Economics Bulletin

Volume 33, Issue 3

Calvo-type rules and the forward-looking behavior of inflation targeting central banks

Eurilton Araújo
Central Bank of Brazil and FUCAPE Business School

Débora Gouveia
Insper Institute of Education and Research

Abstract

We estimate small open economy models in which inflation targeting central banks respond to a discounted infinite sum of expected inflation and output gaps (Calvo-type rules). The results support Calvo-type rules for Australia and Canada, and suggest longer targeting horizons for inflation compared with output gaps.

Financial support from the Brazilian Council of Science and Technology (CNPq) is gratefully acknowledged. The views expressed in this paper are those of the authors and should not be interpreted as representing the positions of the Central Bank of Brazil.
Citation: Eurilton Araújo and Débora Gouveia, (2013) "Calvo-type rules and the forward-looking behavior of inflation targeting central banks", *Economics Bulletin*, Vol. 33 No. 3 pp. 2042-2051.
Contact: Eurilton Araújo - eurilton@gmail.com, Débora Gouveia - dgouveia@al.insper.edu.br.
Submitted: July 03, 2013. **Published:** August 13, 2013.

1. Introduction

Modern central banks stress price stability as their main objective over a medium-term horizon. For instance, inflation targeting countries announce the target in advance for a given time horizon. Consequently, interest rate decisions should be based on inflation expectations and forecasts of future economic conditions.

In general, it is important for the policy instrument to respond directly to inflation forecasts bacause this response allows central banks to deal with the consequences of the transmission lags for monetary policy. If central banks only respond to current inflation, they will be probably acting too late in order to offset the effects of inflationary pressures that have been building up. They need to strike preemptively, responding to forecasts and allowing time for monetary policy to be fully effective. Thus, the forecast horizons depend on the length of the transmission lags. In addition, in the process of forming these forecasts, central banks use all available information that can be helpful in predicting future inflation, taking into account a wide and complex set of economic factors.

This forward-looking behavior anchors private expectations and improves the credibility of monetary policy since it convinces private agents that central banks can anticipate inflation shocks by extracting signals of future inflation dynamics from a large array of current economic information and can act tempestively to offset their effects on the economy. In this context, assessing the degree of forward-lookingness implicit in monetary policy decisions is an important empirical question.

Clarida et al. (1998, 2000) estimated forward-looking Taylor rules, setting the targeting horizons for the forecasts of inflation and the output gap at particular values. Hence, the targeting horizons were not part of the estimated parameters defining the policy rule. Levine et al. (2007) proposed an inflation-forecast-based rule (the Calvo-type rule) which is less prone to induce indeterminacy in macroeconomic models. In addition, this rule allows researchers to directly estimate the targeting horizons for the feedback variables. Gabriel et al. (2009) used GMM to estimate such rule for the U.S.

In this paper, we extend Gabriel et al. (2009) in the following directions. First, we consider different targeting horizons for inflation and output gaps forecasts. Second, we study countries that target inflation explicitly (Australia, Canada and New Zealand), providing empirical evidence that complements their analysis of U.S. policymaking. Third, we use a fullinformation likelihood-based approach for estimation, applying Calvo-type rules in a small open economy model.

Researchers have estimated and studied Taylor rules for the countries we investigate[1]. This literature generally supports forward-looking Taylor rules, but it does not consider the Calvo-type rule as an alternative specification. Our results support Calvo-type rules as plausible descriptions of monetary policy decisions for Australia and Canada, and suggest longer targeting horizons for inflation compared with output gaps.

2. The Model

We estimate a small open economy new Keynesian model, as developed by Buncic and Melecky (2008). The following equations describe the domestic economy.

$$y_t = \rho_y E_t y_{t+1} + (1-\rho_y)y_{t-1} - \delta_1(r_{t-1} - E_{t-1}\pi_t) + \delta_2 q_{t-1} + \delta_3 y_t^* + \varepsilon_t^{is} \quad (1)$$

$$\pi_t = \rho_\pi E_t \pi_{t+1} + (1-\rho_\pi)\pi_{t-1} + \lambda_1 y_t + \lambda_2 q_t + \varepsilon_t^{as} \quad (2)$$

$$E_t \Delta q_{t+1} = (r_t - E_t \pi_{t+1}) - (r_t^* - E_t \pi_{t+1}^*) - \varepsilon_t^{rer} \quad (3)$$

