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Ana Maria Santacreu

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Reaction functions in a small open economy: What role for non-traded inflation?*

Ana Maria Santacreu †

Abstract

I develop a structural general equilibrium model and estimate it for New Zealand using Bayesian techniques. The estimated model considers a monetary policy regime where the central bank targets overall inflation but is also concerned about output, exchange rate movements, and interest rate smoothing. Taking the posterior mean of the estimated parameters as representing the characteristics of the New Zealand economy, I compare the consequences that two alternative reaction functions have on the central bank's loss, for different specifications of its preferences. I obtain conditions under which the monetary authority should respond directly to non-tradable inflation instead of overall inflation. In particular, if preferences are relatively biased towards inflation stabilization, responding directly to overall inflation results in better macroeconomic outcomes. If instead the central bank places relatively more weight on output stabilization, responding directly to non-traded inflation is a better strategy.

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†Address: Ana Maria Santacreu, Economics Department, New York University; *email address: ams458@nyu.edu*.

1 Introduction

In this paper I apply Bayesian techniques to estimate a model of a small open economy with traded and non-traded sectors. Although there are a number of papers that explore this kind of setting, no consensus has yet been reached about the type of monetary policy that should be followed in a multisectoral economy. I examine this issue by establishing whether the central bank's reaction function should be driven by overall inflation (headline inflation in the consumer price index) or by a measure of 'domestic' inflation.

My analysis focuses on the New Zealand (NZ) economy. As the first economy to introduce inflation targeting, the available data sample is longer than for any of the economies that subsequently adopted this type of monetary policy regime. This fact makes it appealing to study the New Zealand economy.

Adopting a multisectoral perspective is likely to be important for New Zealand for a number of reasons. New Zealand is a commodity-focused economy and thus produces different products to those it consumes. In small open economies a significant proportion of total consumption comes from imports. Because New Zealand is small and geographically isolated, there exists a large non-tradables sector. Historically, the aggregate and non-tradable sectors have had differing levels of price change (refer to figures 3 and 3 in appendix A).[1] Although CPI inflation remained inside the Reserve Bank of New Zealand's target range during 2004 and the first half of 2005, non-tradable inflation was above 4 percent during the same period. Non-tradable inflation has been offset in the CPI by relatively low tradable inflation, reflecting the appreciation of the exchange rate.[2] These features mean that developing a multisectoral model is likely to be particularly valuable.

A major area of research activity in recent years is the so called 'new

[1] This characteristic has been noted not only in New Zealand, but also in other economies like Australia and Canada, Bharucha and Kent (1998) and Ortega and Rebei (2005).

[2] For further details see RBNZ (2005).

open economy macroeconomics'.[3] I develop a model within that framework and estimate it for the New Zealand economy using the Bayesian methodology developed by Schorfheide (2000). This type of model has been applied to countries like the United States (US) and the European Union. In this paper, however, the focus is on a small and very open economy with features different than those found in large, almost-closed economies.

According to the 2002 Policy Target Agreements, the Reserve Bank of New Zealand's (RBNZ) primary price stability objective is augmented with secondary considerations for output variability, exchange rate movements, and interest rate smoothing. This suggests the importance of considering the industrial structure of the economy – the split between tradable and non-tradable sectors – when targeting inflation.[4]

In contrast to other authors that have analyzed monetary policy in the framework of 'new open macroeconomic models', I consider the distinction between traded and non-traded goods, similar to Lubik (2003). There are both empirical and theoretical reasons for the central bank of a small open economy to consider the industrial structure of the economy. Empirically, traded and non-traded inflation appear to have different stochastic characteristics. From an empirical point of view, the data suggest that the variability of the economic variables at the disaggregate level is higher than at the aggregate level. As we can see in tables 4 and 5, this is the case for small open economies like New Zealand, Canada, and Australia.

One reason for these sectoral differences is that the two sectors are influenced by monetary policy in different ways. The traded sector is affected by both the exchange rate and interest rate channels of monetary policy, while the non-traded sector is only exposed to the latter. If

[3]See Obstfeld and Rogoff (2000).

[4]The Reserve Bank of New Zealand Act 1989 specifies that the primary function of the Reserve Bank shall be to deliver 'stability in the general level of prices.' Section 9 of the Act then says that the Minister of Finance and the Governor of the Reserve Bank shall together have a separate agreement setting out specific targets for achieving and maintaining price stability. This is known as the Policy Targets Agreement (PTA). For more information, visit *www.rbnz.govt.nz/monpol/pta*.

the central bank does not take into account the different transmission mechanisms, and instead simply aggregates both sectors, it could misstep in setting policy. Furthermore, since different sectors are driven by different shock processes, a separate treatment of the sectors improves the central bank's understanding of the inflation process and therefore its ability to meet its inflation targeting objective.

