Taylor rules and central bank preferences in three small open economies

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Abstract

The objective of this paper is to infer the policy objectives of three inflation targeting central banks using an estimated New Keynesian small open economy model. While we assume that the monetary authorities behave optimally, we depart from previous research by assuming that monetary policy is implemented via simple Taylor-type rules, as suggested by most of the empirical literature. We then derive the weights in the objective function that make the resulting optimal interest rate rule coincide with its estimated counterpart.

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

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

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1 Introduction

This paper derives the weights in the objective functions of three small open economy central banks by making use of an estimated structural model that includes a simple interest rate rule. In other words, it solves a problem of inverse of optimal control. However, unlike previous research, it uses a small open economy model and assumes that policy is implemented via a simple Taylor-type rule where the coefficients in such a rule are chosen optimally by the central bank. In contrast to related work, my procedure estimates the interest rate rule without imposing any optimality constraints upon it, thereby being consistent with empirical Taylor-type rules.

Taylor's (Taylor, 1993) seminal paper sparked a large literature on the conduct of monetary policy via simple interest rate rules in forward-looking sticky-price models. While no central bank explicitly follows a Taylor rule it nonetheless provides a reasonably good description of actual interest rate behaviour and performs well across models.[1] As a result, the majority of the empirical literature – see, for example, Clarida et al. (1998) and Paez-Farrell (2009) – models monetary policy via a Taylor-type rule.[2]

At the same time, research on optimal monetary policy combines the central bank's loss function subject to constraints to derive an optimal rule. While 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). Nonetheless, simple interest rate rules have the benefit of being transparent and easily understood by the public.

While these two strands of the literature on monetary policy are clearly linked there is a clear inconsistency, as the actual behaviour of interest rates – the estimated Taylor rule –

[1] I am abstracting here from issues related to the zero lower bound as they do not apply to the sample period considered in the paper.

[2] Hereafter I shall describe such rules a Taylor rules for simplicity.

has differed markedly from the path that would be prescribed by the optimal policy rules.[3] While some argue that this is evidence that actual monetary policy has not been optimal it can also be caused by using using weights in the objective function that are not consistent with the data (Dennis, 2006) or by using the wrong model relative to the policy maker's.

In order to overcome this discrepancy we need to use the correct objective function and weights that guide policy.[4] In this regard, it is increasingly being recognised – Dennis (2006), Ilbas (2010) – that analysing interest rate rules in isolation tells us little about a central bank's objective of little use as the coefficients in such rules do not have a structural interpretation. For example, Lubik and Schorfheide (2007) estimate a small open economy model using Bayesian methods where monetary policy follows a Taylor-type rule, finding evidence that the Bank of Canada responded to the exchange rate. This is attributed to a concern for exchange rate movements but as Kam et al. (2009) point out, even when the central bank's objective function does not contain the exchange rate it may be still be optimal to stabilise it, for example, when there is an endogenous gap in the law of one price. It is therefore necessary to consider the central bank's objectives and its policies simultaneously and explicitly. The analysis must be based on inverse optimal control where given a model (the central bank's constraint), an objective function and the observed behaviour of the policy instrument, the weights in the objective function are estimated.[5]

The literature on determining or estimating central bank objectives is not new, with Niho and Makin (1978) being the first paper in this area that I am aware of.[6] However, there has been a recent increase in the number of studies aiming to understand the driving factors behind central banks' interest rate decisions. The majority of the studies thus far have focused on the US and have considered backward-looking models, thereby making them subject to the Lucas critique and ignoring the role of expectations in affecting the strategic

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

[4] It is worth noting that the policy maker's objectives and society's need not coincide.

[5] An alternative approach, as in Smith (2009), is it ask policy makers how they would react to a sequence of pairwise choices in order to gather information about their preferences.

[6] I would like to thank Joe Pearlman for making me aware of this paper.

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]

The first paper to consider a forward-looking model was Salemi (2006), who used a simple three equation model where the interest rate reaction function was constrained to respond to lagged variables only. The model was estimated via maximum likelihood on US data over the period 1961-2001 to determine whether there had been a change in the weights in the objective function. In a similar vein, Givens (2012) also used a two-equation forward-looking model estimated on US data (1982-2008) with the objective of determining which form of optimisation by the central bank – commitment or discretion – provided a better description of US data. For the period under consideration, he finds that discretion yields a better fit and that the model with a simple, non-optimised interest rule delivers the worst performance of the three.[8]

The majority of the research on central bank preferences in recent years has considered a richer class of forward-looking models. Dennis (2004a) uses an optimising model where households possess internal consumption habits and firms are subject to Calvo (1983) pricing as well as indexation to past inflation. The policy maker is assumed to optimise under discretion and the model is estimated via maximum likelihood on US data over the period 1966-2002 to assess whether there had been a change in central bank preferences when Volcker became chairman of the Federal Reserve. In line with the empirical literature, a growing body of work is now estimating central bank preferences employing Bayesian methods. Kam et al. (henceforth KLL; 2009) were the first to do so using a variant of the Monacelli (2005) small open economy model. It was estimated on Australia, Canada and New Zealand with the objective of assessing the extent to which these countries' central banks were concerned

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

[8] Most importantly for the objectives of this paper, Givens (2012) makes the same assumption as in Salemi (2006) that the interest rate is constrained to only respond to lagged variables.

with exchange rate stabilisation. Consistent with the argument put forward above, they find that while their estimated objective functions did not place a weight on exchange rate stabilisation the resulting optimal monetary policy did. Similarly, Ilbas (2010) estimated 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) also used the Smets-Wouters model but this time it was estimated on the US with the aim, as in Dennis (2004a), of determining whether there had been a break in monetary after 1982.

This paper bridges the gap between the empirical and inverse control literatures by using a forward-looking model with an empirically-consistent Taylor rule while simultaneously assuming that it is (from the central bank's point of view) optimal. The inverse control literature discussed above yields implicit policy rules that are at odds with those used in empirical work, such as Smets and Wouters (2003) or Justiniano and Preston (2010).[9] Crucially, the literature on inverse optimal control assumes that the policy maker optimises but when the resulting behaviour is compared to that where the interest rate is not constrained to be optimal the latter often provides a better explanation of the data.[10] For example, the results in Kam et al. (2009) – see their tables 8 and 10 – show that a comparison of log data densities provides evidence in favour of the model with a simple interest rate rule as opposed to one where it is estimated with optimal monetary policy under discretion. When these comparisons have been explicit, as in Dennis (2006), Salemi (2006) and Ilbas (2010), such results have been interpreted as evidence that monetary policy has not been optimal without providing an alternative explanation of what drives the behaviour of interest rates. I would argue that such a conclusion is unwarranted and that the superior empirical performance of a model with a 'non-optimal' instrument rule reflects the fact that the policy maker's

[9] I am restricting the discussion to forward-looking models, the focus of this paper.

