A simple model for inflation targeting in Brazil*

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RESUMO

Com base em um modelo de 6 equações de Haldane e Battini (1999), estimamos equações de Philips e IS para o Brasil após o Plano Real, para estudar o mecanismo de transmissão da política monetária. Os resultados mostram que a taxa de juros afeta o hiato de produto com uma defasagem de um trimestre e que o produto está positivamente relacionado com a inflação com uma defasagem apenas. A desvalorização da taxa de câmbio nominal também tem um efeito contemporâneo sobre a inflação. Nós fizemos também simulações estocásticas para descrever a volatilidade dos loci de inflação e de hiato de produto sob regras alternativas do tipo Taylor e sob uma regra ótima que minimiza uma função de perda, a qual depende da média ponderada das variâncias da inflação e do hiato de produto. As simulações estocásticas mostraram que, quando comparada com a variância da inflação, a variância do hiato de produto parece ser mais sensível aos pesos dados na função de perdas. Também mostraram que os procedimentos de otimização mais longos do que 6 períodos são ineficientes e que os horizontes de fronteira mais eficiente são definidos no intervalo de 2 a 4 períodos. Finalmente, regras subótimas simples, como as do tipo Taylor, podem desempenhar tão bem como as regras ótimas, dependendo dos parâmetros escolhidos e das preferências do Banco Central.

Palavras-chave: metas de inflação, mecanismos de transmissão.

ABSTRACT

Based on a 6 equation model by Haldane and Battini (1999), we estimated a Phillips and an IS equations for Brazil after the Real Plan, in order to study the transmission mechanism of the monetary policy. The results show that interest rate affects output gap with a lag of one quarter and output is positively related to inflation with a one lag only. The devaluation of the nominal exchange rate has also a contemporaneous effect on inflation. We also made stochastic simulations in order to depict the inflation and output gap volatility loci under alternative Taylor-type rules and under an optimal rule, which minimizes a loss function that depends on a weighted average of inflation and output gap variances. The stochastic simulation showed that when compare to the variance in inflation, output gap variance appears to be more sensitive to the weights given in the loss function. It also showed that optimization procedures longer than 6 periods are inefficient and the most efficient frontier horizons are set within the range of 2 to 4 periods. Finally, sub-optimal but simple rules, like Taylor type rules can perform as well as the optimal ones, depending on the parameters chosen and on the preferences of the Central Bank.

Key words: inflation targeting, transmission mechanism.

JEL classification: E310, E400.

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1 Introduction

Brazil adopted a formal inflation-targeting regime in June 1999, six months after the switch in the exchange rate regime to a floating system.[1] The main feature of the new monetary policy is to look at (expected) future inflation to decide the current interest rate. The underlying idea is to have an anticipative stance in order to consider the lag effects of interest rate on inflation through the aggregate demand transmission mechanism.[2]

Many Central Banks that adopted this new framework in the nineties were able to control inflation with more transparency and credibility than before. As the name suggests, under an inflation-targeting regime, the Central Bank main objective is to keep inflation within a predefined band. This contrasts with other nominal anchors, like exchange rate and monetary targets. Although there is a theoretical support for a relationship between monetary aggregates and inflation, empirical evidence shows that such relationships are not stable.

Among other papers on inflation targeting models and alternative interest rate rules we focus on three: Haldane and Battini (1999) Levin, Wieland and Williams (1999) and Taylor (1999). Haldane and Battini (1999) emphasize the importance of a forward-looking interest rate rule, which performs almost as good as an optimal rule, even if the output variable is not directly included in the loss function to be minimized. The authors summarize in a 6-equation model the most important features of the inflation target framework.

Levin, Wieland and Williams (1999) analyse four models and compare a wide set of policy rules to conclude that:

> "*even in large models with hundreds of state variables, three variables (the current output gap, a moving average of current and lagged inflation rates, and lagged 'interest rates') summarize nearly all the information relevant to setting the 'interest rate' efficiently.*" (p. 31).

Taylor (1999) summarizes the common features of the models that deal with inflation targeting. All of them are stochastic, dynamic and economy-wide. He also pointed out that:

> "*even the larger models can be described conceptually as "three relationship" system.(one relationship being the policy rule). Equation re-*

1 England and Sweden are examples of countries that also introduced inflation targeting systems after a change in the exchange rate regime. Inflation targeting is also used in New Zealand, Australia, Chile, Israel and Spain.

2 References about the transmission mechanism include King (1997), Ball (1999) and Svenson (1998).

lating consumption, investment and net exports to interest rate and the exchange rate combine to form an IS block of equation; wage and price setting with exchange rate pass through combine to form a price adjustment block of equation."

Taylor (1999) concludes that there is no significant improvement on the results when substituting a simple policy rule for a complex one. In addition complex policy rule that incorporate inertial factors are more dependent on rational expectation assumptions.

The main objective of this paper is to estimate an IS and a Phillips equations for Brazil in order to simulate the effects of different interest rate rules on the variance of inflation and output gap. The benchmark is the optimal interest rate rule, obtained by minimizing a loss function, which is a weighted average of the variance of inflation and output gap.