The rest of the paper is as follows. The theoretical model is presented in section 2. It builds on the model by Gali and Monacelli (2005), but differentiates between traded and non-traded sectors. In section 3, I estimate the model following the Bayesian methodology developed by Schorfheide (2000) and used in Lubik and Schorfheide (2005). A procedure to test if the model fits the data, based on the comparison between the empirical and the model cross-covariances, is also briefly discussed. Section 4 presents the analysis of alternative monetary policy reaction functions: in one case the central bank responds directly to overall inflation, and in the other the central bank responds directly to non-traded inflation. Section 4 identifies conditions under which responding directly to non-traded-inflation is the best alternative. Finally, section 5 concludes.

2 The model

I consider a small open economy that is characterized by the existence of two domestic sectors: a home traded goods sector and a non-traded goods sector.[5] In both sectors prices are sticky according to a Calvo-staggered setting, modified to allow some backward-looking behaviour by firms.[6] Each sector is subject to a specific productivity shock.

I assume complete financial markets: households have access to a complete set of contingent claims that are traded in international markets.

[5] According to the RBNZ definition, the tradable goods sector comprises all those goods and services that are imported or that are in competition with foreign goods, either in domestic or foreign markets. The non-tradable sector comprises all those goods that do not face foreign competition.

[6]I consider a hybrid Phillips curve in the same sense as Gali and Gertler (1999).

This eliminates one potential source of distortion. The only distortions in the economy are due to sticky prices and firms' monopoly power.

The model is closed with alternative Taylor-type policy rules where the central bank responds not only to inflation but also to output growth, interest rates and changes in the nominal exchange rate. This allows me to model and compare different monetary regimes.

There are seven structural shocks in this economy: two productivity shocks, corresponding to each domestic sector, a government shock, a monetary policy shock, and three shocks related to the foreign economy. Apart from these shocks I consider two measurement errors that correspond to deviations from uncovered interest parity (UIP) and terms of trade.

2.1 The consumer's problem

There is a representative household which maximizes the intertemporal utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{\tilde{C}_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\psi}}{1+\psi} \right) \tag{1}$$

subject to the intertemporal budget constraint. σ is the inverse of the elasticity of substitution between consumption and labour and ψ is the inverse labour elasticity. In equation (1)

$$\tilde{C}_t = C_t - hC_{t-1} \tag{2}$$

where h is the parameter of habit persistence, which is an important feature of the model. Recent empirical analysis of aggregate data has obtained substantial evidence of habit persistence.[7] C_t is a consumption index consisting of differentiated goods and N_t is total labour

[7]The idea of habit formation dates back to Duesenberry (1949). Deaton and Muellbauer (1980) provide a survey and early references. These preferences have been used in a rich variety of contexts. Some applications in the real business cycle literature include Boldrin, Christiano and Fisher (2001), Fuhrer (2000), and Lettau and Uhlig (2000).

effort. Labour is supplied to both traded and non-traded sector in the following way,

$$N_t = N_{H,t} + N_{N,t} \tag{3}$$

where the subscript H refers to 'home-produced' tradables, and the subscript N refers to the non-tradable sector. Labour is completely mobile across sectors, which implies that wages in the traded and non-traded sectors are identical.

In aggregate, and assuming complete asset markets, the household's budget constraint is

$$P_t C_t + E_t(Q_{t+1} D_{t+1}) \leq D_t + W_t N_t + T_t \tag{4}$$

P_t is the price index, D_{t+1} is the nominal payoff in period $t+1$ of the portfolio held at the end of period t, $Q_{t,t+1}$ is the stochastic discount factor, W_t is the nominal wage, and T_t are lump-sum taxes.[8]

The consumption bundle, C_t is a constant elasticity of substitution (CES) index composed of both tradable, $C_{T,t}$ and non-tradable goods, $C_{N,t}$,

$$C_t = \left((1-\lambda)^{1/\nu} C_{T,t}^{\frac{\nu-1}{\nu}} + \lambda^{1/\nu} C_{N,t}^{\frac{\nu-1}{\nu}} \right)^{\frac{\nu}{\nu-1}} \tag{5}$$

where λ is the share of non-tradable goods in the economy and ν is the intratemporal elasticity of substitution between tradable and non-tradable goods at Home. I assume $\nu > 0$.