The domestic variables are the output gap (y_t), inflation (π_t), the interest rate (r_t) and the real exchange rate (q_t). The foreign variables are the U.S. output gap (y_t^*), inflation (π_t^*) and interest rate (r_t^*). We assume that the foreign variables evolve according to the following autoregressive processes: $y_t^* = \rho_{y^*} y_{t-1}^* + \eta_t^{y^*}$, $\pi_t^* = \rho_{\pi^*}\pi_{t-1}^* + \eta_t^{\pi^*}$ and $r_t^* = \rho_{r^*} r_{t-1}^* + \eta_t^{r^*}$. The random variables $\eta_t^{y^*}$, $\eta_t^{\pi^*}$ and $\eta_t^{r^*}$ are normally distributed with variances $\sigma_{y^*}^2, \sigma_{\pi^*}^2$ and $\sigma_{r^*}^2$.

Expression (1) is a dynamic IS equation describing aggregate demand; expression (2) is a new Keynesian Phillips curve describing aggregate supply; and expression (3) is the uncovered interest rate parity equation. For each equation, we have stochastic disturbances ε_t^{is}, ε_t^{as} and ε_t^{rer}, which follow

[1] Here is a brief list of papers on Taylor rules for the countries in our sample. For Australia, we emphasize Brower & Gilbert (2005). For Canada, we highlight Cayen, Corbett and Perier (2006). For New Zealand, we stress Huang, Margaritis and Mayes (2001). Lubik & Schorfheide (2007) and Dong (2013) provide estimated Taylor rules for the three countries.

autoregressive processes $\varepsilon_t^j = \rho_j \varepsilon_{t-1}^j + u_t^j$, where u_t^j is normal with zero mean and variance σ_j^2 for $j \in \{is, as, rer\}$.

As in Gabriel et al. (2009), the following equations describe monetary policy.

$$r_t = \rho_m r_{t-1} + \varphi_1 \Theta_t + \varphi_2 \Psi_t + \varepsilon_t^r \tag{4}$$

$$\Theta_t = (1 - \varphi_3) E_t(\pi_t + \varphi_3 \pi_{t+1} + \varphi_3^2 \pi_{t+2} + \varphi_3^3 \pi_{t+3} + ...) \tag{5}$$

$$\Psi_t = (1 - \varphi_4) E_t(y_t + \varphi_4 y_{t+1} + \varphi_4^2 y_{t+2} + \varphi_4^3 y_{t+3} + ...) \tag{6}$$

Equations (4) to (6) describe the Calvo-type monetary policy rule. The coefficients φ_3 and φ_4 satisfy the restrictions $0 < \varphi_3 < 1$ and $0 < \varphi_4 < 1$. We rewrite equations (5) and (6) more conveniently as:

$$\Theta_t = (1 - \varphi_3)\pi_t + \varphi_3 E_t(\Theta_{t+1}) \tag{7}$$

$$\Psi_t = (1 - \varphi_4) y_t + \varphi_4 E_t(\Psi_{t+1}) \tag{8}$$

In the Calvo-type rule, ρ_m captures interest rate inertia, and φ_1 and φ_2 denote policymakers' responses to discounted inflation rates and output gaps, respectively. This rule is analogous to the specification of Calvo (1983) for price-setting behavior. In short, the rule allows for feedback from expected future inflation rates and output gaps that continues at any period t with probabilities φ_3 and φ_4, respectively. Moreover, the mean forecast horizons for inflation and the output gap are $\frac{\varphi_3}{1-\varphi_3}$ and $\frac{\varphi_4}{1-\varphi_4}$, respectively. In addition, we introduce a monetary policy shock that follows an autoregressive process $\varepsilon_t^r = \rho_r \varepsilon_{t-1}^r + u_t^r$, where u_t^r is normal with zero mean and variance σ_r^2.