[10] An exception is Givens (2012), but the comparison is one where the instrument only responds to lagged variables, thereby invalidating the empirical link discussed above. Salemi (2006) considers an optimal simple rule, as this paper does, but his approach constrains the rule to be backward looking and concludes that actual US monetary policy was not optimal.

objectives or constraints may be mis-specified.

To ensure consistency with the empirical 'ad hoc' interest rate rule, I assume that the optimising policy maker faces an additional constraint in that the instrument must follow a simple, empirically-determined, rule. While delving into the reasons for this assumption are beyond the scope of this paper, much of the rationale for modelling policy with simple rules is well known from the Taylor rule literature.[11]

Unlike previous papers on this topic, the model estimation process does not place any optimality conditions on the interest rate rule. Having estimated the full model, I then assume that actual monetary policy has been optimal so that the next step is then to find the objective function that delivers the estimated coefficients in the Taylor rule.

2 The model

The model used in this paper is based on the New Keynesian small open economy model developed by Kam et al. (2009), which is an extension of Monacelli (2005).[12]

Households consume both domestic and foreign goods while their utility function includes external habits in consumption. Both the domestic and import goods sector 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 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

[11]See Dennis (2004b), for example. These include transparency, relatively good performance when compared to the fully optimal policy, etc.

[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 Kam et al. (2009).

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

$$c_t - hc_{t-1} = y_t^* - hy_{t-1}^* + \frac{(1-h)}{\sigma} q_t \tag{1}$$

Where c is aggregate consumption, h represents the degree of habits and the inverse of the elasticity of intertemporal substitution is denoted by σ. With the presence of complete markets, dynamics in the real exchang rate, q, are driven by deviations in the law of one price, to be discussed below. Asterisks are used to denote foreign (world) variables.

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

$$(1 + \beta\delta_h)\,\pi_t^h = \beta E_t \pi_{t+1}^h + \delta_h \pi_{t-1}^h + \frac{(1-\beta\theta_h)(1-\theta_h)}{\theta_h} mc_t + \epsilon_t^h \tag{2}$$

where β is the household's discount factor and ϵ^h represents a shock to domestic firms' mark-ups over real marginal costs, mc. The latter follow

$$mc_t = \phi y_t - (1+\phi)\epsilon_t^a + \alpha s_t + \frac{\sigma}{(1-h)}(c_t - hc_{t-1}) \tag{3}$$

In the expression above $1/\phi$ represents the Frisch labour supply elasticity while ϵ^a is an exogenous technology shock and s denotes the terms of trade, which can be written as

$$\Delta s_t = \pi_t^f - \pi_t^h \tag{4}$$

As with the domestic goods sector, similar assumptions pertain to the importing 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

$$(1 + \beta\delta_f)\,\pi_t^f = \beta E_t \pi_{t+1}^f + \delta_f \pi_{t-1}^f + \frac{(1-\beta\theta_f)\,(1-\theta_f)}{\theta_f}\psi_t + \epsilon_t^f \tag{5}$$

with ψ denoting the deviation in the law from the law of one price arising from the pricing power of import firms

$$\psi_t = q_t - (1-\alpha)s_t \tag{6}$$

Ruling out arbitrage opportunities we also have real uncovered interest parity (UIP)

$$E_t q_{t+1} - q_t = r_t - E_t\pi_{t+1} - \left(r_t^* - E_t\pi_{t+1}^*\right) + \epsilon_t^q \tag{7}$$

where ϵ^q represents a risk premium shock and r is the nominal return on one-period bonds. Domestic output must also satisfy the market clearing equation

$$y_t = (1-\alpha)c_t + \alpha\eta q_t + \alpha\eta s_t + \alpha y_t^* \tag{8}$$

Given the assumption of a small open economy, the world economy is assumed to follow

$$\pi_t^* = \rho_{\pi^*}\pi_{t-1}^* + \epsilon_t^{\pi^*} \tag{9}$$

$$R_t^* = \rho_{R^*} R_{t-1}^* + \epsilon_t^{R^*} \tag{10}$$

$$y_t^* = \rho_{y^*} y_{t-1}^* + \epsilon_t^{y^*} \tag{11}$$

Similarly, the shocks are assumed to follow

$$\epsilon_t^s = \rho_s \epsilon_{t-1}^s + \nu_t^s \tag{12}$$

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

$$\epsilon_t^a = \rho_a \epsilon_{t-1}^a + \nu_t^a \tag{14}$$

$$\epsilon_t^q = \rho_q \epsilon_{t-1}^q + \nu_t^q \tag{15}$$

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

$$R_t = (1 - \rho_R)(\psi_1 \Pi_t + \psi_2 \Delta y_t) + \rho_R R_{t-1} + \epsilon_t^R \tag{16}$$

where R and Π denote the annualised rates of interest rates and inflation, respectively. This rule is the same as that in Liu (2010) and 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 is consistent with the transparency and simplicity argument made above. 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 maker is unconcerned about its volatility.[14]

3 Empirical Analysis

3.1 Data

For each of the three countries – Australia, Canada and New Zealand – the models are estimated using quarterly data for the period 1990Q1 to 2007Q2 on output, inflation, interest rates, the real exchange rate, the terms of trade and import price inflation in home currency as a data counterpart to the model's measure of foreign goods inflation. 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

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

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

calculated using U.S. CPI data, the bilateral nominal exchange rate and each countries 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; this also provides the series for foreign goods inflation (π^f).

The output series as well as those for the real exchange rate and the terms of trade are detrended using the (one-sided) Hodrick-Prescott filter. The interest rate and inflation series are de-meaned. Overall, then, we have nine observable variables and the same number of shocks as is common practice.

3.2 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 derives 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 40% 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).[15]

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.[16] While the prior densities are relatively dispersed they are nonetheless chosen to ensure consistency with the model's theoretical restrictions. Generally, inverse gamma

[15] All estimations were carried out using Dynare (`www.dynare.org`). For further details, see Adjemian et al. (2011).

[16] As in KLL, I calibrate the discount factor and the share of imports in domestic consumption, β and α, at 0.99 and 0.45, respectively.

Table 1: Priors

Parameter		Prior density	Mean	Standard Deviation
Habits	h	B	0.5	0.25
Inverse intertemp. elasticity of substitution	σ	G	1	0.25
Inverse Frisch	ϕ	G	1.5	0.75
Elasticity H-F goods	η	G	1	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	0.25
F. inflation persistence	ρ_{π^*}	B	0.5	0.25
F. interest rate smoothing	ρ_{R^*}	B	0.5	0.25
Technology persistence	ρ_a	B	0.5	0.25
Risk premium persistence	ρ_q	B	0.5	0.25
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_{ν^a}	IG	1.19	∞
s.d. risk premium	σ_{ν^q}	IG	0.5	∞
s.d. domestic cost-push	σ_{ϵ^h}	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.

