



DP2006/08

What do robust policies look like for open  
economy inflation targeters?

Kirdan Lees

September 2006

JEL classification: C51, E52, F41

[www.rbnz.govt.nz/research/discusspapers/](http://www.rbnz.govt.nz/research/discusspapers/)

Discussion Paper Series

DP2006/08

**What do robust policies look like for open economy  
inflation targeters?\***

**Kirdan Lees<sup>†</sup>**

**Abstract**

Typical New Keynesian open economy models suggest a limited response to the exchange rate. This paper examines the role of the open economy in determining robust rules when the central bank fears various model misspecification errors. The paper calibrates a hybrid New Keynesian model to broadly fit the economies of three archetypal open economy inflation targeters – Australia, Canada and New Zealand – and seeks robust time-consistent policy. We find that policies robust to model misspecification react more aggressively to not only the exchange rate, but also inflation, the output gap and their associated shocks. This result generalizes to the context of a flexible inflation targeting central bank that cares about the volatility of the real exchange rate. However, when the central bank places only a small weight on interest rate smoothing and fears misspecification in only exchange rate determination, a more cautious policy is recommended for all but an exchange rate shock. It is also shown that the benefits of an exchange rate channel far outweigh the concomitant costs of uncertain exchange rate determination.

Keywords: Uncertainty; Open Economy; Robust Control

JEL classification: C51, E52, F41

---

\* The views expressed in this paper are those of the author(s) and do not necessarily reflect those of the Reserve Bank of New Zealand. We thank Christie Smith, Shaun Vahney and seminar participants at the Reserve Bank of New Zealand, Victoria University of Wellington, NZAE 2004, ESAM 2004 and SCE 2005 for helpful comments.

<sup>†</sup> Corresponding Address: Kirdan Lees, Economics Department, Reserve Bank of New Zealand, 2 The Terrace, Wellington, 6011, New Zealand. Tel: +64 4 471 3666, Fax: +64 4 473 1209. *email address: leesk@rbnz.govt.nz*

©Reserve Bank of New Zealand

# 1 Introduction

Thinking about best practice monetary policy for policymakers means thinking about uncertainty. And relative to the closed economy case, monetary policymakers operating in an open economy face an additional source of uncertainty – the exchange rate.<sup>1</sup>

This paper seeks to identify policy rules that are robust to the uncertainty around model dynamics that inflation targeters face in practice. An open economy model with an explicit inflation targeting framework is calibrated to broadly match data for three small open inflation targeters, Australia, Canada and New Zealand. These countries are among the earliest explicit inflation targeters and now form a useful dataset for identifying open economy macro-dynamics under inflation targeting. The data from these countries enable us to explore policy rules that are robust to uncertainty around these dynamics.

Thinking about uncertainty has a long history in economics dating back at least as far as Knight (1924). For Knight (1924), uncertainty differs from risk because the policymaker does not know the nature of the uncertainty and is unable to form a probability distribution over different possible models. Hansen and Sargent (2006) apply Knight’s philosophy to the linear-quadratic control framework. Hansen and Sargent (2006), recognizing that policymakers work with models which are approximations to some true, unknown model, seek a rule that is robust to models close to the policymaker’s best approximation.

Several researchers obtain monetary policy rules robust to dynamics in the neighbourhood of a single reference model. Tetlow and von zur Muehlen (2001) study robust policies within the context of a forward-looking closed economy model, similar to the wage-contracting model of Fuhrer and Moore (1995). They conclude that under unstructured uncertainty, where model misspecification arises in the local vicinity of a single model, the implied policy rule is more aggressive than the case where the estimated model is assumed to be the true model. Onatski and Stock (2002) use the Rudebusch and Svensson (1999) model to compare generalized Taylor-type rules that are robust to uncertainty. Within this model, the robust rule is more aggressive than the standard case with no model uncertainty.

---

<sup>1</sup> Meese and Rogoff (1983) note the exchange rate is extremely difficult to distinguish from a random walk. West (2003) aptly relabels UIP “Uncertain Interest rate Parity”.

In the open economy context, Sargent (1999) discusses a preference for robustness in the context of Ball's (1999) backward-looking model. At the other end of the spectrum, Leitimo and Söderström (2004) analyse the case of a purely forward-looking open economy New Keynesian model, developed by Clarida et al (2001) and Galí and Monacelli (2005). Leitimo and Söderström (2004) derive analytical solutions that show that the aggressiveness of the policy responses depends on both the type of shock and the source of the model misspecification.

This paper calibrates an open economy model with both backward- and forward-looking elements to capture the key features of the open economy dynamics for three inflation targeters. This model forms the reference model for open economy inflation targeters that seek robust monetary policy rules. Section 2 describes the linear-quadratic robust control framework. Section 3 gives the model and reveals the match of the model to the data. Section 4 presents optimal rules under a range of assumptions about the model and the policymaker's preference for robustness. Finally, section 5 concludes the paper.

## 2 The robust control framework

Throughout the paper, monetary policy is examined from the perspective of the linear-quadratic optimal control framework. The central bank is assumed to possess a set of goals or objectives for monetary policy. These goals are achieved by setting the interest rate using a rule that responds to the variables in the model of the economy. The behaviour of the economy acts as a constraint on the ability of the central bank to achieve its goals. It is assumed that central bank preferences can be approximated by a quadratic function and, further, that the economy can be approximated by a linear model. When expectations are rational, this set of assumptions delivers a unique optimal interest rate rule.

Giordani and Söderlind (2004) provide a convenient exposition of solution methods for the robust control problem under commitment, discretion and simple monetary policy rules. Here we represent an outline of their solution method, assuming that the central bank implements policy under discretion. The specification of the problem hinges on the addition of an "evil agent" that introduces feared misspecification dynamics to maximise the loss of the

central bank. This *minimax* problem is:

$$\min_{\{u\}_0^\infty} \max_{\{v\}_1^\infty} E_0 \sum_{t=0}^{\infty} \beta^t (x_t' Q x_t + u_t' R u_t + 2x_t' U u_t) \quad (1)$$

$$s.t. \quad A_0 x_{t+1} = A_1 x_t + B_1 u_t + C_1 (\varepsilon_{t+1} + v_{t+1}) \quad (2)$$

$$E_0 \sum_{t=0}^{\infty} \beta^t v_{t+1}' v_{t+1} \leq \eta_0. \quad (3)$$

The matrix  $Q$  captures the central bank's preference for minimising the variance of particular state variables; the matrix  $R$  represents the central bank's preferences for minimising the variance of the policy instrument (most typically the nominal interest rate); and the matrix  $U$  captures any preference over the covariance between state variables and the instrument. The parameter  $\beta$  gives the rate of discounting of expected losses in future periods. The matrix  $A_0$  captures contemporaneous relationships between the state variables,  $A_1$  encapsulates lagged relationships; while the matrix  $B_1$  gives the impact of the policy instrument on the state variables. It is assumed that the initial state vector,  $x_0$ , is given.

Relative to standard linear-quadratic control, the key introduction is the sequence of misspecification errors  $v_{t+1}$ . The evil agent sets these misspecification errors using a rule. The misspecification errors apply to equations that have the usual errors attached and represent relationships the policy-maker regards with uncertainty. The matrix  $C_1$  determines the magnitude of the errors attached to each equation while the evil agent determines the dynamics of the misspecification errors, constrained by equation (3) which states these misspecification errors are subject to the bound  $\eta_0$ .

