

Stabilization bias for a small open economy: The case of New Zealand *

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Abstract

Using a fully specified DSGE model, this paper explores the relationship between a central bank's policy objectives and the stabilization bias. The model is then estimated using data from New Zealand. Results indicate that the size of the stabilization bias is nearly twice as large for a SOE relative to that usually found for closed economies. This partly explains the surge in the number of SOE's adopting an inflation targeting framework as a way of anchoring expectations and minimizing the bias. The results also indicate that the size of the stabilization bias increases with the policymaker's preference for stabilizing exchange rate fluctuations. Hence, a stronger attitude towards pre-commitment of policy will aid in minimizing the inefficiency arising from the stabilization bias when the exchange rate is included as one of the stabilization objectives.

Keywords: Stabilization bias; DSGE models; Bayesian estimation; Small open economy;

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1 Introduction

SINCE the 1990's many small open economies (SOE's) have adopted an institutional framework that emphasizes inflation targeting. No country that has adopted it has abandoned it (Truman, 2003), and the numbers are expected to grow. This paper investigates structural differences between a SOE and a closed economy's monetary policy design problem to illuminate on the question why many SOE's have chosen to implement inflation targeting policies. New Zealand was the first country to explicitly adopt an inflation targeting framework under the Reserve Bank of New Zealand (RBNZ) Act in 1989 with the aim of bringing inflation down to a specific target range. The establishment of the Act generated a great deal of interest among both policy makers and researchers in the early 1990s. In addition to the inflation target, the Policy Target Agreement (PTA) was updated in 1999 to reflect the desire to minimize unnecessary variations in the exchange rate as well as variations in output and interest rates.¹ This legislative framework closely resembles the literature on modeling the behavior of a central bank using a loss function. Together with a relatively long historical data set, available since the adoption of inflation targeting, makes New Zealand an ideal case study to investigate issues related to the stabilization bias for a SOE.

The stabilization bias arising from the time-inconsistency problem has been an active area of research following the seminal work by Kydland and Prescott (1977), and Barro and Gordon (1983) (KPBG). In a simple wage bargaining example, KPBG show that without commitment, the monetary authority's claim to keep inflation low is not credible and is time inconsistent. Agents will take this into account when setting wages, resulting in higher inflation than optimal and output staying at its natural level - discretionary *inflation bias*. Rogoff (1985) proposed delegating the role of setting inflation to an independent authority to solve the inflation bias problem. Since then, the study of commitment and discretionary monetary policy has been extended from the static framework to incorporate realistic persistence in output and inflation. Svensson (1997) demonstrates that discretionary policy can still lead to a *stabilization bias*, which reflects the degree of inefficiency arising from implementing monetary policy in a time-inconsistent manner. It is inefficient in a sense that, inflation variability is too high and output variability is too low, relative to the commitment equilibrium.²

¹See section 4(c) of the Reserve Bank of New Zealand PTA, 1999.

²In cases where it is infeasible to remove the distortions, the commitment equilibrium constitutes the second-

The stabilization problem for a SOE differs from its closed economy counterpart in two important dimensions. First, in addition to the supply and demand shocks also faced by the closed economy, the SOE is subject to various foreign disturbances. Second, the exchange rate implies an additional transmission channel for monetary policy as well as an indirect channel for the transmission of foreign shocks to the domestic economy. Clarida et al. (2001) use a simple canonical New Keynesian model to show that the SOE's optimal monetary policy design problem is isomorphic to that of a closed economy. That is, the nature of the underlying output and inflation tradeoff remains the same. More recently, Monacelli (2005) points out this is no longer true once incomplete pass-through in import prices is incorporated into the SOE model. Allowing for incomplete pass-through bears important implications for the design of the optimal monetary policy problem. Deviations from the law of one price (or purchasing power parity) generates an additional endogenous short-run tradeoff between stabilizing inflation and the output gap. This paper incorporates the more realistic dynamics of an actual economy using a fully specified dynamic stochastic general equilibrium (DSGE) model. In an attempt to further understand the nature of this policy tradeoff, two key questions are studied: the empirical importance of the size of the stabilization bias; and the relationship between the stabilization bias and policy objectives of a SOE central bank.

A number of empirical studies have examined the size of the stabilization bias moving from optimal discretionary policy to commitment (pre-commitment).³ Dennis (2004) measures the improvement from pre-commitment using Clarida et al.'s (1999) closed economy model to be between 0% to 11% (relative to the discretionary equilibrium) depending on the different policy objectives, while the model estimated by Rudebusch (2002) generates only modest gains. Ehrmann and Smets (2003) use a New Keynesian model calibrated to the Euro area and measure the gains from commitment to be between 17% and 31%. Using the *inflation equivalent* measure, Dennis and Soderstrom (2006) considers four models estimated using US data and find that the inflation equivalent measure ranges from 0.05 to 3.6 percentage points. Dennis and Soderstrom also stress the size of the stabilization bias depends critically on the model as well as the underlying parameters describing the economy. Lees (2007) estimates the size of the stabilization best outcome. The discretionary stabilization bias still exists even though the central bank tries to maintain output at potential.

³The terms "stabilization bias" and "gains from pre-commitment", measured as the difference in the loss function between commitment and discretion equilibrium, are used interchangeably.

bias for New Zealand using the inflation equivalent measure to be around 1 percentage point.

The previous literature has largely focus on closed economies. Open economy empirical findings so far, such as [Lees \(2007\)](#), are based on models that lack the rich microfoundations. In the current literature, these are considered to be crucial building blocks for modern workhorse macroeconomic models in performing policy analysis. In addition, conclusions drawn from theoretically elegant models are often based on stylized parameter calibrations that may not actually represent the underlying dynamics of an actual economy. In contrast, this paper presents a fully specified DSGE model to examine issues specifically related to SOE's. The model is empirically estimated to obtain a set of deep structural parameters describing an actual economy. Comparison is also made with previous closed economy studies to highlight key differences for a SOE and the resulting policy implications. As a point of departure, this paper also provides an empirical distribution of the estimated stabilization bias taking into account the parameter uncertainty underlying the estimated model as opposed to just a point estimate.

The analysis begins by presenting a slightly modified version of the workhorse SOE New Keynesian model. The design of the model builds extensively on previous work done in this area, notably by [Gali and Monacelli \(2005\)](#), [Monacelli \(2005\)](#) and [Lubik and Schorfheide \(2007\)](#). The model's key aggregate relationships are derived from micro-foundations with optimizing agents and rational expectations. To confront the model with the data, Bayesian method is used to combine prior information together with information contained in the historical data. The size of the stabilization bias is then estimated from the posterior distribution of the model's parameters.

The paper is organized as follows. Section (2) outlines the small open economy model. Section (3) discusses the estimation methodology and describes the data. Section (4) presents the parameter estimation results. Section (5) estimates the size of the stabilization bias together with some policy discussions. Finally, Section (6) contains concluding remarks.

2 A small open economy model

This section describes the key structural equations implied by the model proposed by [Gali and Monacelli \(2005\)](#) and [Monacelli \(2005\)](#). The model's dynamics are enriched by allowing for external habit formation and indexation of prices, as in [Smets and Wouters \(2004\)](#), and [Christiano et al. \(2005\)](#).

2.1 Households

The economy is inhabited by a representative household who seeks to maximize:

$$E_0 \sum_{t=0}^{\infty} \beta^t \{U(C_t) - V(N_t)\} \quad (1)$$

$$U(C_t) = \frac{(C_t - hC_{t-1})^{1-\sigma}}{1-\sigma} \quad \text{and} \quad V(N_t) = \frac{N_t^{1+\varphi}}{1+\varphi}$$

where β is the rate of time preference, σ is the inverse elasticity of intertemporal substitution, and φ is the inverse elasticity of labour supply. N_t denotes hours of labour, and hC_{t-1} represents habit formation for the optimizing household, for $h \in [0, 1]$. C_t is a composite consumption index of foreign ($C_{F,t}$) and domestically ($C_{H,t}$) produced goods defined as:

$$C_t \equiv \left((1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \quad (2)$$

where $\alpha \in [0, 1]$ is the import ratio measuring the degree of openness, and $\eta > 0$ is the elasticity of substitution between home and foreign goods. The household's maximization problem is completed given the following budget constraint at time t :

$$\int_0^1 \{P_{H,t}(i)C_{H,t}(i) + P_{F,t}(i)C_{F,t}(i)\} di + E_t\{Q_{t,t+1}D_{t+1}\} \leq D_t + W_t N_t \quad (3)$$

for $t = 1, 2, \dots, \infty$, where $P_{H,t}(i)$ and $P_{F,t}(i)$ denote the prices of domestic and foreign good $i \in [0, 1]$ respectively, $Q_{t,t+1}$ is the stochastic discount rate on nominal payoffs, D_t is the nominal payoff on a portfolio held at $t - 1$ and W_t is the nominal wage.⁴

Solving the household's optimization problem yields the following set of first order conditions (FOCs):

$$(C_t - hC_{t-1})^{-\sigma} \frac{W_t}{P_t} = N_t^\varphi \quad (4)$$

$$\beta R_t E_t \left\{ \frac{P_t}{P_{t+1}} \left(\frac{C_{t+1} - hC_t}{C_t - hC_{t-1}} \right)^{-\sigma} \right\} = 1 \quad (5)$$

where $R_t = 1/E_t Q_{t,t+1}$ is the gross nominal return on a riskless one-period bond maturing in $t + 1$ and $P_t = \left[(1-\alpha)P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta} \right]^{\frac{1}{1-\eta}}$ is the Consumer Price Index (CPI). The intra-

⁴The consumption basket is aggregated over all i goods, $i \in [0, 1]$.

temporal optimality condition (4) states that the marginal utility of consumption is equal to the marginal value of labour at any one point of time; (5) gives the Euler equation for inter-temporal consumption.

Households in the foreign economy are assumed to face exactly the same optimization problem with identical preferences. The only difference being that the influence from the other economy is negligible.⁵ One can arrive at a similar set of optimality conditions describing the dynamic behaviour of key variables in the foreign economy.

2.2 Inflation, the real exchange rate and terms of trade

Throughout this paper, the assumption of the *law of one price* (LOP) holds for the export sector, but incomplete pass-through for import prices is allowed. The motivation behind this assumption is that the small open economy is a price taker with little bargaining power in the international markets. For its export bundle, prices are determined exogenously in the rest of the world. On the import side, while competition in the world market brings import prices close to the marginal cost at the wholesale level, but rigidities arising from inefficient distribution networks and monopolistic retailers allows domestic retail import prices to deviate from the world price. Burstein et al. (2003) provide a similar argument, which is supported using United States (US) data.