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.

3.3 Parameter Estimates

Table (2) presents the mean estimates and associated 90% high probability densities of the posterior distributions of the parameters for each economy. The results indicate a similarly moderate level of habits, ranging from 0.55 in Australia to 0.7 in Canada. Price indexation in the domestic goods sector provides a very modest contribution to the model's sources of endogenous persistence and in all three economies the degree of indexation in the domestic goods sector is lower than that in the imported goods sector. At the same time, world output and interest rates are both very persistent. In terms of the shocks, while both technology and risk-premium shocks exhibit a high degree of inertia, the estimates are almost identical for the three countries in the case of the latter, while technology is the most persistent in Canada. The Taylor rule parameters, the focus of this paper, show a strong response to inflation in all cases, especially in Canada with a mean estimate of 2.9. The coefficients on output growth and interest rate smoothing are also similar across all three countries.

4 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

$$L_t = E_t \sum_{j=0}^{\infty} \beta^j \left[z'_{t+j} W z_{t+j} \right] \tag{17}$$

Where $z_t = [y'_t \quad u'_t]'$ in contains the vector of endogenous variables y_t and the policy instrument u'_t (all variables are in percentage deviation from steady state). The policy weights are contained in W, which is a symmetric, positive semi-definite matrix.

The procedure involves three steps. First, one must assume the form of the policy rule. This is decided empirically and in the present paper it is described by equation (16). 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. Lastly, we search for the weights in the objective function that minimise the distance between the actual and optimal simple rules.

Table 2: Posterior estimates for all three countries

Parameter	*Australia*		*Canada*		*New Zealand*	
	Mean	90% HPD	Mean	90% HPD	Mean	90% HPD
h	0.5529	[0.3406, 0.7704]	0.6736	[0.5157, 0.8354]	0.5597	[0.3465, 0.7827]
σ	1.1344	[0.7367, 1.5238]	1.0143	[0.6449, 1.3744]	1.1666	[0.7658, 1.5571]
ϕ	6.6204	[4.5761, 8.5750]	6.2671	[3.9934, 8.5800]	4.2213	[2.8170, 5.6246]
η	5.7670	[3.3908, 8.0522]	3.2088	[1.3395, 5.0613]	6.1805	[3.9220, 8.3749]
δ_h	0.1734	[0.0004, 0.3705]	0.2929	[0.0031, 0.5963]	0.3162	[0.0052, 0.6261]
δ_f	0.5958	[0.3930, 0.8036]	0.6035	[0.3505, 0.8670]	0.4867	[0.3593, 0.6124]
θ_h	0.2561	[0.1765, 0.3348]	0.3046	[0.2104, 0.3964]	0.3232	[0.2458, 0.4004]
θ_f	0.9336	[0.9081, 0.9529]	0.8687	[0.8108, 0.9270]	0.9467	[0.9385, 0.9529]
ρ_{y^*}	0.8927	[0.8221, 0.9655]	0.8951	[0.8256, 0.9675]	0.8909	[0.8221, 0.9647]
ρ_{π^*}	0.2234	[0.0638, 0.3745]	0.2048	[0.0546, 0.3458]	0.2193	[0.0604, 0.3691]
ρ_{R^*}	0.9600	[0.9322, 0.9884]	0.9402	[0.8997, 0.9824]	0.9673	[0.9416, 0.9950]
ρ_a	0.8497	[0.7578, 0.9455]	0.9121	[0.8534, 0.9756]	0.7723	[0.6393, 0.9077]
ρ_q	0.8888	[0.8191, 0.9624]	0.8982	[0.9381, 0.9621]	0.8819	[0.8133, 0.9501]
ρ_R	0.8961	[0.9715, 0.9204]	0.8316	[0.7916, 0.8723]	0.8487	[0.8151, 0.8819]
μ_1	2.1596	[1.6947, 2.6010]	2.9353	[2.4414, 3.4298]	2.6266	[2.1503, 3.1016]
μ_2	0.2386	[0.0296, 0.4392]	0.2468	[0.0317, 0.4575]	0.2151	[0.0277, 0.3933]
σ_{ν^a}	4.1789	[3.5686, 4.7697]	0.4424	[0.3656, 0.5173]	0.7019	[0.5284, 0.8680]
σ_{ν^q}	0.3167	[0.1792, 0.4474]	0.3186	[0.2298, 0.4029]	0.3299	[0.2253, 0.4312]
σ_{ϵ^h}	1.8801	[0.6607, 3.1370]	1.1506	[0.6068, 1.6757]	1.9589	[0.6928, 3.2451]
σ_{ϵ^f}	2.2876	[1.8965, 2.6691]	1.7511	[1.3651, 2.1309]	1.9290	[1.6517, 2.2026]
σ_{ϵ^R}	0.5471	[0.5471, 0.4503]	0.8132	[0.6633, 0.9638]	0.7338	[0.6091, 0.8543]
$\sigma_{\epsilon^{y^*}}$	0.3970	[0.3420, 0.4505]	0.3964	[0.3406, 0.4497]	0.3969	[0.3415, 0.4505]
$\sigma_{\epsilon^{R^*}}$	0.4821	[0.4144, 0.5472]	0.4897	[0.4196, 0.5583]	0.4799	[0.4131, 0.5456]
$\sigma_{\epsilon^{\pi^*}}$	1.4170	[1.2212, 1.6144]	1.4063	[1.2095, 1.5975]	1.4050	[1.2107, 1.5954]

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 $1,000,000$ 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.

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

$$B_0 z_t = B_1 z_{t-1} + B_2 E_t z_{t+1} + B_3 \eta_t \tag{18}$$

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

$$z_t = \theta_1 z_{t-1} + \theta_2 \eta_t \tag{19}$$

The resulting losses are then given by

$$L_t = z_t' P z_t + \frac{\beta}{1-\beta} tr \left[\theta_2' P \theta_2 \Phi\right] \tag{20}$$

where tr denotes the trace of a matrix, Φ is the variance-covariance matrix of η_t and P is the fix point of

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

The optimal interest rate rule then involves a search over the Taylor rule parameters by solving (18) and minimising the resulting loss in (20). Because the optimal interest rate rule depends on the variance-covariance matrix of shocks certainty equivalence does not hold.

The last step involves selecting the W matrix such that the optimal interest rate rule is as close as possible to the estimated one. This is done by minimising the Euclidean distance between the optimal and estimated parameters, standardised by the latter.

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, unlike in Salemi (2006), the approach adopted here does not affect the parameters in the policy rule. 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.