Hansen and Sargent (2006) and Giordani and Söderlind (2004) show that the problem specified in equations (1), (2) and (3) can be represented in a rational expectations, linear quadratic state space form, so that the problem can be treated with standard techniques. With the constraint on the evil agent substituted into the model of the economy, the problem is represented as the following:

$$\min_{\{u\}_0^\infty} \max_{\{v\}_1^\infty} E_0 \sum_{t=0}^{\infty} \beta^t (x_t' Q x_t + u_t' R^* u_t^* + 2x_t' U^* u_t^* - \theta v_{t+1}' v_{t+1}) \quad (4)$$

$$s.t. \quad x_{t+1} = A x_t + B^* u_t^* + C \varepsilon_{t+1}, \quad (5)$$

where:

$$\begin{aligned} R^* &= \begin{bmatrix} R & \mathbf{0}_{k \times n} \\ \mathbf{0}_{k \times n} & -\theta I_{n_1} \end{bmatrix}, & u^* &= \begin{bmatrix} u_t \\ v_{t+1} \end{bmatrix}, \\ B^* &= \begin{bmatrix} B & C \end{bmatrix}, & U^* &= \begin{bmatrix} U & \mathbf{0}_{n \times n} \end{bmatrix}. \end{aligned}$$

and where  $A = A_0^{-1}A_1$ ,  $B = A_0^{-1}B_1$  and  $C = A_0^{-1}C_1$ . The parameter  $\theta$  represents the policymaker's preference for robustness. A low value for  $\theta$  represents a large concern for model uncertainty while the standard case of no concern for uncertainty is recovered for  $\theta = \infty$ . This parameter maps directly to  $\eta_0$ , effectively specifying the bounds on the behaviour of the evil agent – a low value of  $\theta$  translates to a relatively high value of  $\eta_0$  implying the evil agent is less constrained.

Applying standard rational expectations solution techniques to the problem yields a policy rule for the central bank and a rule for the misspecification errors induced by the evil agent, both of which are expressed as a linear function of the state variables. That is,

$$u_t^* = -Fx_t \tag{6}$$

where  $u_t^*$  can be expanded as:

$$\begin{bmatrix} u_t \\ v_{t+1} \end{bmatrix} = - \begin{bmatrix} F_u \\ F_v \end{bmatrix} x_t \tag{7}$$

$F_u$  represents the policy rule for the central bank and  $F_v$  gives the rule used by the evil agent. This constitutes a Nash equilibrium. The evil agent chooses a rule for implementing worst case dynamics given the central bank's preference for robustness. The central bank chooses a rule that minimises its loss function assuming the evil agent implements the plausible worst case dynamics.

In the robust control framework there are two sets of model dynamics that should be considered: (i) the *worst* case dynamics, whereby the central bank slants their rule against feared misspecification errors that occur; and (ii) the *approximating* dynamics, where the central bank slants their rule against feared misspecification dynamics that are unfounded and do not eventuate. The dynamics of the “worst case” model can be expressed as:

$$x_{t+1} = M_w x_t + C \epsilon_{t+1} \tag{8}$$

where:

$$M_w = A - BF_u - CF_v. \quad (9)$$

The dynamics of the approximating model are not affected by the machinations of the evil agent though they are affected by the policymaker's desire for a robust rule. Consequently, the dynamics of the approximating model can be represented as:

$$x_{t+1} = M_a x_t + C\epsilon_{t+1} \quad (10)$$

where:

$$M_a = A - BF_u. \quad (11)$$

Of course, whether the differences between the two sets of dynamics are material depends on the extent to which the policymaker fears misspecification dynamics and desires a rule that is robust to this misspecification. The following section details a useful method due to Hansen and Sargent (2006) for parameterising the policymaker's concerns.

## 2.1 How much robustness?

What is the appropriate choice of robustness for the policymaker? It would clearly be a mistake to adopt a rule that is robust to a model that has zero probability of generating the observed data. Instead, the policymaker desires a rule that is robust to models that are *plausible*, in the sense that they are difficult to distinguish from the policymaker's approximate model of the economy. Implausible models should be discarded from the model set used to derive robust policy. Allowing  $\eta$  to be too large will result in a model that is very unlikely to have generated the data. By restricting  $\eta$ , one can prevent such implausible outcomes and instead focus on the (worst) plausible models in a suitable neighbourhood of the reference model.

Models will be plausible provided that the degree of misspecification that the evil agent can induce is not too large. Thus, we are interested in finding a suitable bound on  $\eta_0$ , or equivalently on  $\theta$  in equation (4), the mapping from  $\eta_0$  to  $\theta$  is both one-to-one and onto.

We can think about measuring the degree of plausibility of a candidate worst case model, relative to the reference or approximating model, by thinking about the probabilistic overlap between the data generating functions. Suppose that model  $i$  is the reference model and model  $j$  is the worst case model. Then one can think of performing a test of model  $i$  against the model  $j$  and of

model  $j$  against model  $i$ , using likelihood ratio statistics. Averaging the type I errors of these tests provides a measure of the overlap in the two probability distributions  $Pr(data|i)$  and  $Pr(data|j)$ .

The degree of overlap is determined by the parameter  $\theta$ . If  $\theta$  is small (equivalently  $\eta$  is large) then the evil agent can induce a large misspecification and the probability functions of the two models will not overlap very much. One way of determining  $\theta$  is thus to specify the error detection probability: the average of rejecting the true model:

$$\frac{1}{2} \cdot \Pr(\text{reject } j \text{ in favour of } i | \text{model } j) + \frac{1}{2} \cdot \Pr(\text{reject } i \text{ in favour of } j | \text{model } i)$$

The value of  $\theta$  that corresponds to the error detection probability can be determined by simulation. Typically the literature has settled on error detection probabilities of 10 and 20 percent (see Hansen and Sargent 2006 and Giordani and Söderlind 2004, for example).

### 3 The model

Of course a key input into obtaining robust monetary policy rules is defining a model or belief about how the economy operates. We use a model with both forward-looking expectations, that internalise agents' beliefs about the nature of monetary policy, and backward-looking elements that allow for the observed lags in the effectiveness of monetary policy.

#### 3.1 Theoretical model

McCallum and Nelson (1999) show how an IS equation, derived from a consumption Euler equation, implies that the output gap is a function of agents' expectations of the output gap in addition to the real interest rate. However, this view of the output gap process is generally inconsistent with the finding that the output gap displays substantial persistence in the data. Fuhrer (2000) shows that the addition of habit formation to the utility function for consumers implies that the lag of output enters the optimizing IS equation. If we appeal to decision-making inertia on the part of consumers and lag the real interest rate, we obtain a closed economy output gap equation largely

constructed from structural parameters yet sufficiently flexible to replicate the observed persistence in output gap data.

McCallum and Nelson (1999) derive an open economy version of their optimizing closed economy IS equation that implies the output gap is a function of the real exchange rate, foreign output, the expectation of the real exchange rate and the expectation of foreign output gap.

