - \delta - n) \tag{9}$$

where λ_t is the Lagrange multiplier.

Using equation (4) and the first order condition for holding domestic bonds given in equation (6) we obtain the Euler equation for the optimal consumption path:

$$U_c(c_t, m_t) = \beta(1 + r_t)E_t U_c(c_{t+1}, m_{t+1})$$

which is the standard intuitive result that the rate of growth in consumption is a function of the rate of interest. In an open economy, this is a function of the returns on a substitutable foreign bond and the expected price of the consumption good in terms of the foreign currency. This can be seen by combining equations (5) and (6) to yield the following no-arbitrage condition for holding domestic and foreign currency bonds:

$$1 + r = E_t \varepsilon_{t+1} + (1 + r^*)$$

Additionally, given equation (4) and the fact that $U(.)$ is twice continuously differentiable and c and m are normal, then there exists some function,

$$U_c(c, L(c, \varepsilon + r^*)) = \lambda$$

Since $U(.)$ is concave and $L_c > 0$, $L_i < 0$, then the implicit partial derivative of the above expression satisfies:

$$sign\frac{\partial c}{\partial \varepsilon} = -sign\,U_{cm}$$

(see Calvo (1986)). This implies that the effect of monetary/exchange rate policy on consumption depends on the value of the cross derivative $U_{cm}(.)$. Specifically, policy will be non-neutral if $U_{cm}(.) \neq 0$ which implies that c and m are Edgeworth dependent.

2.2 Firms

Without loss of generality the production function is highly simplified in this economy. Because we want to focus on exogenous shocks to the economy, we abstract from business cycle fluctuations arising from the labour market. For simplicity we assume that there is a freely accessible constant returns to scale technology and that output can be costlessly transformed into either consumption or investment. The production function in intensive form is therefore given by $y = f(\mu,k)$, where μ is an iid exogenous shock, which is uncorrelated with monetary policy and f satisfies the Inada conditions. Firms will employ capital up to the point where the marginal returns are equal to the cost i.e. $r^k = f_k(uk)$.

2.3 Government

Similar to Calvo (1987), in this model we consolidate the balance sheets of the government and the central bank in an overall public sector budget constraint given by:[9]

$$\Delta b^*_{gt} = \Delta b_{gt} - g_{1} - r_t\, b_{gt-1} + r^*_t b^*_{gt-1} \tag{10}$$

where b^*_{gt} is the net foreign assets which earn the foreign rate of interest r^*. Equation (10) implies that the rate of accumulation of foreign assets by the government is equal to the difference between domestic borrowing and the fiscal deficit.

2.4 Equilibrium

Using equation (10) and the household's budget constraint we obtain the following resource constraint for the economy:[10]

$$s_t \Delta f_t = y_t + r^k_t k_t + (r^*_t - \omega\psi) s_t f_{t-1} - c_t - i_t \tag{12}$$

where $f_t = b^*_t + b^*_{gt} + m^*_t$ is the net foreign asset position of the country and $\lim_{T\to\infty} (1 + r^*)^{-T} f_{t+T} = 0$. This condition simply states that the net accumulation of foreign assets by the economy must be equal to the current account surplus or domestic absorption. Here the accumulation of foreign assets depends on both monetary and fiscal policy and the household's preferences.

Given the stochastic processes $\{\varepsilon_t, \mu_t\}_{t=0}^{\infty}$, the exogenous sequence $\{r^*_t\}_{t=0}^{\infty}$ and the initial conditions k_0, b_0, m_0, m^*_0, a competitive equilibrium can be defined as a set of processes

[9] We suppress the role of seigniorage in government revenues.

[10] This is equivalent to the balance of payments condition found in Calvo (1987).

$\{c_t, m_t, m_t^*, s_t, b_t, k_t, i_t, y_t, f_t, r_t\}_{t=0}^{\infty}$ and a positive scalar λ which satisfy equations (4) – (9) and (12).

2.5 Policy credibility

Since the collapse of the Bretton Woods system, Jamaica has used various exchange rate regimes as an essential element of almost all its stabilization programs. However, the lack of credibility of the various exchange rate based stabilization programmes over the past thirty years, has led to the demise of the various exchange rate systems and hence the stabilization policies. To capture the role of private expectations in economic stabilization, monetary policy is modelled as a regime switching process. The private sector, under each policy regime forms expectations about the ability of the government to maintain the regime.

The government announces a low depreciation stabililization policy in which it sets $\varepsilon_t = \varepsilon^L$. Agents assign an exogenous probability to the government's monetary policy stance given by $z = Pr\left[\varepsilon_t = \varepsilon^H \middle| \varepsilon_{t-1} = \varepsilon^L\right]$ and $\varsigma = Pr\left[\varepsilon_t = \varepsilon^H \middle| \varepsilon_{t-1} = \varepsilon^H\right]$. We assume that the stochastic process driving the policy stance follows the standard regime switching process, where the transition probabilities are defined by an irreducible erogodic Markov chain, with the following AR(1) representation:

$$\xi_t = \Pi \xi_{t-1} + v_t$$

where is $\xi_{t-1} = (1, 0)'$ when $\varepsilon_{t-1} = \varepsilon^H$, $\xi_{t-1} = (0, 1)'$ when $\varepsilon_{t-1} = \varepsilon^L$ and the transition matrix is

$$\Pi = \begin{pmatrix} \varsigma & z \\ 1-\varsigma & 1-z \end{pmatrix}$$

Given this AR(1) representation the average duration of an expansionary episode is $1/(1-\varsigma)$ and low depreciation regime is $1/z$. More importantly the unconditional expectation of ε is

$$E_{t\text{-}1}(\varepsilon_t) = \frac{z}{1 + z - \varsigma} \tag{11}$$

3. MODEL CALIBRATION

The model is solved and calibrated to the Jamaican economy using a linear quadratic approximation (LQ) around the non-stochastic steady state. The calibrations make use of the certainty equivalence principle, which follows from the fact that in LQ problems the optimal value and policy functions are independent of the covariance among the random variables. Using the certainty equivalence, we replace the conditional expectation of the random variables with their unconditional expectation. We make the assumption that in the steady state net external claims are zero. The time unit chosen is a year and the period of analysis covers 1970 to 2001.[11]

The following functions are used to characterize preference and technology:

$$U(c_t, m_t) = \frac{(c_t^{\theta} m_t^{1\text{-}\theta})^{1-\sigma}}{1-\sigma} \tag{12}$$

$$m\left(\frac{M_t}{P_t}, \frac{S_t M_t^*}{Pt}\right) = \left(\frac{M_t}{P_t}\right)^{(1-\gamma)} \cdot \left(\frac{S_t M_t^*}{Pt}\right)^{\gamma} \tag{13}$$

$$y_t = e^{\mu_t} k_t^{\alpha} \tag{14}$$

$$\mu_{t+1} = \rho\mu_t + \upsilon_{t+1} \tag{15}$$

Equation (12) is a CRRA utility function in which θ is the intratemporal elasticity if substitution between consumption and liquidity services. Equation (13) is a weighted aggregator function for money balances. Equation (14) is a standard AK production function used in Cooley and Hansen (1989), where μ_t is a AR(1) exogenous shock, with υ_t being an iid zero mean random variable.

The calibrated parameters of the model are given in Table 1 below. Drawing on the results of Giovannini (1985), the elasticity of the marginal utility of consumption is set at –1.67, which then implies an inter-temporal elasticity of substitution ($1/\sigma$) of 0.44. Although empirical estimates of the elasticity of substitution using Sidrauski's utility functions do produce values above one,[12] this estimate is generally in line with those for a number of other developing countries.[13] Since there is no exact measure for Jamaica, the rate of capital depreciation was chosen so as to yield the best fit to the data. The discount rate is derived from the steady sate

[11] The data used is taken from the IMF's IFS CD-ROM.
[12] See for example Arrau (1990).
[13] See Reinhart and Végh (1995) for a summary.