The weights in the policy maker's loss function from implementing the procedure described above are shown in Table (3), where the weight on inflation has been normalised to one. The weight on output (or its change) are large and exceed those on inflation for all three countries, while interest rate volatility is only a concern for Australia and New Zealand but not for Canada. At the same time, the open economy considerations seem to be most important in the case of Canada, with a weight of 0.33 on nominal exchange rate volatility, substituting for the exchange rate in the objective function. By contrast, for Australia and New Zealand exchange rate volatility (nominal and real, respectively) is a very small concern.

Previous findings have generally estimated the weight on output (or its change) to be lower than that on inflation. Using the Rudebusch-Svensson model on US data Favero and Rovelli (2003) estimated the weights on output and the change in the interest rate to be close to zero, but significant, while in Ozlale (2003) these relative weights were closer to unity although inflation remain the primary objective. Similarly, using the Smets-Wouters model on the euro-area Ilbas (2010) and on US data Ilbas (2012) finds positive but small weights on the policy variables of interest other than inflation (a result similar to that in Givens (2012)). Nonetheless, the finding that inflation has been the most important policy objective has not been unanimous, with Dennis (2006) estimating the weights on output and the change in inflation on US data at 2.9 and 4.5, respectively. Similarly, within the context of a Markov-switching model Assenmacher-Wesche (2006) finds the relative weight on output in the high

Table 3: Weights in the loss function that make observed Taylor rules optimal

Country	Variable						
	π	c	Δy	y	Δr	Δe	q
Australia	1	–	5.8	–	0.25	0.04	–
Canada	1	0.29	4.1	–	–	0.33	–
New Zealand	1	–	0.2	3.1	0.86	–	0.02

Note: For Australia the measure of inflation is $\overline{\pi} = \sum_{j=0}^{3} \pi_{t-j}$. The loss function is normalised so that the weight on inflation equals one.

inflation state of 1.3 in the US and 31 in the UK. This finding is similar to that in Arestis et al. (2011), who extend the static model in Cecchetti et al. (2002), and estimate a low relative weight on inflation for the UK and the European Monetary Union when the economy is in a high inflation volatility regime.

Turning to the importance of exchange rate variables in the objective function, despite the different approaches the results of this paper confirm the negligible weight on exchange rate variables for both Australia and New Zealand although not for Canada but our results suggest that the weight on output, or its change, is larger than that on inflation.

5 Conclusion

This paper has used a New Keynesian small open economy model estimated on Australia, Canada and New Zealand over the period $1990Q1 - 2007Q4$ assuming that monetary policy follows a simple interest rate rule. The objective has been to derive the policy makers' preferences by assuming that the observed behaviour of interest rates has been optimal, at least from each central bank's perspective. The procedure has therefore involved a double optimisation, finding the optimal Taylor rule given the weights in the loss function and at the same time finding the preference parameters that minimise the distance between the observed and estimated coefficients in the Taylor rule. .

The models are estimated using Bayesian methods and the objective functions are assumed to be quadratic. The results indicated a strong weight on economic activity in all three economies. For both Australia and New Zealand the weights on interest rate smoothing are lower than that on inflation while the weights on exchange rate variables, although positive, are negligible. By contrast, for Canada the relative weight on nominal exchange rate volatility, 0.33, seems to have substituted for a concern for interest rate smoothing. Crucially, this result emerges even after estimating an interest rate rule with no role for the exchange rate. Kam et al. (2009) argued that the the presence of the exchange rate in the interest rate rule does not indicate that it is a variable in the policy maker's loss function. This paper takes such a conclusion a step further: even if the exchange rate is not in the rule it may be in the objective function. In both case the same same conclusion arises that considering the reaction function in isolation tells us little about a policy maker's preferences.

The objective of this paper has been to provide a closer link between the central bank preferences and the empirical literature that assumes simple rules. The latter have abstracted from policy objectives and have modelled central bank behaviour with simple Taylor-type rules on the basis of providing fitting the data better. However, the interest rate rules that emerge from the preferences literature have not been consistent with these. This paper has attempted to bridge this gap by assuming that actual interest rate behaviour has been optimal so that one should use the empirically-consistent behaviour of interest rates in order to derive the preferences of central bankers. While central banks have received a large amount of criticism in recent years – Taylor (2014) – one should aim to understand what factors drive their policy decisions and estimating their preferences is an essential component is such an endeavour.