Simplifying open economy effects to the lag of the real exchange rate, the output gap equation takes the following form:

$$\tilde{y}_t = \beta_1 E_t \tilde{y}_{t+1} + (1 - \beta_1) \tilde{y}_{t-1} - \beta_2 r_{t-1} - \beta_3 q_{t-1} + \varepsilon_{\tilde{y}t} \quad (12)$$

where  $\tilde{y}_t$  represents the output gap,  $r_t$  is a long term real interest rate,  $q_t$  represent the real exchange rate (an increase in  $q_t$  represents an exchange rate appreciation) and  $\varepsilon_{\tilde{y}t}$  is an independent and identically distributed (*i.i.d.*) shock. All the coefficients are positive according to theory. The long term *ex ante* real interest rate is defined using a risk neutral arbitrage condition so the long rate is the sum of the sequence of expected short term interest rates, that is:

$$r_t = \frac{1}{d} \sum_{s=0}^{\infty} \left( \frac{d}{1+d} \right)^s E_t (i_{t+s} - \pi_{t+1+s}) \quad (13)$$

where  $d$  defines the number of quarters for the effective long term real interest rate (see Söderlind 1999 for an empirical example of this definition of the long term real interest rate).

A hybrid New Keynesian Phillips curve is used to model domestic inflation. Structural models of the Phillips curve can be derived from wage-contracting behaviour on the part of firms and workers (see Fuhrer 1997, for example). These models suggest that workers form wage demands as an average of the expected real wage and observed past real wages, with a mark-up in good times and a lower real wage in bad times based on the realization of the output gap. Alternatively, pricing behaviour on the part of firms can be used to derive structural equations for inflation that contain forward- and backward-looking components (see Calvo 1983 and Galí and Gertler 1999). These behavioural assumptions generate hybrid domestic inflation equations similar to:

$$\pi_t^d = \alpha_1 E_t \pi_{t+1}^d + (1 - \alpha_1) \pi_{t-1}^d + \alpha_2 \tilde{y}_{t-1} + \varepsilon_{\pi^d t} \quad (14)$$

where  $\pi_t^d$  represents domestic inflation and  $\varepsilon_{\pi^d t}$  is another stochastic *i.i.d.* shock. Inflation equations developed from strict microfoundations predict a

contemporaneous relationship between inflation and the output gap but this is difficult to reconcile with the data and policy practitioners' views of the transmission mechanism.

The foreign good component of inflation is assumed to be a direct mark-up over the change in the exchange rate with incomplete pass-through:

$$\pi_t^f = \kappa\pi_{t-1}^f + (1 - \kappa)\Delta q_t \quad (15)$$

where  $\pi_t^f$  is foreign good inflation and the parameter  $\kappa$  calibrates the degree of exchange rate pass-through. Finally, consumer price inflation is a combination of domestic price inflation and foreign good inflation, weighted according to  $\phi$ , the proportion of foreign goods in the consumer price index:

$$\pi_t = \phi\pi_t^f + (1 - \phi)\pi_t^d. \quad (16)$$

The no-arbitrage condition that is the basis of uncovered interest rate parity (UIP) may be an appealing structural relationship for modelling the real exchange rate, but this condition does not appear to capture the large and persistent cycles observed in the exchange rate, and so we allow for autocorrelated exchange rate errors. Thus the real exchange rate equation is modelled by UIP:

$$q_t = E_t q_{t+1} + (i_t - E_t \pi_{t+1}) - r^* + \varepsilon_{qt}. \quad (17)$$

where  $r^*$  is a constant real world interest rate and  $\varepsilon_{qt}$  is modelled as an AR(1) process:

$$\varepsilon_{qt} = \rho\varepsilon_{qt-1} + \xi_t \quad (18)$$

where  $\xi_t$  is an *i.i.d.* process. The exchange rate errors  $\varepsilon_{qt}$  can be interpreted as autocorrelation in a risk premium term associated with the domestic currency.

Finally the central bank seeks to minimise an intertemporal loss function:

$$\min_{i_t} \sum_{t=0}^{\infty} \beta^t L_t \quad (19)$$

where the period loss function is assumed to take the following quadratic form:

$$L_t = (\pi_t - \pi^*)^2 + \lambda_1 y_t^2 + \lambda_2 (i_t - i_{t-1})^2 + \lambda_3 (q_t - \bar{q})^2 \quad (20)$$

such that the central bank cares about minimising deviations of inflation from target ( $\pi_t - \pi^*$ ), the output gap, the change in the interest rate and deviations of the real exchange rate from its average ( $q_t - \bar{q}$ ), with specific trade-offs over macroeconomic objectives encapsulated by particular values of  $\lambda_y$ ,  $\lambda_r$  and  $\lambda_q$ .<sup>2</sup> The model is de-measured so we abstract from the inflation target,  $\pi^*$ , and the average exchange rate,  $\bar{q}$ .

The inflation, output gap and change in interest rate arguments are relatively standard (see Rudebusch and Svensson 1999 and Svensson 1999 for example), but the exchange rate argument is non-standard. Nevertheless, some micro-founded models suggest that exchange rate volatility may be costly (Obstfeld and Rogoff 1998 and de Paoli 2004) and in practice, many central banks seek to reduce exchange rate volatility by entering into currency unions or exchange rate pegs. Within the context of inflation targeting, clause 4b of the Reserve Bank of New Zealand's Policy Targets Agreement contains an explicit objective for the volatility of the exchange rate:

In pursuing its price stability objective, the Bank shall implement monetary policy in a sustainable, consistent and transparent manner and shall seek to avoid unnecessary instability in output, interest rates and the exchange rate.

Thus we allow for a central bank that may care about exchange rate volatility.

### 3.2 Model calibration

We seek a generic calibration that can broadly explain the data over the period 1992Q1 to 2003Q4, the majority of the inflation targeting period in Australia, Canada and New Zealand.<sup>3</sup> The calibration draws heavily on existing literature and is relatively standard. Table 1 details the model calibration.

<sup>2</sup> Specifying such quadratic preferences clearly only approximates central bank preferences and policy. For example, Australia, Canada and New Zealand announce specific target ranges for inflation rather than point targets. Moreover, these target ranges have sometimes moved over time.

<sup>3</sup> New Zealand was the first country in the world to adopt an explicit inflation targeting framework in February 1990 and Canada adopted an explicit inflation target in February 1991. Australia adopted inflation targeting in early 1993. However, all three countries underwent disinflationary periods that had largely ended by the beginning of 1992. This motivates the choice of the start of the data sample.

**Table 1****Model calibration**

Parameter	Value	Parameter Description
$\beta_1$	0.1	Forward-lookingness in IS equation
$\beta_2$	0.1	Consumption elasticity wrt lagged long term interest rate
$\beta_3$	0.2	Consumption elasticity wrt lagged real exchange rate
$d$	40	Quarters to maturity of the long term interest rate
$\alpha_1$	0.7	Forward-lookingness in the Phillips equation
$\alpha_2$	0.1	Weight on the output gap in the Phillips equation
$\kappa$	0.8	Degree of pass-through in foreign good inflation
$\phi$	0.5	Share of imported good in consumer price inflation
$\rho$	0.8	Degree of autocorrelation in exchange rate errors
$\sigma_y^2$	0.5	Variance of output gap shocks
$\sigma_{\pi^d}^2$	0.5	Variance of domestic inflation shocks
$\sigma_q^2$	0.5	Variance of risk premium shocks
$\lambda_1$	0.5	Weight on output gap stabilisation
$\lambda_2$	0.5	Weight on interest rate smoothing
$\lambda_3$	0	Weight on exchange rate stabilisation

A lack of persistence in the inflation data motivates a large role for expectations in the Phillips equation (a coefficient of 0.7, more than double the coefficient on the lag of domestic inflation of 0.3). As Dennis and Söderström (2005) note, the literature has not settled on an appropriate calibration for the forward-looking component in the Phillips equation. Completely forward-looking inflation equations have difficulty explaining the persistence in US inflation data. Ball (1999) and Rudebusch and Svensson (1999) assume that the Phillips equation has no forward-looking component. Other researchers, for example Fuhrer (1997), Galí and Gertler (1999), Roberts (1997), and Lindé (2001), suggest estimates on the forward-looking component to be in the range 0.1–0.7.