The *terms of trade* (TOT) are defined as $S_t = \frac{P_{F,t}}{P_{H,t}}$ (or in logs $s_t = p_{F,t} - p_{H,t}$).⁶ Log-linearizing the CPI formula around the steady state and taking the first difference yields the following identity linking CPI-inflation, domestic inflation ($\pi_{H,t}$) and the change in the TOT:

$$\Delta s_t = \pi_{F,t} - \pi_{H,t} \tag{6}$$

The change in the TOT is proportional to the difference between import and domestic inflation. In addition, \mathcal{E}_t is the nominal exchange rate (expressed in terms of foreign currency per unit of domestic currency).⁷ Similarly, the real exchange rate and the law of one price (LOP) gap are defined as $\zeta_t \equiv \frac{\mathcal{E}_t P_t}{P_t^*}$ and $\Psi_t = \frac{P_t^*}{\mathcal{E}_t P_{F,t}}$ respectively. If the LOP holds, i.e. if $\Psi_t = 1$, then the

⁵ Assuming the domestic economy is small relative to the foreign economy, foreign consumption approximately comprises only foreign-produced goods such that $C_t^* = C_{F,t}^*$ and $P_t^* = P_{F,t}^*$.

⁶ The terms of trade is thus the price of foreign goods per unit of home good. An increase in s_t is equivalent to an increase in competitiveness for the domestic economy because foreign prices increase and/or home prices fall.

⁷ An increase in \mathcal{E}_t means an appreciation of the domestic currency.

import price index $P_{F,t}$ is the foreign price index divided by \mathcal{E}_t , or $P_{F,t} = \frac{P_t^*}{\mathcal{E}_t}$. The LOP gap is a wedge or inverse mark-up between the *world* price of world goods and the *domestic* price of these imported world goods. Substituting the definition of the CPI, s_t and $\psi_t = \ln(\Psi_t)$ into $q_t = \ln(\zeta_t)$ gives:

$$\begin{aligned} q_t &= e_t + p_t - p_t^* \\ &= -\psi_t - (1 - \alpha)s_t \\ \Rightarrow \psi_t &= -[q_t + (1 - \alpha)s_t] \end{aligned} \tag{7}$$

Consequently, the LOP gap is inversely proportionate to the real exchange rate and the degree of international competitiveness for the domestic economy.

Under the assumption of complete international financial markets and perfect capital mobility, the expected nominal return from risk-free bonds, in domestic currency terms, must be the same as the expected domestic-currency return from foreign bonds, that is $E_t Q_{t,t+1} = E_t(Q_{t,t+1}^* \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t})$. Using this relationship, the intertemporal optimality conditions can be equated for the domestic and foreign households' optimization problem. Assuming the same habit formation parameter across the two countries gives a similar international risk sharing condition as in [Gali and Monacelli \(2005\)](#) under external habit formation:

$$C_t - hC_{t-1} = \vartheta(C_t^* - hC_{t-1}^*)\zeta_t^{-\frac{1}{\sigma}} \tag{8}$$

where ϑ is a constant depending on initial asset positions. Log-linearizing equation (8) around the steady state gives:

$$c_t - hc_{t-1} = (y_t^* - hy_{t-1}^*) - \frac{1-h}{\sigma}q_t \tag{9}$$

In the absence of international trade in the foreign economy, it is assumed that $c_t^* = y_t^*$. The assumption of complete international financial markets and perfect capital mobility leads to a simple relationship linking the domestic economy with world output and the real exchange rate. Furthermore, these assumptions help recover another important relationship, the *uncovered interest parity* (UIP) condition:

$$E_t \left(Q_{t,t+1} \left\{ R_t - R_t^* \frac{\mathcal{E}_t}{\mathcal{E}_{t+1}} \right\} \right) = 0 \tag{10}$$

Log linearizing around the perfect foresight steady state yields the familiar UIP condition for the real exchange rate:⁸

$$E_t \Delta q_{t+1} = - \{ (r_t - E_t \pi_{t+1}) - (r_t^* - E_t \pi_{t+1}^*) \} \quad (11)$$

that is, the expected change in q_t depends on the current real interest rate differentials.

2.3 Firms

2.3.1 Production technology

There is a continuum of identical monopolistically-competitive firms; the j^{th} firm produces a differentiated good, Y_j , using a linear production function:

$$Y_t(j) = A_t N_t(j) \quad (12)$$

where $a_t \equiv \log A_t$ follows an AR(1) process, $a_t = \rho_a a_{t-1} + \nu_t^a$, describing the firm-specific productivity index. Aggregate output can be written as

$$Y_t = \left[\int_0^1 Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}}. \quad (13)$$

where $\varepsilon > 1$ is the elasticity of substitution among varieties. Given each firm has the same technology, the real total cost of production is $TC_t(j) = \frac{W_t}{P_{H,t}} \frac{Y_t(j)}{A_t}$. Hence, the real marginal cost, $MC_t(j) = \frac{W_t}{A_t P_{H,t}} \forall j$, will be common across all domestic firms. Substituting the intertemporal Euler equation (4) and the production function (12) into the marginal cost equation, after log-linearizing obtains:

$$mc_t = \frac{\sigma}{1-h} (c_t - hc_{t-1}) + \varphi y_t + \alpha s_t - (1+\varphi)a_t \quad (14)$$

Thus, marginal cost is an increasing function of domestic output and s_t , and is inversely related to the level of labour productivity.

⁸The risk premium is assumed to be constant in the steady state.

2.3.2 Price setting behaviour and incomplete pass-through

Domestic firms

In the domestic economy, monopolistic firms are assumed to set prices in a Calvo-staggered fashion. In any period t , only $1 - \theta_H$, where $\theta_H \in [0, 1]$, fraction of firms are able to reset their prices optimally, while the other fraction θ_H cannot. Instead, the latter are assumed to adjust their prices, $P_t^I(j)$, by indexing it to last period's inflation as follows:

$$P_{H,t}^I(j) = P_{H,t-1}(j) \left(\frac{P_{H,t-1}}{P_{H,t-2}} \right)^{\delta_H} \quad (15)$$

where $\delta_H \in [0, 1]$ is the degree of price indexation to the previous period's inflation rate.⁹ Consider only the symmetric equilibrium case since all domestic firms face the same pricing problem, that is $P_{H,t}(j) = P_{H,t}(k)$, $\forall j, k$. Let $\bar{P}_{H,t}$ denote the price level that an optimizing firm sets each period. The evolution of the aggregate home goods price index is defined as:

$$P_{H,t} = \left\{ (1 - \theta_H) (\bar{P}_{H,t})^{1-\varepsilon} + \theta_H \left[P_{H,t-1} \left(\frac{P_{H,t-1}}{P_{H,t-2}} \right)^{\delta_H} \right]^{1-\varepsilon} \right\}^{\frac{1}{1-\varepsilon}} \quad (16)$$

When setting the new price, in period t , an optimizing firm will seek to maximize the current value of its dividend stream subject to the sequence of demand constraints such that:

$$\max_{P_{H,t}(j)} \sum_{k=0}^{\infty} (\theta_H)^k E_t \left\{ Q_{t,t+k} Y_{t+k}(j) \left[P_{H,t}(j) \left(\frac{P_{H,t+k-1}}{P_{H,t-1}} \right)^{\delta_H} - P_{H,t+k} MC_{t+k} \right] \right\} \quad (17)$$

$$\text{subject to } Y_{t+k}(j) \leq \left[\frac{P_{H,t}(j)}{P_{H,t+k}} \left(\frac{P_{H,t+k-1}}{P_{H,t-1}} \right)^{\delta_H} \right]^{-\varepsilon} (C_{H,t+k} + C_{H,t+k}^*)$$

where MC_{t+k} is the real marginal cost faced by each firm and the effective stochastic discount rate is now $\theta_H^k E_t Q_{t,t+k}$ to take into account firms have a θ_H probability of not being able to reset prices each period. The corresponding first order condition can be written as:

$$\sum_{k=0}^{\infty} \theta_H^k E_t \left\{ Q_{t,t+k} Y_{t+k} \left[\bar{P}_{H,t} \left(\frac{P_{H,t+k-1}}{P_{H,t-1}} \right)^{\delta_H} - \frac{\varepsilon}{\varepsilon - 1} P_{H,t+k} MC_{t+k} \right] \right\} = 0 \quad (18)$$

where $\frac{\varepsilon}{\varepsilon - 1}$ is the real marginal cost if prices were fully flexible. Log linearizing equation (18)

⁹Christiano et al. (2005) assumes $\delta_H = 1$, here it is left unrestricted to determine the degree of backward lookingness in the Phillips Curves.

yields the following New Keynesian Phillips Curve (NKPC), see Appendix (A) for more detail:

$$\pi_{H,t} = \frac{1}{1 + \beta\delta_H} \left(\beta E_t \pi_{H,t+1} + \delta_H \pi_{H,t-1} + \lambda_H m c_t \right) \quad (19)$$

where $\lambda_H = \frac{(1-\beta\theta_H)(1-\theta_H)}{\theta_H}$. The Calvo pricing structure yields a familiar NKPC, where domestic inflation has a forward looking and backward-looking component depending on the degree of price indexation. On the other hand, the elasticity of domestic inflation with respect to changes in the marginal cost depends on the frequency of price adjustments, the sticky price parameter θ_H .