TABLE 1: PARAMETER VALUES

	Description	*Definition*	*Value*
r	Domestic real treasury bill interest rate	$i_t - \pi_{t+1}$	-0.01
r^*	Foreign real treasury bill interest rate	$i_t^* - \pi_{t+1}^*$	0.015
γ	Rate of unofficial dollarization		0.25
z	Conditional probability of high given low inflation		0.3
ς	Conditional probability of high given high inflation		0.5
σ	Preference parameter	$1 - \frac{1+\eta_{cc}}{\theta}$	2.28
θ	Preference parameter		0.52
η_{cc}	Elasticity of the marginal utility of consumption	$\frac{U_{cc}(c,m).c}{U_c(c,m)}$	-1.67
ω	Steady state growth in money supply		0.21
ψ	Steady state money to foreign assets		1.1
α	Share of capital		0.30
ρ	Autocorrelation coefficient		0.92
δ	Steady state capital depreciation		0.25

condition in the model, with the steady state real interest rate calculated as the average of the trend component over the sample period.

Because Jamaica is a small open economy, reliant on exports, exchange rate policy invariably has sought to allow adjustments in the exchange rate so as to offset the inflation differential. In this context we define a low depreciation stabilization scenario as one in which the change in the exchange is less than or equal to the inflation differential. Using this definition, the average duration of high depreciation over the sample period is 1.7 years, which implies that ς is 0.5. The average duration of low depreciation policy is 2.6 years, implying that z is 0.3.

The parameters θ and γ, characterise the demand for real money balances. From the first order conditions, equations (12) to (13) and Fisher parity, the demand for domestic and foreign currency balances are given by:

$$\frac{M_t}{p_t} = \frac{(1-\gamma)\theta}{1-\theta} \cdot \frac{c_t}{p_t}\left(\frac{r_t}{1+r_t}\right)^{-1}$$

and

$$\frac{S_t M^*_t}{p_t} = \frac{S_t \gamma\theta}{1-\theta} \cdot \frac{c_t}{p_t}\left(1 - \frac{S_t}{1+r^*_t}\right)^{-1}$$

We set $\gamma = 0.25$, average ratio of foreign currency to domestic currency liabilities of the banking system. Using this, θ is obtained from a non-linear least squares estimation of the equation for domestic money demand, where the domestic 180-day Treasury bill rate was used as the measure for the opportunity cost.

TABLE 2: ACTUAL AND PREDICTED CO-MOVEMENTS

	gdp	*c*	*i*	*m**
Std. deviation (%)				
Actual	4.24	4.02	13.29	43.86
Model	7.04	6.75	17.54	30.12
Serial correlation				
Actual	0.89	0.81	0.79	0.20
Model	0.75	0.60	0.91	0.68
Corr. with GDP				
Actual	1.00	0.93	0.68	-0.33
Model	1.00	0.78	0.88	-0.21

To evaluate the model we compare the co-movements in the aggregate variables, measured in per capita terms, implied by the model to that observed in the data for the Jamaican economy over the period 1970-2001. The evaluation of foreign currency holdings is done over the period 1991-2001 as holdings of these balances were only possible after 1990. The results, presented in Table 2, suggest that the dynamics of the model are broadly consistent with that observed in the data. The implied volatility of investment is higher than the actual, which maybe due to the fact that adjustment costs of capital stock are not accounted for in the model. The evidence on serial correlation indicates that the persistence in the variables generated by the model is similar to that in the actual data. The model correctly predicts that consumption and investment are positively correlated with output and foreign currency holdings are negatively correlated. Thus the model generally captures the co-movements of the main macroeconomic variables and thus permits a reasonable analysis of the welfare effects of alternative stabilization policies.

4. WELFARE ANALYSIS

As is standard, the welfare costs of alternative stabilization policies is measured by the fraction of steady-state consumption that households would be willing to forego such that they would be indifferent with respect to their utilities under the various regimes. Specifically, following Schmitt-Grohe and Uribe (2001) let c and m be the non-stochastic steady state values of consumption and currency holdings and $\{c_t, m_t\}$ the equilibrium values for consumption and money for a particular stabilization policy, then the welfare cost of such a policy is given by a constant φ such that

$$U\big((1-\varphi)c, m\big) = EU(c_t, m_t)$$

This implies that a particular stabilization regime is costly if φ is positive and beneficial if negative. φ is estimated by taking a second order Taylor expansion of the above expression around (ln(c), ln(m)). This yields:

$$\varphi = 1 - \left[1 + \frac{(1-\sigma)^2}{2} Var(\hat{x}_t)\right]^{\frac{1}{\theta(1-\sigma)}}$$

where $x_t = c_t^{\theta} m_t^{1-\theta}$ and $\hat{x}_t = ln x_t - x$. The welfare costs will be increasing in $Var(\hat{x}_t)$ if $\sigma > 1$. It should be noted however, than when assessing welfare this way one should see the results as more indicative rather than concrete statements about utility costs.

We consider three different types of stabilization policies. The first is an inflation- targeting regime. This monetary policy framework has been studied extensively in the literature recently for small open economies[14] and has been adopted by a number of emerging market economies. Similar to previous studies, in this paper we assume that inflation targeting corresponds to a constant inflation rate. Given the assumption about purchasing power parity this implies that $\varepsilon_t = \bar{\varepsilon}$ for all t. Inflation targeting in this setting therefore corresponds to a perfectly credible ex-

[14] See for example Svensson (2001).

change rate based stabilization policy under a free float. The second policy involves monetary stablization, in which the money growth rate is fixed at $\varpi_t = \varpi$. The third regime is that of a currency board in which the stock of domestic currency is held in a fix proportion to foreign reserves at a fixed exchange rate. We therefore set $\psi = 1$, $S = 1$ and $\varepsilon_t = 0$. The final policy option considered is the extreme case where the domestic currency is abandoned and monetary policy ceded to an external authority i.e. official dollarization. The only difference between this and the currency board is that there is no domestic currency and as such $\gamma = 1$, $S = 1$, $\varepsilon_t = 0$, $\psi = 1$ and ω is set equal to the trend growth rate of US $M2$. The nominal interest rate also falls to the US rate.

Table 3 gives the welfare costs associated with the different policy alternatives. The results indicate that dollarization is the most inferior option among the policy alternatives considered. Agents would be willing to give up between 10 percent and 11 percent of their non-stochastic steady state consumption rather than have a dollarized regime. In other words for agents to be as well off in a dollarized economy relative to an inflation targeting or monetary stabilization regime, their consumption path would have to increase by 11 and 10 percent per period. The rationale behind this result arises from the fact that interest rates and relative prices are determined externally in this model under dollarization, thus consumption smoothing would entail either lower levels of consumption overall or higher external debt in the event of a shock to output. Alternatively, in a dollarized regime, to maintain cur-

TABLE 3: WELFARE COSTS OF ALTERNATIVE: STABILIZATION POLICIES

Policy	*Welfare costs*	*Output (% Std. Dev.)*
Inflation target		
10%	0.190	18.2
5%	0.190	18.2
2%	0.181	18.3
Money growth target		
15%	0.187	18.7
10%	0.185	19.6
5%	0.180	23.6
Currency Board	*0.191*	*18.4*
Dollarization	*0.287*	*19.9*

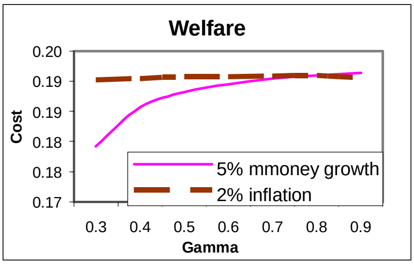
rent real consumption following an adverse shock that lowers income, requires increase borrowing which lowers net wealth, thereby constraining future consumption. Under a flexible exchange rate regime, one off adjustments in the exchange rate could be used to offset this wealth effect through holdings of foreign currency.

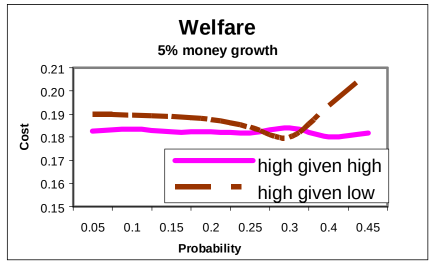
The most optimal stabilization policy from the perspective of consumer welfare is monetary stabilization. However agents are indifferent at very low levels of inflation between money-based stabilization and inflation targeting. Further, consistent with most predictions, output is generally least volatile in an inflation targeting regime. This is consistent with some of the observations of Mishkin (2000) who concludes that an inflation-targeting regime relative to one based on monetary rules does not lead to increase output fluctuations. One reason is that the link between money, output and prices, particularly in the short run, can be obscure and changes from time to time. Given that agents are indifferent between inflation targeting and money based stabilization at low levels of inflation, the lower output volatility would make the former more appealing. A currency board regime is preferred only to official dollarization.

