Taylor rules, central bank preferences and inflation targeting

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Abstract

The objective of this paper is to infer the policy preferences of three inflation targeting central banks, Australia, Canada and New Zealand, using an estimated New Keynesian small open economy model. While I assume that the monetary authorities optimise, I depart from previous research by assuming that monetary policy is implemented via simple Taylor-type rules, as suggested by most of the empirical literature. I then derive the weights in the objective function that make the resulting optimal interest rate rule coincide with its estimated counterpart. Therefore, from the central bank's point of view, actual policy is optimal.

Keywords: Small open economies; monetary policy; policy preferences; Taylor rule; inverse optimal control; inflation targeting.

JEL Classification Numbers: E52; E58; E61; F41.

*Address: 9 Mappin Street, Sheffield, UK, S1 4DT; e-mail: *j.paez-farrell@sheffield.ac.uk*. A previous version of this paper was circulated under the title 'Taylor rules and central bank preferences in three small open economies'. The paper has greatly benefited from discussions with Pelin Ilbas, Tatiana Kirsanova, Charles Nolan, Joe Pearlman, Konstantinos Theodoridis, Christoph Thoenissen and Eugenia Vella as well as seminar participants at the Dynare Conference in Brussels 2015, the Money, Macro and Finance Conference (UK) 2015 and the Sheffield Macroeconomics Workshop 2015.

1 Introduction

The starting premise underlying this paper is that one should think of policy makers as optimising agents, with the result that policy actions are neither truly exogenous or random. Instead, they emanate from policy makers' objectives combined with their view of the world – their perceived model – in addition to any other constraints that they may be subject to. Viewed this way, from the policy maker's point of view policies in place are already optimal and criticisms of current policy or normative assessments on the gains from modifying current policies should take these factors into consideration.[1] It is for this reason that understanding the underlying factors that drive policy makers to make particular choices can provide useful insights.

The aim of this paper is to suggest that actual policy reflects optimising behaviour by the central bank, regardless of whether it is best described by a simple interest rate rule or as a targeting rule derived from a specific objective function. In other words, if actual policy is best described by a Taylor-type rule then it must be because it is optimal for the policy maker to do so given the constraints she faces. Svensson (2003) argues that one should consider central bankers to be as optimising and forward-looking as private agents and that modelling monetary policy via simple instrument rules is highly unsatisfactory. In this paper I propose an alternative interpretation: optimising behaviour on the part of policy makers and simple rules need not be mutually inconsistent.[2] Viewed this way reinstates the symmetric treatment for all economic agents within the model that Wolden Bache et al. (2010) suggest is a desirable feature in a model and there may be several reasons why a rational and optimising central bank may follow a Taylor-type rule. In an inflation targeting framework a simple instrument rule is easily verifiable and would help assess central bank performance but more importantly, it would provide greater transparency and help private agents understand policy actions. Hence, the use of simple interest rate rules does not represent either a lack of optimising behaviour or sophistication on the part of the central bank and it could even be interpreted that it is the lack of full information on the part of the private sector that compels the policy maker to use a simple rule with the objective of being clearly understood.

This paper is therefore the first to show that Taylor-type rules, as descriptions of actual monetary

[1] See Taylor (2014) for a recent example.

[2] It should be noted that the key arguments in this paper are not restricted to monetary policy alone.

policy, are consistent with optimising behaviour on the part of central banks as long as a suitable objective function is used.

For the three economies considered in this paper, I find that all three of their central banks share similar objectives. In all cases interest rate smoothing is an important concern, as are the volatilities of both output and the real exchange rate. However, New Zealand shows the least concern with respect to output stabilisation and this is consistent with its remit of focusing on price stability. Most importantly, I also find that interaction terms, in the form of the output-inflation covariance, are essential if one is to account for the observed behaviour of interest rates. Lastly, I also show that even if interest rates do not respond directly to exchange rate movements its stabilisation may still be a policy objective.

There are two main approaches to modelling monetary policy. Much of the empirical and positive literature models policy in the form of simple interest rate rules, based on Taylor's (Taylor, 1993) seminal paper.[3] Even if no central bank explicitly follows a Taylor-type rule it nonetheless provides a reasonably good description of actual interest rate behaviour and performs well across models. Simple interest rate rules are transparent, easily understood and often approximate the optimal policy in forward-looking models (Batini and Haldane, 1999). Nonetheless, analysing interest rate rules in isolation tells us little about a central bank's objectives (Dennis, 2006).

The second strand of research has focused on optimal policy by combining the central bank's loss function subject to constraints to derive an optimal rule.[4] Although the objective function may be model-consistent or ad hoc the resulting policy is generally described in the form of targeting rules (Svensson and Woodford, 2004). Within this framework simple interest rate rules are suboptimal since with fully optimal pre-commitment or optimal discretionary rules all state variables enter the rule (Dennis, 2004b).

There is an inconsistency between these two view of monetary policy as the actual behaviour of interest rates – the estimated Taylor rule – has differed markedly from the path that would be

[3]See, for example, Clarida et al. (1998) and Paez-Farrell (2009).

[4]A word of caution is in order. Generally, optimal policy implies that it is the one that maximises the representative agent's welfare but in the literature referred to in this paper it is interpreted as the one that maximises the policy maker's objective function. The two need not coincide.

prescribed by the optimal policy rules.[5] This may be seen as evidence that actual monetary policy has not been optimal but it can also arise from not using the objective function that describes the policy maker's preferences (Dennis, 2006). In order to overcome this discrepancy we need to use the correct objective function and weights that guide policy.

In recent years there has been increased interest in using models incorporating optimal policy to estimate policy makers' preferences. The majority of the studies on central bank preferences thus far have relied on combining a macroeconomic model with the policy maker's first order conditions.[6] Furthermore, much of this has been carried out with backward-looking models, thereby making them subject to the Lucas critique and ignoring the role of expectations in affecting the strategic decisions between the policy maker and the private sector. For example, Salemi (1995) uses a vector autoregression to model the central bank's constraint while the majority of the early literature on this topic used variants of the Rudebusch and Svensson (1999) backward-looking model.[7]

More recent work has estimated policy preferences in forward-looking models including Salemi (2006), Givens (2012), Dennis (2004a) and Kam et al. (2009), with the latter being the first to do so employing Bayesian methods. Similarly, Ilbas (2010) employed the Smets and Wouters (2003) model to estimate the preferences of the ECB assuming that policy operated under commitment, finding that the central bank placed a large weight on inflation. Ilbas (2012) estimated the Smets-Wouters model on US data with the aim, as in Dennis (2004a), of determining whether there had been a break in monetary policy after 1982. A further methodological extension is provided by Chen et al. (2013) and Chen et al. (2014) who estimate a DSGE model incorporating Markov switching in both policy preferences and shocks' volatilities on US and euro zone data, respectively. They consider a policy objective function that possesses the same variables as the approximation to the representative agent's welfare function but allow the weights to be endogenously determined. In both cases, the best fit is provided by the model where policy operates under discretion.