The effect of the output gap on inflation is calibrated to 0.1; incomplete pass-through from the exchange rate to the price of foreign goods is modelled by setting  $\kappa = 0.8$ , and domestic and foreign goods are weighted equally within the consumer price index, so  $\phi = 0.5$ . Serial correlation in the risk premium shock, with  $\rho = 0.8$ , is necessary to explain the persistent deviations of the real exchange rate from UIP.

Within the IS equation, consumption has a high degree of persistence from a large role for habit formation,  $\beta_1 = 0.1$ . This calibration is much lower

than the calibration of 0.5 in Söderström et al (2005), yet is in line with the results reported in Fuhrer and Rudebusch (2004) and is close to the estimate of 0.3 in Fuhrer (2000).

The sensitivity of the output gap to the real interest rate is set so that  $\beta_2 = 0.1$ . This is half the calibrated value in the open economy of Ball (1999), lower than the open economy calibration of 0.5 in Batini and Haldane (1999), but slightly higher than the parameter estimated in Söderlind (1999) and Rudebusch and Svensson (1999) – both closed economy models. The coefficient on the lag of the real exchange rate,  $\beta_3$ , is set to 0.2, twice the value in Ball (1999).

The variance of the shocks to the inflation, output gap and exchange rate error equations are set to 0.5. The baseline loss function for the central bank is calibrated such that the central bank is twice as concerned with stabilizing inflation relative to stabilizing the output gap,  $\lambda_1 = 0.5$ , and desires interest rate smoothing,  $\lambda_2 = 0.5$ . This is required to mimic the volatility and persistence in the nominal interest rate series.

Observed autocorrelations and standard deviations in the data are used to assess the broad match of the model to the three datasets. The output gap is obtained by HP-filtering data 1985Q1 to 2003Q4 (with the smoothing parameter set to 1600) and then truncating the time series to mitigate some of the effects of the end point problem. Inflation is annualized quarterly consumer price inflation in core inflation measures. The inflation measures exclude volatile items for Australia, and are weighted median measures for Canada and New Zealand. The real exchange rate standard deviations are trade-weighted CPI based measures expressed in percentage terms. The interest rate series are quarterly averages of monthly ninety day series.

This dataset is compared to autocorrelations and standard deviations based on 9,000 simulated observations from the model.<sup>4</sup> Table 2 depicts this comparison.

Looking at the first column of the table, the calibration of the baseline model is very close to the standard deviation observed in Canadian data but the New Zealand output gap is about 50 percent more volatile than both the model and the Canadian data. The standard deviation of inflation implied by the model is close to that of Australia and New Zealand, but overstates

---

<sup>4</sup> This was based on simulating 10,000 observations from the reduced form with initial period values set to 0. The initial 1,000 observations are discarded.

the volatility evident in the Canadian data series.

However, this may be due to alternatives methods in the measurement of core inflation across all three countries. The model appears to mimic the observed volatility in the real exchange rate particularly well. The implied volatility in the nominal interest rate is bracketed by lower volatility in the Australian dataset and slightly higher volatilities for Canada and New Zealand.

**Table 2**  
**Model fit: Australia, Canada and New Zealand 1992Q1–2003Q4**

	Std. dev.	Autocorrelation							
		1	2	3	4	5	6	7	8
Panel 1: Output gap									
Model	1.07	0.72	0.45	0.26	0.14	0.06	0.03	0.00	-0.02
Australia	0.80	0.72	0.44	0.24	0.17	0.20	0.14	-0.06	-0.20
Canada	1.12	0.87	0.64	0.44	0.19	-0.01	-0.17	-0.31	-0.37
New Zealand	1.58	0.86	0.71	0.47	0.26	0.09	0.04	-0.12	-0.20
Panel 2: Inflation									
Model	0.84	0.54	0.23	0.03	-0.07	-0.09	-0.04	-0.03	-0.03
Australia	1.01	0.48	0.16	0.04	0.01	-0.03	0.13	0.08	-0.09
Canada	0.51	0.45	0.25	0.26	0.03	0.17	0.06	-0.00	0.02
New Zealand	0.90	0.40	0.16	0.18	0.10	-0.01	0.03	0.01	-0.14
Panel 3: Nominal interest rate									
Model	1.27	0.88	0.69	0.52	0.38	0.29	0.23	0.17	0.12
Australia	1.09	0.83	0.61	0.43	0.21	0.01	-0.12	-0.20	-0.25
Canada	1.55	0.77	0.56	0.39	0.08	-0.13	-0.18	-0.17	-0.07
New Zealand	2.22	0.83	0.58	0.38	0.24	0.17	0.16	0.15	0.07
Panel 4: Real exchange rate									
Model	1.45	0.82	0.56	0.34	0.19	0.09	0.03	0.00	-0.04
Australia	1.42	0.75	0.60	0.45	0.34	0.15	0.05	0.00	-0.01
Canada	1.47	0.83	0.68	0.57	0.46	0.35	0.24	0.13	0.06
New Zealand	1.55	0.93	0.83	0.75	0.64	0.52	0.36	0.21	0.07

Turning to the autocorrelations, the model matches the persistence observed in the Australian output gap remarkably well. However, the corresponding autocorrelation functions for Canadian and New Zealand data show slightly more persistence than the model. The inflation persistence in the model is slightly higher than the observed persistence in inflation for all three countries. The model does not match the strong persistence observed in the New

Zealand exchange rate but is broadly similar to the persistence for the Australian and Canadian exchange rates. The model appears to slightly overstate the persistence in the nominal interest rate for Australia and Canada but is representative of the persistence observed in the New Zealand ninety day interest rate.

## 4 Robust policies

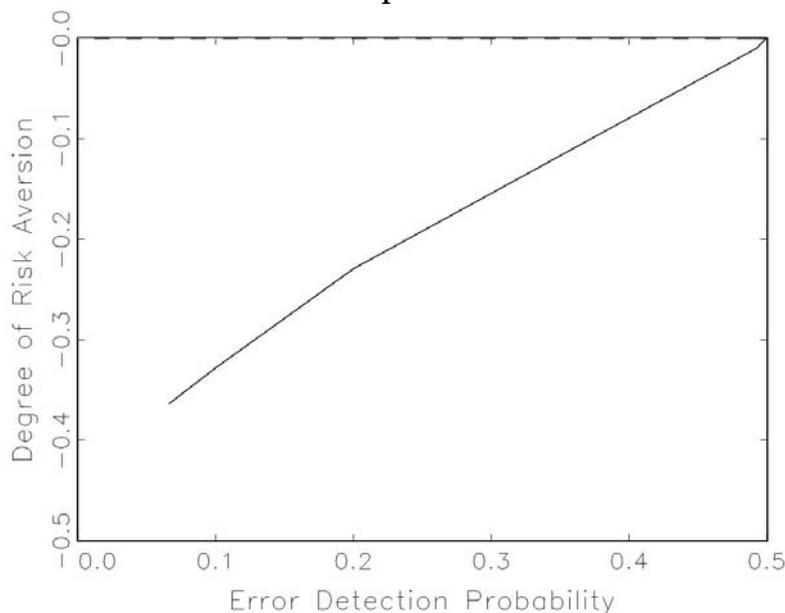
### 4.1 Robust rules

Prior to constructing robust rules, an appropriate preference for robustness must be calculated by calculating the error detection probabilities. Figure 1 presents the map from error detection probabilities to the risk sensitivity parameter under the baseline model. Reading the solid black line to the  $x$ -axis, we see that under the assumption that the observed data sample contains sixty time periods, an error detection probability of 0.1 is associated with a degree of risk aversion of -0.328, which maps to a preference for  $\theta = 3.05$ .