The figures below show the sensitivity of the simulated results for money-based stabilization to variations in key parameters such as the degree of unofficial dollarization, γ, and policy maker's credibility.[15] The latter is measured by the conditional probabilities z and ς. The regimes used correspond to those that had the lowest welfare cost. While there is a slight inverse relation between costs and unofficial dollarization under inflation targeting, the welfare cost of monetary stabilization increases monotonically the higher the degree of unofficial dollarization. Generally, the higher the proportion of banking system liabilities denominated in foreign currency, the more ineffective are money-based stabilization programs and hence a movement to an inflation targeting regime could be more beneficial. With respect to credibility, the key measure is the probability of a reversal from a low depreciation/inflation to a high depreciation/inflation regime. At low probability levels the welfare cost declines. Beyond a critical threshold, however, as credibility wanes the cost increases significantly, tending towards the cost associated with official dollarization. Thus one can conclude that there is some low level of credi-

[15] The simulations are done for parameter values that permit convergence to the optimal value function.

bility for which the welfare costs of money base stabilization would be equivalent to that of dollarization i.e. dollarization would be more appropriate.





5. CONCLUDING REMARKS

Robinson (2001) argued that dollarization is not an optimal stabilization policy choice for Jamaica. This paper uses a general equilibrium model to study this proposition. In terms of welfare gains, the analysis finds favour with alternate stabilization policies, in particular monetary stabilization. One implication of the results, however, is that as inflation falls a switch to a full fledge inflation targeting regime could be considered.

While the results do indicate the more optimal policy direction, it is important to note that the simulations assumed that the policies were credible and to a lesser extent permanent. In fact the appeal of these results derives from the fact that the private sector believes in the commitment of the policy maker. Ironically this is the same result that extreme policies such as currency boards and dollarization are supposed to ensure. The analysis suggests, however, that the alternate mechanisms to establishing credibility are less costly relative to the extreme of relinquishing monetary policy. One such mechanism suggested in the literature is an independent central bank with a conservative governor.

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Gonzalo Llosa
Shirley Miller

Using additional information in estimating the output gap in Peru: a multivariate unobserved component approach

1. MOTIVATION

One of the key elements for the implementation of Inflation Targeting regime is the right identification of inflationary or disinflationary pressures. It is important to have a reliable indicator of these pressures because the central bank will use it for guiding its monetary policy to achieve its inflation target. The central bank will engage on tight (expansive) policy whenever the indicator signs inflationary (disinflationary) pressures that risks achieving its target.

In general, the indicator used is the output gap. This variable

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tries to measure the short run pressures of marginal costs over inflation generated by a demand expansion and an inaccurate distribution of the productive factors of the economy. Unfortunately, the output gap is an unobservable variable and its value must be inferred from the information contained in other economic variables. To this respect, the estimation of the output gap has been the focus of considerable research effort of many central banks.[1]

The most common techniques are based on univariate filters, which only use gross domestic product (GDP) information.[2] These methodologies assumed that output is an isolate process from the rest of macroeconomic time series. In most of the cases, this simplicity implies a high degree of uncertainty in the output gap measure, specially at the end of the sample.[3] Moreover, in the cases that other relevant variables have affected output gap, these univariate approaches do not allow to identify them,[4] thus disturbing the decisions of monetary policy.[5]

As an alternative, different multivariate methods have been developed, each one is based on a particular theory and implementation technique. One of the most common multivariate methods is the Production Function approach, which consists on a neoclassical production function with different inputs, generally capital stock, labor force and total factor productivity (Solow residual). Often, researchers attempting to apply this technique use an univariate method to estimate the trend of productivity.[6] As a consequence, uncertainty remains on this component affecting the output gap reliability.

Another way to impose structural restrictions is using the

[1] See for example, Benes and N'Diaye (2002) and Butler (1996).

[2] See for example, Hodrick and Prescott (1997), Beveridge and Nelson (1981), Baxter and King (1995) and Harvey and Jaeger (1993).

[3] Several studies have addressed this problem in univariate methods. For example, Orphanides and van Norden (1999) studied uncertainty in US output gap estimation process and Gruen *et al.* (2002) do the same for Australian GDP. Their results confirm that end of problem is the principal source of uncertainty affecting output gap estimation.

[4] For example, Haltmaier (2001) uses cyclical indicators to adjust Japanese output gap estimates derived from the Hodrick and Prescott filter over the most recent period.

[5] Smets (2002) and Gaudich and Hunt (2000) found that the bigger the uncertainty surrounding output gap estimates, the smaller the reaction of monetary policy to it.

[6] See for example, Miller (2004a) and Texeira (2002).

SVAR identification of Blanchard and Quah (1989). The SVAR output gap is the component not affected by permanent shocks and related to the employment rate or inflation in a transitory way. This method has several limitations, it is not accurate to identify permanent and transitory shocks and its performance could be undermined by omitted variable problems.[7]

More recently, a new group of multivariate methods use unobserved component models, which combine structural relationships with properties of statistical filter. Their main characteristic is that they include an explicit relation between output and inflation (Phillips Curve), and/or between the output gap and the unemployment rate (Okun's law). Several authors have used multivariate techniques based on unobserved component models, whose estimation is carried out via the Kalman filter algorithm.[8] This approach benefits from correlation in the data and model structure, mixing this information according to the lower prediction error. This technique has been successfully applied, increasing the accuracy and reliability of output gap estimations.[9]

In order to show the limitations of univariate methods in figure (1) we plot the annual variation of the core Consumer Price Index and the output gap, estimated with the univariate Hodrick-Prescott (HP) filter for the quarterly period 1992-2003. The inflation process in Peru presents two episodes. The first one (1992-1994) is characterized by a continuous disinflation process from high (more than 80 percent during 1992) to moderate inflation rates (around 20 percent in 1994). In the second episode (1995-2003), the inflation rate continues decreasing, but at a lower pace, moving from moderate (around 11 percent in 1995) to low inflation rates (one-digit inflation in 1997 and lower than 5 percent since 1999).

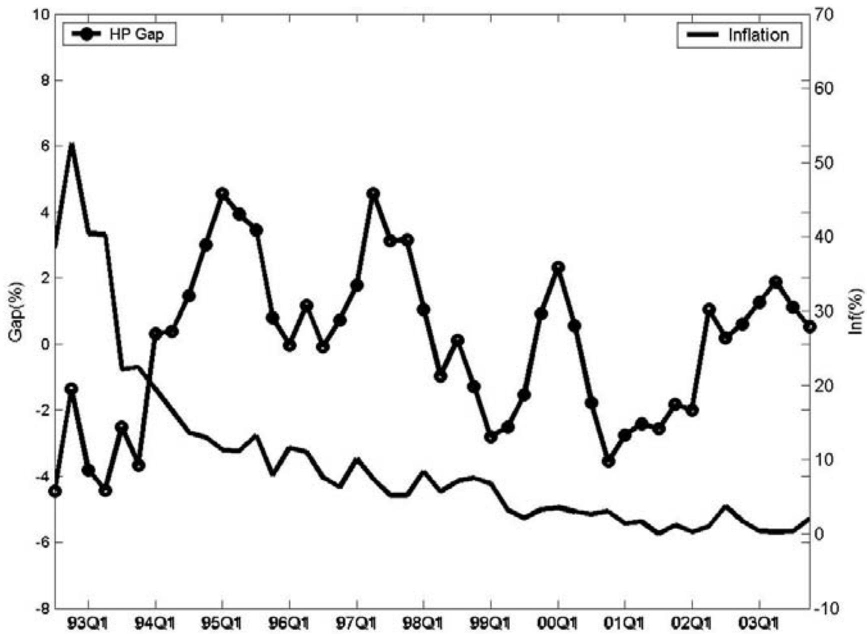
On the other hand, the HP output gap during the first episode (specifically in 1994-1996) indicates high excess demand conditions, which implies the presence of strong inflationary pressures.

[7] See for a technical details van Norden (1995), Blanchard and Quah (1989) and Cerra and Chaman (2000).

[8] For example, see De Brouwer (1998), Scott (2000b), Camba-Mendez and Rodriguez-Palenzuela and Benes (2001) and N'Diaye (2002). Alternatively, Laxton and Tetlow (1992) and Hirose and Kamada (2001) propose a multivariate Hodrick and Prescott filter.