In a link to the empirical literature on Taylor rules discussed above, some of these papers have also

[5]See, for example, the papers in Taylor (1999).

[6]It is worth noting that that there are several ingenious alternative approaches. For example, Smith (2009) attempts to extract policy makers' preferences at the Reserve Bank of New Zealand by directly having them answer sets of questions related to policy trade-offs, while Levieuge and Lucotte (2014) relies on the central bank's first order conditions to obtain a measure related to the relative concern for inflation stabilisation.

[7]See Favero and Rovelli (2003), Ozlale (2003) and Dennis (2006).

compared the empirical performance of models embodying optimal policy to alternatives where policy is described by an ad hoc Taylor-type rule. On this front, the evidence is mixed, with several authors finding that the model with an exogenous Taylor-type rule provides a better explanation of the data. These include Adolfson et al. (2011) using Swedish data over the period 1993Q1 to 2007Q3, Ilbas (2010) for the euro area and Adjemian et al. (2008) for the US when comparing the interest rate rule to the Ramsey policy. Wolden Bache et al. (2010) compare the empirical fit of the two policies in an estimated model of the Norwegian economy over the period 1987Q1 to 2007Q4 and their forecasting performances are almost identical, even though the simple interest rate rule is modelled without an error term. Similarly, Dennis (2006), Givens (2012) and Salemi (2006) find that, based on a likelihood ratio test, the US economy is best characterised by a model with an exogenous interest rule rather than with optimal policy.[8] By contrast, Ilbas (2012), Chen et al. (2013) and Chen et al. (2014) among others have found that model incorporating the optimal policy yields the best fit. However, these comparisons have generally been made against only one specific Taylor-type rule, leaving unanswered the question of whether there may be an alternative interest rate rule that outperforms optimal policy.

Regardless of the outcome, comparisons between ad hoc Taylor rules and optimal policy have always been interpreted as assessing whether actual policy was set optimally.[9] Indeed, Wolden Bache et al. (2010) argue that the optimal policy approach provides a more symmetric treatment of both the policy maker and the private sector by assuming that both sets of agents behave optimally and make efficient use of all the available information.

In this paper I propose a simple but novel method for deriving the weights in the objective function of a central bank in a manner that is consistent with the empirical literature by assuming that monetary policy is implemented via a Taylor-type rule. This is therefore a problem of inverse optimal control such that the coefficients in the estimated interest rate rule are the result of the monetary authority optimising an initially undetermined objective function. Unlike previous research on policy objectives the procedure I propose estimates the interest rate rule without imposing any optimality constraints upon it; instead, the full model is estimated and the policy rule coefficients

[8]However, when using pseudo-Bayesian analysis the results in Givens (2012) point to discretion as the preferred model.

[9]See Dennis (2006), Ilbas (2010) and Wolden Bache et al. (2010).

are simply those that provide the best fit. This permits a fairly general description of monetary policy, such as an inflation forecast-based interest rate rule to be considered when trying to model the behaviour of the central bank.

To clarify the approach proposed in this paper, the next section provides a simple example using a well known estimated model.

2 An example

To illustrate the merit of the approach, let us re-visit the analysis in Dennis (2006). He used the Rudebusch and Svensson (1999) model estimated on US data over the period 1982Q1-2000Q2. The model is given by

$$y_t = 1.596y_{t-1} - 0.683y_{t-2} - 0.021\left(i^a_{t-1} - \pi^a_{t-1}\right) + g_t \tag{1}$$

$$\pi_t = 0.401\pi_{t-1} + 0.080\pi_{t-2} + 0.407\pi_{t-3} + (1 - 0.401 - 0.080 - 0.407)\,\pi_{t-4} + 0.144y_t + v_t \tag{2}$$

Where y_t, π_t and i_t denote the output gap, the inflation rate and the nominal interest rate, respectively.[10] The superscript denotes annual variables while g_t and v_t can be interpreted as demand and supply shocks, respectively, with $\sigma^2_g = 0.312$ and $\sigma^2_v = 0.492$. Dennis (2006) then considers a standard loss function of the form

$$Loss = E_t \sum_{j=0}^{\infty} \beta^j \left((\pi^a_{t+j})^2 + \lambda y^2_{t+j} + \nu \Delta i^2_{t+j}\right) \tag{3}$$

He then solves for a simple forward-looking Taylor rule whose optimal values in the case where $\lambda = 1$, $\nu = 0.25$ and $\beta = 0.99$ is

[10] Both rates variables are annualised.

$$i_t = 2.633 E_t \pi^a_{t+1} + 1.750 y_t + 0.172 i_{t-1} \tag{4}$$

while its empirical counterpart is given by (standard errors are omitted)

$$i_t = 0.478 E_t \pi^a_{t+1} + 0.131 y_t + 0.807 i_{t-1} + \widehat{\omega}_t \tag{5}$$

As Dennis (2006) points out, there are marked differences between the optimal interest rate rule using a standard loss function with fairly conventional values relative to the estimated rule. One could interpret this as evidence that central banks are not optimising agents. However, using the procedure outlined below with monetary policy constrained to take the form (5), a loss function with a unit coefficient on $\pi_t^{a^2}$ and also containing Δi_t^2, Δy_t^2 and $\pi_t y_t$ with coefficients 15.2, 30 and 7.1, respectively make (5) optimal.[11]

3 The small open economy model

The model used in this paper is based on the New Keynesian small open economy model developed by Justiniano and Preston (2010), which is an extension of Monacelli (2005).[12]

Households consume a basket of domestic and foreign goods while their utility function includes external habits in consumption. Both the domestic and import goods sectors are subject to staggered price setting as well as partial indexation to past inflation. The inclusion of habits and indexation lead the model to exhibit greater persistence in response to shocks. Moreover, the presence of monopolistic competition in the imported goods sector implies that there is incomplete exchange rate pass-through.

There are five groups of agents in this model. Households consume a basket of consumption goods that includes both domestic and foreign goods. They supply labour and can purchase one-period

[11] In the limiting case as β approaches one the loss function can be interpreted in terms of variances, a terminology that will be maintained in the rest of the paper.