3. Empirical Analysis

3.1. Data and Estimation

We analyze Australia, Canada and New Zealand, employing quarterly data from 1991 to 2009. We compute inflation as the log difference in CPI. The percentage deviation of output from its trend, obtained from the Hodrick-Prescott filter, measures the output gap. The U.S. economy is the proxy for the rest of the world. The real exchange rate is the log difference between the nominal exchange rate and the ratio between the U.S. and

Economics Bulletin, 2013, Vol. 33 No. 3 pp. 2042-2051

domestic CPIs. For Australia, the data come from the Reserve Bank of Australia website. For Canada and New Zealand, we compiled the data from the IFS database. Finally, U.S. data come from the FRED database. We use y_t, π_t, r_t, Δq_t, y_t^*, π_t^* and r_t^* as observable variables, demeaning all series prior to estimation. Equations (1) to (4), (7), (8), the autoregressive processes for the foreign variables and the shocks compose the small open economy model.

We estimate the parameters using likelihood-based Bayesian methods[2], which combine prior information with information contained in a given data set. Consider the vector Φ containing the parameters of the model. The prior density $p(\Phi)$ summarizes the non-sample information. Let Y_T denote the observed macroeconomic series of length T. The likelihood function $p(Y_T|\Phi)$ contains all the information in the sample Y_T. Since the solution of the model takes the form of a state space representation, researchers compute the likelihood function by means of the Kalman filter algorithm. Then, for any specification of the prior distribution, the Bayes rule allows researchers to update the prior using the likelihood function. Therefore, the posterior distribution is $p(\Phi|Y_T) = \frac{p(Y_T|\Phi)p(\Phi)}{p(Y_T)}$. In general, analytical expressions for posterior distributions are rare. Thus, the strategy is to find a numerical approximation of the posterior distribution of Φ, by drawing elements belonging to it, employing Bayesian simulation techniques[3]. Moreover, in the Bayesian framework, we compare models by means of the ratio of marginal likelihoods for different models. The expression for the computation of the marginal likelihood is $p(Y_T) = \int p(Y_T|\Phi)p(\Phi)d\Phi$.

Table 1 shows the priors for the parameters and reports the mean and standard deviation of each prior distribution. We use beta distributions for the parameters restricted to the interval $[0, 1]$, inverse gamma distributions for standard errors of the shocks and normal distributions for the remaining parameters.

[2]Chapter fourteen of Dave and DeJong (2011) gives a more complete account of Bayesian estimation procedures.

[3]A popular family of simulation techniques is the Markov chain Monte Carlo (MCMC) methods. In this paper, we use a particular MCMC method called Metropolis-Hastings algorithm.

Table 1. Prior Distributions

Parameters	Australia	Canada	New Zealand
	Prior (mean, std dev)	Prior (mean, std dev)	Prior (mean, std dev)
ρ_y	Beta(0.5,0.2)	Beta(0.5,0.2)	Beta(0.5,0.2)
δ_1	Normal(0.05,0.01)	Normal(0.05,0.01)	Normal(0.05,0.01)
δ_2	Normal(0.05,0.01)	Normal(0.05,0.01)	Normal(0.05,0.01)
δ_3	Normal(0.05,0.01)	Normal(0.05,0.01)	Normal(0.05,0.01)
ρ_π	Beta(0.5,0.2)	Beta(0.5,0.2)	Beta(0.5,0.2)
λ_1	Normal(0.05,0.005)	Normal(0.05,0.005)	Normal(0.05,0.005)
λ_2	Normal(0.05,0.01)	Normal(0.05,0.01)	Normal(0.05,0.01)
φ_3	Beta(0.5,0.1)	Beta(0.5,0.1)	Beta(0.5,0.1)
φ_4	Beta(0.5,0.1)	Beta(0.5,0.1)	Beta(0.5,0.1)
φ_1	Normal(1.5,0.2)	Normal(1.5,0.2)	Normal(1.5,0.2)
φ_2	Normal(0.5,0.2)	Normal(0.5,0.2)	Normal(0.5,0.2)
ρ_m	Beta(0.5,0.2)	Beta(0.5,0.2)	Beta(0.5,0.2)
ρ_{is}	Beta(0.5,0.2)	Beta(0.5,0.2)	Beta(0.5,0.2)
ρ_{as}	Beta(0.5,0.2)	Beta(0.5,0.2)	Beta(0.5,0.2)
ρ_{rer}	Beta(0.5,0.2)	Beta(0.5,0.2)	Beta(0.5,0.2)
ρ_r	Beta(0.5,0.2)	Beta(0.5,0.2)	Beta(0.5,0.2)
ρ_{y^*}	Beta(0.5,0.2)	Beta(0.5,0.2)	Beta(0.5,0.2)
ρ_{π^*}	Beta(0.5,0.2)	Beta(0.5,0.2)	Beta(0.5,0.2)
ρ_{r^*}	Beta(0.5,0.2)	Beta(0.5,0.2)	Beta(0.5,0.2)
σ_{is}	Inverse Gamma(0.5,10)	Inverse Gamma(0.1,10)	Inverse Gamma(0.5,10)
σ_{as}	Inverse Gamma(0.5,10)	Inverse Gamma(0.1,10)	Inverse Gamma(0.5,10)
σ_{rer}	Inverse Gamma(4,10)	Inverse Gamma(0.1,10)	Inverse Gamma(4,10)
σ_r	Inverse Gamma(1,10)	Inverse Gamma(0.1,10)	Inverse Gamma(1,10)
σ_{y^*}	Inverse Gamma(0.5,10)	Inverse Gamma(0.1,10)	Inverse Gamma(0.5,10)
σ_{π^*}	Inverse Gamma(0.5,10)	Inverse Gamma(0.1,10)	Inverse Gamma(0.5,10)
σ_{r^*}	Inverse Gamma(0.5,10)	Inverse Gamma(0.1,10)	Inverse Gamma(0.5,10)