[9] See for example, Rünstler (2002). Although, it worths to say that the improvement depends on the structure imposed, and calibration or parameters estimation, see Butler (1996).

FIGURE 1. OUTPUT GAP CORRESPONDS TO HODRICK AND PRESCOTT ESTIMATE WITH SMOOTHING PARAMETER OF 1600. THE INFLATION RATE IS CALCULATED ON QUARTERLY BASE (ANNUALIZED)



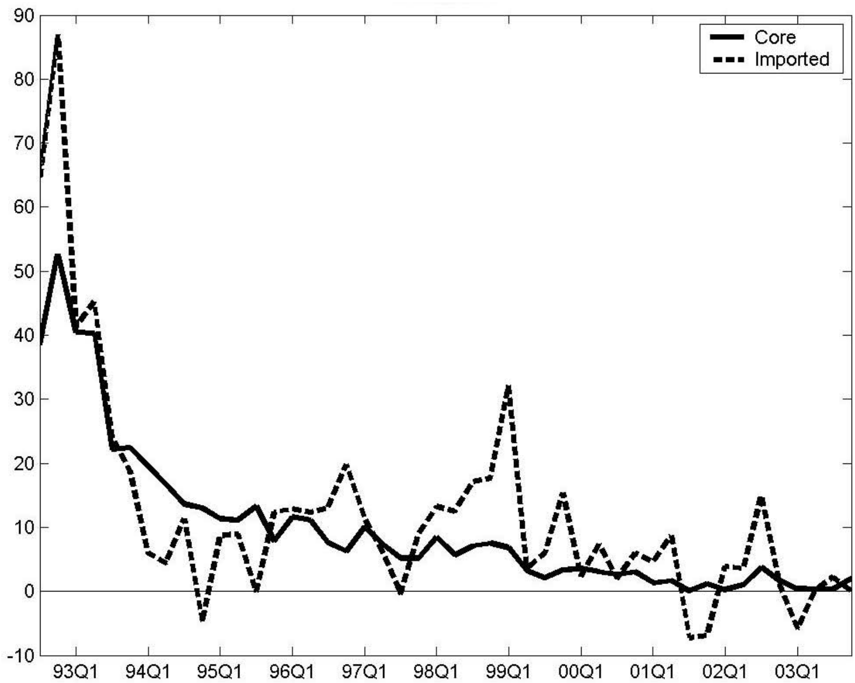
Nevertheless, this result does not seem to be in line with the persistent decline in inflation along the nineties. Another similar episode to highlight is observed at the end of the sample, where inflation is relatively stable but the HP output gap is positive, indicating inflationary pressures. In this context, the results obtained with the HP filter do not permit to analyze and explain correctly the evolution of the inflation, particularly during periods where output was growing significantly and inflation was falling or was stable. This univariate technique only captures the output process, without taking into account any structure or the dynamics process of other important macroeconomic variables.

Given that Peruvian economy is a small open economy, many other variables (for example, imported inflation) are critical in understanding inflation dynamics. Figure (2), plots the Core CPI inflation and imported inflation rates.[10] Core inflation has been evolving together with imported inflation except in two remark-

[10] Imported inflation is calculated from US inflation and nominal exchange rate depreciation (appreciation).

able cases: 1994-1996 and 1998-1999. During the former period, inflation is higher than imported inflation suggesting that some inflationary pressures might have restrained the total pass-through. The opposite happens in the second case: imported inflation is higher than core inflation, and this coincides with a weak output phase. This analysis suggests that imported inflation is a key variable that have to be considered in the determination of the output gap.

FIGURE 2. QUARTERLY CORE INFLATION AND IMPORTED INFLATION. IMPORTED INFLATION IS COMPUTED BY PPP CONDITION



For the Peruvian case, most of the studies had based on univariate filters.[11] Given the advantages of multivariate unobserved component models, the aim of this paper is to provide an estimation of the output gap using this technique. The model employed

[11] For example, Cabredo and Valdivia (1999), Caballero and Gallegos (2001) and Miller (2004a) compare different output gap estimates using those techniques. Their results indicate that production function output gap is the best indicator of inflation pressures in Peru.

relies on an explicit short run relation between the output gap and inflation rate (Phillips Curve) and structural restrictions over output dynamics. We estimate the model via Kalman Filter for the period 1992-2003.

The results show that the multivariate unobserved component output gap (MUC) is less sensible to end of sample problems and presents a better relation with the Peruvian inflation process than other estimates, calculated with the Hodrick-Prescott filter and the production function approach. In particular, in periods of high output growth together with disinflationary or stable inflation environments, MUC output gap is lower than the ones obtained with the alternative methods mentioned. Besides, MUC identification is quite related to pass-through effect from imported prices to consumer prices. In particular, whenever imported inflation was higher (lower) than domestic inflation, the system found a negative (positive) output gap. Furthermore, the diagnostic statistics report that MUC estimate is more reliable than other alternatives and increases out of sample predictive power for inflation.

The document is organized in the following form. In the second section, the structure of the model used, as well as its implementation and the data, are explained and analyzed. In next section, we present the most important features of MUC estimate, and some of its properties: updating properties and inflation forecasts power. Finally, in the fourth section, we conclude.

2. THE MODEL

We use a semi-structural model for a small open economy. The system is based on three behavioral equations:

– Uncovered interest parity.

– Phillips curve.

– Aggregate demand.

The uncovered interest parity allows us to estimate the permanent and transitory components of real interest rate and real exchange rate. Combining the gaps of real interest rate and real exchange rate, we construct a real monetary condition index.[12] Tak-

[12] This index captures the general orientation of monetary policy affecting the aggregate demand with the aim to control the inflation rate, see Dennis

ing this index as an exogenous variable, we use the aggregate demand equation and Phillips curve to calculate the output gap related to the evolution of real activity and inflation. The model takes the following form,

$$y_t = \bar{y}_t + \hat{y}_t \tag{1}$$

$$B(L)\hat{y}_t = \kappa RMCI_t + \eta_t^y \qquad \eta_t^y \sim N(0,\sigma_{\eta y}^2) \tag{2}$$

$$\pi_t = \tilde{\pi}_t + \varepsilon_t^\pi \qquad \varepsilon_t^\pi \sim N(0,\sigma_{\varepsilon\pi}^2) \tag{3}$$

$$\tilde{\pi}_t = \alpha_1 \tilde{\pi}_{t-1} + \alpha_2 \tilde{\pi}_t^m + (1-\alpha_1-\alpha_2)\hat{\tilde{\pi}}^e_{t,t+1} + \gamma y_t + \eta_t^\pi \tag{4}$$

$$\eta_t^\pi \sim N(0,\sigma_{\eta\pi}^2)$$

From equation (1), output y_t (in logarithms) is decomposed into potential output $\bar{y}_t$ and the output gap $\hat{y}_t$. The second equation describes the output gap dynamics influenced by the real monetary condition index, $RMCI_t$. The lag polynomial is defined by $B(L)=1-\beta$, which represent an AR(1) stationary process. Equation (3) decomposes the CPI core inflation, π_t, into its forecastable component,[13] $\tilde{\pi}_t$, and an stochastic shock η_t^π. The underlying inflation is modeled using a Phillips curve for a small open economy, equation (4). According to this equation, this measure is influenced by its own inertia, imported inflation $\tilde{\pi}_t^m$, inflation expectations $\tilde{\pi}^e_{t,t+1}$ and the output gap $\hat{y}_t$.
Potential output $\bar{y}_t$ follows a random walk process with a stochastic slope μ_t. The slope is modeled as an stationary autoregressive process with constant, μ, reflecting the growth rate of potential output in steady state.[14]

$$\bar{y}_t = \bar{y}_{t-1} + \mu_t \tag{5}$$

(1997) for technical discussion. Given the trends in the data, the index is constructed using gaps instead of levels. The details are shown in appendix A.

[13] Forescastable inflation may be interpreted as a measure of underlying or trend inflation, which is filtered from high frequency fluctuations. Arguably, a central bank should be responsible primarily for development in underlying inflation and not for high frequency inflation, which is unable to control.

[14] A local linear trend model for potential output was proved. The results indicate that a steady state growth rate of potential output reduces end of sample revisions. For a technical discussion of local level and local linear trend models see Harvey (1993).

$$\mu_t = \phi\mu_{t-1} + (1-\phi)\overline{\mu} + \eta_t^u \qquad \eta_t^u \sim N(0,\sigma^2_{\eta\mu}) \tag{6}$$

The model is completed by the assumption that stochastic shocks $\varepsilon_t^\pi, \eta_t^\pi, \eta_t^y$, and η_t^u are normally and independently distributed and mutually uncorrelated.