Import retail firms

For the import retailing sector, it is assumed the LOP holds at the wholesale level. However, inefficiency in distribution channels together with monopolistic retailers keep domestic import prices over and above the marginal cost (the world price). As a result, the LOP fails to hold at the retail level for domestic consumers. Following a similar Calvo-pricing argument as before, an import retailer will try and maximize the following objective function subject to domestic import demand:

$$\max_{P_{F,t}(j)} \sum_{k=0}^{\infty} (\theta_F)^k E_t \left\{ Q_{t,t+k} C_{F,t+k}(j) \left[P_{F,t}(j) \left(\frac{P_{F,t+k-1}}{P_{F,t-1}} \right)^{\delta_F} - \frac{P_{t+k}^*(j)}{\varepsilon_{t,k}} \right] \right\} \quad (20)$$

$$\text{subject to } C_{F,t+k}(j) \leq \left[\frac{P_{F,t}(j)}{P_{F,t+k}} \left(\frac{P_{F,t+k-1}}{P_{F,t-1}} \right)^{\delta_H} \right]^{-\varepsilon} C_{F,t+k}$$

where P_{t+k}^* is the world competitive price in foreign currency, $\theta_F \in [0, 1]$ is the fraction of importer retailers that cannot re-optimize their prices every period, $\delta_F \in [0, 1]$ is the degree of price indexation in the import retailing sector and both θ_H and δ_H are allowed to differ from its domestic counterpart. Recall the LOP $\Psi_t = \frac{P_t^*}{\varepsilon_t P_{F,t}}$, the corresponding first order condition can be written as:

$$\sum_{k=0}^{\infty} \theta_F^k E_t \left\{ Q_{t,t+k} C_{F,t+k} \left[\bar{P}_{F,t} \left(\frac{P_{F,t+k-1}}{P_{F,t-1}} \right)^{\delta_F} - \frac{\varepsilon}{\varepsilon - 1} P_{F,t+k} \Psi_{t+k} \right] \right\} = 0 \quad (21)$$

In setting the new price for imports, domestic retailers are concerned with the future path of import inflation as well as the LOP gap, Ψ_t . Essentially, Ψ_t is the margin over and above the wholesale import price. A non-zero LOP gap represents a wedge between the *world* and

domestic import prices. This provides a mechanism for incomplete import pass-through in the short-run, implying changes in world import prices have a gradual effect on the domestic economy. Similarly, the import price inflation dynamic can be shown to follow the following NKPC:

$$\pi_{F,t} = \frac{1}{1 + \beta\delta_F} \left(\beta E_t \pi_{F,t+1} + \delta_F \pi_{F,t-1} + \lambda_F \psi_t \right) \quad (22)$$

where $\lambda_F = \frac{(1-\beta\theta_F)(1-\theta_F)}{\theta_F}$. Log-linearizing the definition of CPI and taking the first difference yields the following relationship for overall inflation:

$$\pi_t = (1 - \alpha)\pi_H + \alpha\pi_F \quad (23)$$

Taking the definition for overall inflation (23) together with equations (19) and (22) completes the specification of inflation dynamics for the SOE.

2.4 Equilibrium

2.4.1 Aggregate demand and output

Goods market clearing in the domestic economy requires that domestic output is equal to the sum of domestic consumption and foreign consumption of home produced goods (exports):

$$y_t = c_{H,t} + c_{H,t}^* \quad (24)$$

The optimal demand functions for $C_{H,t}$ and $C_{H,t}^*$ are given by:

$$C_{H,t} = (1 - \alpha) \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} C_t \quad \text{and} \quad C_{H,t}^* = \alpha \left(\frac{P_{F,t}}{P_t} \right)^{-\eta} C_t^* \quad (25)$$

and taking the log of the two demand functions and using the definitions of the log of TOT (s_t) and the log of the LOP gap (ψ_t) gives:

$$c_{H,t} = (1 - \alpha)[\alpha\eta s_t + c_t] \quad (26)$$

$$c_{H,t}^* = \alpha[\eta(s_t + \psi_t) + c_t^*] \quad (27)$$

From equation (26), an increase in s_t (equivalent to an increase in domestic competitiveness in the world market) will see domestic agents substitute out of foreign-produced goods into home-produced goods for a given level of consumption. The magnitude of substitution will depend on η , the elasticity of substitution between foreign and domestic goods; and the degree of openness, α . Similarly, from equation (27) an increase in s_t will see foreigners substitute out of foreign goods and consume more home goods for a given level of income.

Substituting equations (26) and (27) into (24) yields the goods market clearing condition for the SOE as:

$$y_t = (1 - \alpha)c_t + \alpha c_t^* + (2 - \alpha)\alpha\eta s_t + \alpha\eta\psi_t \quad (28)$$

Notice that when $\alpha = 0$, the closed economy case, it gives $y_t = c_t$.

2.5 A simple reaction function

In order to estimate the deep structural parameters, the behavior of the domestic monetary authority is specified to complete the small open economy model. The aim of the monetary authority is to stabilize both output and inflation according to a simple Taylor type rule such that:

$$r_t = \rho_r r_{t-1} + (1 - \rho_r)[\phi_1 \pi_t + \phi_2 \Delta y_t] \quad (29)$$

where ρ_r is the degree of interest rate smoothing, ϕ_1 and ϕ_2 are the relative weights on inflation and output growth respectively. The approach here follows [Orphanides \(2003\)](#) in including output growth rather than the traditional output gap measure in the Taylor rule to provide a historical view on the central bank's behavior over the sampling period.

2.6 The linearized model

This subsection summarizes the complete log-linearized model. Log-linearizing the intertemporal Euler equation (5) gives the following dynamic equation relating past, current and future consumption with the real interest rate:

$$c_t - hc_{t-1} = E_t(c_{t+1} - hc_t) - \frac{1-h}{\sigma}(r_t - E_t\pi_{t+1}) \quad (30)$$

Using the model's definition for the terms of trade, the terms of trade growth can be rewritten

as:

$$\Delta s_t = \pi_{F,t} - \pi_{H,t} + \nu_t^s \quad (31)$$

where ν_t^s represents the measurement error from the model's definition. The assumption of perfect capital mobility and complete international markets gives the usual UIP condition (11) plus a risk premium term (ν_t^q) as:

$$\Delta E_t q_{t+1} = -\{(r_t - E_t \pi_{t+1}) - (r_t^* - E_t \pi_{t+1}^*)\} + \nu_t^q \quad (32)$$

In addition to the UIP condition, domestic consumption is tied with foreign consumption through the international risk sharing condition in equation (9) as:

$$c_t - hc_{t-1} = y_t^* - hy_{t-1}^* - \frac{1-h}{\sigma} q_t \quad (33)$$

The dynamic behavior of domestic inflation can be summarized using a Phillips curve under the assumption of monopolistic producers together with the Calvo pricing mechanism as:

$$\pi_{H,t} = \frac{1}{1 + \beta\delta_H} \left(\beta E_t \pi_{H,t+1} + \delta_H \pi_{H,t-1} + \lambda_H mc_t \right) + \nu_t^{\pi_H} \quad (34)$$

where $mc_t = \frac{\sigma}{1-h}(c_t - hc_{t-1}) + \varphi y_t + \alpha s_t - (1 + \varphi)a_t$ is the log of the marginal cost, and $\nu_t^{\pi_H}$ is the measurement error of the domestic inflation Phillips curve. The assumption of monopolistic importers gives a similar Phillips curve describing the behavior of import inflation:

$$\pi_{F,t} = \frac{1}{1 + \beta\delta_F} \left(\beta E_t \pi_{F,t+1} + \delta_F \pi_{F,t-1} + \lambda_F \psi_t \right) + \nu_t^{\pi_F} \quad (35)$$

where $\psi_t = -[q_t + (1 - \alpha)s_t]$ is the log of LOP gap that give rise to imperfect exchange rate pass-through, and $\nu_t^{\pi_F}$ is the measurement error of the import inflation Phillips curve. From the definition of the CPI, overall inflation can be written as:

$$\pi_t = (1 - \alpha)\pi_{H,t} + \alpha\pi_{F,t} \quad (36)$$

The goods market clearing condition requires that domestic output is equal to the sum of

domestic consumption plus exports gives:

$$y_t = (2 - \alpha)\alpha\eta s_t + (1 - \alpha)c_t + \alpha\eta\psi_t + \alpha y_t^* \quad (37)$$

The behavior of the central bank is described using a Taylor type reaction function:

$$r_t = \rho_r r_{t-1} + (1 - \rho_r)(\phi_1 \pi_t + \phi_2 \Delta y_t) + \nu_t^r \quad (38)$$

where ν_t^r is the measurement error to the policy maker's reaction function. To complete the linearized model, three exogenous AR(1) driving processes are included for a_t , y_t^* and $r_t^* - \pi_t^*$ with AR(1) coefficients ρ_a , ρ_{y^*} and ρ_{r^*} respectively.

3 Empirical analysis

This section outlines the procedure used to obtain the posterior distribution of the structural parameters underlying the model described in section (2).

3.1 The Bayesian approach

Fernandez-Villaverde and Rubio-Ramirez (2004) showed the Bayesian estimator is consistent in large samples such that the posterior distribution of the parameters collapses to its pseudotrue values. The use of prior, $p(\Theta)$, allows researchers to include information about the possible values of parameters that is considered to be outside the formal modeling framework. Adding $\ln p(\Theta)$ smoothes the often uneven surface of the log likelihood function making estimation much easier. However, a tightly specified prior can give the illusion that the econometrician has collected useful evidence, i.e.: a relatively small standard error for the estimated coefficient.¹⁰ This paper takes an agnostic approach where the prior specifications are relatively diffuse.

In the Bayesian context, all inference about the parameter Θ is contained in the posterior distribution. The posterior density of the model parameter θ can be written as:

$$p(\Theta|Y^T) = \frac{L(Y^T|\Theta)p(\Theta)}{\int L(Y^T|\Theta)p(\theta)d\Theta} \quad (39)$$

¹⁰The problem is more severe if the likelihood function has little information.

where $p(\Theta)$ is the prior density and $L(Y^T|\Theta)$ is the likelihood conditional on the observed data Y^T . The likelihood function can be computed via the state-space representation of the model together with the measurement equation linking the observed data to the state vector. The solution of the linearized economic model described in section (2.6) has the following state-space representation:

$$X_{t+1} = \Gamma_1 X_t + \Gamma_2 w_{t+1} \quad (40)$$

$$Y_t = \Lambda X_t + \mu_t \quad (41)$$

where X_t is the state vector, Y_t is the vector observed variables, ϵ_t is the vector of state innovations, μ_t is the measurement error, Γ_1 and Γ_2 are the solution matrices of the rational expectations model, and Λ is the matrix defining the relationship between the state vector and the observed variables. Assuming the state innovations and measurement errors are normally distributed with mean zero and variance-covariance matrices Ξ and Υ respectively, the likelihood function of the model is given by:

$$\ln L(Y^T|\Gamma_1, \Gamma_2, \Lambda, \Xi, \Upsilon) = -\frac{TN}{2} \ln 2\pi - \sum_{t=1}^T \left[\frac{1}{2} \ln |\Omega_{t|t-1}| + \frac{1}{2} \mu_t' \Omega_{t|t-1}^{-1} \mu_t \right] \quad (42)$$

where $\Theta = \{\Gamma_1, \Gamma_2, \Lambda, \Xi, \Upsilon\}$, $\Omega_{t|t-1} = \Lambda' \Sigma_{t|t-1} \Lambda + \Upsilon$ and $\Sigma_{t|t-1} = \Gamma_1 \Sigma_{t-1|t-1} \Gamma_1' + \Gamma_2 \Xi \Gamma_2'$. Given some initial state value, $S_0 \sim N(\bar{S}_0, \Sigma_0)$, the likelihood function (42) can be evaluated using the Kalman filter algorithm described in [Anderson et al. \(1996\)](#). Recognizing that $\int L(Y^T|\theta)p(\theta)d\theta$ is a constant, it is only necessary to be able to evaluate the posterior density up to a proportionate constant using the following relationship:

$$p(\Theta|Y^T) \propto L(Y^T|\Theta)p(\Theta) \quad (43)$$

The posterior density summarizes the information contained in the likelihood function weighted by the prior density $p(\Theta)$. The prior can be used to bear information not contained in the sample, Y^T . The random walk Metropolis Hastings algorithm described in [An and Schorfheide \(2007\)](#) is used to simulate the Markov Chain Monte Carlo (MCMC) draws to construct the posterior distribution of the model's parameters.