Households allocate aggregate expenditure based on the following demand functions:

$$C_{T,t} = (1-\lambda) \left(\frac{P_{T,t}}{P_t} \right)^{-\nu} C_t \tag{6}$$

$$C_{N,t} = \lambda \left(\frac{P_{N,t}}{P_t} \right)^{-\nu} C_t \tag{7}$$

[8]Note that money is not modelled in the utility function or in the budget constraint. I assume a cashless economy where the coefficient of the real money balances in the utility function can be approximated to zero.

Tradable goods consumption is determined as a CES index composed of the tradable goods that home consumers buy from the home sector and the goods bought from the foreign sector,

$$C_{T,t} = \left((1-\alpha)^{1/\eta} C_{H,t}^{\frac{\eta-1}{\eta}} + \alpha^{1/\eta} C_{F,t}^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}} \tag{8}$$

where α is the share of the foreign consumption component in the tradable consumption index and η is the intratemporal elasticity of substitution between home and foreign goods.

The demand for domestic goods and imports is given by,

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_{T,t}}\right)^{-\eta} C_{T,t} \tag{9}$$

$$C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_{T,t}}\right)^{-\eta} C_{T,t} \tag{10}$$

and the price indexes are

$$P_{T,t} = \left((1-\alpha)P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta}\right)^{\frac{1}{1-\eta}} \tag{11}$$

$$P_t = \left((1-\lambda)P_{T,t}^{1-\nu} + \lambda P_{N,t}^{1-\nu}\right)^{\frac{1}{1-\nu}} \tag{12}$$

The demand for home tradable goods is

$$Y_{H,t}^d = \left(\frac{P_{H,t}}{P_{T,t}}\right)^{-\eta}\left((1-\alpha)C_{T,t} + \alpha\left(\frac{1}{Q}\right)^{-\eta} C_t^*\right) + G_{H,t} \tag{13}$$

and for non-tradable goods

$$Y_{N,t}^d = C_{N,t}^d + G_{N,t} \tag{14}$$

I assume that the government only demands domestically produced goods, G_t such that

$$G_t = G_{H,t} + G_{N,t} \tag{15}$$

where $G_{H,t}$ is government spending in home traded goods and $G_{N,t}$ is government spending in non-traded goods.

Government spending is exogenously determined and exhibits persistent variations. In particular, it follows an AR(1) process in loglinearized terms,

$$g_t = \rho_g g_{t-1} + \varepsilon_{g,t} \tag{16}$$

where g_t is the amount spent by the government and $\varepsilon_{g,t}$ is distributed normally with mean 0 and variace σ_g^2. Lowercase letters are used to denote the logs of their uppercase counterparts.

The first order conditions of the household's optimization problem are given by

$$\tilde{C}_t^{\sigma} N_t^{\psi} = \frac{W_t}{P_t} \tag{17}$$

$$\beta\left(\frac{\tilde{C}_{t+1}}{\tilde{C}_t}\right)^{-\sigma}\left(\frac{P_t}{P_{t+1}}\right) = Q_{t,t+1} \tag{18}$$

$$\beta R_t E_t\left(\left(\frac{\tilde{C}_{t+1}}{\tilde{C}_t}\right)^{-\sigma}\left(\frac{P_t}{P_{t+1}}\right)\right) = 1 \tag{19}$$

where $R_t^{-1} = E_t\{Q_{t,t+1}\}$ is the price of a riskless one-period bond. R_t is then the gross interest rate of that bond.

In loglinearized terms

$$\sigma\tilde{c}_t + \psi n_t = \omega_t - p_t \tag{20}$$

$$\tilde{c}_t = E_t\tilde{c}_{t+1} - \frac{1}{\sigma}(r_t - \pi_{t+1}) \tag{21}$$

$$\tilde{c}_t = \frac{c_t - hc_{t-1}}{1-h} \tag{22}$$

Then, combining equations (21) and (22) results in a process for consumption,

$$c_t = \frac{h}{1+h}c_{t-1} + \frac{1}{1+h}E_t c_{t+1} - \frac{1-h}{\sigma(1+h)}(r_t - E_t\pi_{t+1}) \tag{23}$$

2.2 Tradable-sector firms

There exists a continuum of identically monopolistic competitive firms in the tradable sector. Firms operate the linear technology

$$Y_{H,t} = A_{H,t}N_{H,t} \tag{24}$$

which in loglinearized terms is

$$y_{H,t} = a_{H,t} + n_{H,t} \tag{25}$$

Producers solve the cost minimization problem

$$\min \frac{W_t}{P_{H,t}}N_{H,t} \tag{26}$$

subject to the production function in equation (24).