When the policymaker desires a rule robust against models that have at least a 20 percent chance of generating the observed data, the error detection probability of 0.2 is associated with a degree of risk aversion of -0.229 and a robustness parameter of 4.36. Thus a policymaker that demands rules robust to a smaller set of models, is less risk averse and has a higher robustness parameter that places a stricter bound on the nature of the worst case dynamics the evil agent can generate.

Robust rules for the baseline model are presented in the first section of table 3. The standard rule – with no preference for robustness – is labelled “F” and presented in the first row of the table. The appropriate interest rate response (in percentage point terms) to the state variables in the model, labelled at the head of each column, are contained within each cell of the table. For example, the baseline rule indicates that the nominal interest rate should be increased 0.157 percentage points in response to a unit shock to domestic inflation.

Sensibly, the baseline rule indicates that the nominal interest rate should be lowered in response to a positive real exchange shock, the lag of the real ex-

**Figure 1****Baseline error detection probabilities**

change rate and lowered a little if the lag of the long term real interest rate is above its equilibrium value. The interest rate should be increased in response to positive shocks to output and domestic inflation. The response to the lag of the output gap is substantially more aggressive than the corresponding response to the lag of domestic inflation, reflecting the large role for inflation expectations within the Phillips equation. Finally, the coefficient on the lag of the nominal interest rate is 0.33 – noticeably lower than many other studies (see for example, Lansing 2002, Sack and Wieland 2000, Rudebusch 2002).

The second row of the table, labelled “F(20%)”, presents the robust rule associated with an error detection probability of 20 percent. This rule recommends more aggressive policy. The response to a domestic inflation shock approximately doubles to 0.340, the response to the exchange rate and output gap shocks increase substantially. This more aggressive policy response is consistent across each of the state variables with one exception – the rule suggests less interest rate smoothing. Robust policies for open economy inflation targeters are more aggressive than standard rules.

**Table 3**  
**Optimal and robust rules: Baseline model**

Rule	$\varepsilon_{\pi^d t}$	$\varepsilon_{qt}$	$\varepsilon_{\tilde{y}t}$	$\tilde{y}_{t-1}$	$\pi_{t-1}^d$	$q_{t-1}$	$i_{t-1}$	$\pi_t^f$	$R_{t-1}$
Loss function (i): $L_t = \pi_t^2 + 0.5\tilde{y}_t^2 + 0.5\Delta i_t^2$									
F	0.157	-0.575	0.548	0.509	0.047	-0.186	0.330	0.051	-0.055
F(20%)	0.340	-0.640	0.825	0.777	0.102	-0.359	0.246	0.131	-0.083
F(10%)	0.457	-0.683	1.005	0.950	0.137	-0.471	0.186	0.181	-0.101
F( $\varepsilon_\pi$ )	0.711	-0.702	1.071	1.035	0.213	-0.623	0.058	0.283	-0.107
F( $\varepsilon_q$ )	0.186	-0.727	0.655	0.608	0.056	-0.228	0.168	0.062	-0.065
F( $\varepsilon_{\tilde{y}}$ )	0.230	-0.580	0.755	0.703	0.069	-0.289	0.316	0.084	-0.076
Loss function (ii): $L_t = \pi_t^2 + 0.5\tilde{y}_t^2 + 0.1\Delta i_t^2$									
F	0.231	-0.745	0.755	0.703	0.069	-0.238	0.192	0.077	-0.076
F(20%)	0.553	-0.757	1.137	1.079	0.166	-0.511	0.160	0.224	-0.114
F(10%)	0.714	-0.763	1.303	1.244	0.214	-0.643	0.141	0.294	-0.130
F( $\varepsilon_\pi$ )	0.808	-0.774	1.164	1.128	0.242	-0.649	0.124	0.329	-0.116
F( $\varepsilon_q$ )	0.224	-0.809	0.749	0.696	0.067	-0.230	0.123	0.076	-0.075
F( $\varepsilon_{\tilde{y}}$ )	0.302	-0.731	0.949	0.885	0.091	-0.336	0.197	0.111	-0.095
Loss function (iii): $L_t = \pi_t^2 + \tilde{y}_t^2 + \Delta i_t^2$									
F	0.126	-0.519	0.533	0.492	0.038	-0.181	0.376	0.038	-0.053
F(20%)	0.253	-0.596	0.738	0.689	0.076	-0.304	0.277	0.090	-0.074
F(10%)	0.338	-0.638	0.860	0.808	0.101	-0.382	0.208	0.125	-0.086
F( $\varepsilon_\pi$ )	0.440	4.091	0.650	0.629	0.132	-0.377	0.160	0.161	-0.065
F( $\varepsilon_q$ )	0.144	-0.620	0.603	0.557	0.043	-0.208	0.266	0.043	-0.060
F( $\varepsilon_{\tilde{y}}$ )	0.159	-0.533	0.656	0.606	0.048	-0.235	0.358	0.052	-0.066
Loss function (iv): $L_t = \pi_t^2 + y_t^2 + \Delta i_t^2 + q_t^2$									
F	0.184	-0.669	0.646	0.600	0.055	-0.296	0.243	0.056	-0.065
F(20%)	0.235	-0.685	0.942	0.871	0.070	-0.388	0.204	0.078	-0.094
F(10%)	0.262	-0.689	1.135	1.048	0.079	-0.445	0.184	0.090	-0.113
F( $\varepsilon_\pi$ )	0.498	-0.795	1.743	1.619	0.150	-0.716	-0.017	0.183	-0.174
F( $\varepsilon_q$ )	0.194	-0.756	0.067	0.619	0.058	-0.305	0.159	0.057	-0.067
F( $\varepsilon_{\tilde{y}}$ )	0.203	-0.665	0.838	0.775	0.061	-0.347	0.232	0.064	-0.084

NB. Under the baseline rule 'F', there is no preference for robustness and  $\theta = \infty$ .

That robust policy calls for more aggressive policy within the model is underlined by the rule associated with an error detection probability of 10 percent. Interest rate smoothing is reduced and the response to the other state variables increases dramatically. For example, the response to the domestic inflation shock is about triple the response under the standard rule.

The rules  $F(\varepsilon_\pi)$ ,  $F(\varepsilon_q)$  and  $F(\varepsilon_{\tilde{y}})$  show the result of alternative sets of restrictions on the misspecification dynamics that sets the variance of all but the bracketed shock equal to zero. For example rule  $F(\varepsilon_\pi)$  sets the variance of the output gap and exchange rate shocks to zero. This restricts the evil agent to inducing misspecification in only the inflation equation. Of course, under standard policy with no preference for robustness, certainty equivalence applies and the policy rule will be identical to the baseline rule. However, within the robust control framework, certainty equivalence does not hold because restricting the dimensions of the shocks acts as an additional constraint on the behaviour of the evil agent.