[12] Here I only present the main features of the model as well as the resulting log-linearised equations. For the details surrounding all of the model's assumptions as well as the original non-linear equations the reader is referred to Justiniano and Preston (2010).

bonds. Preferences are identical globally and the model assumes the existence of incomplete markets for trading in state-contingent claims. As a result, the efficiency condition for bond holdings by residents gives

$$(1+h)c_t - hc_{t-1} = E_t c_{t+1} - \frac{(1-h)}{\sigma}\left(r_t - E_t\pi_{t+1} - u_t^g + E_t u_{t+1}^g\right) \tag{6}$$

Where c_t is aggregate consumption and q_t is real exchange rate. The rate of consumer price inflation is represented by π_t while the interest rate on domestic nominal one-period bonds is denoted by r_t. The model includes habits in consumption, whose degree is given by h and σ represents the inverse of the elasticity of intertemporal substitution. The variable u_t^g is a preference shock that is assumed to follow an AR(1) process

$$u_t^g = \rho_g u_{t-1}^g + \epsilon_t^g \tag{7}$$

Domestic goods firms produce a differentiated good under monopolistic competition. They are subject to Calvo (1983) pricing, with the probability of re-setting prices optimally each period being equal to $1-\theta_h$. At the same time, the remaining fraction of firms unable to change their prices simply partially index their prices – with indexation parameter δ_h – to the previous period's inflation rate. As a result, the rate of inflation in the domestic goods sector is given by

$$(1+\beta\delta_h)\,\pi_t^h = \beta E_t\pi_{t+1}^h + \delta_h\pi_{t-1}^h + \frac{(1-\beta\theta_h)(1-\theta_h)}{\theta_h}mc_t \tag{8}$$

where β is the household's discount factor and mc_t denotes real marginal cost, which is given by

$$mc_t = \phi y_t - (1+\phi)\mu_t^a + \alpha s_t + \frac{\sigma}{(1-h)}\left(c_t - hc_{t-1}\right) \tag{9}$$

In the expression above $1/\phi$ represents the Frisch labour supply elasticity while μ_t^a is an exogenous technology shock that follows an AR(1) process

$$\mu_t^a = \rho_a \mu_{t-1}^a + \epsilon_t^a \tag{10}$$

The terms of trade, s_t, can be written as

$$\Delta s_t = \pi_t^f - \pi_t^h \tag{11}$$

Where π_t^f is the rate of inflation in the imported good sector. As with the domestic goods sector, similar assumptions pertain to the imported goods retailers. Given their pricing power there will be short-run deviations from the law of one price so that inflation in this sector is given by

$$(1+\beta\delta_f)\,\pi_t^f = \beta E_t \pi_{t+1}^f + \delta_f \pi_{t-1}^f + \frac{(1-\beta\theta_f)\,(1-\theta_f)}{\theta_f}\psi_t + \mu_t^{\pi f} \tag{12}$$

where μ_t^f represents a shock to the markup of import prices over marginal costs and with ψ_t denoting the deviation from the law of one price arising from the pricing power of importing firms

$$\mu_t^{\pi f} = \rho_\pi \mu_{t-1}^{\pi f} + \epsilon_t^{\pi f} \tag{13}$$

$$\psi_t = q_t - (1-\alpha) s_t \tag{14}$$

Ruling out arbitrage opportunities we also have real uncovered interest parity (UIP) where asterisks denote foreign variables

$$E_t q_{t+1} - q_t = r_t - E_t \pi_{t+1} - \left(r_t^* - E_t \pi_{t+1}^*\right) + \chi a_t + u_t^q \tag{15}$$

the domestic economy's net foreign asset position is given by a_t, with χ representing the elasticity of the foreign exchange risk premium to a_t. The model includes a risk premium shock that follows an AR(1) process

$$u_t^q = \rho_q u_t^q + \epsilon_t^q \tag{16}$$

Domestic output, y_t, must also satisfy the market clearing equation

$$y_t = (1-\alpha)c_t + \alpha\eta q_t + \alpha\eta s_t + \alpha y_t^* \tag{17}$$

Given the assumption of a small open economy, world inflation, output and interest rates are assumed to follow autoregressive processes

$$\pi_t^* = \rho_{\pi^*}\pi_{t-1}^* + \epsilon_t^{\pi^*} \tag{18}$$

$$R_t^* = \rho_{R^*}R_{t-1}^* + \epsilon_t^{R^*} \tag{19}$$

$$y_t^* = \rho_{y^*}y_{t-1}^* + \epsilon_t^{y^*} \tag{20}$$

Lastly, in line with much of the empirical literature discussed above, the monetary authority is assumed to follow a Taylor-type rule

$$r_t = (1-\rho_r)\left(\psi_1 E_t\pi_{t+1} + \psi_2\Delta y_t\right) + \rho_r r_{t-1} + \epsilon_t^r \tag{21}$$

The reaction to output growth follows Orphanides (2003). The exclusion of a direct response to the exchange rate is intentional and is done for several reasons. First, a parsimonious representation of the Taylor rule would make monetary policy more transparent and easily understood by the public, which would be regarded as desirable by an inflation targeting central bank. Secondly, the evidence on whether central banks react directly to the exchange rate remains inconclusive.[13] Lastly, I want to determine whether a simple Taylor combined with a concern for exchange rate stabilisation gives rise to optimal simple rules consistent with the actual behaviour of interest rates. In other words, not responding to the exchange rate does not necessarily indicate that the policy

[13] See Lubik and Schorfheide (2007) and Kam et al. (2009).

maker is unconcerned about its volatility.[14]

4 Empirical Analysis

4.1 Data

This paper uses data on three countries – Australia, Canada and New Zealand – are they were among the first to adopt inflation targeting, providing us with a useful benchmark. The model is estimated for each country using quarterly data for the period 1990Q1 to 2007Q2 on output, inflation, interest rates, the real exchange rate and the terms of trade as a data counterpart to the model's measure of foreign goods inflation.[15] In addition, it is also assumed that the foreign block – comprised of output, inflation and the nominal interest rate – is observable and that it is well proxied by US data.

For Australia, the CPI inflation data are adjusted to take into account the introduction of the goods and services tax in 2000-2001. The inflation series for Canada were adjusted for 1991Q1 for similar reasons.

All U.S. data were downloaded from the FRED, while the individual country data are from the IMF's International Financial Statistics database, with the exception of the CPI series for Australia and New Zealand, which were obtained from the Reserve Bank of Australia and the Reserve Bank of New Zealand websites, respectively. The real exchange rate is calculated using U.S. CPI data, the bilateral nominal exchange rate and each country's CPI series. The terms of trade are measured as the ratio of import prices to export prices using the corresponding price deflator from the quarterly national accounts for each economy.

The output series are linearly de-trended while the real exchange rate and terms of trade are differenced. The interest rate and inflation series are de-meaned. Overall, we have eight observable variables and the same number of shocks as is common practice.