3.2 Data and priors

New Zealand data from 1990Q1 to 2006Q4 is used to estimate the SOE New Keynesian model. Quarterly observations on log of domestic output (y_t), interest rates (r_t), overall inflation (π_t), import inflation ($\pi_{F,t}$), log of real exchange rate (q_t), the log of terms of trade (s_t), log of foreign output (y_t^*), and foreign real interest rate ($\bar{r}_t^* = r_t^* - \pi_t^*$) are taken from Statistics New Zealand and the RBNZ database. All variables are re-scaled to have a mean of zero and could be interpreted as an approximate percentage deviation from the mean.¹¹ See Appendix (B) for a more detailed description of the data transformations.

The choice of priors for the estimation are guided by several considerations. At the basic level, the priors reflect the modeler's beliefs and confidence about the likely location of the structural parameters. Information on the structural characteristics of the New Zealand economy, such as the degree of openness, being a commodity producer and its institutional settings, were all taken into account. In the case of New Zealand, micro-level studies are relatively scarce. Priors from similar studies using New Zealand data, for example [Justiniano and Preston \(2004\)](#), and [Lubik and Schorfheide \(2007\)](#), were also considered. Finally, the choice of prior distributions reflects restrictions on the parameters such as non-negativity or interval restrictions. Beta distributions were chosen for parameters that are constrained on the unit-interval. Gamma and normal distributions were selected for parameters in \mathfrak{R}^+ , while the inverse gamma distribution was used for the variance of the shocks.

The priors on the model's parameters are assumed to be independent of each other, which allows for easier construction of the joint prior density used in the MCMC algorithm. Furthermore, the parameter space is truncated to avoid indeterminacy or non-uniqueness in the model's solution.¹² The marginal prior distributions for the model's parameters are summarized in Table (1).

3.3 Estimation and convergence diagnostics

Given the data and prior specifications in section (3.2), two parallel 2 million draws of the Markov chain were generated.¹³ The Markov chains are generated conditional on the degree of openness

¹¹Apart from the interest rate and inflation data which are already in percentage terms.

¹²This only accounts for a very small proportion of the draws, around 0.2%.

¹³Each chain is generated at different starting values. It takes approximately 25 CPU hours to generate each independent chain using the APAC linux cluster machine.

(α) and the time preference (β) parameters, which are fixed at 0.3 and 0.99 respectively. $\alpha = 0.3$ coincides with the proportion of imported goods in the CPI basket over the sample period and $\beta = 0.99$ corresponds with a risk free rate of 4 percent.

Various convergence diagnostic statistics were computed after an initial 75% burn-in period. The aim is to assess whether the sequence of Markov chain draws has converged to its target distribution to ensure the reliability of the estimates generated from the Metropolis Hastings algorithm. The first column of Table (2) shows the mean of the posterior distribution. The NSE refers to the Numeric Standard Error as an approximation to the true posterior standard error and the p-value is the test between the means generated from the two independent chains as in Geweke (1999). For each of the parameter estimates, there is no indication the two means generated from the two chains are significantly different from each other. The seventh column shows the univariate “shrink factor” using the ratio of between and within variances as in Brooks and Gelman (1998). A shrink factor close to 1 is evidence for convergence to a stationary distribution. All MCMC diagnostic tests suggest that the Markov chains have converged to its stationary distribution after 2 million iterations.¹⁴

4 Posterior parameter estimates

Based on the two independent Markov Chains, the posterior mean and the 95 percent probability intervals are computed for each of the parameters, with results reported in Table (2). The prior and estimated posterior marginal densities are plotted in Figure (1). The plots indicate there is a substantial amount of information contained in the data to help update the prior beliefs on the model’s parameters. The posterior marginal densities are noticeably more concentrated relative to the prior densities.

The results indicate there is a relatively high degree of habit persistence, with $h = 0.94$, compared to other studies for the US and the Euro area, eg: Smets and Wouters (2004) and Lubik and Schorfheide (2005).¹⁵ The high degree of habit formation limits the elasticity of consumption with respect to real interest rate changes, while the impact from consumption on domestic inflation is much stronger. The inverse elasticity of intertemporal substitution, σ , is

¹⁴The number of iterations required to guarantee convergence is much larger than those often reported in the literature.

¹⁵All the results reported here are based on the mean of the posterior distribution.

estimated to be 1.20. The estimate is very close to the prior value of 1 and similar to the calibrated values used in business cycle models. The elasticity of substitution between home and foreign goods, η , is around 1.02. The unitary elasticity is in line with the prior that New Zealand is a small open commodity-producer and its consumption basket relies heavily on foreign produced goods. The estimated inverse elasticity of substitution for labor, $\varphi = 0.62$, turns out to be less than 1. This means a 1 percent increase in the real wage will result in more than a 1 percent increase in the labor supply.

On the production side, the probability of not changing prices in a given quarter is estimated to be around 93 percent for domestic firms and lower for import retailers at 77 percent. The estimated Calvo coefficients imply the average duration of price contracts is around twelve quarters for domestic firms and four quarters for import retailers (degree of incomplete pass-through).¹⁶ The degree of home price stickiness is much greater than those reported for the Euro area and the US whereas, the degree of import price stickiness is inline with previous empirical estimates. On the other hand, the degree of price indexation is estimated to be 0.58 for domestic firms and 0.46 for import retailers. Together, the Phillips Curves estimates imply there is a greater amount of stickiness in the price setting behavior of domestic firms relative to import retailers where they face stronger competition. This in turn implies greater persistence in the dynamics of domestic inflation relative to import inflation.

The simple reaction function used in the model provides a fairly good description of monetary policy over the stable inflation period in New Zealand. The posterior median for the degree of interest rate smoothing is estimated to be 0.78 with 1.25 and 0.50 being the weight on inflation and output respectively. The results obtained here are consistent with empirical estimates of Taylor rule coefficients in [Plantier and Scrimgeour \(2002\)](#).

The last column (flat prior) of Table (2) reports the mean of the Markov Chain draws with a non-informative prior. The mean of the parameters does not change significantly compared to the model estimated with informative priors.¹⁷ However, there are a few exceptions with the mean of the non-informative estimate falling outside the informative estimate's 95 percent probability interval. The elasticity of substitution between home and foreign goods (η) is slightly lower at 0.81 compared to 1.02. This suggests New Zealand's small open economy characteristic is

¹⁶Duration = $\frac{1}{1-\theta_i}$.

¹⁷The flat prior estimates are still subject to the same interval constraints.

more pronounced with limited substitutability between its production and consumption basket of goods. The inverse elasticity of labour supply (φ) also turns out to be smaller compared with the informative estimate, suggesting an even more elasticity labor supply. The stickiness parameter for import prices (θ_F) is estimated to be slightly larger at 0.83. However, the conclusion that domestic prices are observed to be much more sticky still holds. Finally, the response of the interest rate to output (ϕ_2) in the reaction function is slightly lower, though this coefficient will not significantly affect the optimal policy simulation results presented here. Overall, the Bayesian estimators are robust to the prior specification with the mean of all non-informative estimates falling inside the 99 percent posterior probability intervals.

5 Stabilization bias for a small open economy

It is well recognized that commitment policy will produce a universally superior inflation outcome compared with the discretionary equilibrium due to the time-inconsistency problem advocated by KPBG and Svensson (1997). The analysis here tries to quantify the size of the stabilization bias for a SOE using the model described in section (2) and parameters estimated in section (4) for New Zealand.

For a very small class of models, the model's theoretically consistent social welfare function can be derived from taking the second order approximation of the representative household's discounted life-time utility, see Erceg et al. (2000) and Woodford (2002) for example. However, this approach is only feasible for a small subset of models or as a special case by restricting the model's parameters.¹⁸ As an alternative, it is commonly accepted in the literature and among policy makers that monetary policy should be aimed at stabilizing inflation and some measure of real activities. In the case of New Zealand, the policy objectives are explicitly set out in the Policy Target Agreement (PTA) between the Bank and the Minister of Finance.

“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.”¹⁹

¹⁸Gali and Monacelli (2005) derived the social welfare function using the second order approximation of the household's utility by setting $\sigma = \eta = \varphi = 1$.

¹⁹Extract from Section 4(c) of the PTA agreement, 1999, available on the RBNZ website: <http://www.rbnz.govt.nz/monpol/pta/>.

Here, the social objective function is set up to be consistent with the PTA agreement, one that penalizes squared deviations in inflation from target, squared deviation in output from potential, squared deviation in the exchange rate and an interest rate smoothing term. The interest rate smoothing term ensures policy changes in response to shocks occur in small steps. [Sack and Wieland \(2000\)](#) argues that including the interest rate smoothing term may in fact be optimal even though the central bank’s main objective is to replicate the second best outcome due to data and parameter uncertainty. Following the literature, the social objective function is approximated using the following linear quadratic loss function:

$$L(t, \infty) = E_t \sum_{j=0}^{\infty} \delta^j [\pi_{a,t+j}^2 + \lambda y_{t+j}^2 + \varsigma q_{t+j}^2 + \nu \Delta r_{t+j}^2] \quad (44)$$

where $\pi_{a,t}$ is annualized inflation, y_t is output, q_t is the real exchange rate and Δr_t is the change in the nominal interest rate; and λ , ς and ν are the weights relative to inflation. All variables are written as deviations from its steady state.