The next section presents the Haldane-Battini model and the structure of the IS and Phillips equations. Section 3 contains the estimations of the 2 equations, section 4 shows the results of the stochastic simulations for optimal and alternative Taylor-type rules. The last section presents the conclusive remarks. The stochastic simulation showed that when compared to the variance in inflation, output gap variance is more sensitive to the weights given in the loss function. It also showed that optimization procedures longer than 6 periods are inefficient and the most efficient frontier horizons are between 2 and 4 periods. Finally, sub-optimal but simple rules, like Taylor type rules can perform as well as the optimal ones, depending on the parameters chosen and on the weights given in the loss function. This is a similar result to the one found in Levin, Wieland and Williams (1999) and is good news in the sense that the monetary authority may be able to adopt simpler rules with few consequences in terms of generating excessive output and inflation volatility.

2 A model for the transmission mechanism using output gap

2.1 Haldane and Battini model

As a starting point we used a small, open-economy, log-linear rational expectations macro-model found in Haldane and Battini (1999), which has 6 equations:

$$y_t - y_t^* = \alpha_1 y_{t-1} + \alpha_2 y_{t+1} + \alpha_3 [i_t - E_t(\pi_{t+1})] + \alpha_4 (e_t + p_t^c - p_t^{cf}) + \varepsilon_{1t} \tag{1}$$

$$m_t - p_t^c = \beta_1 y_t + \beta_2 i_t + \varepsilon_{2t} \tag{2}$$

$$E_t(e_{t+1}) = e_t + i_t - i_t^f + \varepsilon_{3t} \tag{3}$$

$$p_t^d = 1/2[w_t + w_{t-1}] \tag{4}$$

$$w_t - p_t^c = \chi_0[E_t(w_{t+1}) - E_t(p_{t+1}^c)] + (1-\chi_0)[w_{t-1} - p_{t-1}^c] + \chi_1(y_t - y_t^*) + \varepsilon_{4t} \tag{5}$$

$$p_t^c = \phi p_t^d + (1-\phi)e_t \tag{6}$$

where, y is the log of the real GDP, y* is the log of the potential output, i is nominal interest rate, E(π) is the inflation expectation, ε is the nominal exchange rate, p^f is the international price index, p^c is the price index, and the last term of IS equation is ε_1 is the demand shock. For the LM equation, m is the monetary basis and e_2 is the monetary shock. i^f is the nominal foreign interest rate and ε_3 is the risk premium. For the wage formation equation, w is the nominal wage and ε_4 is the wage shock.

Equation (1) is a usual IS curve, where the output gap depends negatively on the real interest rate and positively on the real exchange rate. Equation (2) is a regular LM curve, in which money demand depends on nominal interest rate and output. Equation (3) is an uncovered interest parity, that does not included a risk premium variable.

Equation (4) and (5) are the supply side. Equation (4) is a mark-up over weighted average contract wages. Equation (5) is a wage contracting equation. The lag/lead weights sum up to one to generate a vertical log-run Phillips curve. The output gap also is included in this equation.

Equation (6) is consumption price index, depending on the domestic goods and imported goods.

After some manipulation in (4)–(6), the authors come with a reduced-form Phillips curve of the model:

$$\pi_t = \chi_0 E_t(\pi_{t+1}) + (1+\chi_0)\pi_{t-1} + \chi_1(y_t - y_{t-1}) + \mu[(1-\chi_0)\Delta c_t - \chi_0 E_t \Delta c_{t+1})] + \varepsilon_5 \tag{7}$$

where c_t is the real exchange rate. There is a term for the output gap (which is the most important to explain the interest rate transmission mechanism), and the weighted backward and forward-looking inflation terms represent the inflation persistence. The last two terms are the exchange rate pass-through, where m is the pass-through coefficient and ε_5 is the cost-push shock. The long-run vertical Phillips curve restriction is only in the lag and lead term for inflation.

2.2 Two equation model

This paper is going to work with an even simpler model, with three equations: an IS curve, a Phillips curve; and an equation for nominal exchange rate:

$$y_t - y_t^* = \beta_1 r_{t-1} + \beta_3 (y_{t-1} - y_{t-1}^*) + \beta_2 fd_{t-1} + \beta_3 c_{t-1} + \varepsilon_t \tag{8}$$

$$\pi_t = \alpha_1 \pi_{t-1} + \alpha_2 (y_{t-1} - y_{t-1}^*) + \alpha_3 (e_t - e_{t-1}) + \eta_t \tag{9}$$

$$e_t = e_{t-1} + v_t \tag{10}$$

Equation (8) is an open economy IS curve, where output gap (y – y*) depends on its own lags, on the lagged ex-post real interest rate (r), on the lagged real exchange rate (Δc), on the lagged fiscal deficit (fd) and on a demand shock (ε).

Equation (9) is an open economy Phillips curve. Inflation (π) depends on a lag of itself, on a lag of output gap, on a change in the nominal exchange rate (Δe) and on a shock (η). The exchange rate affects inflation directly through the price of imports and indirectly thorough its effects on the output gap. The main differences from Haldane-Battini model are the absence of a forward-looking term for inflation and the nominal exchange instead of the real one in the Phillips curve.[3]

Equation (10) is the exchange rate determination, which is assumed to follow a random walk.