The set of rules obtained under restricted misspecification dynamics are generally more aggressive than the baseline although there are exceptions. For example, when the central bank is assumed to have a relatively small weight on interest rate smoothing (loss function (ii), in table 3), the model that restricts the evil agent to misspecification in the real exchange rate equation indicates that policy should respond less aggressively to all but the real exchange shock. This result echoes the finding of Leitimo and Söderström (2004) who find that the policy response should be mitigated when the misspecification dynamics originate in the real exchange rate equation only.

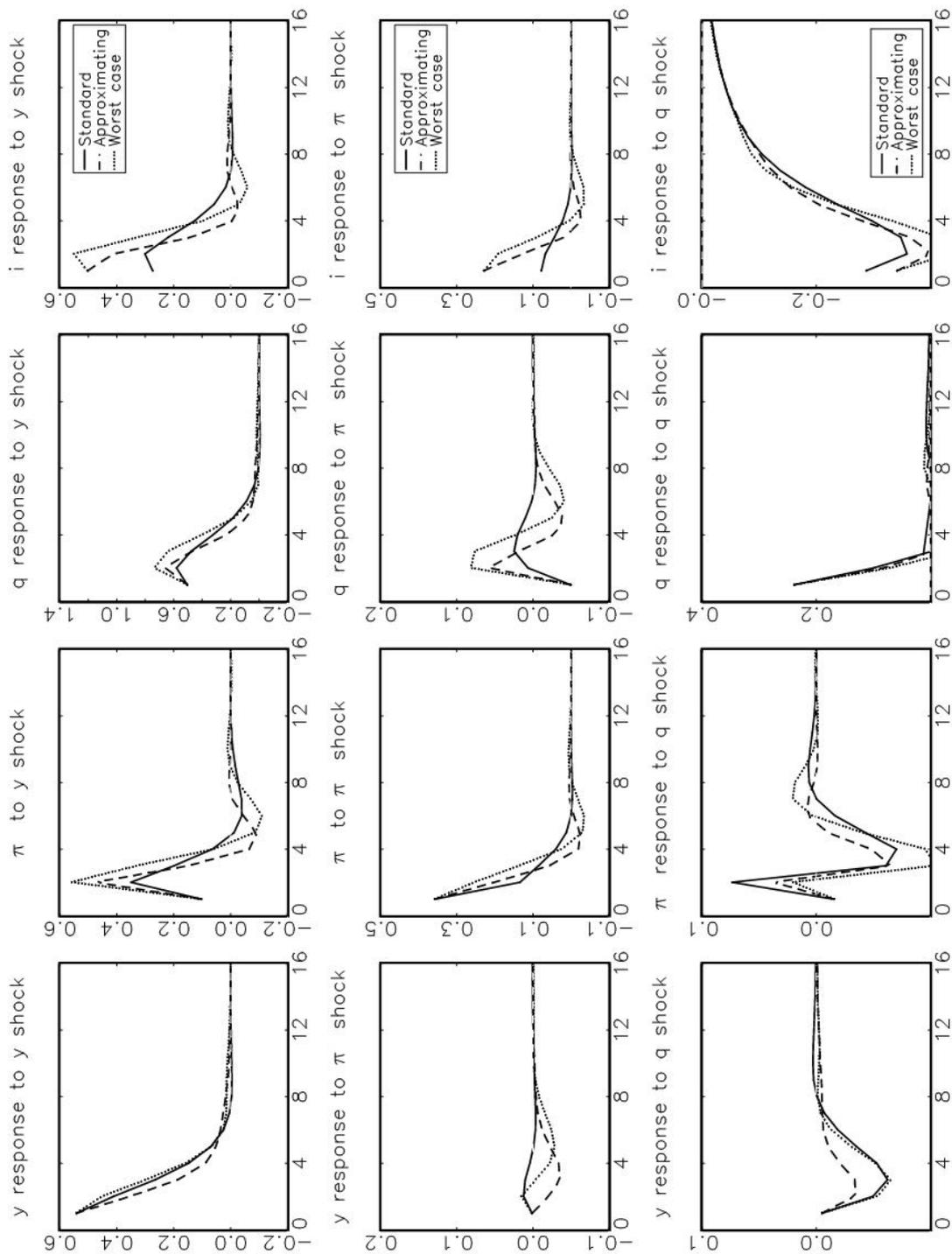
## 4.2 Robust control dynamics

To illuminate the differences in model dynamics when the policymaker adopts typically more aggressive robust rules against unknown misspecification errors, the dynamics of the model are depicted in figure 2 for three alternative scenarios.

The standard case, where the policymaker does not in fact slant their rule against misspecification is depicted with a solid black line. The case where the policymaker slants the rule against unknown errors that do not eventuate, such that the underlining model of the constraint is the approximating model, is depicted with a dashed line. The worst case scenario, where the mis-

Figure 2

## Impulse responses functions for alternative robustness preferences



specification errors feared by the policymaker eventuate and the evil agent's rule for nature is incorporated into the underlying model of the economy, is depicted with the dotted line.

The first row of figure 2 depicts the response of the key macroeconomic variables to an output gap shock. The behaviour of the output gap following its own shock is broadly similar across the three alternative scenarios. After the initial shock, the output gap decreases, falling to zero approximately four to six quarters after the shock. Under the worst case scenario, when the feared misspecification errors occur, the output gap remains above the baseline case for some time but this difference is barely discernible. Under the approximating scenario, where the worst-case misspecification dynamics do not occur, the output gap is returned to zero slightly more quickly than the standard case.

For the standard case, domestic inflation increases relatively sharply initially, before returning towards zero after approximately four quarters. The increase in domestic inflation is more pronounced under the worst case model and domestic inflation remains higher for a number of periods more than the standard case.

This is because the evil agent, aiming to maximise the loss of the central bank, delivers dynamics that increase the persistence of both the output gap shock and domestic inflation. To protect against these feared misspecification dynamics the policymaker slants its rule. If these misspecification errors do not in fact occur, yet the policymaker uses a rule slanted against feared misspecified dynamics a third permutation arises, depicted with a dashed line. Under this scenario, domestic inflation increases initially yet is returned towards target rapidly and actually falls below the path of domestic inflation for the standard case.

Turning to the behaviour of the real exchange rate, in response to the output gap shock, there is little discernible difference in the behaviour of the real exchange rate across the three alternative scenarios. Recall that the baseline loss function does not include the real exchange rate. Given a limited effective budget to manipulate the model's dynamics, the evil agent focuses their activities on manipulating the persistence of the process that affect the paths of the key macroeconomic variables that enter the central bank's loss function.

The response of the nominal interest rate is revealing about how the ag-

gressiveness of the robust policy rule translates into the three alternative dynamic structures. Under the standard model, the nominal interest rate ticks up approximately 30 basis points in response to the output gap shock before decreasing close to zero after about eight quarters. The initial response of the nominal interest rate under the approximating and worst case models is stronger – an increase of approximately 50 basis points. Note that the initial increase in the nominal interest rate is identical under both the approximating and worst case models because the policy rule is identical and the misspecification dynamics take time to impact on the paths of the variables.