[14] The error term ϵ_t^R is introduced in order to avoid stochastic singularity. It can be interpreted as measurement error and will be discussed further below.

[15] The sample ends in 2007Q2 in order to avoid the Great Recession and hence to ensure a single monetary regime.

4.2 Bayesian Estimation

In order to consider the weights in the policy maker's loss function the model's structural parameters must first be estimated. For each of the three economies the model is estimated using Bayesian methods, which derive the posterior density by combining the prior distributions for the model's parameters with the likelihood function, evaluated using the Kalman filter. The posterior kernel is evaluated numerically using the Metropolis-Hastings algorithm, using 5 blocks of $1,000,000$ draws where the first 30% are used as a 'burn-in' period in order to report the mean, the 90% lower and upper bounds and to evaluate the marginal likelihood of the model. Convergence is assessed graphically in order to check and ensure the stability of the posterior distributions as described in Brooks and Gelman (1998).[16]

The values for the priors are mostly taken from Justiniano and Preston (2010) and Kam et al. (2009). Table (1) provides an overview of the priors used, which are the same for the three countries.[17] While the prior densities are relatively dispersed they are nonetheless chosen to ensure consistency with the model's theoretical restrictions. Generally, inverse gamma distributions are used as priors where parameters are constrained to be non-negative and beta distributions for fractions and persistence parameters. Hence, the priors for h, δ_h, δ_f, θ_h, θ_f, ρ_{y^*}, ρ^{π^*}, ρ^{R^*}, ρ_a, ρ^q and ρ^R are all set to 0.5.

4.3 Parameter Estimates

Table (2) presents the mean posterior estimates and associated 90% high probability densities of the posterior distributions of the parameters for each economy.[18] As the results indicate, sources of endogenous persistence commonly introduced in closed economy models such as indexation and habits – except for Canada – are rather muted in all three countries. However, this is compensated by the high degree of persistence in the shocks to world output and interest rate.

The key parameters for this paper are the interest rate rule coefficients on inflation (ψ_1), output (ψ_2)

[16] All estimations were carried out using Dynare. See Adjemian et al. (2011).

[17] As in Justiniano and Preston (2010), I calibrate the discount factor and the share of imports in domestic consumption, β and α. The former is set equal to 0.99 while for the latter the values of 0.185 0.28 and 0.29 for Australia, Canada and New Zealand, respectively.

[18] See also the appendix.

Table 1: Priors

Parameter		Prior density	Mean	Standard Deviation
Habits	h	B	0.5	0.25
Inverse intertemp. elasticity of substitution	σ	G	1.5	1
Inverse Frisch	ϕ	G	1.5	0.75
Elasticity H-F goods	η	G	1.5	0.75
Home indexation	δ_h	B	0.5	0.25
Foreign indexation	δ_f	B	0.5	0.25
Calvo home	θ_h	B	0.5	0.1
Calvo foreign	θ_f	B	0.5	0.1
F. output persistence	ρ_{y^*}	B	0.5	0.2
F. inflation persistence	ρ_{π^*}	B	0.5	0.1
F. interest rate smoothing	ρ_{R^*}	B	0.5	0.25
Technology persistence	ρ_a	B	0.5	0.25
Preference persistence	ρ_g	B	0.5	0.25
Risk premium persistence	ρ_q	B	0.5	0.25
F. persistence cost-push	ρ_{π^f}	B	0.5	0.2
Interest rate smoothing	ρ_R	B	0.5	0.25
Taylor coefficient inflation	μ_1	G	1.5	0.3
Taylor coefficient output growth	μ_2	G	0.25	0.15
s.d. technology	σ_{ϵ^a}	IG	1.19	∞
s.d. risk premium	σ_{ϵ^q}	IG	0.5	∞
s.d. preference	σ_{ϵ^g}	IG	2.66	∞
s.d. foreign cost-push	σ_{ϵ^f}	IG	2.67	∞
s.d. Taylor rule	σ_{ϵ^R}	IG	0.5	∞
s.d. foreign output	$\sigma_{\epsilon^{y^*}}$	IG	1.19	∞
s.d. foreign interest rate	$\sigma_{\epsilon^{R^*}}$	IG	1.19	∞
s.d. foreign inflation	$\sigma_{\epsilon^{\pi^*}}$	IG	1.19	∞

Distributions: B, Beta; G, Gamma, IG, Inverse Gamma.

and the lagged interest rate (ρ_r). While all countries respond aggressively to inflation deviations, Canada shows the strongest response to both inflation and output while it also exhibits the lowest degree of interest rate persistence. Australia's response to output is similar to Canada's but with a much larger degree of interest rate persistence. In contrast, New Zealand's reaction to output fluctuations is much lower than in the other two countries. As discussed above, without a measure of the weights in each central bank's loss function these values cannot be interpreted in terms of policy objectives so a method for deriving this is considered in the next section.[19]

5 Central Bank Preferences

Having estimated the models above, the next step is to derive the weights in the loss that make the estimated Taylor rule coefficients optimal. The objective function is initially assumed to take the general form

$$L_t = E_t \sum_{j=0}^{\infty} \beta^j \left[z'_{t+j} W z_{t+j} \right] \tag{22}$$

Where $z_t = [y'_t \; u'_t]'$ contains the vector of endogenous variables y_t and the policy instrument u_t. The policy weights are contained in W, which is a symmetric, positive semi-definite matrix.

The procedure involves the following three steps:

1. First, one must assume the form of the policy rule. This is decided empirically and in the present paper it is described by equation (21), where we can define the Taylor rule coefficients by Γ.

2. The second step is to 'guess' an objective function and, for given policy weights, to derive the optimal interest rate rule that minimises the policy maker's loss. The first parameter in W is normalised to one as only the relative weights are identified. It is important to note that the postulated loss function only contains a –plausible –subset of the endogenous variables to avoid multicollinearity.

[19] Prior to estimation parameter identification is verified using the tests in Ratto and Iskrev (2011).

3. Lastly, I search for the weights in the objective function that minimise the distance between the actual and optimised simple rules. Letting Ψ denote the $n_{\Psi}x1$ vector of coefficients in the policy rule with a tilde (asterisk) represent the estimated (optimal) values, we can define

$$\Psi^d = \Psi^* - \widehat{\Psi}$$

Letting Λ denote an n_{Ψ} diagonal matrix with $\Lambda(i,i) = \Psi(i)$ the distance is given by

$$d = \Psi^{d'} \Lambda^{-1} \Psi^d$$

This is simply a criterion to enable the optimisation software to home in on the solution and is just a mean of ensuring that Ψ^* is as close as possible to $\widehat{\Psi}$.

The process therefore employs a double search algorithm: it searches for the optimal Γ given W and then it searches for the W that minimises the distance d.