3 We also do not include a forward term for the output gap, we did include a term for the primary budget surplus on the IS curve. The random walk hypothesis for the exchange rate is also mild, since no one really believes in the UPI. See discuss about exchange rate forecast in Muinhos, Freitas e Araujo (2001)

In this model, the transmission mechanism from interest rate to inflation occurs only through the aggregate demand channel, and it takes two periods for interest rate changes to affect inflation. Observe that modeling exchange rate through a random walk precludes the often-mentioned exchange rate channel, where its appreciation follows increases in interest rates via UIP. Despite the theoretical appealing of modeling exchange rate through UIP, predictions of future exchange rate using a random walk specification usually outperforms the predictions based on UIP.[4]

Given equations (8)-(10), the Central Bank chooses interest rate at each period and such decision will affect inflation from two periods ahead on. It is therefore necessary to specify the Monetary Authority decision mechanism. Among others Taylor type rules and optimal rules are the most popular ones.

In the case of Taylor rules, the interest rate is set as a linear function of to the current behavior of two variables: the wedge between observed inflation and the target and the output gap. Such rules can also be extended including other variables, like exchange rate or past interest rate, as well as using expected variables instead of observed ones.

In the case of optimal rules are ones were the interest rate is the solution of a minimization of a loss function subject to some constraints that should characterize the transmission mechanism. For example, the Central bank chooses the real interest rate that minimize the following loss function:

$$\underset{r_t}{Minimize}\, L_t = \sum_{i=0}^{T} \delta^t \{\lambda E_t\left[(\pi_{t+i} - \pi^*_{t+i})^2\right] + (1-\lambda) E_t\left[(y_{t+i} - y^*_{t+i})^2\right]\}$$

s.t. equations (8) - (10).

This is a typical problem in the literature of inflation targeting,[5] where λ is the weight the Central Bank places on the variance of inflation, δ is the discount factor, y is output, y* is potential output and π^* is the targeting for inflation.

4 See, for example, Wadhwani (1999).

5 See, for instance, Svensson (1995) and Svensson (1997).

3 Estimations

The estimation used quarterly data and the variables are expressed in their logarithms. Inflation is measured by the general price index IGP-DI/FGV. The output proxy is GDP, and the gap is estimated by log of GDP minus log of potential output. The estimation of the potential output is a difficult and controversial task and we used the Hodrick-Prescott filter. The nominal exchange rate is the period average of the ask prices, and the nominal interest rate is the Selic rate, the equivalent to US Fed funds rate. The fiscal variable chosen is the federal government primary deficit, measured as percentage of the GDP. The real interest rate was calculated by deflating the nominal interest rate using the IGP-DI. In order to obtain the real exchange rate, the nominal one was multiplied by the US producer price index and divided by the IGP-DI.

The sample period ranged from 1992:4 to 1999:1 to estimate the IS equation and ranged from 1995:1 to 1999:2 to estimate the Phillips curve. We decided to restrict the data range for the Phillips equation, restricting the sample after the Real Plan in order to avoid high inflation contamination in the coefficients.

The choice to use quarterly data for such a short sample period poses the problem of too few degrees of freedom. On the other hand, quarterly data are less noisy than monthly ones. Besides, the transmission mechanism should take at least 2 quarters to occur. Consequently it would not be feasible to work with monthly data to forecast inflation one or two years ahead, as it is needed in an inflation target framework, since the standard errors of the forecasts would become very large. Finally, despite the few degrees of freedom, most of the estimated coefficients turned out to be statistically significant.

The equations were estimated using OLS. The IS curve does not contains a real exchange rate term neither a fiscal term in the present specification. But all the others term are very significant and with the expected sign. The real interest rate was included with 1 lag. A lag of the output gap, a pulse dummy for the Real plan and a dummy for the third quarter of 1998 were also included as explanatory variables.[6] Equation (12) shows the coefficients and their respective t-statistics.

6 Although agents take decisions based on long-term real interest rates, we used the short rate in this specification. The reasons for adopting the short rates, instead of the long ones are: i) there is a close relationship between the two rates in Brazil, if one considers 6 months as long term; ii) only after the Real Plan there is a reliable 6-month interest rate swap. Therefore, estimations using such rates would reduce the sample size and the degrees of freedom.

$$h_{t+1} = \underset{2.58}{0.02} - \underset{-2,16}{0{,}39} r_t + \underset{7.25}{0.73} h_t + \underset{3.05}{0.38} D\mathrm{Real}_t - \underset{-2.5}{0.22} D983_t + \eta_{t+1} \quad (12)$$

N=29 R-squared = 0.79 F-statistic = 22.8

The Phillips equation was estimated with one lagged term for inflation. The output gap entered the equation with one lag, and the devaluation of the nominal exchange rate seems to be contemporaneous, with a pass-through of 20%.