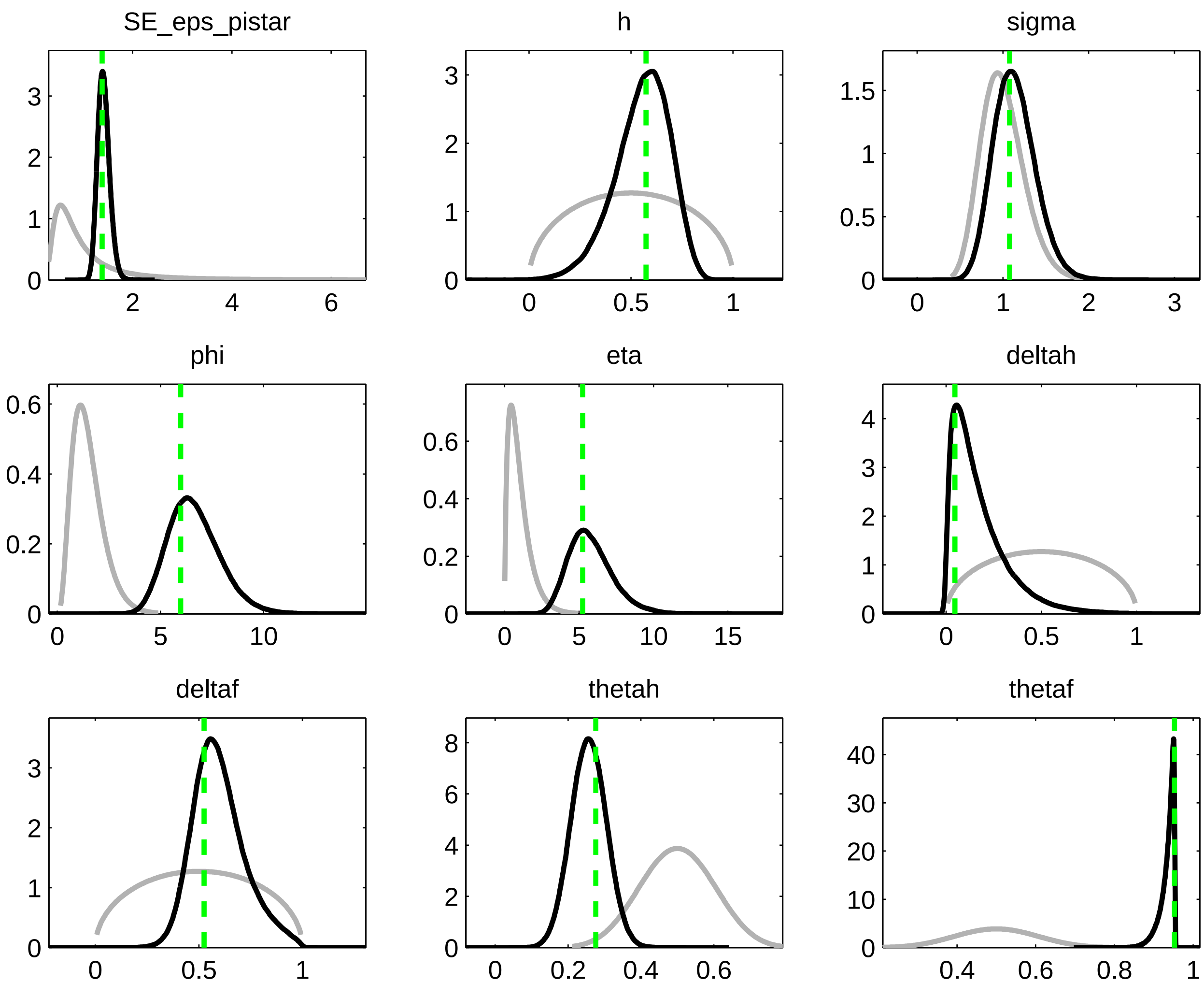

Figure 1: Posterior distribution of model parameters for Australia

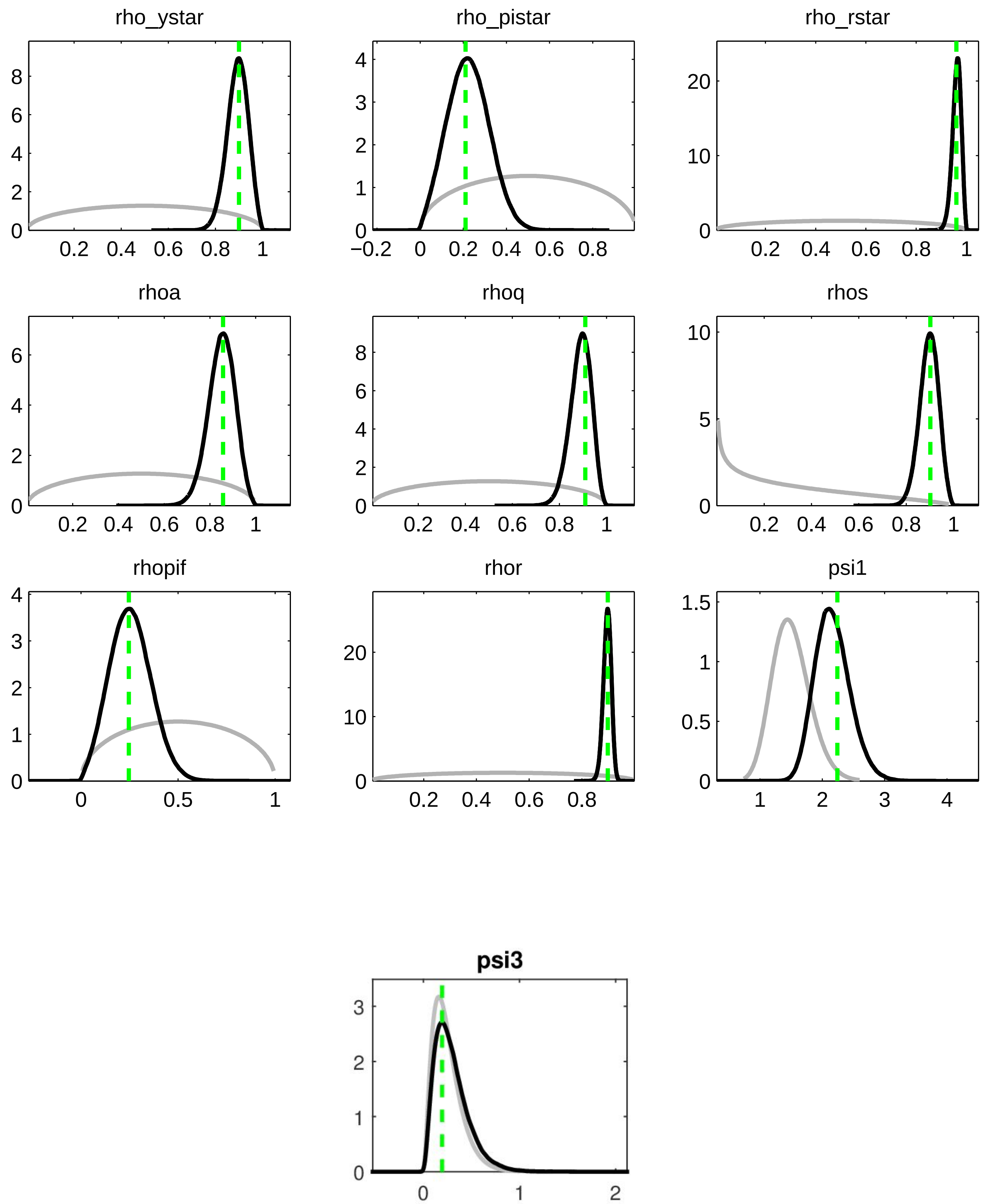

Figure 2: Posterior distribution of model parameters for Australia

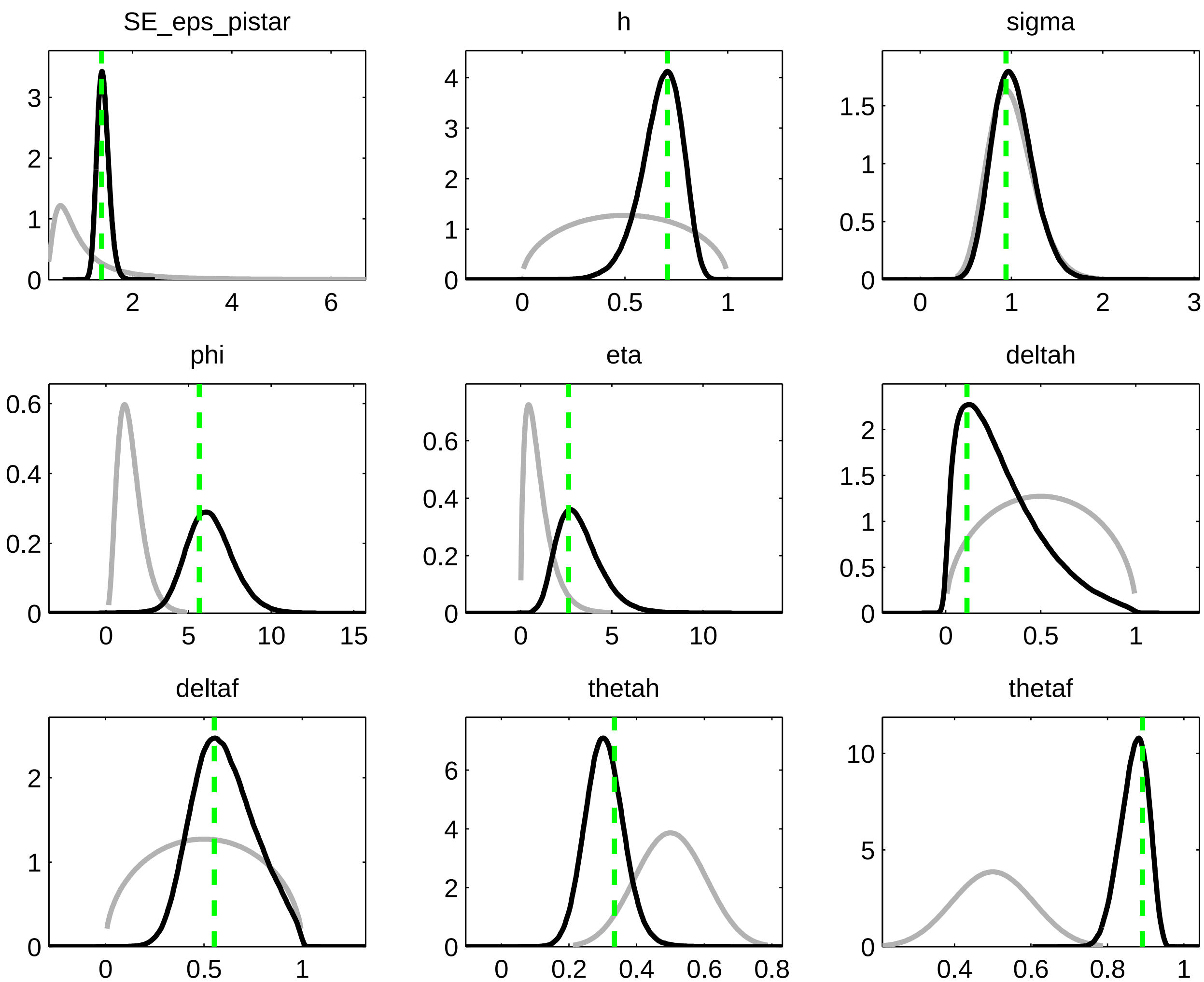

Figure 3: Posterior distribution of model parameters for Canada

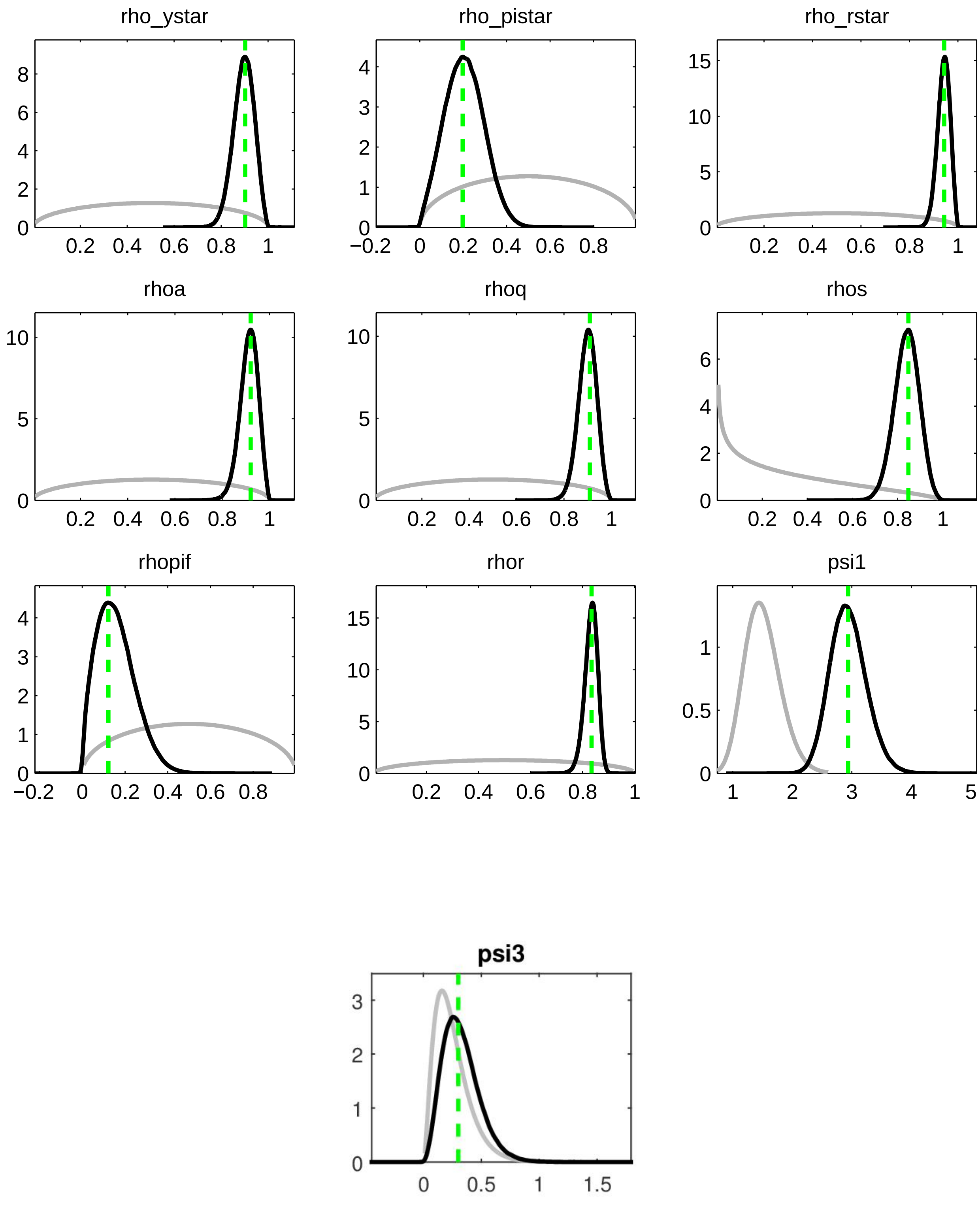

Figure 4: Posterior distribution of model parameters for Canada

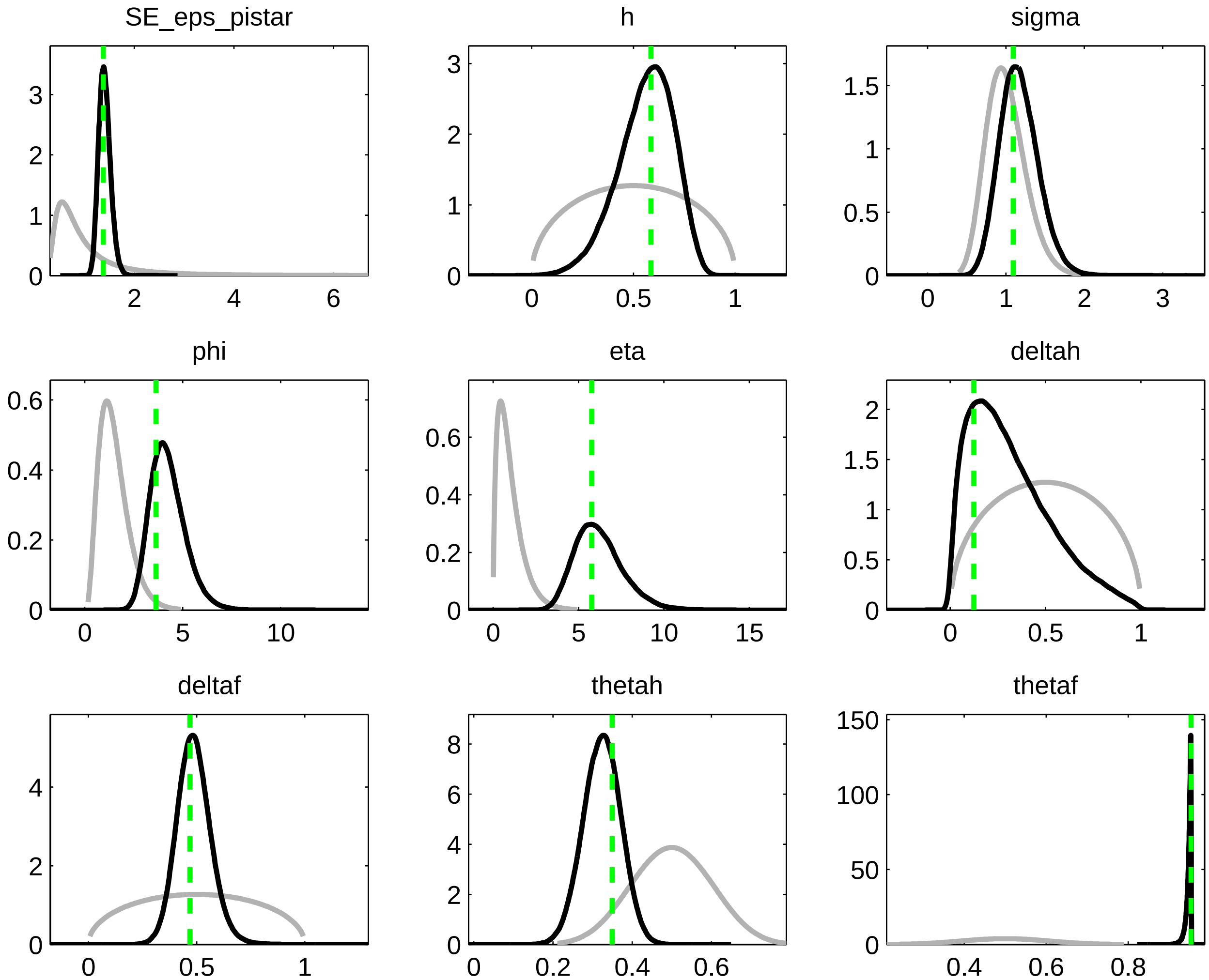

Figure 5: Posterior distribution of model parameters for New Zealand

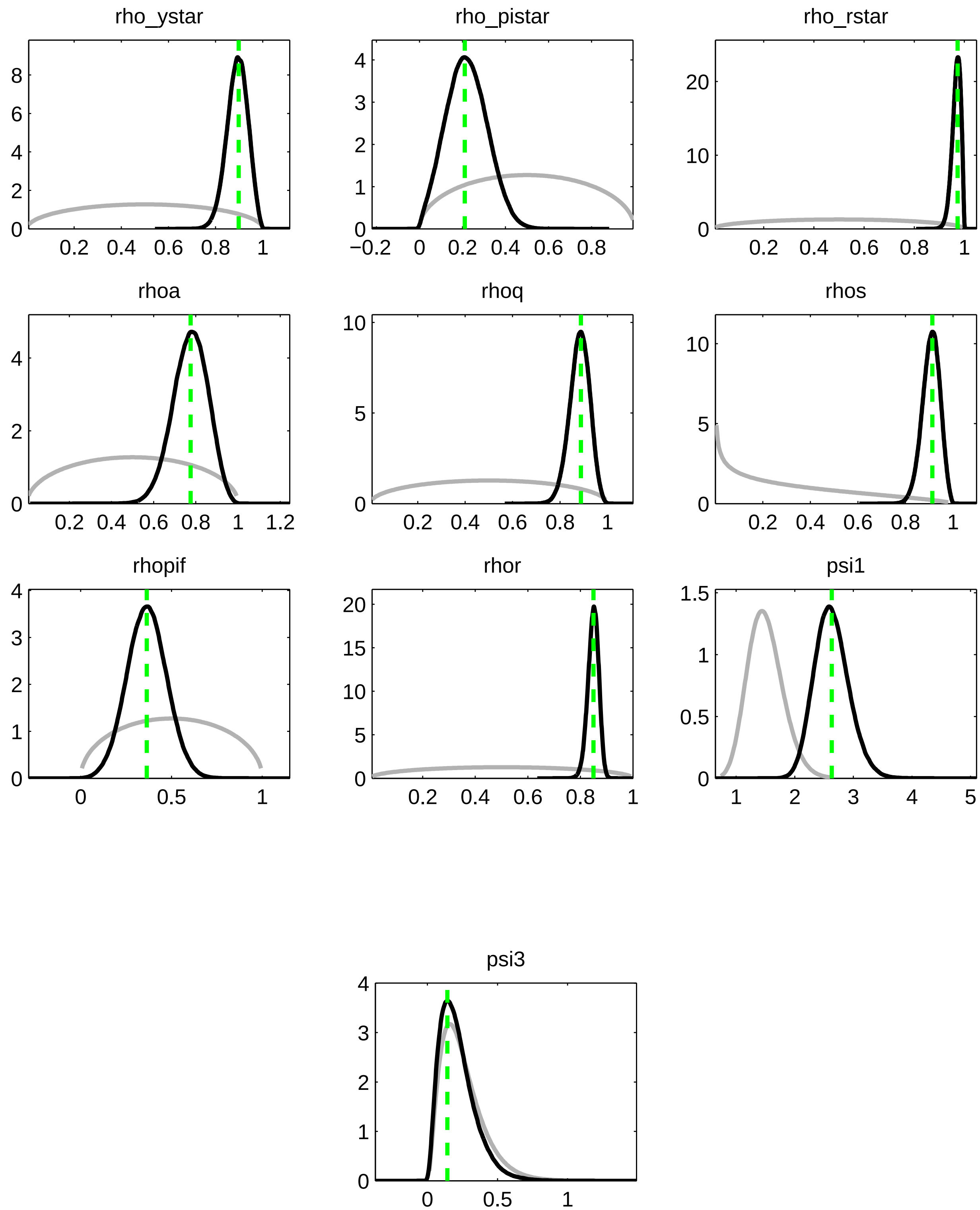

Figure 6: Posterior distribution of model parameters for New Zealand

Appendix

References

Adjemian, S., H. Bastani, M. Juillard, F. Mihoubi, G. Perendia, M. Ratto, and S. Villemot, "Dynare: reference manual, version 4," Working Papers 1, Dynare working papers September 2011.

Arestis, Philip, Michail Karouglou, and Kostas Mouratidis, "Monetary Policy Preferences of the European Monetary Union and the UK," Working Papers 2011019, The University of Sheffield, Department of Economics September 2011.

Assenmacher-Wesche, Katrin, "Estimating Central Banks' preferences from a time-varying empirical reaction function," *European Economic Review*, November 2006, *50* (8), 1951–1974.

Brooks, S. P. and A. Gelman, "General methods for monitoring convergence of iterative simulations," *Journal of Computational and Graphical Statistics*, 1998, *7* (4), 434–455.

Calvo, Guillermo, "Staggered contracts in a utility-maximising framework," *Journal of Monetary Economics*, 1983, *12*, 383–398.