3.2. Results

Table 2 shows the estimation results, i.e., posterior means and 90% highest posterior density intervals for the estimated parameters. The data seem to be informative about the parameters. In our sample, the data are not informative enough about δ_3 (Australia and New Zealand) and λ_1 for all countries. Concerning the Calvo-type rule parameters, the data are more informative about φ_3 than about φ_4. For Australia and New Zealand, the posterior mean of φ_4 is close to its prior mean, implying a mean forecast horizon of approximately one quarter. In contrast, the mean forecast horizon based on posterior means of φ_3 are 3.15 quarters (Australia), 19 quarters (Canada) and 1.5 quarters (New Zealand).

Additionally, we compare models with a Calvo-type rule with specifications featuring a contemporaneous Taylor rule, i.e., we impose the restrictions $\varphi_3 = \varphi_4 = 0$. We compare the ratio of marginal likelihoods associated with model M_1 (Calvo-type rule) and model M_2 (simple Taylor rule). Thus, the comparison is based on the ratio $R_{12} = \frac{p(M_1|y)}{p(M_2|y)}$ in logarithmic scale, where $p(M_j|y)$ denotes the marginal likelihood of model M_j. In the field of Bayesian estimation, if $\log_{10} R_{12} > 1$ then the empirical evidence strongly favors the Calvo-type rule. The values of $\log_{10} R_{12}$ are 6.13 (Australia), 54.13 (Canada) and -1.46 (New Zealand). Thus, the evidence supports Calvo-type rules over contemporaneous Taylor rules ($\varphi_3 = \varphi_4 = 0$) for Australia and Canada, but not for New Zealand.

Central banks in Australia and Canada seem to put substantial weight on forward-looking behavior concerning inflation. In what follows, we argue that this characteristic is an ingredient of their flexible inflation targeting frameworks. In fact, according to Hammond (2012), Australia explicitly targets inflation over the medium-term horizon, without defining precisely this concept. Thus, the implied range for the posterior of φ_3 (from 1.93 to 6.35 quarters) contains plausible definitions of the medium-term horizon over which the central bank forecasts and targets inflation. For Canada, the long inflation mean forecast horizon is consistent with evidence, presented in Ruge-Murcia (2009) and Kamenik et al. (2008), that Canada has followed some form of price level targeting. Since Nessén and Vestin (2005) show that targeting inflation over a lengthy time horizon resembles the outcomes from some form of price level targeting, our findings support the view that the Bank of Canada partially corrects the effects of inflation shocks on the price level path.