Equation (13) shows the coefficients and their respective t-statistics.

$$\pi_{t+2} = \underset{(-1.63)}{-0.006} + \underset{(3.2)}{0.80} \pi_{t+1} + \underset{(2.26)}{0.31} h_{t+1} + 0.20 \Delta e_{t+2} + \varepsilon_{t+2} \quad (13)$$

N = 18 R-Squared = 0.72 F-statistic = 12,31

We are imposing a long-run vertically in the Phillips equation, restricting to 1 the sum of the coefficients of lagged inflation and of nominal exchange rate variation. What means that any devaluation in the exchange rate will be completely passed through prices in the long-run. Although we did not impose the restriction of no constant when estimating the parameters, this term was dropped in the simulations presented below.[7]

The effect of interest rate on inflation is indirect and takes two periods to occur. So, the control lag is two quarters. A one-percentage point increase in the real interest rate will affect negatively the output gap in 0,39 percentage point. Given that a decrease of 1 percentage point in the output gap reduces inflation by 0,31 percentage point, the final effect of the increase of 1 percentage point in interest rate will be a reduction of 0,12 percentage point in inflation in the short run. In the long run, taking into consideration the auto-regressive coefficients, the final effect would be a reduction in inflation of 0.6 pp.

In both equations we test the residuals for auto correlation. The correlograms do not show evidence of this problem. The test of the cross-correlation of the two equations residuals was also done and the result shows no evidence of that.

7 The pass-through coefficient is not stable. It suffers a structural break in 1999 1° quarter with the exchange regime switch. See Muinhos (2001)

4 The optimal rule

The Central Bank is assumed to choose an interest rate path that minimize the following loss function:

$$\min_{\{i_{t+j}\}_j^n} \ell = \frac{\lambda}{2}\sum_{j=1}^{T}\rho^j E_t(\pi_{t+j}-\pi_t^*)^2 + \frac{(1-\lambda)}{2}\sum_{j=1}^{T}\rho^j E_t(h_{t+j})^2$$ [8]

subject to (8) –(10), ie, the IS, Phillips and exchange rate equations, and to:

$$\mathrm{i}_t = \mathrm{i}_{t+1} = \mathrm{i}_{t+2} = \ldots = \mathrm{i}_{t+n-1} = \mathrm{i}$$

where λ is the weight the Central Bank gives to inflation variance compared to output gap variance. When the value of λ is 0, the optimal rule puts all weight on the output. Conversely, when $\lambda = 1$ means the Central Bank cares only about inflation variance.

Restriction (i) is equivalent to assume that, when setting interest rates at *t*, the Central Bank commits to keep the interest rate unchanged between period *t* and t+T-1. Observe that this procedure may be considered a myopic optimization problem because it only takes into account expected inflation and output gap T periods ahead, ignoring the effects of interest rate on inflation and output gap from period T+1 on. The use of such myopic approach, though, simplifies considerably the solution. Besides, we calculated optimal interest rates with T ranging from 2 to 8 periods and it could be concluded that it was inefficient for the Central Bank to take into consideration more than 6 quarters in the loss function.

The optimal interest rate is given by:[9]

$$i_t^* = \frac{-\left\{\lambda\sum_{j=1}^{n}\rho^j(E_t\tilde{\pi}_{t+j}-\pi_t^*)a_{i,j} + (1-\lambda)\sum_{j=1}^{n}\rho^j E_t h_{t+j} b_{1,j}\right\}}{\lambda\sum_{j=1}^{n}\rho^j a_{i,j}(a_{i,j}+a_2) + (1-\lambda)\sum_{j=1}^{n}\rho^j b_{1,j}(b_{1,j}+b_2+b_3)} \tag{14}$$

8 Strella and Michkin (data) shows that if model parameters are uncorrelated with interest rate, the optimization problem above is the same as:

$$\min_{i_t} \ell = \frac{\lambda}{2}\sum_{j=1}^{n}\rho^j(E_t\pi_{t+j}-\pi_t^*)^2 + \frac{(1-\lambda)}{2}\sum_{j=1}^{n}\rho^j(E_t h_{t+j})^2$$