Cecchetti, Stephen G, Margaret M McConnell, and Gabriel Perez-Quiros, "Policymakers' Revealed Preferences and the Output-Inflation Variability Trade-Off: Implications for the European System of Central Banks," *Manchester School*, Special I 2002, *70* (4), 596–618.

Clarida, Richard, Jordi Gali, and Mark Gertler, "Monetary policy rules in practice Some international evidence," *European Economic Review*, June 1998, *42* (6), 1033–1067.

Dennis, Richard, "Inferring policy objectives from economic outcomes," *Oxford Bulleting of Economics and Statistics*, 2004, *66* (Supplement), 735–764.

— , "Solving for optimal simple rules in rational expectations models," *Journal of Economic Dynamics and Control*, June 2004, *28* (8), 1635–1660.

— , "The policy preferences of the US Federal Reserve," *Journal of Applied Econometrics*, 2006, *21* (1), 55–77.

Favero, Carlo and Riccardo Rovelli, "Macroeconomic stability and the preferences of the Fed: a formal analysis, 1961-98," *Journal of Money, Credit and Banking*, August 2003, *35* (4), 545–556.

Givens, Gregory E, "Estimating central bank preferences under commitment and discretion," *Journal of Money, Credit and Banking*, September 2012, *44* (6), 1033–1061.

Ilbas, Pelin, "Estimation of monetary policy preferences in a forward-looking model: a Bayesian approach," *International Journal of Central Banking*, 2010, *6* (3), 169–209.

— , "Revealing the preferences of the US Federal Reserve," *Journal of Applied Econometrics*, April/May 2012, *27*, 440–473.