2.1. Inflation expectations

One important issue is the measurement of inflation expectations. Typically, the New Keynesian Phillips curve stresses on forward looking behavior in the price setting process[15]. Particularly, the forward-looking component on inflation is quite important during disinflation episodes.[16]

On the other hand, empirical work usually assumes totally backward looking expectations,[17] implying that the output gap has permanent effects on the level inflation rate.[18]

Confronting this trade off between theoretical and empirical grounds, we consider a simple error correction mechanism for inflation expectations which allows us to incorporate the deceleration on Peruvian inflation without assuming totally backward looking expectations:[19]

$$\tilde{\pi}^e_{t,t+1} = \overline{\pi}_{t+1} + (\tilde{\pi}_t - \overline{\pi}_t) = \tilde{\pi}_t + \Delta\overline{\pi}_{t+1} \tag{7}$$

where $\tilde{\pi}_t$ is underlying inflation, $\tilde{\pi}^e_{t,t+1}$ represent inflation expectations over next quarter, and $\overline{\pi}_t$ is interpreted as inflation target rate.[20] Given (7), if underlying inflation is higher (lower) than the target, inflation expectations raises (decreases). If inflation is aligned to the target, expectations do not change. Considering this structure, replace (4) with:[21]

[15] See Calvo (1983) and Clarida *et al.* (2002).

[16] See Mankiw and Reis (2001).

[17] See for example, Rünstler (2002).

[18] Also, this structure implies that the level of inflation rate is unforecastable, which is a clear contradiction to inflation targeting policy framework.

[19] A more suitable technique could be related to adaptative learning expectations, see Evans and Honkapohja (2001).

[20] Formally, inflation targeting was adopted as a monetary policy framework in Peru in 2002. Nevertheless, the Central Reserve Bank of Peru has been announcing inflation targets since 1994. See Rossini (2001) for details.

[21] Although the variance term has changed, we maintain its nomenclature.

$$\tilde{\pi}_t = \frac{\alpha_1}{\alpha_1+\alpha_2}\tilde{\pi}_{t-1} + \frac{\alpha_2}{\alpha_1+\alpha_2}\pi_t^m + \frac{(1-\alpha_1-\alpha_2)}{\alpha_1+\alpha_2}\Delta\overline{\pi}_{t+1} + \frac{\gamma}{\alpha_1+\alpha_2}\hat{y}_t + \eta_t^\pi \quad (8)$$

We assume that in the long run, real exchange rate depreciation is zero and inflation target is constant. Thus, there is not a relationship between output gap and the inflation in the steady state.[22]

2.2. The state space form

For estimation, the model must be put in its state space form, which comprises two equations[23]. Measurement equation (9) relates observations x_t at time $t, t=1,\ldots,T$, to the unobserved state vector α_t.[24] Transition equation (10) denotes the stochastic dynamic behavior governing the state vector.

$$x_t = Z\alpha_t + \varepsilon_t \quad (9)$$

$$A_0\alpha_t = c + A_1\alpha_{t-1} + B\varphi_t + R_0\eta_t \quad (10)$$

where:

$x_t = \begin{bmatrix}\pi_t & \Delta y_t\end{bmatrix}'$ is the observable vector,

$\alpha_t = \begin{bmatrix}\tilde{\pi}_t & \hat{y}_t & \hat{y}_{t-1} & \mu_t\end{bmatrix}'$ is the state vector,

$\varphi_t = \begin{bmatrix}\pi_{t-1}^m & \Delta\overline{\pi}_{t+1} & RMCI_t\end{bmatrix}'$ is the exogenous vector

$\varepsilon_t = \begin{bmatrix}\varepsilon_t^\pi & 0\end{bmatrix}'$ and $\eta_t = \begin{bmatrix}\eta_t^\pi & \eta_t^y & 0 & \eta_t^\mu\end{bmatrix}'$ are innovation vectors.

Matrices are given by:

[22] This also implies that in the long run inflation rate is constant and output gap is zero.

[23] Because output has a unit root, the model was stationarized differencing output equation. Differentiation permits direct calculation of Kalman Filter initial conditions from the model structure and data, without applying diffuse priors for initial conditions, which modifies severely the results at the beginning of the sample.

[24] We present an structural version of state equation, which incorporates contemporaneous effects between underlying inflation and output gap. To get the autoregressive form, invert the left matrix of the state system.

$$Z = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & -1 & 1 \end{bmatrix}$$

$$A_0 = \begin{bmatrix} 1 & \frac{-\gamma}{\alpha_1+\alpha_2} & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ (1-\phi)\overline{\mu} \end{bmatrix},$$

$$A_1 = \begin{bmatrix} \frac{\alpha_1}{\alpha_1+\alpha_2} & 0 & 0 & 0 \\ 0 & \beta & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & \phi \end{bmatrix},$$

$$B = \begin{bmatrix} \frac{\alpha_2}{\alpha_1+\alpha_2} & \frac{1-\alpha_1-\alpha_2}{\alpha_1+\alpha_2} & 0 \\ 0 & 0 & \kappa \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$R_0 = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Innovations η_t and ε_t are mutually uncorrelated and have diagonal covariance matrices. Both are modeled as multivariate gaussian distributions. Matrices A_0, A_1, B, R_0 and vector c depend on unknown hyperparameters,[25] After fixing hyperparameters, prediction, updating and smoothing algorithms are applied.

[25] The next section focus on the criteria utilized for hyperparameters calibration.

To get the usual state space representation, take into account the following equalities:

$$T = A_0^{-1}A_1, \text{ is the transition matrix,}$$

$$d = c + A_0^{-1}B\varphi_t, \text{ summarizes exogenous variables,}$$

$$R = A_0^{-1}R_0.$$

2.3. Calibration

The model (1)-(6) incorporates several hyperparameters, coefficients $\{\beta, \kappa, \alpha_1, \alpha_2, \gamma, \phi, \mu\}$ and variances $\{\sigma^2_{\varepsilon\pi}, \sigma^2_{\eta\pi}, \sigma^2_{\eta y}, \sigma^2_{\eta\mu}\}$. This hyperparameters can be estimated using maximum likelihood procedure. However there are several issues with this approximation. First, for the sample selected, the inflation rate shows a persistent dynamics can be explained by a non-stationary homogenous component in the stochastic dynamic equation of inflation.[26] Second, the quarterly sample used is too short to permit a reliable econometric estimation. Third, we suspect that structural breaks, due to institutional changes and structural reforms in Peru, could prevent a suitable econometric identification.[27]

CHART 1: MODEL PARAMETERS

Parameter	*Calibrated value*
Inflation persistence (α_1)	0.70
Pass through (α_2)	0.15
Output gap to inflation (γ)	0.70
Output gap persistence (β)	0.70
RMCI to output gap (κ)	0.10
Potential slope persistence (ϕ)	0.80
Potential quarterly growth (μ)	0.01

As an alternative, we choose to calibrate the model using external information. In order to get priors, a Phillips curve and a aggregate demand function, similar to equations (2) and (8), were

[26] This phenomenon may invalidate any econometric estimation. For a technical discussion, see Enders (1995) chapter 1.

[27] There exist some evidence about structural breaks in Peruvian data, see Quispe (1999). In general, structural breaks could distort inflation - output relationship, see Clark and McCracken (2003).

estimated econometrically using Hodrick and Prescott output gap.[28] The chart 1 reports the selected values.

In the Phillips curve, we calibrate the parameter α_1 in 0.7. The inflation elasticity to output gap (γ) is calibrated in 0.7. This value is higher than the ones found for other countries.[29] However, it reflects the low sacrifice ratio during the disinflation process in the last ten years.[30] Additionally, we set the pass-through effect from imported inflation over CPI core inflation captured by α_2 in 0.15, according to those found by Miller (2004b) and Winkelried (2004).