9 The derivation of equation (14) is shown in the appendix.

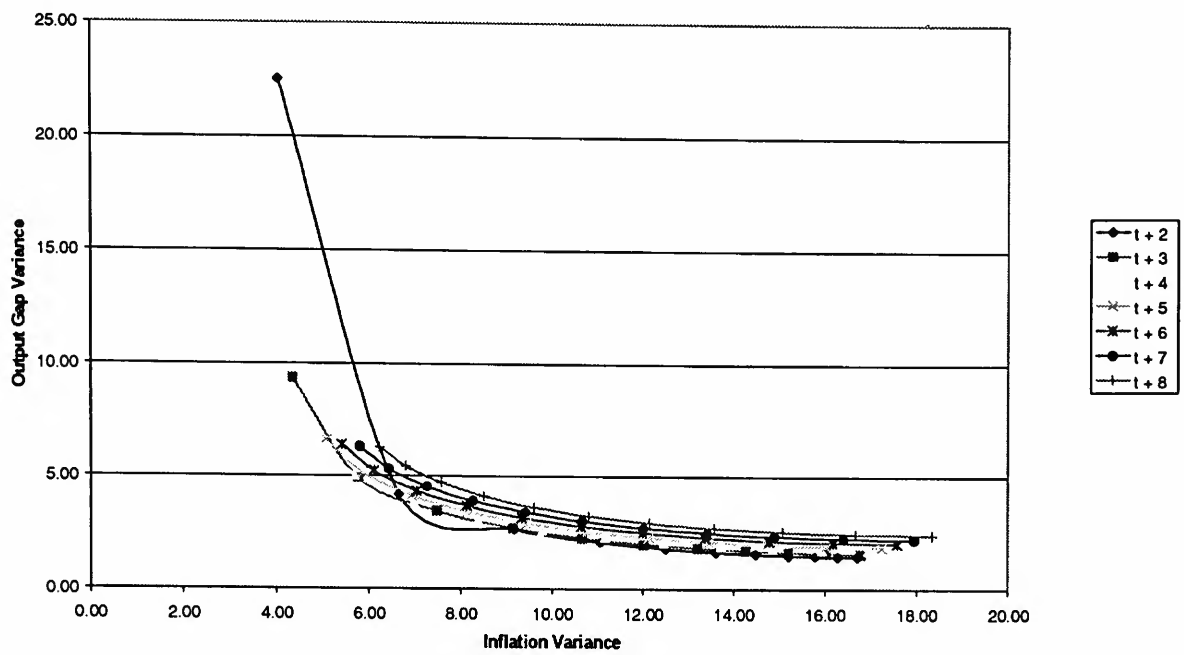
where $\tilde{\pi}_t$ and $\tilde{h}_t$ are the components of inflation and output gap that do not depend on current and future interest rates.

From (14) one can see that, in order to calculate the optimal interest rate, it is necessary to have estimates of $E_t \tilde{\pi}_{t+i}$ and $E_t \tilde{h}_{t+i}$, $i \leq T$ The appendix shows that these variables depend on the realizations of π and h at time *t*, on the interest rate path from *t* to *t+i-1* and on expected exchange rate variation from *t* to *t+i*. At time *t*, only π_t and h_t are known. The interest rate path is the outcome of the optimization procedure. Therefore, it is still necessary to define the exchange rate variations path. This path was constructed assuming exchange rate follows a random walk. As explained before, a drawback of this hypothesis is the lack of response of exchange rate to interest rate decisions. However, an adequate way to incorporate such responses is beyond the scope of this paper and other simpler responses, like the widely used uncovered interest rate parity condition, may yield a worse fit than random walk.

Given the interest rate rule, a stochastic simulation was made in order to build an efficient frontier, showing the output gap and inflation variance for different values of λ and different time horizons. The result is shown in Chart 1 and will be commented below. The first step is to generate a series of simulated inflation and output. At period 1, both inflation and output gap are known and the Central Bank is assumed to choose an interest rate according to the optimization problem. At period 2, shocks on inflation, output gap and exchange rate hit the economy and a new interest rate is set. The errors are assumed to be normally distributed with mean zero and diagonal covariance matrix. The variances of inflation and output gap are the ones obtained in the regressions. Concerning the shock on exchange rate, it was imputed a standard deviation of 5%. This imputation was necessary because there were only two observations in the sample with a floating exchange rate regime. This procedure was repeated for 200 periods and the efficient frontier corresponded to the variance of inflation and output gap obtained in this simulation from period 50 on.

Chart 1 presents the trade-off between inflation and GDP output that is behind the selection of a specific λ and optimization periods. Along each line, the optimization period is held constant and λ varies from 1 (all weight given to inflation variance) to 0 (all weight given to output gap variance). For low values of λ, optimization taking into account only 2 periods ahead is the most efficient while for higher values of λ (ie, higher weight to inflation variance), the efficient frontier refers to optimization procedures with horizons of 3 and 4 quarters.