Under optimal commitment policy, the central bank optimizes once at $t = 0$ by minimizing the loss function given in equation (44) subject to the dynamic constraints of the economy, and permanently commits to the optimal plan. In this case, the dynamic equilibria of the economy will be augmented to reflect the commitment made earlier by the central bank.²⁰ Optimal discretionary policy is one where the central bank optimizes equation (44) on a period by period basis. The problem occurs once private agents form expectations about the future. There is then no incentive for the central bank to follow through with earlier policy announcements – the classic time-inconsistency problem. The dynamic behavior of the economy under discretion constitutes a Stackelberg-Nash equilibria in which policymakers optimizing today are the Stackelberg leaders, and private agents and future policymakers are Stackelberg followers. The algorithms described in [Dennis \(2007\)](#) are used to solve the commitment and discretionary dynamic equilibria and the value of the loss function is calculated for each case.

To define a common metric for the size of the stabilization bias, [Dennis and Soderstrom \(2006\)](#) use the permanent deviation of inflation from target that is equivalent to moving from discretionary policy to commitment. The *inflation equivalent* measure for a particular set of

²⁰The solution of the model will include a set of dynamic lagrange multipliers.

model parameters, Θ , is given by:

$$\hat{\pi}(\Theta) = \sqrt{L_d(\Theta) - L_c(\Theta)} \quad (45)$$

where $L_c(\Theta)$ and $L_d(\Theta)$ are the values of the optimized loss function for a particular set of parameters Θ under commitment and discretion respectively. Other studies also report the *percentage gain* measure relative to the commitment equilibria defined as $100 \left(1 - \frac{L_c(\Theta)}{L_d(\Theta)}\right)$. The discussions here will focus on the inflation equivalent measure which is also intuitively more appealing.

5.1 Baseline closed economy simulation

A closed economy is one where trade (the import share $\alpha \rightarrow 0$) and financial (the exchange rate channel is turned off) linkages with the rest of the world are shut off. The model collapses to the standard canonical closed economy representation similar to the one in [Clarida et al. \(2001\)](#). The exercise here is to isolate the open economy effects and to aid comparison with previous closed economy studies. The model is then simulated using parameters drawn from the posterior distribution to evaluate the size of the stabilization bias.²¹ Even though the PTA gives some guidance on the choice of target variables, their relative weights in the loss function are not explicitly specified or announced publicly. For the baseline scenario, the weights on output (λ) and interest rate smoothing (ς) are chosen to be 0.5. These weights coincide with baseline values used in [Svensson \(2000\)](#) and [Dennis and Soderstrom \(2006\)](#).

Figure (2) plots the empirical distribution of the estimated stabilization bias with detailed statistics reported in Table (3).²² The mean of the inflation equivalent measure is calculated to be 0.65% with a standard deviation of 0.32. The estimate is comparable with the results reported in [Dennis and Soderstrom \(2006\)](#) using the same loss function parameters across four closed economy models (ranging between 0.15% to 1.43%) once parameter uncertainty is taken into account.

²¹10,000 random draws from the stationary Markov chains distribution is selected for the simulation of the results.

²²Figure (2) and Table (3) contains simulation results for other policy parameters that is to be discussed later.

5.2 size of the stabilization bias

Using the same baseline loss function parameters, the full open economy model is simulated to calculate the stabilization bias for the SOE. The estimated mean of the distribution is 1.24% with a standard deviation of 0.33. The estimated standard deviation is about the same as the closed economy simulations while the mean is much higher. As a result of higher variability coming from international shocks, the values of the optimized loss function under both commitment and discretion are higher compared with the closed economy case. Once the exchange rate is included in the loss function, even with a relatively small weight ($\nu = 0.1$), the values of the optimized loss function under both commitment and discretion are marketably higher. This is mainly due to the relatively high variance of the real exchange rate entering into the objective function. The estimated stabilization bias more than doubles to 2.75% with a similar standard deviation of 0.30.²³

To aid comparison and check on the robustness of the results, five other different combinations of policy preferences are calculated with the density plots shown in Figure (2).²⁴ The size of the stabilization bias is estimated to vary between 0.82-4.16% with standard deviations between 0.23-0.57 depending on the loss function parameters. Across all loss function parameterizations, the estimated stabilization bias is much greater compared with the closed economy baseline simulation. Furthermore, the size of the stabilization bias in the SOE appears to be higher than the closed economy results (between 0.05-3.6%) reported in [Dennis and Soderstrom \(2006\)](#) across a range of loss function parameterizations.

One important observation from the simulation results is that the estimated stabilization bias for a SOE is much higher compared with the closed economy case. The conclusion is robust across different loss function parameterizations and model parameters. In the closed economy, only expectations of future domestic inflation matters. In which case, the stabilization bias only relates to the tradeoffs between stabilizing domestic inflation and output in the face of cost push disturbances. For a small open economy, the policy tradeoffs are much more complex with the presence of the exchange rate and effects from international disturbances. First, policies that moves the short-term interest rate to offset the impacts of demand or supply disturbances will

²³The implication of including the exchange rate as one of the objectives will be discussed in more detail in the sub-section.

²⁴The chosen loss function parameters are by no means exhaustive, instead, these are chosen to provide a reasonable comparison with previous studies.

also affect the exchange rate. This, in turn, affects the rate of domestic inflation. Both output and inflation objectives cannot be achieved simultaneously hence increasing the size of the stabilization bias. Second, the presence of incomplete pass-through in import prices represents an additional channel for the central bank to manipulate expectations of future imported goods inflation and the exchange rate. Any attempts by the central bank to try and stabilize domestic or foreign disturbances using the interest rate will indirectly affect the LOP gap ($\psi_t = -[q_t + (1 - \alpha)s_t]$). Therefore, monetary policy cannot simultaneously stabilize domestic cost push shocks and the LOP gap which directly affects import inflation. In addition to the tradeoff between domestic inflation and output, the stabilization bias now also involves the tradeoff between import inflation and the LOP gap.

As the degree of pass-through gets lower ($\theta_F \rightarrow 1$), this reduces the sensitivity of import inflation to the LOP gap in equation (22) which helps lessen the degree of tradeoff between output and overall inflation. Even with a relatively high degree of import price stickiness, θ_F was estimated to be 0.77. The empirical results suggest the gains from commitment policy are marketably higher for a SOE. The size of the stabilization bias under the baseline parameterizations is nearly twice as large for a SOE relative to that usually found for closed economies. The result offers a possible explanation for the motivation behind many SOE central banks' move towards inflation targeting framework as a way of anchoring expectations and minimizing the bias. A more transparent and credible policy environment helps minimize the inefficiencies arising from the time-inconsistency problem.

5.3 The increasing desire for exchange rate stability

There has been an increasing debate on whether SOE central banks should focus more on exchange rate stabilization. In the case of New Zealand, this desire was reflected in the updated PTA in 1999 to minimize exchange rate fluctuations in the operation and implementation of monetary policy over the business cycle. Subsequently, following several public comments by the New Zealand Finance Minister expressing discomfort over the high volatility of the New Zealand dollar, the RBNZ was granted the capacity to intervene if the foreign exchange market became "disorderly".²⁵ Even though the RBNZ has not yet publicly acknowledged the use of its new intervention capacity, it is useful to investigate how the increasing preference for minimizing

²⁵See RBNZ press release on 30th March 2004, <http://www.rbnz.govt.nz/news/2004/0148546.html>.

exchange rate fluctuations may impact on the size of the stabilization bias. The changing policy preference may not be unique to the case of New Zealand with other SOE's such as Australia and Canada currently also facing unprecedented rise in commodity prices.

To address this important policy question, Figure (3) plots the estimated stabilization bias with respect to the the weights on output (λ) and exchange rate (ς) while fixing the weight on the interest rate smoothing term (ν) to be 0.5.²⁶ The first observation is that the size of the stabilization bias is a non-decreasing function with respect to the weight placed on output for a given weight on the exchange rate. This essentially replicates the well documented closed economy result, where discretion policy will result in inflation variability being too high, and output variability too low, relative to the commitment equilibrium. The higher preference for output stability in the face of cost push shocks will induce greater incentive for the central bank to manipulate private agent's expectations, increasing the size of the stabilization bias.

The second observation is that for a given weight on output, the stabilization bias is a monotonic increasing function with respect to the weight placed on the exchange rate. This offers some interesting insights into the operation of monetary policy for a SOE. Under commitment, the central bank trades off some volatility in the output gap in order to achieve greater stability in domestic inflation and the LOP gap, hence indirectly lowering the variability of the exchange rate.²⁷ Monacelli (2005) found similar results looking at only productivity shocks. At first, this may seem a little counter intuitive. Essentially, a more stable level of overall inflation will be accompanied with less frequent interest rate changes or more persistent policy behavior. This in turn translates into more stable exchange rate fluctuations via the UIP in equation (11) for a given level of risk premium shock. As the preference for a more stable exchange rate increases, this will result in the central bank trying to stabilize domestic inflation and the LOP gap even more to indirectly keep exchange rate fluctuations lower. However, this will induce greater output fluctuations, relative to the discretion outcome, hence increasing the size of the stabilization bias.

An important policy implication from the simulation results is that increasing policy preference for exchange rate stability will result in larger gains from commitment. The updating of the

²⁶The simulation results are generated using the mean of the posterior distribution of the model's structural parameters.

²⁷ Detailed simulation results of the unconditional variance of the state variables are available from the author upon request.

PTA to include the exchange rate as one of the policy objectives essentially requires the RBNZ to implement monetary policy in a more time-consistent manner. The ability of the central bank to fully commit to preannounced policies is viewed as a much more important mechanism in achieving a more stable exchange rate, along with its other policy objectives, rather than the need for direct foreign exchange rate interventions.