After the initial increase, the nominal interest rate decreases particularly rapidly under the approximating model, passing under the path of the standard model between three and four quarters. Under the worst case model, the machinations of the evil agent results in dynamics that force the nominal interest rate to remain about 25 basis points higher than the approximating model for about six quarters.

That the worst case dynamics map into a higher loss can be seen in table 4.

The table depicts the losses under the approximating and worst case models for a range of central bank preferences, robustness preferences and a range of constraints on the nature of the misspecification dynamics.

Firstly, the table shows that the loss the central bank incurs is always higher when the evil agent is able to implement the worst case dynamics. This of course is unsurprising because the task of the evil agent is to induce misspecified dynamics that impact negatively on the loss the central bank occurs.

Secondly, we observe an increase in the loss when the central bank begins to slant their rule against misspecified dynamics – even when the worst case dynamics do not eventuate. This can be observed in the second row of table 4 where the loss increases by about 20 percent when the central bank slants their rule against misspecified dynamics that have an error detection probability of 20 percent.

### 4.3 The exchange rate transmission channel

A key feature of the small open economy New Keynesian model is that the policymaker can no longer perfectly offset demand shocks. Interest rate

**Table 4**  
**Loss comparison under robust policy: Baseline model**

	20%	10%	$\varepsilon_\pi$	$\varepsilon_{\tilde{y}}$	$\varepsilon_q$
Loss function (i): $L_t = \pi_t^2 + 0.5\tilde{y}_t^2 + 0.5\Delta i_t^2$					
$M_s$	72.82	72.82	15.73	49.99	7.10
$M_a$	88.45	97.37	27.48	53.82	9.05
$M_w$	89.54	102.57	37.28	58.44	9.08
Loss function (ii): $L_t = \pi_t^2 + 0.5\tilde{y}_t^2 + 0.1\Delta i_t^2$					
$M_s$	62.27	62.27	15.46	44.85	1.96
$M_a$	80.72	75.66	24.53	50.49	2.14
$M_w$	86.35	77.96	29.28	53.22	2.15
Loss function (iii): $L_t = \pi_t^2 + \tilde{y}_t^2 + \Delta i_t^2$					
$M_s$	108.79	108.79	16.06	80.20	12.52
$M_a$	124.45	135.98	26.55	84.70	14.71
$M_w$	126.64	136.40	32.32	92.85	15.08
Loss function (iv): $L_t = \pi_t^2 + \tilde{y}_t^2 + \Delta i_t^2 + q_t^2$					
$M_s$	210.46	210.46	16.78	176.38	17.30
$M_a$	258.21	300.85	25.68	209.47	19.46
$M_w$	284.16	336.26	32.26	240.12	19.62

changes alter the exchange rate which plays a direct role in determining inflation via the price of foreign goods in the consumer price index. Although the link between the interest rate and exchange rate may hinder the central bank in the face of demand shocks, this link opens the exchange rate channel to the central bank, enhancing the effectiveness of policy via the impact of the exchange rate on both the output gap and inflation.

This section explores a particularly simple experiment for examining the role of the exchange rate channel for inflation targeters operating under uncertainty. The exchange rate channel is closed off by setting the parameters of the model in a manner that allows no role for the exchange rate – shifting the model from an open economy paradigm to a closed economy world.<sup>5</sup> Clearly this model will no longer approximate the data for Australia, Canada and New Zealand. The exercise is simply a hypothetical experiment to facilitate comparison between closed economy and open economy worlds. That the exchange rate channel is useful is evident in table 5.

**Table 5**  
**Loss comparison under robust policy: Closed economy model**

	20%	10%	$\varepsilon_\pi$	$\varepsilon_{\tilde{y}}$
Loss function (i): $L_t = \pi_t^2 + 0.5\tilde{y}_t^2 + 0.5\Delta i_t^2$				
$M_s$	289.43	289.43	59.91	229.52
$M_a$	418.86	510.98	85.20	268.21
$M_w$	453.46	561.59	101.73	313.84
Loss function (ii): $L_t = \pi_t^2 + 0.5\tilde{y}_t^2 + 0.1\Delta i_t^2$				
$M_s$	189.72	189.72	58.85	130.87
$M_a$	269.73	334.19	82.24	144.46
$M_w$	279.24	343.95	97.56	167.99
Loss function (iii): $L_t = \pi_t^2 + \tilde{y}_t^2 + \Delta i_t^2$				
$M_s$	410.23	410.23	60.46	349.76
$M_a$	568.06	665.74	86.27	404.03
$M_w$	636.34	764.24	103.05	478.99

Table 5 depicts the expected loss under the closed economy model for a range of loss function specifications and restrictions on the nature of the misspecification dynamics. Clearly, the central bank prefers to operate within

<sup>5</sup> The component of foreign goods in the consumer price index is set to zero,  $\mu = 1$ ; the role of the exchange rate in determining the output gap removed,  $\beta_3 = 0$ ; and exchange rate shocks are completely removed from the model.

the open economy world relative to its closed economy counterpart. The loss under the standard case is 289.43 – about 4 times the loss under the open economy model (72.43) shown in table 4.

Turning to the baseline reaction function for the closed economy model (row 1 in table 6), there is no response to the lag of the exchange rate, the exchange rate shock, and the foreign good component of domestic inflation because these variables no longer affect the transmission mechanism.

**Table 6**  
**Optimal and robust rules: Closed economy model**

Rule	$\varepsilon_{\pi^d t}$	$\varepsilon_{qt}$	$\varepsilon_{\tilde{y}t}$	$\tilde{y}_{t-1}$	$\pi_{t-1}^d$	$q_{t-1}$	$i_{t-1}$	$\pi_t^f$	$R_{t-1}$
Loss function (i): $L_t = \pi_t^2 + 0.5\tilde{y}_t^2 + 0.5\Delta i_t^2$									
Baseline*	0.252	0	1.429	1.312	0.076	0	0.778	0	-0.143
Robust (i)	0.507	0	2.549	2.345	0.152	0	0.678	0	-0.255
Robust (ii)	0.676	0	3.332	3.066	0.203	0	0.606	0	-0.333
Robust ( $\varepsilon_\pi$ )	1.087	0	4.954	4.457	0.326	0	0.455	0	-0.495
Robust ( $\varepsilon_{\tilde{y}}$ )	0.378	0	2.021	1.857	0.113	0	0.727	0	-0.202
Loss function (ii): $L_t = \pi_t^2 + 0.5\tilde{y}_t^2 + 0.1\Delta i_t^2$									
Baseline*	0.618	0	2.458	2.274	0.185	0	0.743	0	-0.246
Robust (i)	1.299	0	4.324	4.021	0.390	0	0.632	0	-0.432
Robust (ii)	1.788	0	5.779	5.380	0.536	0	0.544	0	-0.578
Robust ( $\varepsilon_\pi$ )	2.300	0	6.930	6.467	0.690	0	0.466	0	-0.693
Robust ( $\varepsilon_{\tilde{y}}$ )	0.881	0	3.264	3.026	0.264	0	0.700	0	-0.326
Loss function (iii): $L_t = \pi_t^2 + \tilde{y}_t^2 + \Delta i_t^2$									
Baseline*	0.166	0	1.193	1.090	0.050	0	0.790	0	-0.119
Robust (i)	0.331	0	2.096	1.919	0.099	0	0.695	0	-0.210
Robust (ii)	0.424	0	2.627	2.407	0.127	0	0.639	0	-0.263
Robust ( $\varepsilon_\pi$ )	0.781	0	4.243	3.897	0.234	0	0.452	0	-0.424
Robust ( $\varepsilon_{\tilde{y}}$ )	0.251	0	1.703	1.558	0.075	0	0.739	0	-0.170

\*Under the baseline rule, there is no preference for robustness and  $\theta = \infty$ .