Chart 1
Efficient Frontiers



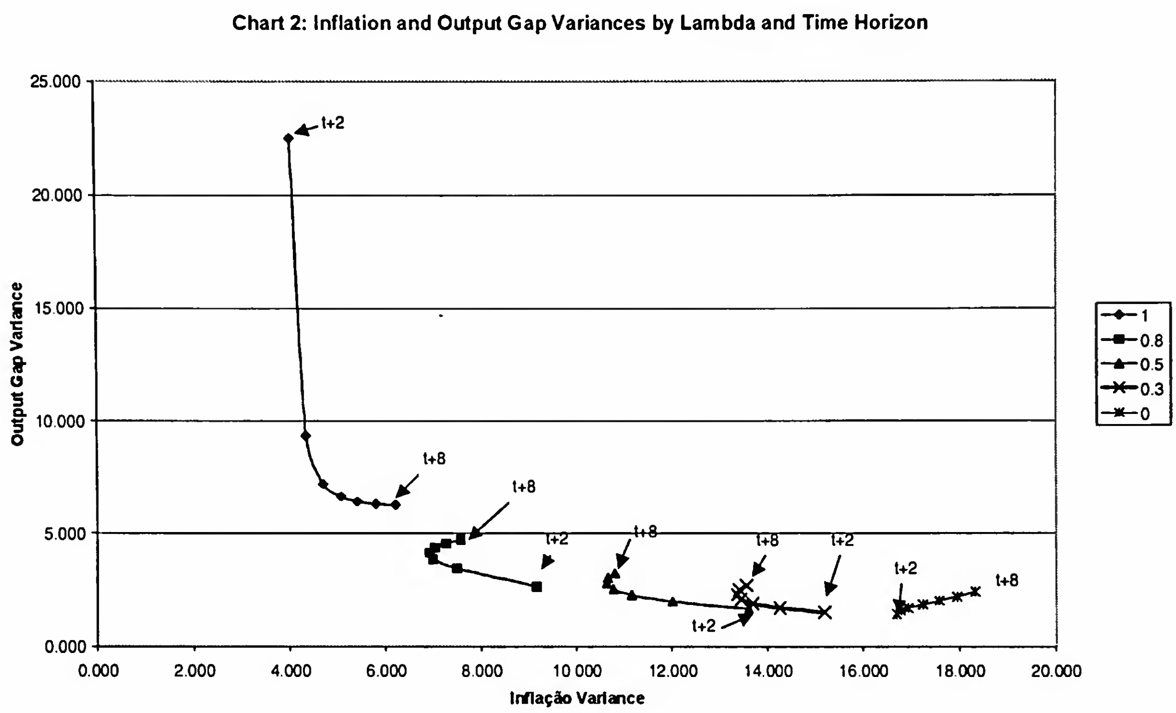
This result was to some extent surprising. It was already expected that for very short time horizons and high weight on inflation, output variance should be higher, given the greater sensitivity of output gap to interest rate. But we did not expected that output gap variance would reduce so sharply when the time horizon of the loss function increased only from 2 to 3 periods ahead. Table 1 shows that the greatest reduction in relative variances occurs exactly when the time horizon increases from 2 to 3 periods.

Table 1
Variance Rations by Lambda and Time Horizon

Horizon	Variance	Lambda										
		1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
t + 2	Inflation	1.0	1.6	2.3	2.7	3.1	3.4	3.6	3.8	3.9	4.0	4.1
	Output	15.9	2.9	1.9	1.5	1.3	1.2	1.1	1.1	1.0	1.0	1.0
t + 3	Inflation	1.0	1.3	1.7	2.1	2.5	2.8	3.0	3.3	3.5	3.7	3.9
	Output	6.0	3.2	2.2	1.7	1.4	1.3	1.2	1.1	1.0	1.0	1.0
t + 4	Inflation	1.0	1.2	1.5	1.8	2.1	2.4	2.7	2.9	3.2	3.4	3.6
	Output	4.3	3.0	2.3	1.8	1.5	1.3	1.2	1.1	1.1	1.0	1.0
t + 5	Inflation	1.0	1.2	1.4	1.6	1.9	2.1	2.4	2.7	2.9	3.2	3.4
	Output	3.6	2.8	2.2	1.9	1.6	1.4	1.2	1.1	1.1	1.0	1.0
t + 6	Inflation	1.0	1.1	1.3	1.5	1.7	2.0	2.2	2.5	2.7	3.0	3.3
	Output	3.2	2.6	2.2	1.8	1.6	1.4	1.2	1.1	1.1	1.0	1.0
t + 7	Inflation	1.0	1.1	1.3	1.4	1.6	1.8	2.1	2.3	2.6	2.8	3.1
	Output	2.9	2.4	2.1	1.8	1.5	1.4	1.2	1.1	1.1	1.0	1.0
t + 8	Inflation	1.0	1.1	1.2	1.4	1.5	1.7	2.0	2.2	2.4	2.7	3.0
	Output	2.6	2.3	2.0	1.7	1.5	1.3	1.2	1.1	1.1	1.0	1.0

Chart 2 illustrates this point more clearly. Along each line in Chart 2, λ is held constant and the optimization horizon is varying from t+2 to t+8 periods. When $\lambda=1$, a slight increase in inflation variance is compensated by a substantial reduction in the variance of output gap, as the optimization horizon moves from t+2 to t+4 periods. In all cases, though, using more than 6 periods in the loss function is inefficient.

Chart 2
Inflation and Output Gap Variances by Lambda and Time Horizon



In order to compare the robustness of our model with other rules, we proceeded a test similar with the one done in Levin, Wieland and Williams (1998). The alternative rules follow the equation:

$$r_t = \rho r_{t-1} + \alpha(\pi_t - \pi^*) + \beta y_t \tag{15}$$

Table 2 shows different values for the coefficients above for alternative rules. Rule A is the traditional Taylor rule. All other rules preserve the stability condition that the coefficient a should be greater than 1.[10]