5.4 Robustness analysis

One of the crucial assumptions underlying the set of estimated parameters is the detrending method use to extract the cyclical component of the output data. [Canova \(1998\)](#) emphasized different detrending methods can imply quite different business cycle dynamics and therefore affects the set of estimated parameters underlying the model. [Cho and Moreno \(2006\)](#) highlighted the coefficients in front of the real interest rate in the IS curve, and the marginal cost in the Phillips Curve are particularly sensitive to the different detrending methods employed. The former governs the transmission mechanism of monetary policy on consumption while the latter relates to the tradeoff between inflation and output. Both of these parameters are crucial to the optimal policy analysis presented here. To assess the robustness of the conclusions highlighted above with respect to the different data treatments, the model outlined in (2) is re-estimated using different detrending methods (linear and quadratic trend) for domestic and foreign output.²⁸

The estimation results confirms [Cho and Moreno's \(2006\)](#) previous analysis. One advantage of using a micro-founded model is that it allows one to uncover which “deep” parameters are particularly sensitive to the different detrending methods.²⁹ Two parameters were identified, the elasticities of intertemporal substitution (σ) and labour supply (φ). σ relates to the elasticity of consumption with respect to changes in the real interest rate, while φ relates to the tradeoff between output and domestic inflation in the Phillips Curve. The mean of σ is estimated to be 1.19, 1.27 and 0.84 for the HP, linear and quadratic trend respectively. While the linear trend estimate falls within the HP trend's 95% probability interval, the quadratic trend estimate is statistically smaller. On the other hand, the mean estimate of φ for the HP and linear trend is very similar, around 0.62 and 0.60 respectively, while the quadratic trend is slightly higher

²⁸Detailed statistics of the estimation results are available upon request.

²⁹In [Cho and Moreno \(2006\)](#), the parameters in front of the real interest rate and marginal cost in IS and Phillips curve are combinations of the “deep” parameters.

around 0.76. The price stickiness parameters, θ_H and θ_F which also relates to the degree of tradeoff between inflation and output is observed to be fairly robust across the different detrending methods. The same applies to the rest of the parameter estimates underlying the model.

Despite some small differences in some of the key parameters underlying the model, the general conclusion highlighted in sections (5.2) and (5.3) holds across the different detrending methods. For the baseline loss function parameterizations, the estimated size of the stabilization bias for the SOE is still more than double that of the closed economy, 0.92% relative to 0.40% using a linear trend, and 1.27% relative to 0.63% using a quadratic trend. Simulation results continue to show a monotonically increasing relationship between the weight on the exchange rate and the size of the stabilization bias.

6 Concluding remarks

This paper develops an empirical model to investigate the degree of inefficiencies arising from discretionary policy relative to the commitment equilibrium. Much of the discussion is devoted to analyzing the policy tradeoffs faced by the central bank within a SOE, and how that differs from a closed economy. Two key results emerge from the analysis. First, the estimated size of the stabilization bias for a SOE is found to be nearly twice as large relative to that is usually found in the closed economy counterpart. The result is robust across different loss function parameterizations and model parameters. This offers a possible explanation behind the motivation of many SOE central banks' recent move toward inflation targeting. Second, the size of the stabilization bias increases with the policymaker's preference for stabilizing exchange rate fluctuations. This implies that a stronger attitude towards pre-commitment of policy will aid in minimizing the inefficiency arising from the stabilization bias when the exchange rate is included as one of the stabilization objectives.

Two parameters, the elasticities of intertemporal substitution and labour supply, were identified to be particularly sensitive to the different data treatments. Both parameters, which relate to the elasticity of consumption with respect to changes in the real interest rate and the tradeoff between output and domestic inflation in the Phillips Curve, are crucial to the analysis presented here. Despite some small differences in these parameters, the two key results highlighted in the

paper holds across different detrending methods.

The analysis was restricted to a relatively simple specification of the model with only two sources of nominal rigidities, and a linear production function in labour. However, the results suggests that it would be worthwhile expanding the analysis to incorporate other factors influencing the size of the stabilization bias from pre-commitment, including: (i) capital accumulation and investment rigidities; (ii) labour market rigidities; and (iii) explicit optimizing behavior of the central bank in estimating the model. In addition, the key results and policy implications highlighted in the paper rests on the assumption of UIP holding. While the UIP hypothesis is an ongoing debate in the literature, it would be useful to relax this assumption. This would lead to more robust estimates and minimize the effects of a potential misspecification contaminating other parts of the model.

Appendix

A Deriving the Domestic NKPC

Rewriting the first order condition for domestic firm's pricing decision in equation (18):

$$\sum_{k=0}^{\infty} \theta_H^k E_t \left\{ Q_{t,t+k} Y_{t+k} \left[\bar{P}_{H,t} \left(\frac{P_{H,t+k-1}}{P_{H,t-1}} \right)^{\delta_H} - \frac{\varepsilon}{\varepsilon - 1} P_{H,t+k} MC_{t+k} \right] \right\} = 0 \quad (46)$$

Substitute $Q_{t,t+k} = \beta^k \left(\frac{C_{t+k}}{C_t} \right)^{-\sigma} \left(\frac{P_t}{P_{t+k}} \right)$ from the consumption Euler equation in (5) in equation (46) yields:

$$\sum_{k=0}^{\infty} (\beta \theta_H)^k P_t^{-1} C_t^{-\sigma} E_t \left\{ P_{t+k}^{-1} C_{t+k}^{-\sigma} Y_{t+k} \left[\bar{P}_{H,t} \left(\frac{P_{H,t+k-1}}{P_{H,t-1}} \right)^{\delta_H} - \frac{\varepsilon}{\varepsilon - 1} P_{H,t+k} MC_{t+k} \right] \right\} = 0 \quad (47)$$

Since $P_t^{-1} C_t^{-\sigma}$ is known at date t , it can be taken out of the expectation summation, after rearranging yields:

$$\sum_{k=0}^{\infty} (\beta \theta_H)^k E_t \left\{ P_{t+k}^{-1} C_{t+k}^{-\sigma} Y_{t+k} \left[\bar{P}_{H,t} \left(\frac{P_{H,t+k-1}}{P_{H,t-1}} \right)^{\delta_H} - \frac{\varepsilon}{\varepsilon - 1} MC_{t+k} P_{H,t+k} \right] \right\} = 0 \quad (48)$$

Log-linearizing equation (48) around the zero inflation steady state to obtain the decision rule for $\bar{p}_{H,t}$ gives:

$$\begin{aligned}\bar{p}_{H,t} - \delta_H p_{H,t-1} &\approx (1 - \beta\theta_H) E_t \sum_{k=0}^{\infty} (\beta\theta_H)^k [p_{H,t+k} - \delta_H p_{H,t+k-1} + mc_{t+k}] \\ &= (1 - \beta\theta_H) [p_{H,t} - \delta_H p_{H,t-1} + mc_t] \\ &\quad + \beta\theta_H (1 - \beta\theta_H) E_t \sum_{k=0}^{\infty} \beta\theta_H [p_{H,t+k+1} - \delta_H p_{H,t+k} + mc_{t+k+1}]\end{aligned}\tag{49}$$

Recognizing the last term in equation (49) is equal to $\beta\theta_H[\bar{p}_{H,t+1} - \delta_H p_{H,t}]$, the expression can be rewritten as:

$$\bar{p}_{H,t} - \delta_H p_{H,t-1} \approx (1 - \beta\theta_H) [p_{H,t} - \delta_H p_{H,t-1} + mc_t] + \beta\theta_H [\bar{p}_{H,t+1} - \delta_H p_{H,t}]\tag{50}$$

Log-linearizing the domestic aggregate price level in equation (16) yields:

$$\pi_{H,t} = (1 - \theta_H)(\bar{p}_{H,t} - p_{H,t-1}) + \theta_H \delta_H \pi_{H,t-1}\tag{51}$$

Combining equations (50) and (51) yields:

$$\pi_{H,t} - \delta_H \pi_{H,t-1} = \beta E_t (\pi_{H,t+1} - \delta_H \pi_{H,t}) + \lambda_H mc_t\tag{52}$$

where $\lambda_H = \frac{(1-\beta\theta_H)(1-\theta_H)}{\theta_H}$. Rearrange to obtain equation (22) in the text:

$$\pi_{H,t} = \frac{1}{1 + \beta\delta_H} [\beta E_t \pi_{H,t+1} + \delta_H \pi_{H,t-1} + \lambda_H mc_t]\tag{53}$$

B Data description

- Domestic output (y_t) is seasonally adjusted log real GDP for New Zealand detrended using the HP filter with $\lambda = 1600$.
- Overall inflation (π_t) is the annualized quarter to quarter growth rate of the consumer price index (CPI) for New Zealand.
- Import inflation ($\pi_{F,t}$) is the annualized quarter to quarter growth rate of the import deflator for New Zealand.
- Nominal interest rate (r_t) is the 90-day Bank Bill rate for New Zealand.
- Competitive price index (s_t) is the merchandize terms of trade measured “at the dock” using overseas trade statistics.
- Real exchange rate (q_t) is the log of the real exchange rate (using CPI) between New Zealand and the US.
- Foreign output (y_t^*) is seasonally adjusted log real GDP for the US detrended using the HP filter with $\lambda = 1600$.
- Foreign real interest rate (\bar{r}_t^*) is the short term US real interest rates.

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Table 1: Prior distributions statistics

Parameter	Domain	Density	Mean	Std dev.	2.5%	97.5%
h	$[0, 1]$	Beta	0.500	0.200	0.128	0.871
σ	\mathbb{R}^+	Normal	1.000	0.400	0.376	1.923
η	\mathbb{R}^+	Gamma	1.000	0.400	0.375	1.922
φ	\mathbb{R}^+	Gamma	1.000	0.400	0.377	1.917
θ_H	$[0, 1]$	Beta	0.500	0.150	0.214	0.787
θ_F	$[0, 1]$	Beta	0.500	0.150	0.213	0.786
δ_H	$[0, 1]$	Beta	0.500	0.200	0.128	0.871
δ_F	$[0, 1]$	Beta	0.500	0.200	0.132	0.870
ϕ_1	\mathbb{R}^+	Gamma	1.500	0.250	1.050	2.031
ϕ_2	\mathbb{R}^+	Gamma	0.250	0.100	0.094	0.479
ρ_r	$[0, 1]$	Beta	0.500	0.200	0.128	0.871
ρ_{r^*}	$[0, 1]$	Beta	0.500	0.200	0.129	0.871
ρ_a	$[0, 1]$	Beta	0.500	0.200	0.127	0.869
ρ_{y^*}	$[0, 1]$	Beta	0.500	0.200	0.129	0.872
σ_a	\mathbb{R}^+	InvGamma	1.000	0.300	0.598	2.000
σ_s	\mathbb{R}^+	InvGamma	1.000	0.300	0.597	1.997
σ_q	\mathbb{R}^+	InvGamma	1.000	0.300	0.598	1.988
σ_{π_H}	\mathbb{R}^+	InvGamma	1.000	0.300	0.602	1.989
σ_{π_F}	\mathbb{R}^+	InvGamma	1.000	0.300	0.600	2.000
σ_r	\mathbb{R}^+	InvGamma	1.000	0.300	0.600	1.997
σ_{y^*}	\mathbb{R}^+	InvGamma	1.000	0.300	0.597	1.991
σ_{r^*}	\mathbb{R}^+	InvGamma	1.000	0.300	0.601	1.997