For the output gap equation we use the econometric estimation to set the inertia parameter β in 0.7, the effect of the real monetary condition index κ in 0.1 and the value of ϕ in 0.8. The steady state growth rate of potential output was fixed in 4 per cent (annualized), according to the mean growth rate of potential output calculated using the production function approach.[31]

All variances, except that for the growth rate of potential output, were normalized. For filtering process, we have to identify the permanent and transitory components of output. The signal extraction problem is basically related to the variance ratio between growth rate of potential output and output gap,[32] $\sigma^2_{\eta\mu}/\sigma^2_{\eta y}$. We set this value to 1/64. This smoothes potential output and increases the relation between the cyclical component of output and inflation.

2.4. The data

We use quarterly data form the Central Reserve Bank of Peru.

[28] We must take these results with caution because the presence of persistent dynamics on inflation can invalidate statistical inference and also the use of an incorrect output gap measure distort coefficient values. Nevertheless, the estimations give useful information about the parameter values and their uncertainty. In particular, we found that $\{\gamma, \kappa\}$ are blurred by tremendous uncertainty.

[29] For Germany 0.40 and United States 0.44, see Ball (1994), and Czech Republic 0.22, see Benes *et al.* (2002).

[30] See Zegarra (2000).

[31] See Miller (2004a).

[32] Signal extraction problem is practically intractable without imposing some ad-hoc restrictions, see Quah (1992) for a technical discussion. For example, the direct estimation of variance ratio between transitory and permanent component of a time series tend to differ to those recommended by Hodrick and Prescott, see for example, Blith *et al.* (2001).

The sample spans from 1992 to 2003. We utilized the real GDP calculated using 1994 prices. Inflation is represented by core CPI inflation and nominal exchange rate by soles/US$ parity. As an international interest rate we use monthly LIBOR rate. External inflation is approximated by United States CPI inflation rate. Imported inflation is constructed using PPP condition: $\pi_t^m = \pi_t^{US} + \Delta e_t$, where π_t^{US} is US CPI inflation and Δe_t is the exchange rate depreciation (appreciation).

The real exchange rate is measured by the imported prices index deflated by core consumer prices index. On the other hand, the ex-post real interest rate is measured as: $r_t = i_t - \pi_t^{core}$, where i_t is the annualized interbank interest rate and π_t^{core} is year-to-year core inflation rate. Real monetary condition index is constructed with real interest rate and real exchange rate gaps. The risk premium is calculated as the uncovered interest parity condition residual.

Finally, the inflation target rate is the HP filtered of core inflation, restricted to the last announced target (2.5 percent) as a final level prior since 2002.[33]

3. RESULTS

In this section, first we describe the MUC output gap, comparing it to HP filtered and the production function estimates. Then, properties of revisions in the output gap estimates and inflation forecast performance are discussed. Finally, we evaluate which output gap estimate improves inflation predictability. The results indicate that the MUC estimate shows more relation with the Peruvian inflation process, reduces end of sample uncertainty and improves inflation forecast.

3.1. Output gap estimates

Panel (a) of figure (3) plots the MUC output gap estimate using the multivariate unobserved component approach, based on the model defined by (1)-(6) and (8).

According to the results, Peruvian output gap has fluctuated inside the range of -7 to 2 per cent. Four periods of inflationary pressures can be identified: 1994Q2-1995Q4, 1997Q1-1997Q4,

[33] For a discussion of prior's inclusion on Hodrick and Prescott filter, see St. Amant y van Norden (1997).

1999Q4-2000Q2, and more recently 2002Q2-2002Q4. The first two periods have been the most outstanding and the longest, reaching levels near 2 per cent. With regard to the disinflationary pressures' episodes, they have been longer and have presented a higher average magnitude than inflationary ones. Four periods have been also identified: 1992Q3-1994Q2, 1996Q1-1996:Q4, 1998Q2-1999Q4, and 2000Q4-2002Q1, being the first one the most significant, -7 per cent.

Panel (b) of figure (3) plots quarterly underlying inflation and imported inflation. Both series show a high correlation during the ninety's. However, this relation breaks in two remarkable periods: 1994-1995 and 1998-1999. In the first one, underlying inflation is higher than imported inflation. At the same time, a positive output gap is identified, explaining the incomplete pass-through. The opposite happens in the second period: underlying inflation is lower than imported inflation, phenomenon accompanied with a negative output gap.[34]

FIGURE 3. OUTPUT GAP CORRESPOND TO MUC SMOOTHER ESTIMATE. UNDERLYING INFLATION IS COMPUTED USING SEMI-STRUCTURAL MODEL AND IMPORTED INFLATION IS COMPUTED BY PPP CONDITION

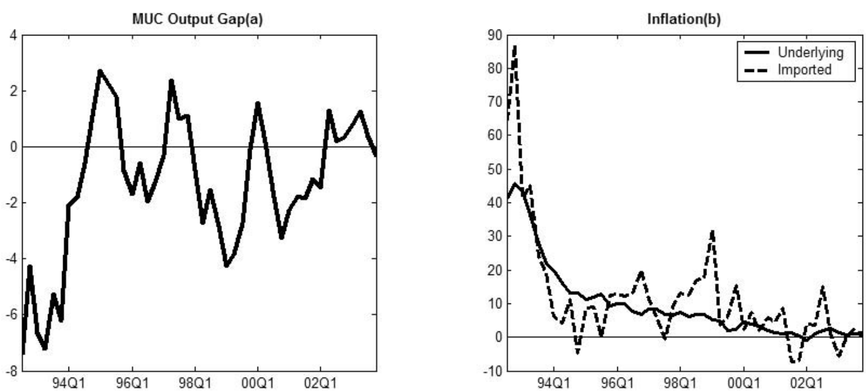


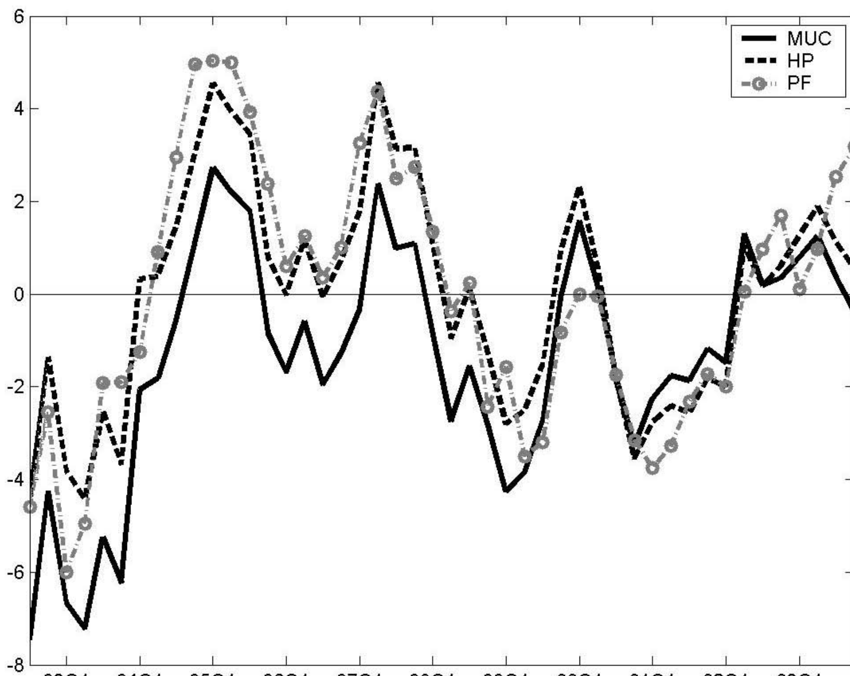
Figure (4) displays the MUC output gap estimate alongside to the Hodrick-Prescott filtered (HP) and the production function (PF) estimates.

MUC, HP and PF output gap estimates are very similar for the

[34] This kind of non linear pass-through has been discussed recently in Winkelried (2004).

entire sample. However, our estimate is lower than the alternatives in two periods: 1994-1997 and at the end of the sample (2003). The most remarkable feature about those episodes is that combine high output growth rates with a disinflationary process (1994-1997) or stable inflation environment (2003). On one hand, HP and PF methods tends to link the output gap evolution with the economic cycle, even when this cycle had not affected the inflation rate. On the other hand, MUC estimate is influenced not only by output behavior but also by domestic and imported inflation.