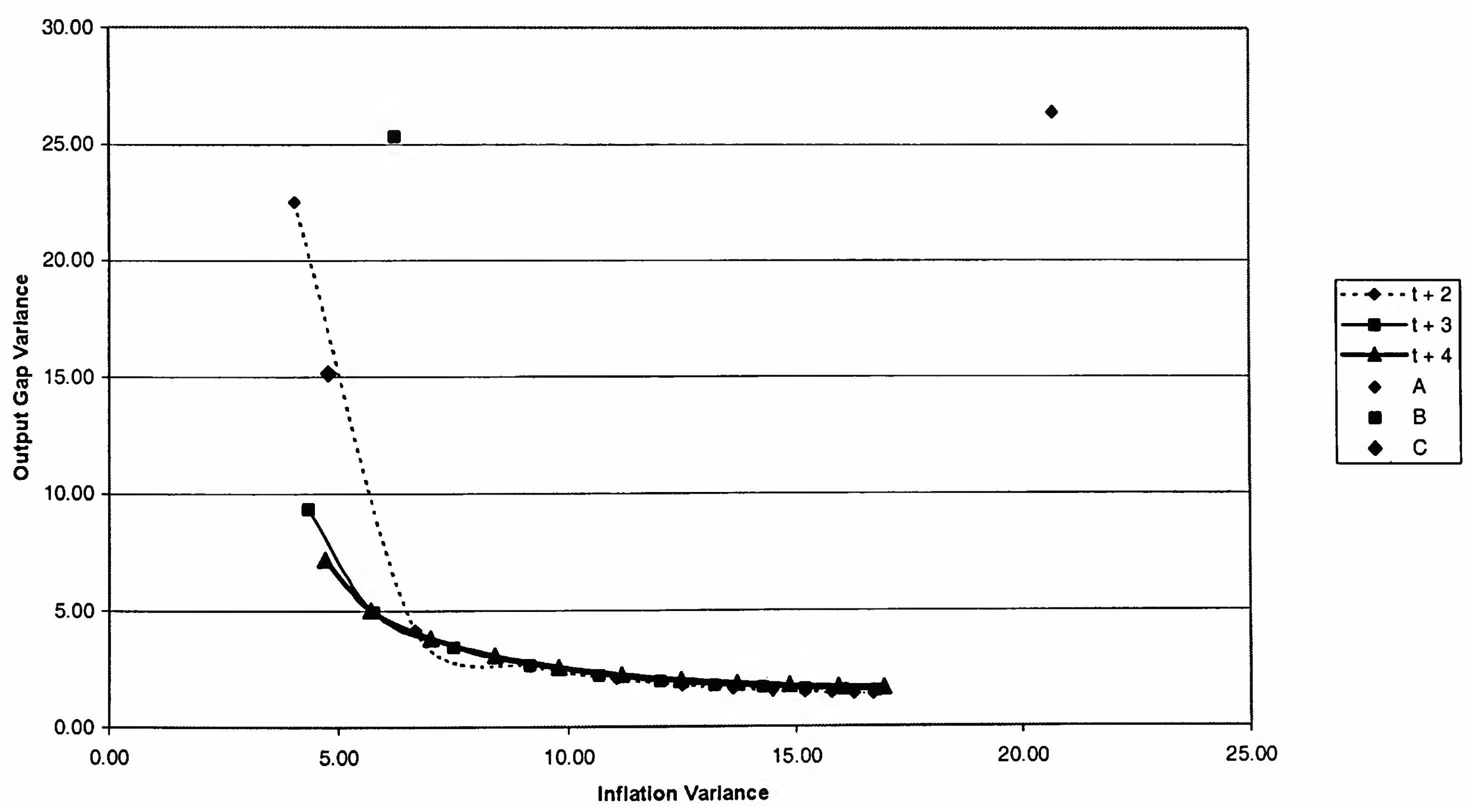
10 We conducted some simulations using different values for r, but the results were inferior to the ones presented in this paper.

Table 2
Coefficients Used in the Taylor-Type Rules

Coefficient	Rule A	Rule B	Rule C
α	1.5	5	5
β	0.5	1.5	3

Chart 1a shows how these simple rules perform relative to the optimal ones. Actually, the traditional Taylor rule (A) presents a poor performance. As we increased the weights on both inflation and output gap variance, the performance improved. Rule C can be even considered a reasonable alternative (to the optimal) rule if the Central Bank has a strong bias against inflation variance.

Chart 1a
Efficient Frontier with Aleternatuve Taylor-Type Rules



5 Concluding remarks

In the IS equation, all the estimated coefficients presented the expected sign. The only not significant one was the first difference of the real exchange rate. Estimation of the lead to a Phillips equation pass-through from nominal exchange rate depreciation to inflation (measure by IGP-DI) of approximately 15%. The monetary transmission mechanism from interest rate to inflation implied that each percentage point increase in real interest rate would provoke a 0.12 p.p. decrease in inflation after two quarters and a 0.6 pp in the long run.

Regarding the optimal rules, the stochastic simulation showed that when compared to the variance in inflation, output gap variance is more sensitive to the weights given in the loss function. This sensitiveness drops sharply when the horizon embodied in the loss function rises between 2 to 3 periods. In general, the optimal horizons ranged from 2 to 4 periods and optimization procedures longer than 6 quarters were inefficient.

Finally, sub-optimal but simple rules, like Taylor type rules can perform reasonably well if the Central Bank has a strong bias against inflation variance and if it reacts more fiercely to the output gap and to deviations of inflation than the traditional Taylor rule suggests.