Figure 1: Posterior and prior marginal density plot

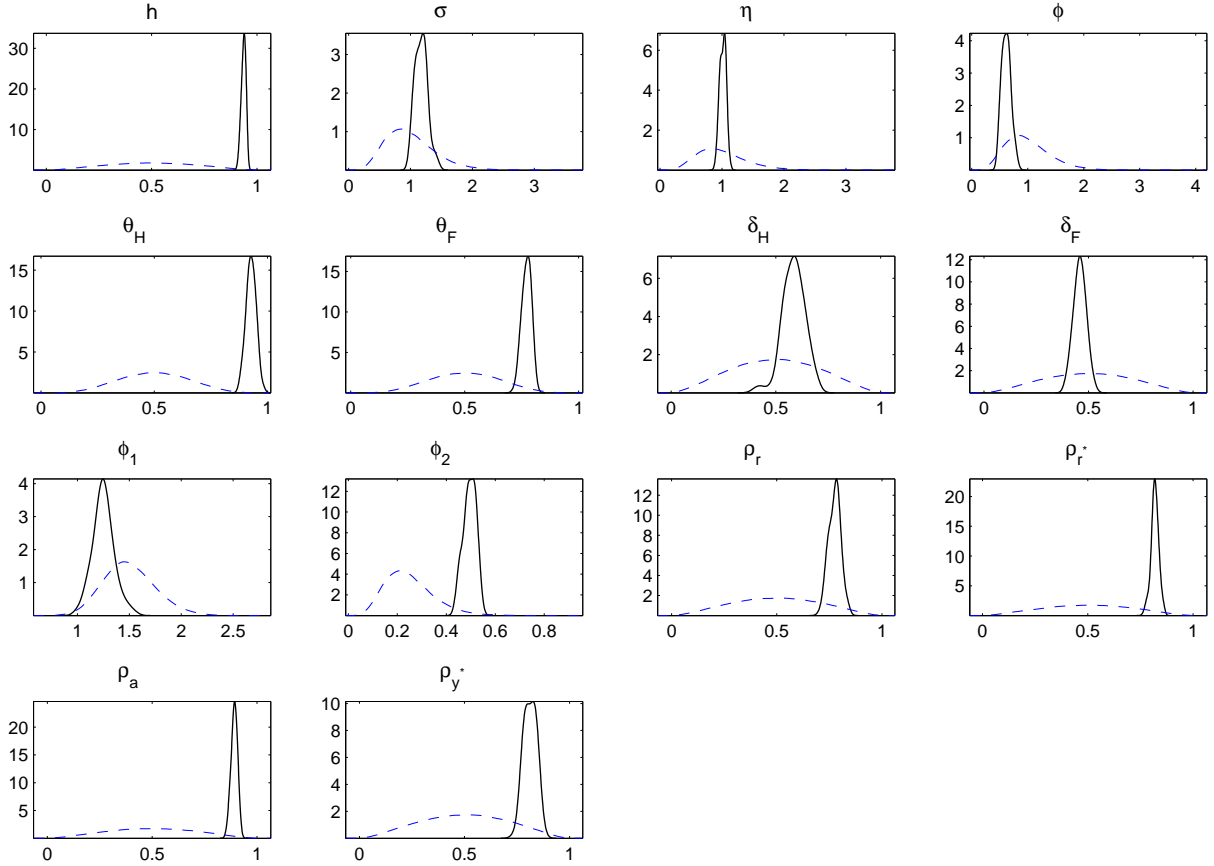


Table 2: Posterior estimates and MCMC diagnostic statistics

parameters	Post Mean	Post Std	2.5%	97.5%	NSE	p-value	B-G	Flat prior
h	0.937	0.011	0.914	0.955	0.001	0.254	1.042	0.953
σ	1.195	0.097	1.012	1.396	0.010	0.113	1.122	1.101
η	1.016	0.049	0.918	1.102	0.009	0.106	1.124	0.811
φ	0.620	0.079	0.483	0.779	0.013	0.501	1.021	0.442
θ_H	0.927	0.021	0.884	0.967	0.003	0.554	1.013	0.950
θ_F	0.771	0.021	0.731	0.807	0.003	0.332	1.030	0.832
δ_H	0.581	0.053	0.458	0.683	0.008	0.413	1.030	0.648
δ_F	0.460	0.030	0.399	0.517	0.004	0.065	1.125	0.440
ϕ_1	1.247	0.102	1.051	1.483	0.017	0.722	1.006	1.112
ϕ_2	0.498	0.025	0.448	0.537	0.004	0.052	1.182	0.414
ρ_r	0.775	0.028	0.722	0.831	0.004	0.228	1.057	0.775
ρ_{r^*}	0.819	0.018	0.779	0.855	0.002	0.374	1.020	0.833
ρ_a	0.891	0.015	0.861	0.919	0.002	0.210	1.041	0.910
ρ_{y^*}	0.812	0.030	0.757	0.865	0.005	0.412	1.026	0.818
σ_a	0.900	0.097	0.676	1.041	0.014	0.064	1.147	0.964
σ_s	3.633	0.178	3.342	3.995	0.028	0.051	1.151	4.062
σ_q	6.171	0.163	5.874	6.495	0.026	0.237	1.056	6.510
σ_{π_H}	1.219	0.068	1.074	1.347	0.010	0.087	1.122	1.079
σ_{π_F}	2.540	0.190	2.096	2.842	0.024	0.547	1.018	2.401
σ_r	0.799	0.054	0.702	0.901	0.009	0.616	1.012	0.802
σ_{y^*}	0.480	0.044	0.407	0.569	0.007	0.700	1.006	0.459
σ_{r^*}	0.638	0.052	0.561	0.748	0.009	0.597	1.013	0.599
Log marginal likelihood	-1072.5							-1053.9

1. The parameters α and β were fixed at 0.3 and 0.99 respectively.
2. Posterior statistics are computed after 75% burn in, the acceptance rate for both of the Markov chains was around 20%.
3. NSE is the Numeric Standard Error as defined in Geweke (1999) .
4. The P-Value refers to test of two means generated from two independent chains, the test statistics is computed with $L = 0.08$, see Geweke (1999).
5. Univariate “shrink factor” for monitoring the between and within chain variance, see Brooks and Gelman (1998).

Table 3: Estimated stabilization bias from commitment policy

λ	ν	ζ	Loss		Percent gain	Inflation equiv.	Prob interval		Std dev
			Commit.	Discretion			2.5%	97.5%	
Closed economy			2.90	3.42	13.81	0.65	0.16	1.32	0.32
0.5	0.5	0.0	4.20	5.85	26.63	1.24	0.84	2.01	0.33
0.5	0.5	0.1	19.82	27.50	27.70	2.75	2.28	3.51	0.30
1.0	1.0	0.0	5.57	7.47	25.03	1.36	1.09	1.93	0.23
1.0	1.0	0.1	16.81	26.10	35.21	3.03	2.46	3.90	0.35
1.0	1.0	0.2	30.81	48.42	35.84	4.16	3.21	5.51	0.57
0.0	1.0	0.0	0.58	3.16	78.55	1.56	0.86	2.22	0.38
1.0	0.0	0.0	3.38	4.23	16.29	0.82	0.22	1.67	0.41

1. The closed economy is simulated in the absence of international shocks and the exchange rate.
2. The percentage gain measure is calculated by $\left(1 - \frac{L_c(\Theta)}{L_d(\Theta)}\right) 100$.
3. The inflation equivalent measure is calculated by $\sqrt{L_d(\Theta) - L_c(\Theta)}$.