While the objective function could be based on a second order approximation to the representative agent's utility function the non-normative focus of this paper takes a more agnostic approach. The computation of the optimal simple rule is conducted following the steps outlined in Dennis (2004b) and a brief description is provided below. The full model, including the monetary policy rule, can be written as

$$B_0 z_t = B_1 z_{t-1} + B_2 E_t z_{t+1} + B_3 \eta_t \tag{23}$$

Assuming that the policy rule is such that the system has a unique stationary equilibrium, the MSV solution for z_t can be written as

$$z_t = \theta_1 z_{t-1} + \theta_2 \eta_t \tag{24}$$

The resulting losses are then given by

$$L_t = z_t' P z_t + \frac{\beta}{1-\beta} tr \left[\theta_2' P \theta_2 \Phi \right] \tag{25}$$

where tr denotes the trace of a matrix, Φ is the variance-covariance matrix of η_t and P is the solution to the discrete Sylvester equation

$$P = W + \beta \theta_1' P \theta_1$$

The optimal interest rate rule then involves a search over the Taylor rule parameters by solving (23) and minimising the resulting loss in (25). Because the optimal interest rate rule depends on the variance-covariance matrix of shocks certainty equivalence does not hold.

To the extent that the coefficients in the optimised monetary policy rule coincide (or are within 90% of their HPD values) with those that have been estimated one can defend the argument that the observed behaviour of the nominal interest rate is consistent with the model and objectives used in the paper. Therefore, the approach adopted in this paper for determining the preference weights W does not affect the estimation of the policy parameters. Nonetheless, an issue that may arise is that the the optimised and estimated interest rate rule coefficients differ. In that case, we can interpret such a result as indicating that either the model does not provide a good description of the economy as perceived by the policy maker or that the objective function being used is the inappropriate one.

6 Results

The loss functions that make the estimated Taylor rules optimal are shown in Table 3, where some other loss functions have been included for comparison purposes and the weight on inflation has been normalised to one.[20] Several results are common for all three countries. First, for all three countries the optimal Taylor rule that arises from using the standard quadratic loss function where

[20] As is widely recognised, the change in the nominal interest rate is generally required to enter the loss function in order to account for the observed degree of interest rate smoothing encountered in the data. It is worth noting that using the level of the interest rate instead of its difference in the loss function only worsened the results.

central banks are only concerned with stabilising the inflation rate, output and the change in the interest rate is inconsistent with those estimated.[21] That said, interest rate smoothing, output and inflation are important objectives for all three economies but limiting the loss function to this form does not make the estimated Taylor rule optimal. It is worth noting that much of the previous work on central bank preferences has often been restricted to loss functions of this type – see for example, Dennis (2006) and Ilbas (2012) – but doing so may yield an incomplete picture. For all three countries a penalty pertaining to output-inflation interactions is essential for explaining the estimated Taylor rules, with a weight that is in all cases larger than that on inflation.

Several patterns are apparent and some intuition behind the results can be gleaned by relating the loss function weights to the estimated coefficients in the Taylor rule. [22] First, a stronger weight attached to interest rate smoothing is in all cases directly linked to a higher level of ρ_r as well as a lower response of interest rates to inflation. This is rather intuitive, as a greater desire to smooth interest rates will not only lead to a greater persistence in the Taylor rule but it will also make the central banker less aggressive towards inflation. Secondly, a greater penalty on output volatility – as well as the inflation-output interaction term – is matched by a greater Taylor rule coefficient on output. While the first factor is to be expected, the table shows that the latter is essential for reducing the responsiveness of interest rates to inflation within each country. Lastly, the inclusion of the real exchange rate as an objective has the effect of reducing the interest rate response to output across countries. This may be interpreted in terms of a greater relative focus on inflation in the Taylor rule and in the presence of nominal rigidities, greater exchange rate stability.

As all three economies are inflation targeters one may have assumed that their preferences would have been very similar but this ignores the fact that their central banks' remits and implementation differ substantially.[23] Also, it is important to note that central bankers' objectives and their remits may not exactly coincide. A central banker with a clear remit to focus on stabilising inflation may still consider stabilising the exchange rate good policy. In that case she may not be obviously reacting to exchange rate movements by excluding them from the interest rate rule, but her rule

[21] In these cases the optimal response to inflation would be much larger than the observed one, as discussed in Rotemberg and Woodford (1999) and Boehm and House (2014).

[22] It is important to note that as optimised simple interest rate rules are not certainty equivalent there is no guarantee that the link between objective weights and rule coefficients is a straightforward one.

[23] A discussion of each country's implementation of inflation targeting can be found in Chevapatrakul and Paez-Farrell (2014).

may already be factoring in exchange rate considerations. The results of this paper suggest that there is some evidence of this for all three countries. Australia's large weight on output stabilisation is not surprising given the important role attached to output stabilisation in its policy objectives. Likewise, the low importance attached to output found for New Zealand is consistent with it probably being the strictest inflation targeter and stability of the general level of prices as a stated overriding objective. While Canada attaches the largest weight to output stabilisation, it is also the country that attaches the largest penalty on output-inflation movements, thereby also increasing the importance of the latter as an objective.

It is interesting to assess how the results of this paper compare to previous findings in the literature. Focusing on the US, several papers have found the weight on output to be very small or insignificant, such as Castelnuovo and Surico (2004), Dennis (2004b) and Favero and Rovelli (2003), among others.[24] At the other end, the estimate in Ozlale (2003) for the Volcker-Greenspan period is 0.5, while that in Assenmacher-Wesche (2006) for the period 1973Q1-2007Q4 ranged from 1.2 to 1.3 (depending on the prevailing regime). However, there is a wider range of estimates for the weight on output when one considers other central banks. At the lower end Ilbas (2010) obtains an estimate of 0.04 for the euro area in the context of the Smets-Wouters model while Assenmacher-Wesche (2006) using the Rudebusch-Svensson model finds weights of 0.6 to 31 for the UK, with the estimates depending on the inflation regime. More closely related to this paper, Kam et al. (2009) estimate a small open economy model with complete markets where monetary policy operates under discretion. Their estimated weights on output for Australia, Canada and New Zealand of 0.4, 0.15 and 0.22, respectively, are not too dissimilar from those found for the US. Moreover, they find that for all three countries the data favour the model where the real exchange rate is not a policy objective.

The prevalence of findings where central banks attach a zero or very low weight to output stabilisation is hard to reconcile with the standard assumption that central banks do aim to stabilise the real economy.[25] Furthermore, focusing on stabilising both inflation and output – albeit with different time frames and priorities – is a defining feature of inflation targeting as well and to some

[24] Although as Dennis (2004b) acknowledges, a zero weight on output is at odds with both the general view and central bankers' announcements.