Justiniano, Alejandro and Bruce Preston, "Monetary policy and uncertainty in an empirical small open-economy model," *Journal of Applied Econometrics*, 2010, *25* (1), 93–128.

Kam, Timothy, Kirdan Lees, and Philip Liu, "Uncovering the Hit List for Small Inflation Targeters: A Bayesian Structural Analysis," *Journal of Money, Credit and Banking*, 06 2009, *41* (4), 583–618.

Liu, Philip, "Stabilization bias for a small open economy: The case of New Zealand," *Journal of Macroeconomics*, September 2010, *32* (3), 921–935.

Lubik, Thomas A. and Frank Schorfheide, "Do central banks respond to exchange rate movements? A structural investigation," *Journal of Monetary Economics*, May 2007, *54* (4), 1069–1087.

Monacelli, Tommaso, "Monetary Policy in a Low Pass-Through Environment.," *Journal of Money, Credit & Banking (Ohio State University Press)*, 2005, *37* (6).

Niho, Yoshio and John H Makin, "A Solution to the Inverse Problem of Optimal Control: A Note," *Journal of Money, Credit and Banking*, August 1978, *10* (3), 371–77.

Orphanides, Athanasios, "Historical monetary policy analysis and the Taylor rule," *Journal of Monetary Economics*, July 2003, *50* (5), 983–1022.

Ozlale, Umit, "Price stability vs. output stability: tales of federal reserve administrations," *Journal of Economic Dynamics and Control*, 2003, *27* (9), 1595–1610.

Paez-Farrell, Juan, "Monetary policy rules in theory and in practice: evidence from the UK and the US," *Applied Economics*, 2009, *41* (16), 2037–2046.