FIGURE 4. SMOOTHER OUTPUT GAP ESTIMATE



3.2. Properties of revisions: end of sample problem

In this section, we analyze the updating properties of MUC, HP and PF estimates. Measuring output gap revisions due to additional observations is one way of evaluating the uncertainty surrounding different methods.[35] In fact, the higher uncertainty

[35] See Gruen *et al.* (2002) and Orphanides and van Norden (1999).

around output gap estimate, the lower is the sensitivity of monetary authority reactions to it.[36]

In order to compare the reliability of each method we calculated the real-time estimates and the final estimates of the output gap.[37] The uncertainty that each method introduce in the output gap estimation is determined by the comparison between the final estimate and the real time estimate.

The results of this exercise are shown in the figure (5). The left panel plots the real-time and final estimates calculated with MUC, HP and PF methods. It is evident that revisions of the MUC estimate of the real-time output gap in response to new data are much smaller than those of HP and PF. In the right panel, the scatter graphs between real-time and final estimates are presented. Those graphs allow to have a clearer picture of the uncertainty degree surrounding each method. The graphs are divided in 4 areas: Areas I and III show the points where the final and real-time estimates provide contradictory signals, while areas II and IV present those occasions in which both estimations give similar signals. The results indicate that MUC estimates are grouped around the 45° line (areas II and IV), while HP and PF provide contradictory signals (areas I and II).

With the aim of quantifying the uncertainty degree, we calculated the correlation coefficients and concordance indices.38 Additionally, we test the reliability of output gap estimates using the Pesaran and Timmermann (1992) test.[39] The results are summarized in chart 2. The correlation coefficients indicate that the output gaps calculated (final and real-time) with MUC present hig-

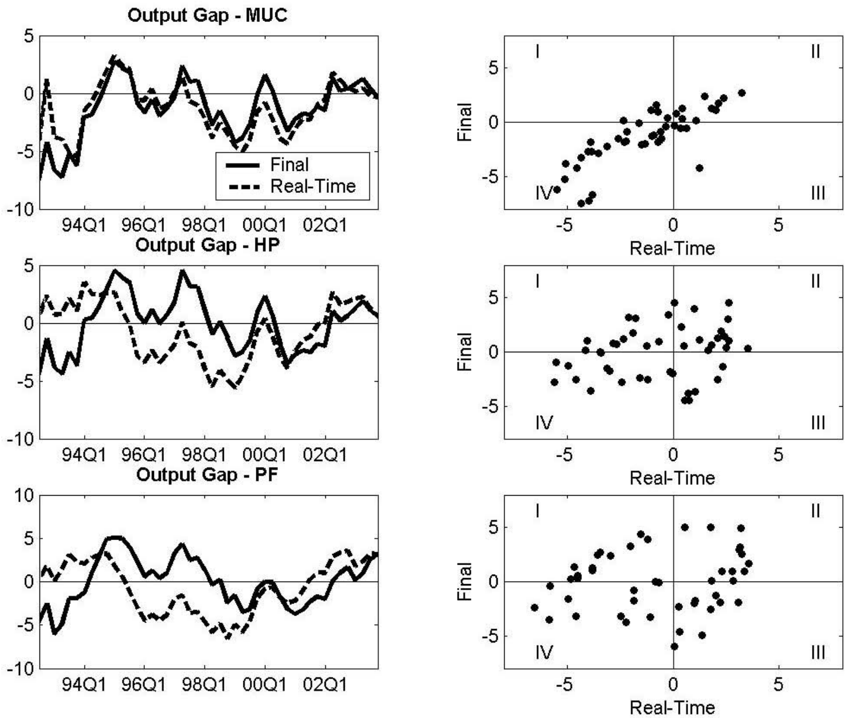
[36] See Gaudich and Hunt (2000) and Smets (2002).

[37] The real time estimates correspond to updated state estimate in Kalman Filter recursion, conditional to past and current observation of the published data available. This means that we are not considering the ex-post revisions of published data, see for example Orphanides and van Norden (1999). On the other hand, final estimates are equivalent to smoother estimates in Kalman Filter, reflecting all available information to forecast sequentially observable variables. To get updated estimates of Hodrick and Prescott filtered we use its state space representation, see Scott (2000b).

[38] The concordance index is simply a non parametric statistic method that measures the time proportion in which two time series are in the same state. Thus, the degree of concordance will be 1 if both output gap measures have the same sign for a determined period. By contrast, it will take a zero value if the sign of both measures (final and real-time) are always opposite. For more details of this indicator see McDermott and Scott (1999).

[39] Quoted in Camba-Mendez and Rodriguez-Palenzuela (2001).

FIGURE 5. FINAL ESTIMATES CORRESPOND TO SMOOTHER ESTIMATES. REAL-TIME ESTIMATES CORRESPOND TO UPDATED ESTIMATES



her co-movements (0.65) than those obtained with HP (0.26) and PF (0.16). In the same way, the concordance statistic indicates that real-time and final estimates with MUC provides similar signals (0.73), better than HP (0.63) and PF (0.52) do. Moreover, the application of the Pesaran and Timmermann test shows that the acceptance probability of similar signals in the case of MUC is 70.89 per cent, in contrast with the 0.01 per cent and 0.00 per cent of HP and FP, respectively. Those results suggest that the multivariate approach provides more reliable estimates.[40]

[40] A variety of studies evaluates the reliability of different univariate and multivariate methods, comparing the real-time estimates relative to final ones. Butler (1996), Conway and Hunt (1997), Camba-Mendez and Rodriguez-Palenzuela (2001), De Brouwer (1998) and Scott (2000a) compare the updating properties of different output gaps measures for Canada, European Union, United States, Australia and New Zealand. Their results suggest that multivariate output gaps estimates are statistically more reliable. Rünstler (2002) concentrated only on

CHART 2: EVALUATION STATISTICS

	MUC	*HP*	*PF*
Correlation coefficient	0.65	0.26	0.16
Concordance index	0.73	0.63	0.52
Pesaran and Timmerman test*	70.89%	0.01%	0.00%

* Acceptance probability of the null hypothesis that the sign of real-time and final estimates is the same.

What explains these results? Because future data always contains relevant information to the current decomposition of transitory and permanent shocks, the most recent estimates of output gap will invariably change as the persistence characteristics of past shocks become more apparent. With structural restrictions, the MUC approach exploits the correlation in the data, guiding the output gap estimation at the end of the sample.

3.3. Inflation forecast

The predictive power of the output gap for inflation through the short run supply curve (Phillips curve) is an essential precondition for the economic validity of any output gap estimate. This section test the information content of different real-time output gap estimates as a leading indicator for future inflation change. For this purpose, we analyze the following regression,

$$\Delta\tilde{\pi}_t = \theta\,\hat{y}_{t|t} + \sum_{i=1}^{k}\Delta\tilde{\pi}_{t-i} + \varepsilon_t \qquad (11)$$

where $\hat{y}_{t|t}$ is the real time output gap estimate and $\tilde{\pi}_t$ is the underlying inflation measure calculated from Kalman Filter recursion.[41]

We apply this equation on real-time output gap estimates computed with different methods: MUC, HP and PF. Additionally an ARIMA regression is estimated, which is taken as a benchmark. In all cases, order lags k is found from Akaike criterion minimization.

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unobservable components methods, univariate and multivariate. As well as in the preceding cases, his study indicates that bigger information levels increase the confidence of the output gap estimate in European Union.

[41] The use of inflation changes eliminates the excessive persistence on inflation. Econometrically, this approach is optimal since improves the short run forecast.

We evaluate out-sample performance using the following steps. First, the equation (11) and ARIMA equation are estimated for the sample selected. Second, the out of sample forecasts of inflation changes over the next four quarters are computed. Third, another observation to the sample is added and the first two steps are applied. We start this procedure with a sample from 1992Q1 to 1997Q4, expanding it until 2002Q2.

Chart 3 reports the mean square error of forecast for underlying inflation using different output gap estimates in relation to the benchmark equation.

CHART 3: OUT-SAMPLE FORECASTS PERFORMANCE

MSE-ratio (in percentages)	*Forecast Horizon*			
	+1	*+2*	*+3*	*+4*
MUC	57	55	65	67
HP	66	73	77	84
PF	75	77	78	85

NOTES: MSE-ratio denotes the mean square error of the inflation forecast relative to MSE of the random walk forecast. MSE's of the out-of-sample random walk forecast are given 1.56, 1.61, 1.76, and 1.29 for 1,2,3,4 quarters ahead, respectively. Initial sample: 1992Q1 –1997Q4.