[25] Although a very low weight on output may be consistent with the approximation to the social welfare function in New Keynesian models no central bank has publicly stated this as its primary objective.

extent the US. The recent experience of the UK, another inflation targeter, overshooting its target during the Great Recession would add further validity to the argument that central banks' weight on output stabilisation is not negligible.

7 Conclusion

This paper proposes that one should think of policy makers as optimising agents. The implication therefore is that policy choices – interest rates, government spending levels or tax rates – are the result of an optimisation exercise subject to the constraints that she faces. In other words, actual policy *is* optimal policy, at least from the policy maker's point of view. This then leads one to ask what specific objectives are driving policy. In this paper I suggest an alternative approach to derive policy preferences with the aim of ensuring consistency with the empirical literature that describes policy primarily by relying on simple rules. The algorithm is simple to implement and could be applied to a general class of simple policies, such as fiscal policy rules.

I apply this approach to monetary policy and Taylor rules given the large amount of existing research on central bank preferences and focus on three inflation targeting countries as we would a priori expect inflation and output to be key policy objectives. I estimate a small open economy for Australia, Canada and New Zealand using Bayesian methods and find that the estimated Taylor rules can be motivated by a quadratic loss function. All three countries are concerned with interest rate smoothing, the variances of inflation, output, the real exchange rate as well as the output-inflation covariance. Non-diagonal elements of the objective function, covariance terms, are found important in accounting for observed behaviour of interest rates and this is a factor often neglected in the literature.

Moreover, the results of the paper suggest that the absence of a specific variable from the policy rule – here, the real exchange rate – does not imply that it is not a policy objective. While this may be motivated by reasons of transparency via very simple rules or from deviations of the policy remit inference about central bankers' loss functions can only inform us about their objectives, but not why this is so.

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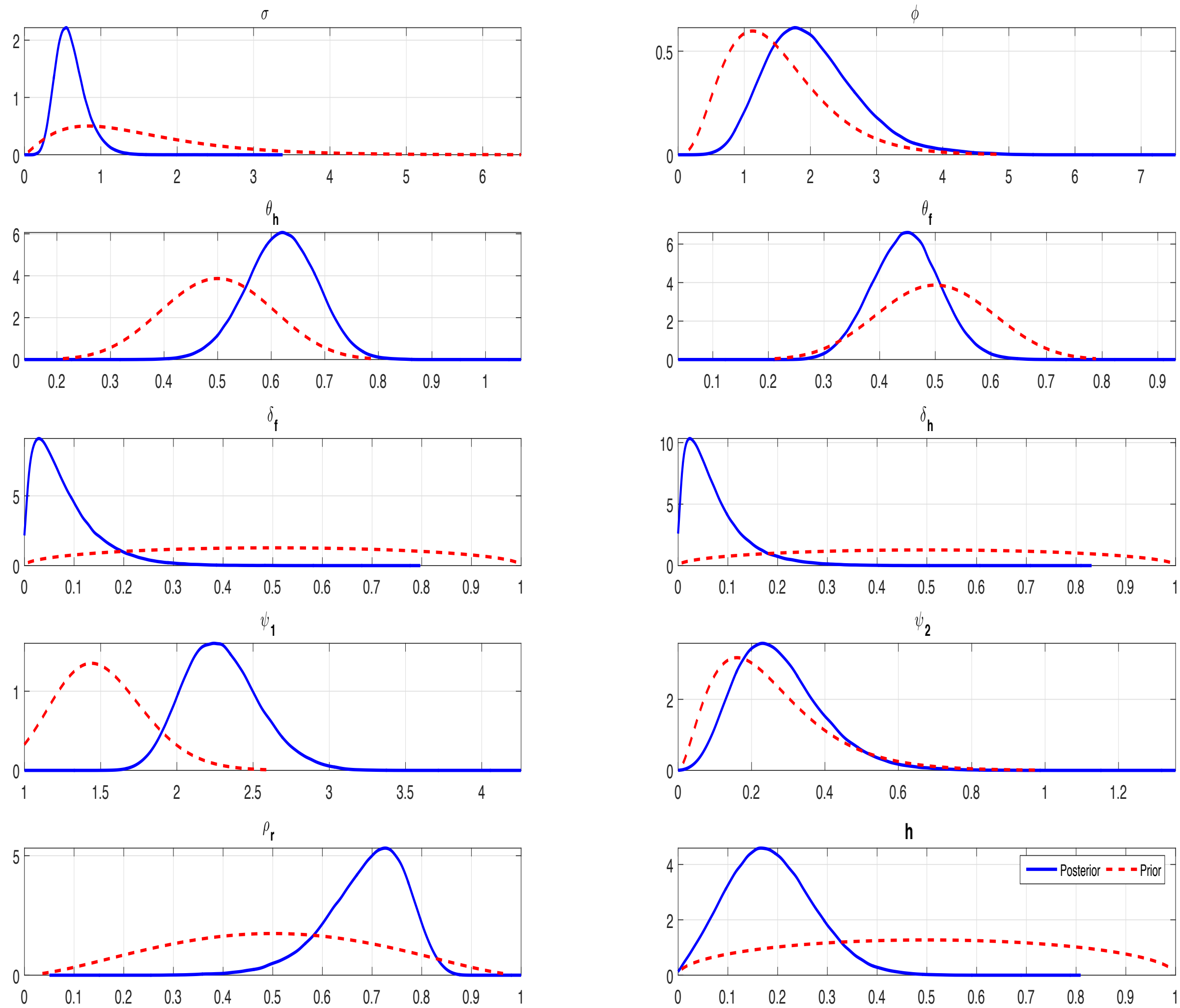
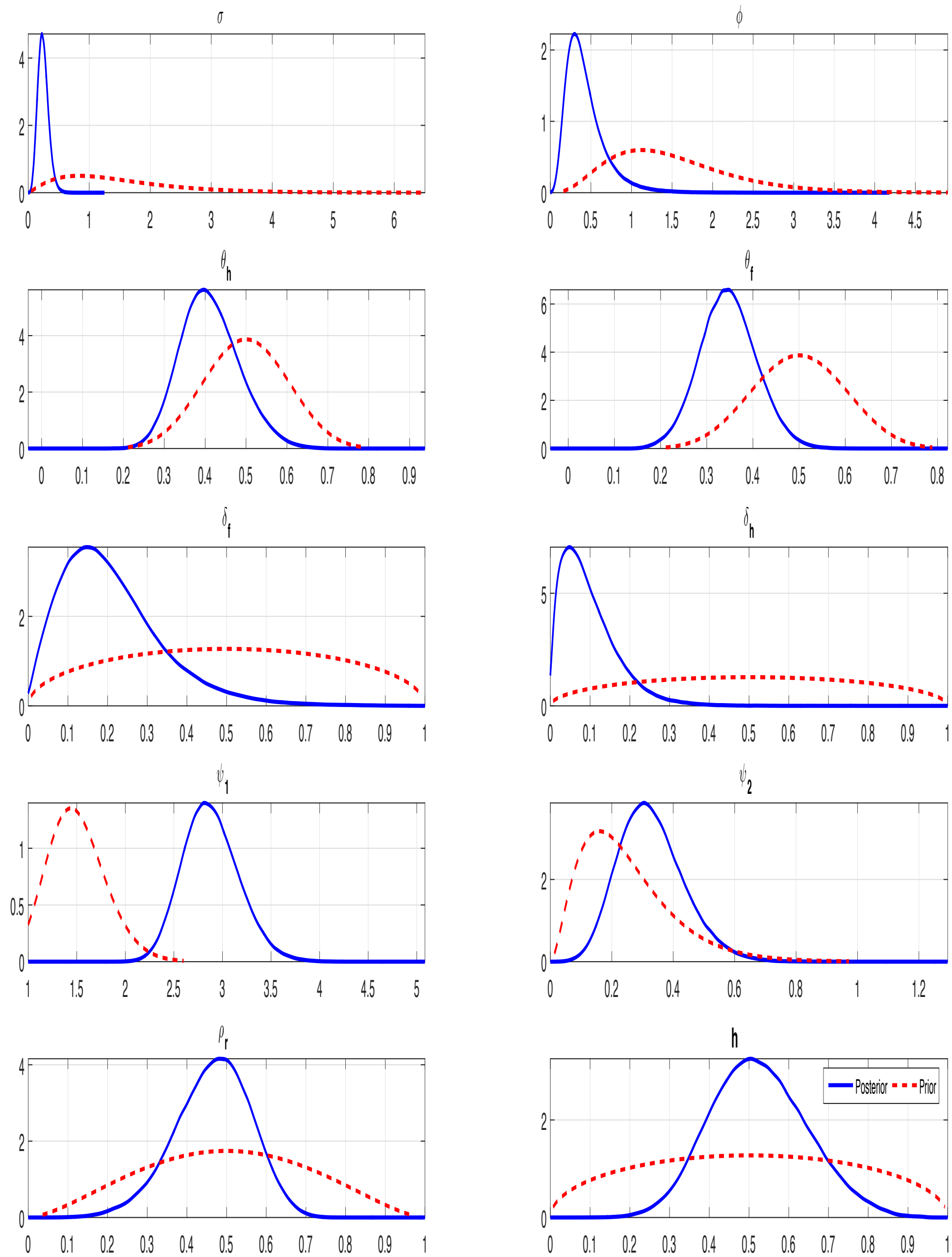
8 Appendix