New Zealand is a different case. Estimation results suggest that expected inflation target leads to a worse model fit. Lubik and Schorfheide (2007) and Dong (2013), using structural new Keynesian models with standard forward-looking Taylor rules, report similar findings. A plausible explanation for this finding relies on Bache et al. (2011) who show that the Calvo-type interest rate rule is optimal under central bank's preference[4] for a gradual adjustment toward a non-inertial target rate[5]. Thus, compared with Australia and Canada, our finding suggests that the Reserve Bank of New Zealand attaches a relative small weight on costs of deviating from a specified target rate, leading to a worse model fit when we use the Calvo-typer rule.

[4]This preference differs from the interest rate smoothing term in stardard loss functions which reflects costs of changing the interest rate.

[5]A simple Taylor rule may describe this target rate.

Table 2. Posterior Distributions

Parameters	Australia	Canada	New Zealand
	Posterior Mean; 90% HPDI	Posterior Mean; 90% HPDI	Posterior Mean; 90% HPDI
ρ_y	0.834; [0.723, 0.942]	0.564; [0.507, 0.622]	0.755; [0.615, 0.905]
δ_1	0.043; [0.027, 0.059]	0.065; [0.051, 0.079]	0.043; [0.027, 0.059]
δ_2	0.042; [0.029, 0.054]	0.002; [0.001, 0.003]	0.028; [0.018, 0.038]
δ_3	0.051; [0.033, 0.065]	0.035; [0.019, 0.049]	0.051; [0.034, 0.067]
ρ_π	0.886; [0.805, 0.976]	0.944; [0.905, 0.986]	0.823; [0.713, 0.939]
λ_1	0.051; [0.042, 0.058]	0.051; [0.043, 0.057]	0.052; [0.044, 0.061]
λ_2	0.001; [-0.001, 0.002]	0.001; [-0.001, 0.002]	0.001; [-0.001, 0.002]
φ_3	0.759; [0.659, 0.864]	0.950; [0.947, 0.953]	0.610; [0.463, 0.748]
φ_4	0.518; [0.364, 0.672]	0.604; [0.421, 0.799]	0.487; [0.334, 0.633]
φ_1	1.216; [0.873, 1.566]	1.233; [1.059, 1.391]	1.413; [1.100, 1.734]
φ_2	0.591; [0.391, 0.793]	0.128; [-0.004, 0.297]	0.767; [0.505, 1.023]
ρ_m	0.919; [0.861, 0.981]	0.929; [0.871, 0.990]	0.883; [0.807, 0.965]
ρ_{is}	0.889; [0.849, 0.929]	0.609; [0.474, 0.738]	0.918; [0.876, 0.962]
ρ_{as}	0.174; [0.041, 0.300]	0.071; [0.022, 0.119]	0.210; [0.054, 0.356]
ρ_{rer}	0.814; [0.741, 0.891]	0.929; [0.884, 0.977]	0.817; [0.731, 0.908]
ρ_r	0.554; [0.413, 0.695]	0.546; [0.327, 0.794]	0.309; [0.162, 0.456]
ρ_{y^*}	0.119; [0.021, 0.209]	0.102; [0.015, 0.182]	0.116; [0.022, 0.208]
ρ_{π^*}	0.894; [0.829, 0.962]	0.878; [0.806, 0.955]	0.895; [0.830, 0.961]
ρ_{r^*}	0.945; [0.912, 0.979]	0.795; [0.749, 0.841]	0.944; [0.911, 0.978]
σ_{is}	0.298; [0.235, 0.361]	0.045; [0.032, 0.057]	0.184; [0.137; 0.228]
σ_{as}	0.417; [0.334, 0.498]	0.533; [0.456, 0.610]	0.301; [0.239, 0.363]
σ_{rer}	1.232; [0.928, 1.527]	0.419; [0.182, 0.642]	1.442; [1.054, 1.809]
σ_r	0.494; [0.395, 0.591]	0.086; [0.061, 0.115]	0.831; [0.699, 0.958]
σ_{y^*}	0.187; [0.161, 0.212]	0.183; [0.157, 0.207]	0.186; [0.161, 0.211]
σ_{π^*}	0.856; [0.738, 0.969]	0.852; [0.737, 0.964]	0.857; [0.739, 0.972]
σ_{r^*}	0.508; [0.435, 0.575]	0.610; [0.514, 0.702]	0.505; [0.436, 0.572]

Note:We use the Metropolis-Hastings algorithm, running separate chains composed of 400,000 draws, discarding the first 25% as initial burn-in. We assess the convergence of the estimations using diagnostic statistics described in Brooks and Gelman (1998).