The log-linearized first order conditions around the steady state are given by

$$\omega_t - p_{H,t} = mc_{H,t} + a_{H,t} \tag{27}$$

The productivity variable, $a_{H,t}$, is assumed to follow in logarithms an AR(1) process[9]

$$a_{H,t} = \rho_H a_{H,t-1} + \varepsilon_{H,t} \tag{28}$$

where $\varepsilon_{H,t}$ is distributed normally with mean 0 and variance σ_{ε_H}.

I assume that firms set prices in a staggered fashion, according to the Calvo setting. With probability θ_H a firm keeps its price fixed and with

[9]The process followed by the level of the productivity variable is then, $A_{H,t} = A_{H,t-1}^{\rho_H}e^{(\varepsilon_{H,t})}$.

probability $(1-\theta_H)$ it sets its price $P^0_{H,t}$ optimally. However, I depart from Calvo by following the formulation of Gali and Gertler (1999). (I alter their notation slightly, omitting the * that they use to denote prices that have been optimally re-set.) A fraction $1-\omega_H$ of the firms behave as in Calvo's model; these are the 'forward-looking firms'. The remaining ω_H firms use a rule of thumb based on the recent history of aggregate price behaviour.

The aggregate price level of domestically-produced traded goods evolves according to

$$p_{H,t} = \theta_H p_{H,t-1} + (1-\theta_H)\bar{p}_{H,t} \tag{29}$$

where $\bar{p}_{H,t}$ is an index for the prices set in period t.

$$\bar{p}_{H,t} = (1-\omega_H)p^f_{H,t} + \omega_H p^b_{H,t} \tag{30}$$

where $p^f_{H,t}$ is the price set by a 'forward-looking firm' and p^b_t is the price set by a 'backward-looking firm'.

Forward looking firms behave as in the Calvo model,

$$p^f_{H,t} = (1-\beta\theta_H)\sum_{k=0}^{\infty}(\beta\theta_H)^k E_t\{mc^n_{H,t+k}\} \tag{31}$$

The 'backward-looking firms' set prices according to the rule

$$p^b_{H,t} = \bar{p}_{H,t-1} + \pi_{H,t-1} \tag{32}$$

The notation $\bar{p}_{H,t-1}$ refers to the prices that were re-set at time $t-1$.

The following hybrid Phillips curve is obtained by combining equations (29) to (32):

$$\pi_{H,t} = \lambda_H mc_{H,t} + \gamma_{f,H}E_t\{\pi_{H,t+1}\} + \gamma_{b,H}\pi_{H,t-1} \tag{33}$$

where

$$\lambda_H = (1-\omega_H)(1-\theta_H)(1-\beta\theta_H)\phi_H^{-1}$$
$$\gamma_{f,H} = \beta\theta_H\phi_H^{-1}$$
$$\gamma_{b,H} = \omega_H\phi_H^{-1}$$

with $\phi_H = \theta_H + \omega_H(1-\theta_H(1-\beta))$.

2.3 Non-tradable-sector firms

Similar to the traded sector, firms in the non-tradable sector are monopolistic competitors and operate the linear technology

$$Y_{N,t} = A_{N,t} N_{N,t} \tag{34}$$

Producers solve the cost minimization problem

$$\min \frac{W_t}{P_{N,t}} N_{N,t} \tag{35}$$

subject to the production function in equation (34).

The loglinearized first order conditions are given by

$$\omega_t - p_{N,t} = mc_{N,t} + a_{N,t} \tag{36}$$

where I assume that the productivity variable, $a_{N,t}$, follows the AR(1) process

$$a_{N,t} = \rho_N a_{N,t-1} + \varepsilon_{N,t} \tag{37}$$

where $\varepsilon_{N,t}$ is distributed normally with mean 0 and variance σ_{ε_N}.

Similar to the approach followed in the traded sector, the hybrid Phillips curve for the non-traded sector is

$$\pi_{N,t} = \lambda_N mc_{N,t} + \gamma_{f,N} E_t\{\pi_{N,t+1}\} + \gamma_{b,N}\pi_{N,t-1} \tag{38}$$

where

$$\lambda_N = (1-\omega_N)(1-\theta_N)(1-\beta\theta_N)\phi_N^{-1}$$
$$\gamma_{f,N} = \beta\theta_N\phi_N^{-1}$$
$$\gamma_{b,N} = \omega_N\phi_N^{-1}$$

with $\phi_N = \theta_N + \omega_N(1-\theta_N(1-\beta))$.