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Appendix

1) Derivation of the optimal rule

The Phillips and IS equations (equations x and y) can be written in matrix notation as:

$$\begin{bmatrix} \pi_t \\ h_t \end{bmatrix} = \begin{bmatrix} \alpha_0 & \alpha_3 & \alpha_4 \\ \beta_0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ \Delta e_t \\ DS_t \end{bmatrix} + \begin{bmatrix} \alpha_1 & \alpha_2 \\ -\beta_1 & \alpha_3 \end{bmatrix} \begin{bmatrix} \pi_{t-1} \\ h_{t-1} \end{bmatrix} + \begin{bmatrix} 0 \\ \beta_1 \end{bmatrix} i_{t-1} + \begin{bmatrix} \varepsilon_\tau \\ n_\tau \end{bmatrix} \qquad \text{(I)}$$

or:

$$X_t = A_0 K_t + A_1 X_{t-1} + A_2 i_{t-1} + \mathrm{E}_t$$

where X is the vector of inflation and output gap; A_i are the coefficient matrices; and E is the error vector.

Through recursive substitution and taking expectations at time t, we find:

$$E_t X_{t+n} = \sum_{j=1}^{n} A_1^{n-j} A_0 \; E_t K_{t+j} + A_1^{n} \; X_t + A_1^{n-1} A_2 i_t \; + \; A_1 A_2 i_{t+n-2|n\geq 3} + A_2 i_{t+n-1|n\geq 2} \qquad \text{(II)}$$

Now, define:

$E_t \tilde{\pi}_{t+n} = [1 \quad 0] \left[\sum_{j=1}^{n} A_1^{n-j} A_0 E_t K_{t+j} + A_1^{n} \; X_t \right]$ as the expectation taken at time t of the component of inflation at (t + n) that does not depend on the interest rate decision at time t.

Also, define:

$a_{1,n} = [1 \quad 0] A_1^{n-1} A_2$, as the coefficient of i_t on expected inflation at (t + n);

$$a_2 = \begin{cases} [1 \quad 0] A_1 A_2 & if\, n \geq 3 \\ 0 & \text{otherwise} \end{cases}$$, as the coefficient of i_{t+n-2} on expected inflation at (t+n)

$a_3 = [1 \quad 0] A_2 = 0$, as the coefficient of i_{t+n-1} on expected inflation at (t+n)

Similarly, define:

$$E_t \tilde{h}_{t+n} = [0 \quad 1] \left[\sum_{j=1}^{n} A_1^{n-j} A_0 E_t K_{t+j} + A_1^n X_t \right]$$ as the expectation taken at time t of the component of output gap at time (t + n) that does not depend on the interest rate decision at time t.

$b_{1,n} = [0 \quad 1] \; A_1^{n-1} A_2$, as the coefficient of i_t on expected output gap at (t + n);

$$b_2 = \begin{cases} [0 \quad 1] A_1 A_2 & \text{if } n \geq 3 \\ 0 & \text{otherwise} \end{cases}$$, as the coefficient of i_{t+n-2} on expected output gap at (t+n)

$$b_3 = \begin{cases} [0 \quad 1] A_2 & \text{if n } \geq 2 \\ 0 & \text{otherwise} \end{cases}$$, as the coefficient of i_{t+n-1} on expected output gap at (t+n)

Therefore:

$$E_t \pi_{t+n} = E_t \tilde{\pi}_{t+n} + a_{1,n} i_t + a_2 i_{t+n-1} \qquad \text{(IV)}$$

and

$$E_t h_{t+n} = E_t \tilde{h}_{t+n} + b_{1,n} i_t + b_2 i_{t+n-2} + b_3 i_{t+n-1} \qquad \text{(V)}$$

The optimization problem is defined as:

$$\min_{i} \ell = \frac{\lambda}{2} \sum_{j=1}^{n} \rho^j E_t (\pi_{t+j} - \pi_t^*)^2 + \frac{(1-\lambda)}{2} \sum_{j=1}^{n} \rho^j E_t (h_{t+j})^2$$ [11]

where ρ is the discount factor and λ is the weight given to inflation variance in the loss function.

Needs to assume $i_t = i_{t+n-1} = i_{t+n-2}$

Substituting (IV) and (V) into the loss function and solving for the optimal interest rate, i_t^*, we find:

$$i_t^* = \frac{-\left\{ \lambda \sum_{j=1}^{n} \rho^j (E_t \tilde{\pi}_{t+j} - \pi_t^*) a_{i,j} + (1-\lambda) \sum_{j=1}^{n} \rho^j E_t h_{t+j} b_{1,j} \right\}}{\lambda \sum_{j=1}^{n} \rho^j a_{i,j} (a_{i,j} + a_2) + (1-\lambda) \sum_{j=1}^{n} \rho^j b_{1,j} (b_{1,j} + b_2 + b_3)}$$

11 Strella and Mishkin (s.d) shows that if model parameters are uncorrelated with interest rate, the optimization problem above is the same as:

$$\min_{i_t} \ell = \frac{\lambda}{2} \sum_{j=1}^{n} \rho^j (E_t \pi_{t+j} - \pi_t^*)^2 + \frac{(1-\lambda)}{2} \sum_{j=1}^{n} \rho^j (E_t h_{t+j})^2$$