Out-of-sample forecasts using output gap estimates improve substantially on the random walk forecast at all the four quarters ahead. However, the improvement varies across different methodologies considered. MUC output gap increases inflation predictability more than HP and PF gaps estimates do. Additionally, the forecast performance of the MUC estimate is nearly stable as the forecast horizon increases. In that sense, HP and PF perform worse, showing MSE-ratios increments as the forecast horizon is expanded. At best, the four quarter forecast of HP and PF improve only slightly relative to the random walk model.

4. FINAL REMARKS

With the objective of improving output gap measurement in Peru, we develop a semi-structural model for a small open economy, The model was estimated as a multivariate unobserved component model using the Kalman Filter technique. The system incorporates explicitly a short run relation between output gap and inflation process through a Phillips Curve and also adds some other structural restrictions over potential output dynamics. The model parameters were calibrated using external information sources. Our results indicate that the MUC output gap estimate outperforms alternatives such as the HP filter or PF estimates.

The results indicate that the MUC output gap is quite similar to alternatives measures. However, in periods of high output growth rate together with a disinflation or stable inflation context, our estimate indicate lower demand pressures than other estimates do. In particular, at the end of the sample (characterized by an environment of stable inflation), HP and FP are biased toward excess demand conditions. Besides, MUC output gap identification is quite related to pass-through effect from imported prices to consumer prices. In particular, whenever imported inflation was higher (lower) than domestic inflation, the system found a negative (positive) output gap.

Furthermore, we studied updating properties comparing the smoother estimates and the updated estimates of the three competitive approaches. The diagnostic statistics report that MUC estimate is the most reliable of the group. Finally we explore the out-sample predictive power for inflation of different output gap estimates. The results indicate that the MUC estimates forecasts better inflation changes, confirming the essential precondition for the economic validity of any output gap estimate.

The advantages above-mentioned prove the importance of adding structural information on output gap calculation. For monetary policy purposes, this outcome could imply a significant uncertainty reduction and could improve future inflation control. Given that, a future research agenda could be oriented to explore additional cyclical indicators to improve output decomposition, in that sense, we recommend Rünstler (2002). Further, as the model presented here was calibrate, uncertainty involved in this process must be quantified. Regarding to this, Bayesian analysis of posterior densities of hyperparameters as in Harvey *et al.* (2002) could be implemented.

Appendix A

The real monetary condition index

A real monetary condition index summarizes the main transmission channels of monetary policy: the direct real interest rate, and the indirect real exchange rate channels.[42] The index is calculated as a linear combination of real interest rate and real exchange rate gaps,

$$RMCI_t = -\theta \hat{r}_t + (1-\theta)\hat{q}_t \qquad (A.1)$$

where $\hat{r}_t$ and $\hat{q}_t$ are the gaps of real interest rate and real exchange rate, respectively. The coefficient θ measures the relative importance of the real interest.[43] A positive (negative) real monetary condition index implies an expansionary (contractionary) monetary policy stance.

Real interest rate and real exchange rate gaps were computed using a Kalman filtering technique. The model is based on uncovered interest parity condition.

$$r_t - r_t^* = 4\Delta q_t + \rho_t \qquad (A.2)$$

where r_t is the domestic real interest rate; r_t^* is the external real interest rate; q_t is the real exchange rate (in logarithms) and ρ_t represents the risk premium level. We can decompose every variable in the UIP equation into transitory (gap) and trend components.

$$r_t - 4\Delta q_t - \rho_t = \hat{r}_t + \bar{r}_t - 4\Delta\hat{q}_t - 4\Delta\bar{q}_t - \hat{\rho}_t - \bar{\rho}_t$$
$$r_t - 4\Delta q_t - \rho_t = \left[\hat{r}_t - 4\Delta\hat{q}_t - \hat{\rho}_t\right] + \left[\bar{r}_t - 4\Delta\bar{q}_t - \bar{\rho}\right]$$

Taking UIP as a cointegration relation implies that the real interest rate, the change in real exchange rate and the risk premium move together around a long run equilibrium.[44]

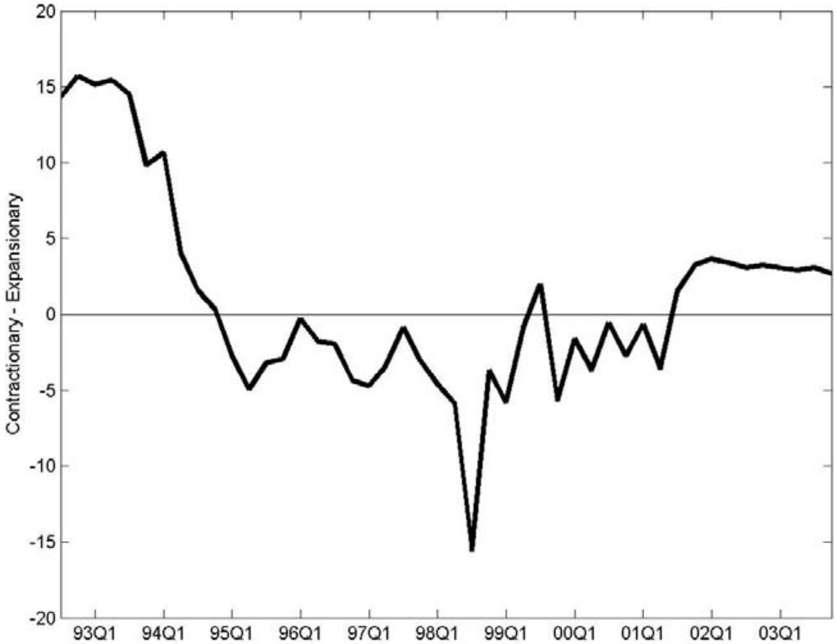
$$\bar{r}_t - \bar{r}_t^* = 4\Delta\bar{q}_t + \bar{\rho}_t$$

[42] See Dennis (1997). Typically, monetary condition indexes are calculated in level. However, to be consistent to the semi-structural model employed, we center the monetary condition index detrending its component.

[43] A higher value of θ indicates that real interest rate channel is more important than real exchange rate channel. Therefore, a higher real depreciation (appreciation) is required to off set the effects of real interest rate increment (reduction).

[44] In this long run equilibrium, external real interest rate is taking as an exogenous variable, which do not adjust to any domestic disequilibrium.

FIGURE 6. REAL MONETARY CONDITIONS INDEX IS COMPUTED AS A LINEAR COMBINATION OF THE REAL INTEREST RATE AND THE REAL EXCHANGE RATE GAPS



Considering the above-mentioned, we rearrange the UIP equation as:

$$x_t = \left[\hat{r}_t - 4\Delta\hat{q}_t - \hat{\rho}_t\right] + \bar{x}_t$$

where $x_t = r_t - 4\Delta q_t - \rho_t$

We need to specify the stochastic laws of motion of the real interest rate, the real exchange rate and the risk premium. These three variables follow a local level model $\left(z_t = r_t, \Delta q_t, \rho_t\right)$[45] as:

$$z_t = \bar{z}_t - \hat{z}_t$$

$$\bar{z}_t = \bar{z}_{t-1} + \bar{\eta}_t \qquad \bar{\eta}_t \sim N\left(0, \sigma^2_{\bar{\eta}}\right)$$

$$\hat{z}_t = \hat{\eta}_t \qquad \hat{\eta}_t \sim N\left(0, \sigma^2_{\hat{\eta}}\right)$$

[45] For technical discussion of local linear trend models and local level models, see Harvey (1993).

where $\bar{z}_t$ and $\hat{z}_t$ represent the permanent (trend) and transitory (gap) component, respectively. To compute the gaps we calibrate the signal extraction ratio between transitory and permanent shocks.

Figure (6) plots the real monetary condition index calculated. We set $\theta = 0.9$.[46] The results indicates two stages of monetary policy stance. Expansionary during 1992Q3-1995Q4 and 2001Q1-2003Q4 and contractionary during 1996Q1-2001Q4.

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[46] To calibrate this parameter we estimate equation (2) for HP output gap with the real interest rate and the change in real exchange rate in gaps separately. The results show that the real interest rate gap is more important in output gap determination than real exchange rate depreciation (appreciation) gap. Furthermore, we explore alternative specifications with primary and non-primary sectors instead of the total GDP. We found that the real interest rate gap has more effect on non-primary output gap, while the real exchange rate depreciation (appreciation) gap has more effect on primary. Given that the contribution of non-primary sector on total GDP is more than 60% (in average), the results obtained with total GDP output gap are reasonable.

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