Rudebusch, Glenn and Lars E.O. Svensson, "Policy Rules for Inflation Targeting," in "Monetary Policy Rules" NBER Chapters, National Bureau of Economic Research, Inc, April 1999, pp. 203–262.

Salemi, Michael K., "Revealed preference of the Federal Reserve: using inverse-control theory to interpret the policy equation of a vector autoregression," *Journal of Business & Economic Statistics*, October 1995, *13* (4), 419–433.

_ , "Econometric Policy Evaluation and Inverse Control," *Journal of Money, Credit and Banking*, October 2006, *38* (7), 1737–1764.

Smets, Frank and Raf Wouters, "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area," *Journal of the European Economic Association*, 09 2003, *1* (5), 1123–1175.

Smith, Christie, "Revealing monetary policy preferences," Reserve Bank of New Zealand Discussion Paper Series DP2009/01, Reserve Bank of New Zealand April 2009.

Svensson, Lars E.O. and Michael Woodford, "Implementing Optimal Policy through Inflation-Forecast Targeting," in "The Inflation-Targeting Debate" NBER Chapters, National Bureau of Economic Research, Inc, October 2004, pp. 19–92.

Taylor, John B., "Discretion versus policy rules in practice," *Carnegie-Rochester Conference Series on Public Policy*, December 1993, *39* (1), 195–214.

_ , *Monetary Policy Rules* NBER Books, National Bureau of Economic Research, Inc, December 1999.

_ , "The Role of Policy in the Great Recession and the Weak Recovery," *American Economic Review*, May 2014, *104* (5), 61–66.