4. Conclusion

We estimated small open-economy models for Australia, Canada and New Zealand with Calvo-type rules describing monetary policy as an alternative to Taylor rules. Empirical evidence supports Calvo-type rules for Australia and Canada, suggesting a substantial degree of forward-looking behavior concerning inflation for these countries. In contrast, the evidence favors a contemporaneous Taylor rule for New Zealand. In addition, our estimates also suggest that targeting horizons for inflation tend to be longer compared with output gaps.

Our findings have some implications for economic agents living in Australia and Canada. First, to perform forecasting exercises, central banks have to develop more precise forecasting models for long horizons and select variables which are informative about economic conditions far into the future. Second, private agents have to gather the best available information to predict economic conditions for each relevant horizon to infer monetary policy changes in order to currently set prices and wages, as well as to choose the levels of consumption and investment. This information gathering can be more costly compared with the costs of building the information set needed for short-term projections. Moreover, aggregate demand, as well as current nominal variables, may become more sensitive to revisions of expectations for long horizons. For economic agenst living in New Zealand, these informational costs are smaller since the relevant horizons are shorter.

References

Bache, I.,Ø. Røisland and K. Torstensen (2011) "Interest rate smoothing and "Calvo type" interest rate rules: A comment on Levine, McAdam and Pearlman, 2007" *International Journal of Central Banking* **3**, 79-90.

Brooks, S. and A. Gelman (1998) "General methods for monitoring convergence of iterative simulations" *Journal of Computational and Graphics Statistics* **7**, 434-455.

Buncic, D. and M. Melecky (2008) "An Estimated New Keynesian Policy Model for Australia" *The Economic Record* **84**, 1-16.

Calvo, G.A. (1983) "Staggered prices in utility-maximizing framework" *Journal of Monetary Economics* **12**, 383-398.

Cayen, J.P., A. Corbett and P. Perrier (2006) "An optimized monetary policy rule for ToTEM" Bank of Canada working paper number 2006-41.

Clarida, R., J. Galí and M. Gertler (1998) "Monetary Policy Rules in Practice: Some International Evidence" *European Economic Review* **42**, 1033-1067.

Clarida, R., J. Galí and M. Gertler, 2000 "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory" *The Quarterly Journal of Economics* **115**, 147-180.

Dave, C. and D. DeJong (2011) *Structural Macroeconometrics, 2nd edition*, Princeton University Press: Princeton.

De Brower, G. and J. Gilbert (2005) "Monetary Policy Reaction Function in Australia" *The Economic Record* **81**, 124-134.

Dong, W. (2013) "Do central banks respond to exchange rate movements? Some new evidence from structural estimation" *Canadian Journal of Economics* **46**, 555-586.

Gabriel, V.J., P. Levine and C. Spencer (2009) "How Forward-Looking is the Fed? Direct estimates from a Calvo-Type Rule" *Economics Letters* **104**, 92-95.

Hammond, G. (2012) *Centre for Central Banking Studies Handbook n. 29: State of the Art of Inflation Targeting – 2012,* Bank of England: London.

Kamenik, O., H. Kiem, V. Klyuev and D. Laxton, 2008 "Why is Canada's price level so predictable?" International Monetary Fund working paper number 08/25.

Huang, A., D. Margaritis and D. Mayes (2001) "Monetary policy rules in practice: Evidence from New Zealand" Bank of Finland discussion paper number 18-2001.

Levine, P., P. McAdam and J. Pearlman (2007) "Inflation forecast rules and indeterminacy: a puzzle and a resolution" *International Journal of Central Banking* **4**, 77-110.

Lubik, T.and F. Schorfheide (2007) "Do central banks respond to exchange rate movements? A structural investigation" *Journal of Monetary Economics* **54**, 1069-1087.

Nessén, M and D. Vestin (2005) "Average Inflation Targeting" *Jounal of Money, Credit and Banking* **37**, 837-863.

Ruge-Murcia, F. J. (2009) "Do inflation-targeting Central Banks implicitly target the price level?" University of Montral working paper number 2009-15.