Figure 1: Prior (dashed) and posterior (solid) distributions of key parameters for Australia



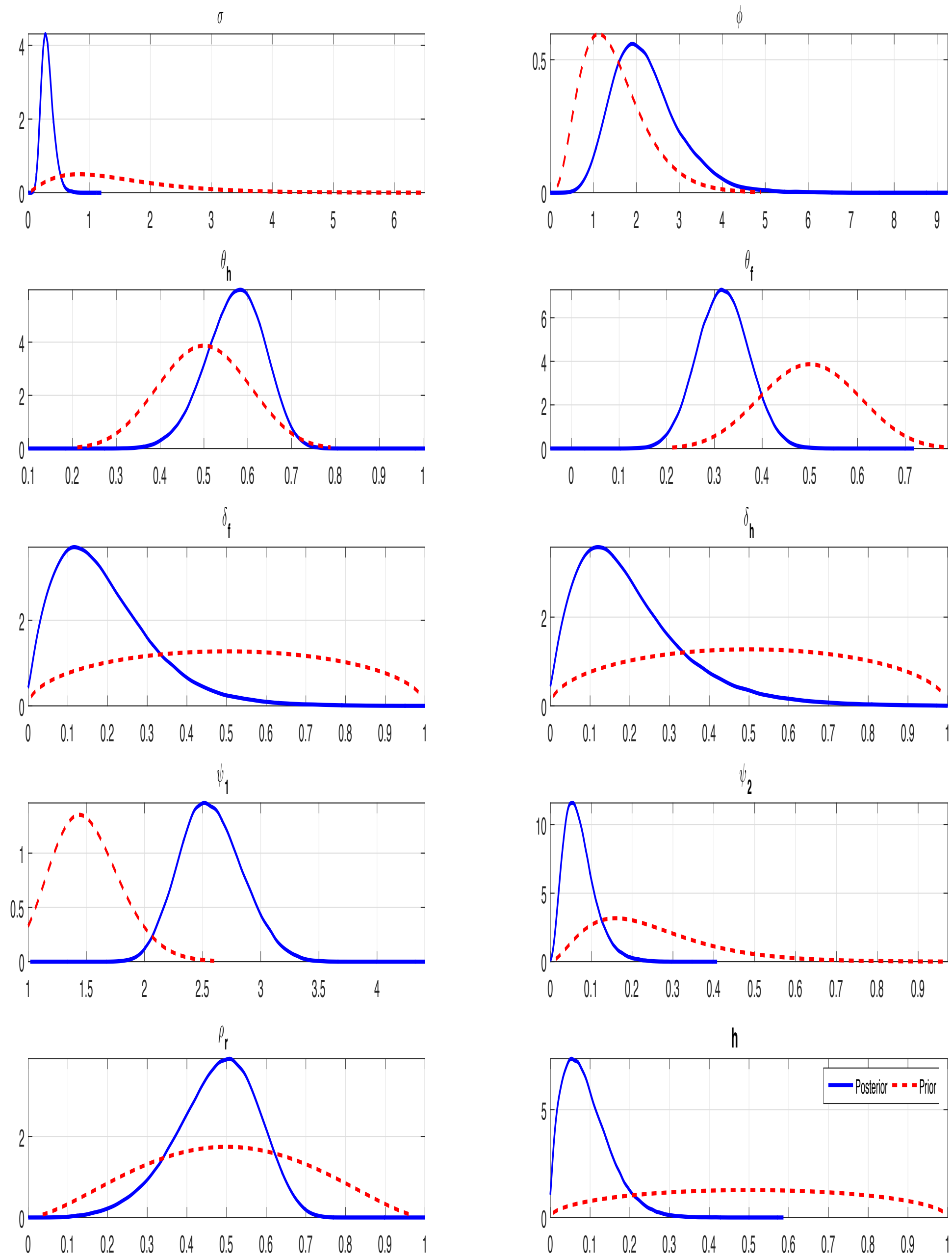
Note: The Metropolis-Hastings sampling algorithm is based on one million draws.