\*\* The rules robust to  $e_\pi$  shocks are only robust at the 33% error detection probability.

The coefficients on the remaining state variables have identical signs but are larger than their counterparts in the small open economy model. The policymaker must respond more aggressively to the state variables to stabilise the economy in the absence of an exchange rate transmission channel, a similar response to that Leitemo and Söderström (2004) find in the context of a purely forward-looking open economy model.

A preference for robustness enhances the relative aggression observed in closed economy rules. Relatively extreme responses for the nominal interest rate are implied. This result holds when misspecification dynamics are included in the analysis. Similar increases in the loss can be observed when the policymaker slants their rule when they fear, to different degrees, model misspecification. There is a substantial increase in the loss the central bank incurs when operating within the closed economy world both for the standard and robust cases.

## 5 Concluding remarks

A small open economy New Keynesian model, calibrated to recent data from Australia, Canada and New Zealand, proves a useful environment for identifying robust monetary policy for open economy inflation targeters. The calibrated model appears capable of capturing key features of the Australian, Canadian and New Zealand data. A comparatively high weight on inflation expectations within the Phillips equation appears necessary to capture the relative lack of persistence in inflation compared to US data. This results in policy responding particularly strongly to the output gap relative to domestic inflation.

Robust policies for this model tend to translate into more aggressive responses to the macroeconomy and reduced interest rate smoothing relative to policy rules that ignore robustness concerns. This finding generally holds when the model uncertainty is restricted to particular equations within the model. However, when the central bank places a relatively low weight on interest smoothing and misspecification is restricted to the exchange rate equation, the policy response is less aggressive.

Finally, the role of the exchange rate channel is explored within a closed economy counterpart of the baseline model. For the parameterisation of uncertainty within the paper, the uncertainty that surrounds the UIP condition is not sufficient to offset the benefit of enhanced effectiveness of monetary policy that arises from influencing the exchange rate. According to the expected sum of discounted future losses, the central bank prefers the open economy with its concomitant UIP uncertainty, over the closed economy environment. Policy rules for the closed economy model are consistently more aggressive than the rules for the open economy.

## References

- Ball, L (1999), “Policy rules for open economies,” in *Monetary Policy Rules*, ed J B Taylor, 127–156, NBER, The University of Chicago Press, Chicago.
- Calvo, G A (1983), “Staggered prices in a utility-maximizing framework,” *Journal of Monetary Economics*, 12(3), 383–98.
- Clarida, R, J Gali, and M Gertler (2001), “Optimal monetary policy in open versus closed economies: An integrated approach,” *American Economic Review*, 91(2), 248–52.
- de Paoli, B (2004), “Monetary policy and welfare in a small open economy,” *London School of Economics, Centre for Economic Performance Discussion Paper*, 639.
- Dennis, R and U Söderström (2005), “How important is precommitment for monetary policy?” *Journal of Money, Credit and Banking*, 38(4), 847–872.
- Fuhrer, J C (1997), “Inflation/output variance trade-offs and optimal monetary policy,” *Journal of Money, Credit and Banking*, 29(2), 214–234.
- Fuhrer, J C (2000), “Habit formation in consumption and its implications for monetary-policy models,” *American Economic Review*, 90(3), 367–390.
- Fuhrer, J C and G R Moore (1995), “Monetary policy trade-offs and the correlation between nominal interest rates and real output,” *American Economic Review*, 85, 219–239.
- Fuhrer, J C and G D Rudebusch (2004), “Estimating the Euler equation for output,” *Journal of Monetary Economics*, 51(6), 1133–1153.
- Gali, J and M Gertler (1999), “Inflation dynamics: A structural econometric analysis,” *Journal of Monetary Economics*, 44, 195–222.
- Gali, J and T Monacelli (2005), “Monetary policy and exchange rate volatility in a small open economy,” *Review of Economic Studies*, 72(3), 707–34.
- Giordani, P and P Söderlind (2004), “Solution of macromodels with Hansen-Sargent robust policies: Some extensions,” *Journal of Economic Dynamics and Control*, 28(12), 2367–2397.
- Hansen, L P and T J Sargent (2006), “Robustness,” Unpublished manuscript.
- Knight, F (1924), *Risk, Uncertainty and Profit*, Houghton Mifflin Company, Boston, MA.

- Lansing, K (2002), “Real-time estimation of trend output and the illusion of interest rate smoothing,” *Federal Reserve Board of San Francisco Economic Review*, 0(0), 159–178.
- Leitemo, K and U Söderström (2004), “Robust monetary policy in the New Keynesian framework,” *Macroeconomic Dynamics*, forthcoming.
- Lindé, J (2005), “Estimating New-Keynesian Phillips curves: A full information maximum-likelihood approach,” *Journal of Monetary Economics*, 52(6), 1135–1149.
- McCallum, B T and E Nelson (1999), “An optimizing IS-LM specification for monetary policy and business cycle analysis,” *Journal of Money, Credit and Banking*, 31(Part 1), 296–316.
- Meese, R and K Rogoff (1983), “Empirical exchange rate models of the seventies: Do they fit out of sample?” *Journal of International Economics*, 14, 3–24.
- Obstfeld, M and K Rogoff (1998), “Risk and exchange rates,” *National Bureau of Economic Research, Working Paper*, 6694.
- Onatski, A and J H Stock (2002), “Robust monetary policy under model uncertainty in a small model of the US economy,” *Macroeconomic Dynamics*, 6(1), 85–110.
- Roberts, J M (1997), “Is inflation sticky?” *Journal of Monetary Economics*, 39(2), 173–196.
- Rudebusch, G D (2002), “Assessing nominal income rules for monetary policy with model and data uncertainty,” *The Economic Journal*, 112, 402–432.
- Rudebusch, G D and L E O Svensson (1999), “Policy rules for inflation targeting,” in *Monetary Policy Rules*, ed J B Taylor, 203–62, NBER, The University of Chicago Press, Chicago.
- Sack, B and V Wieland (2000), “Interest rate smoothing and optimal monetary policy: A review of recent empirical evidence,” *Journal of Business and Economic Statistics*, 52(1–2), 205–228.
- Sargent, T (1999), “Comment: Policy rules for open economies,” *Monetary Policy Rules, NBER Conference Report Series*, 144–54.
- Söderlind, P (1999), “Solution and estimation of RE macromodels with optimal policy,” *European Economic Review*, 43, 813–823.
- Söderlind, P, U Söderström, and A Vredin (2005), “New-Keynesian models and monetary policy: A reexamination of the stylized facts,” *Scandinavian Journal of Economics*, 107(3), 521–546.
- Svensson, L E O (1999), “Inflation targeting: Some extensions,” *Journal*

*of Scandinavian Economics*, 101(3), 337–361.

Tetlow, R J and P von zur Muehlen (2001), “Robust policy with misspecified models: Does model uncertainty always call for attenuated monetary policy?” *Journal of Economic Dynamics and Control*, 25(4), 911–949.

West, K D (2003), “Monetary policy and the volatility of exchange rates in New Zealand,” *Reserve Bank of New Zealand, Discussion Paper*, DP2003/09.