Figure 2: Inflation equivalent ($\hat{\pi}$) for various policy preferences

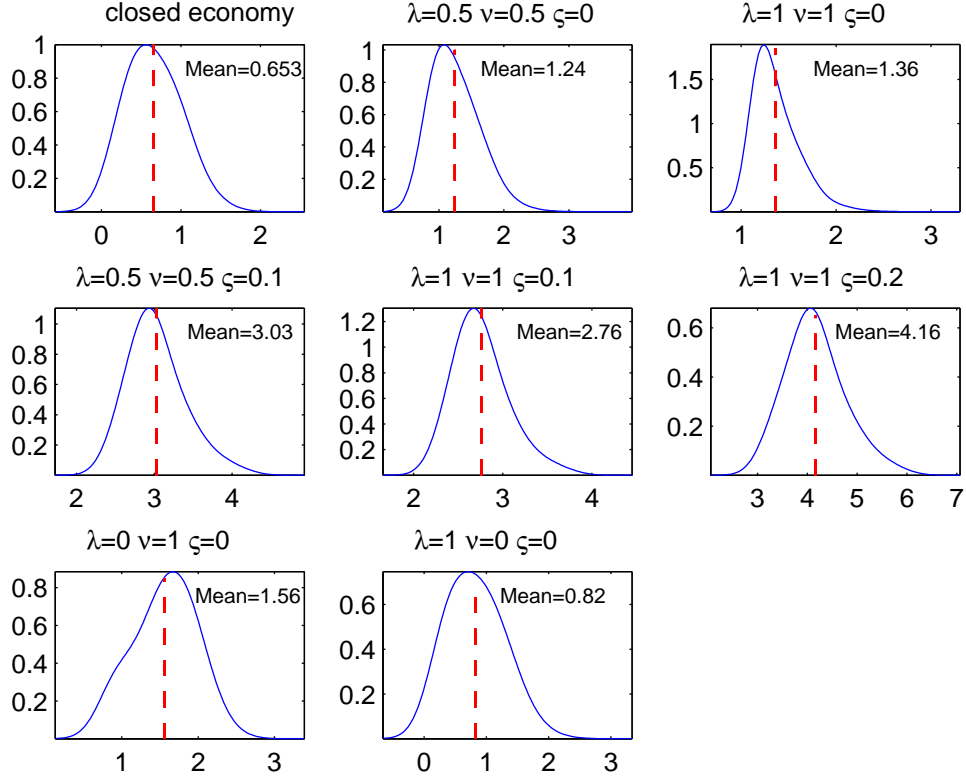
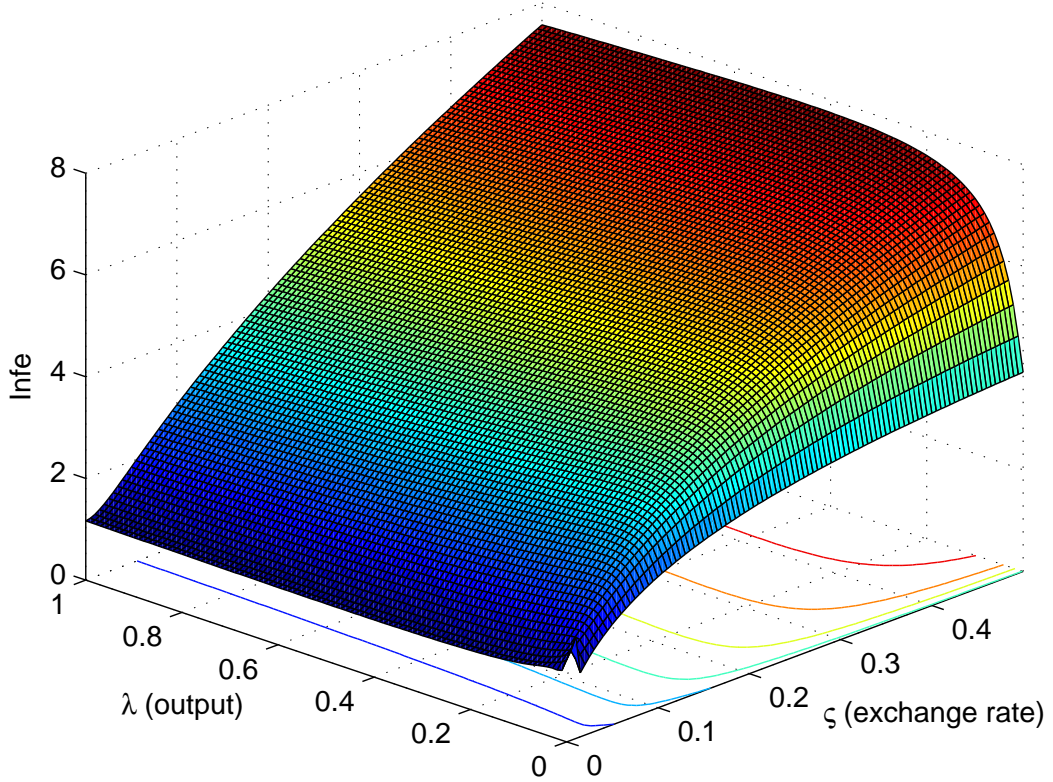


Figure 3: Inflation equivalent ($\hat{\pi}$) for λ and ζ



Additional statistical tables for referees, not for publication:

- Table (4) refers to the discussion in footnote (27) of the main text.
- Table (5) and (6) refers to the robustness discussions in section (5.4) of the main text.

Table 4: Unconditional volatility under different loss function parameters

Optimal Policy	Parameters			Standard deviation				
	λ	ν	ς	σ_ψ	σ_π	σ_y	σ_q	$\sigma_{\Delta r}$
Discretion	Closed economy			-	2.36	0.42	-	1.99
Commitment	Closed economy			-	2.24	0.72	-	1.53
Discretion	0.50	0.50	0.00	8.60	2.96	1.49	13.92	0.98
Commitment	0.50	0.50	0.00	8.00	2.57	1.63	13.83	0.68
Discretion	0.50	0.50	0.10	7.95	2.95	2.43	13.17	1.63
Commitment	0.50	0.50	0.10	6.65	2.57	2.74	10.30	1.47
Discretion	1.00	1.00	0.00	8.52	2.97	1.49	13.89	0.98
Commitment	1.00	1.00	0.00	7.15	2.67	1.47	13.90	0.66
Discretion	1.00	1.00	0.10	7.93	2.97	1.94	13.47	1.33
Commitment	1.00	1.00	0.10	6.62	2.65	1.92	11.06	1.19
Discretion	1.00	1.00	0.20	8.07	2.95	2.81	13.16	1.63
Commitment	1.00	1.00	0.20	7.50	2.64	2.35	10.32	1.48

Table 5: Posterior parameter estimates across different detrending assumptions

parameters	Hodrick Prescott (95% interval)	Linear (95% interval)	Quadtratic (95% interval)
h	0.94 [0.91, 0.95]	0.92 [0.90, 0.94]	0.95 [0.93, 0.96]
σ	1.19 [1.01, 1.40]	1.27 [1.13, 1.47]	0.84 [0.76, 0.96]
η	1.02 [0.92, 1.10]	0.93 [0.85, 0.99]	0.92 [0.86, 0.98]
φ	0.62 [0.48, 0.78]	0.60 [0.47, 0.78]	0.76 [0.62, 0.97]
θ_H	0.93 [0.88, 0.97]	0.94 [0.90, 0.97]	0.93 [0.88, 0.97]
θ_F	0.77 [0.73, 0.81]	0.78 [0.73, 0.83]	0.76 [0.71, 0.80]
δ_H	0.58 [0.46, 0.68]	0.54 [0.44, 0.62]	0.52 [0.44, 0.61]
δ_F	0.46 [0.40, 0.52]	0.44 [0.39, 0.48]	0.37 [0.30, 0.44]
ϕ_1	1.25 [1.05, 1.48]	1.26 [1.12, 1.44]	1.28 [1.14, 1.47]
ϕ_2	0.50 [0.45, 0.54]	0.36 [0.32, 0.41]	0.48 [0.43, 0.53]
ρ_r	0.77 [0.72, 0.83]	0.79 [0.75, 0.84]	0.77 [0.73, 0.82]
ρ_{r^*}	0.82 [0.78, 0.86]	0.81 [0.77, 0.84]	0.82 [0.78, 0.85]
ρ_a	0.89 [0.86, 0.92]	0.88 [0.85, 0.90]	0.89 [0.86, 0.92]
ρ_{y^*}	0.81 [0.76, 0.87]	0.82 [0.78, 0.86]	0.80 [0.72, 0.87]
σ_a	0.90 [0.68, 1.04]	0.91 [0.77, 1.03]	1.03 [0.88, 1.19]
σ_s	3.63 [3.34, 3.99]	3.79 [3.47, 4.07]	3.82 [3.50, 4.21]
σ_q	6.17 [5.87, 6.49]	7.17 [6.87, 7.58]	6.31 [5.98, 6.62]
σ_{π_H}	1.22 [1.07, 1.35]	1.15 [1.05, 1.23]	1.16 [1.03, 1.31]
σ_{π_F}	2.54 [2.10, 2.84]	2.21 [1.92, 2.49]	2.50 [2.01, 2.86]
σ_r	0.80 [0.70, 0.90]	0.82 [0.72, 0.91]	0.78 [0.70, 0.85]
σ_{y^*}	0.48 [0.41, 0.57]	0.52 [0.44, 0.61]	0.48 [0.41, 0.56]
σ_{r^*}	0.64 [0.56, 0.75]	0.66 [0.60, 0.72]	0.65 [0.57, 0.74]

1. The parameters α and β were fixed at 0.3 and 0.99 respectively.
2. Posterior statistics are computed after 75% burn in, the acceptance rate for all the Markov chains was around 20-30%.

Table 6: Stabilization bias across different detrending assumptions

λ y_t^2	ν $(\Delta r_t)^2$	ς q_t^2	Loss		Percent gain	Inflation equiv.	Prob interval		Std dev
			Commit.	Discretion			2.5%	97.5%	
Hodrick Prescott trend									
Closed economy			2.90	3.42	13.81	0.65	0.16	1.32	0.32
0.5	0.5	0.0	4.20	5.85	26.63	1.24	0.84	2.01	0.33
0.5	0.5	0.1	19.82	27.50	27.70	2.75	2.28	3.51	0.30
1.0	1.0	0.0	5.57	7.47	25.03	1.36	1.09	1.93	0.23
1.0	1.0	0.1	16.81	26.10	35.21	3.03	2.46	3.90	0.35
1.0	1.0	0.2	30.81	48.42	35.84	4.16	3.21	5.51	0.57
0.0	1.0	0.0	0.58	3.16	78.55	1.56	0.86	2.22	0.38
1.0	0.0	0.0	3.38	4.23	16.29	0.82	0.22	1.67	0.41
Linear trend									
Closed economy			2.26	2.44	7.56	0.40	0.13	0.69	0.16
0.5	0.5	0.0	3.12	3.98	21.53	0.92	0.79	1.15	0.10
0.5	0.5	0.1	17.08	26.47	34.96	3.04	2.41	3.96	0.41
1.0	1.0	0.0	4.35	5.69	23.61	1.15	1.05	1.28	0.06
1.0	1.0	0.1	14.35	25.34	42.71	3.28	2.58	4.28	0.45
1.0	1.0	0.2	26.70	48.52	44.26	4.63	3.61	6.04	0.65
0.0	1.0	0.0	0.47	1.53	65.76	0.99	0.76	1.69	0.28
1.0	0.0	0.0	2.04	2.26	8.83	0.44	0.21	0.79	0.17
Quadratic trend									
Closed economy			2.67	3.14	13.79	0.63	0.18	1.15	0.27
0.5	0.5	0.0	4.06	5.80	28.09	1.27	0.87	2.10	0.34
0.5	0.5	0.1	19.24	26.46	27.17	2.68	2.25	3.17	0.23
1.0	1.0	0.0	5.42	7.36	25.80	1.37	1.07	1.99	0.23
1.0	1.0	0.1	16.29	25.06	34.75	2.95	2.43	3.54	0.28
1.0	1.0	0.2	29.94	46.37	35.05	4.03	3.16	4.95	0.46
0.0	1.0	0.0	0.57	3.22	80.71	1.60	0.89	2.09	0.29
1.0	0.0	0.0	3.30	4.19	17.84	0.86	0.21	1.73	0.40

1. The closed economy is simulated in the absence of international shocks and the exchange rate.

2. The percentage gain measure is calculated by $\left(1 - \frac{L_c(\Theta)}{L_d(\Theta)}\right) 100$.

3. The inflation equivalent measure is calculated by $\sqrt{L_d(\Theta) - L_c(\Theta)}$.