Figure 2: Prior (dashed) and posterior (solid) distributions of key parameters for Canada



Note: The Metropolis-Hastings sampling algorithm is based on one million draws.

Figure 3: Prior (dashed) and posterior (solid) distributions for New Zealand



Note: The Metropolis-Hastings sampling algorithm is based on one million draws.

Table 2: Posterior estimates for all three countries

Parameter	*Australia*		*Canada*		*New Zealand*	
	Mean	90% HPD	Mean	90% HPD	Mean	90% HPD
h	0.1858	[0.0427, 0.3192]	0.5236	[0.3253, 0.7221]	0.0914	[0.0026, 0.1737]
σ	0.6074	[0.2945, 0.9150]	0.2445	[0.1014, 0.3815]	0.3156	[0.1566, 0.4697]
ϕ	2.0216	[0.9107, 3.0822]	0.4298	[0.0921, 0.7645]	2.2255	[0.9992, 3.4523]
η	0.9004	[0.7132, 1.0816]	0.5927	[0.4734, 0.7061]	0.6846	[0.5634, 0.8021]
δ_h	0.0709	[0.0001, 0.1494]	0.0968	[0.0013, 0.1912]	0.2038	[0.0061, 0.3956]
δ_f	0.0793	[0.0004, 0.1655]	0.2099	[0.0133, 0.3878]	0.1917	[0.0081, 0.3633]
θ_h	0.6188	[0.5100, 0.7249]	0.4108	[0.2917, 0.5271]	0.5704	[0.4643, 0.6787]
θ_f	0.4473	[0.3452, 0.5449]	0.3460	[0.2444, 0.4468]	0.3178	[0.2304, 0.4079]
ρ_{y^*}	0.9339	[0.8846, 0.9861]	0.9195	[0.8693, 0.9715]	0.9340	[0.8864, 0.9840]
ρ_{π^*}	0.3210	[0.2084, 0.4345]	0.4266	[0.2922, 0.5598]	0.3183	[0.2077, 0.4336]
ρ_{R^*}	0.8956	[0.8554, 0.9363]	0.8773	[0.8363, 0.9201]	0.9014	[0.8614, 0.9419]
ρ_a	0.9361	[0.8937, 0.9819]	0.9598	[0.9301, 0.9910]	0.9278	[0.8896, 0.9672]
ρ_g	0.9693	[0.9511, 0.9874]	0.9526	[0.9270, 0.9800]	0.9505	[0.9213, 0.9815]
ρ_q	0.9351	[0.8944, 0.9785]	0.9032	[0.8443, 0.9634]	0.9292	[0.8834, 0.9766]
ρ_{π^f}	0.9758	[0.9616, 0.9810]	0.9725	[0.9569, 0.9887]	0.9795	[0.9676, 0.9919]
ρ_r	0.6869	[0.5608, 0.8153]	0.4640	[0.3059, 0.6192]	0.4726	[0.3049, 0.6423]
ψ_1	2.2890	[1.8845, 2.6886]	2.8775	[2.4059, 3.3449]	2.5725	[2.1274, 3.0069]
ψ_2	0.2755	[0.0849, 0.4569]	0.3227	[0.1536, 0.4979]	0.0721	[0.0132, 0.1278]
σ_{ϵ^a}	0.8996	[0.6241, 1.1574]	0.5645	[0.4152, 0.7099]	1.4109	[1.1083, 1.7032]
σ_{ϵ^q}	4.1748	[2.0867, 6.1223]	0.2107	[0.1418, 0.2766]	0.2580	[0.1662, 0.3470]
σ_{ϵ^g}	1.8801	[0.6607, 3.1370]	3.4429	[1.8040, 5.0541]	3.4693	[1.5030, 5.4228]
σ_{ϵ^f}	3.4590	[1.7639, 5.1351]	2.7954	[1.4777, 4.0425]	6.3577	[3.7443, 9.2505]
σ_{ϵ^r}	0.1679	[0.1287, 0.2065]	0.2193	[0.1719, 0.2654]	0.1946	[0.1466, 0.2425]
$\sigma_{\epsilon^{y^*}}$	0.5336	[0.4599, 0.6089]	0.5371	[0.4595, 0.6106]	0.5355	[0.4592, 0.6112]
$\sigma_{\epsilon^{R^*}}$	0.1339	[0.1142, 0.1530]	0.1369	[0.1164, 0.1571]	0.1328	[0.1134, 0.1516]
$\sigma_{\epsilon^{\pi^*}}$	0.3543	[0.3054, 0.4029]	0.1007	[0.0870, 0.1146]	0.3536	[0.3052, 0.4014]
ML(Laplace)	-925		-755		-1015	

Note: HPD: high probability density. The parameters α and β were fixed at 0.99 and 0.45, respectively. The posterior statistics were computed from 5 MCMC chains of 1000000 draws each, after a 40% burn-in. Convergence is assessed graphically using the Brooks and Gelman (1998) MCMC univariate diagnostics for each individual parameter and with the MCMC multivariate diagnostics for all parameters. ML(Laplace) denotes the log marginal likelihood computed via the Laplace approximation.

Table 3: Weights in loss function and optimised Taylor rule coefficients

Country	Loss function weights				Optimal rule			Estimated rule		
	Δr	y	q	$y\pi$	ψ_1	ψ_2	ρ_r	ψ_1	ψ_2	ρ_r
Australia	0.00	1.12	-	-	5	0.27	0.73	2.29	0.28	0.69
	0.00	1.11	0.01	-	5	0.27	0.69	2.29	0.28	0.69
	13.0	7.32	0.82	1.87	2.29	0.28	0.69	2.29	0.28	0.69
Canada	0	2.4	-	-	5	0.33	0.49	2.88	0.32	0.46
	0.03	2.2	0.01	-	5	0.32	0.49	2.88	0.32	0.46
	2.9	13	0.38	2.2	2.88	0.33	0.46	2.88	0.32	0.46
New Zealand	0.00	2.32	-	-	5	0.06	0.59	2.57	0.07	0.47
	0.00	0.00	0.19	-	5	0.06	0.53	2.57	0.07	0.47
	5.4	0.39	0.90	1.07	2.57	0.07	0.47	2.57	0.07	0.47

Note: The weight on inflation, π has been normalised to one. Δr represents the weight on Δr^2 in the loss function etc. except for the interaction term πy. In searching for the optimal Taylor rule coefficients an upper bound of 5 has been imposed on ψ_1 and ψ_2. The third, sixth and ninth row show the weights that make the estimated rule optimal. The remaining rows present the results from widely used specifications and are shown for comparison.