2.4 Inflation, terms of trade and the real exchange rate

CPI inflation and domestic inflation

In an open economy, there exists a distinction between CPI inflation and domestic inflation, due to the influence that the prices of imported goods have on the domestic economy.

The loglinearized expression for CPI inflation is given by,

$$\pi_t = (1-\lambda)\pi_{T,t} + \lambda\pi_{N,t} \tag{39}$$

and tradable inflation is

$$\pi_{T,t} = (1-\alpha)\pi_{H,t} + \alpha\pi_{F,t} \tag{40}$$

where $\pi_{H,t}$ is the domestic tradable inflation and $\pi_{F,t}$ is the inflation of imported goods expressed in home currency. Note that since the foreign economy behaves as a closed economy, the foreign price coincides with the foreign currency price of foreign goods, ie $P^*_{F,t} = P^*_t$. In the above equation α is the share of domestic consumption allocated to imported goods (α is an index of openness).

Domestic inflation is a weighted average of domestic tradable and non-tradable inflation,

$$\pi^d_t = (1-\lambda)\pi_{H,t} + \lambda\pi_{N,t} \tag{41}$$

The terms of trade

The terms of trade are treated as exogenous to the small open economy. I define the terms of trade as the relative price of exports in terms of imports,

$$S_t = \frac{P_{H,t}}{P_{F,t}} \tag{42}$$

Loglinearizing around the steady state,

$$s_t = p_{H,t} - p_{F,t} \tag{43}$$

The evolution of the terms of trade is captured by the following expression

$$\Delta s_t = \pi_{H,t} - \pi_{F,t} \tag{44}$$

Note that changes in the terms of trade represent changes in the economy's competitiveness.

The real exchange rate

Define the real exchange rate as the ratio of foreign prices in domestic currency to the domestic prices, ie,

$$Q_t = \frac{\mathcal{E}_t P_t^*}{P_t} \tag{45}$$

where $\mathcal{E}_t$ is the nominal exchange rate. The superscript * here denotes 'foreign'.

In loglinearized terms, with lowercase letters being the log of their uppercase counterparts, equation (45) becomes

$$q_t = e_t + p_t^* - p_t \tag{46}$$

The evolution of the real exchange rate is given by

$$\Delta q_t = \Delta e_t + \pi_t^* - \pi_t \tag{47}$$

I assume that there is complete pass-through of the exchange rate. That is, the law of one price for imported goods holds:

$$p_{F,t} = e_t + p_{F,t}^* \tag{48}$$

Substracting the lag of equation (48) from equation (48) and using $p_{F,t}^* = p_t^*$, I obtain an expression for foreign inflation

$$\pi_{F,t}^* = \pi_t^* = \pi_{F,t} - \Delta e_t \tag{49}$$

CPI inflation and the terms of trade

Equation (40) can be rewritten in terms of Δs_t

$$\begin{aligned} \pi_{T,t} &= \pi_{H,t} - \alpha(\pi_{H,t} - \pi_{F,t}) \\ &= \pi_{H,t} - \alpha \Delta s_t \end{aligned} \tag{50}$$

CPI inflation is, then

$$\pi_t = (1-\lambda)(\pi_{H,t} - \alpha \Delta s_t) + \lambda \pi_{N,t} \tag{51}$$

The terms of trade and the real exchange rate

Using the definition of the real exchange rate, I obtain the following relationship

$$\begin{aligned} q_t &= p_{F,t} - p_t \\ &= p_{F,t} - (1-\lambda)(p_{H,t} - \alpha s_t) - \lambda p_{N,t} \\ &= -(1-\alpha(1-\lambda))s_t - \lambda(p_{N,t} - p_{H,t}) \end{aligned} \tag{52}$$

Note that even though the law of one price holds for any individual good, the real exchange rate may still fluctuate. This is a result of variations in the relative price of domestic traded goods with respect to non-traded goods and variations in the relative price of domestic tradable goods and foreign-produced tradables.

Nominal exchange rate and terms of trade dynamics

From the definition of real exchange rate, I obtain an expression for the evolution of the nominal exchange rate

$$\Delta e_t = \pi_t - \pi_t^* + \Delta q_t \tag{53}$$

Similarly, from the definition of the terms of trade

$$\Delta s_t = e_t + \pi_{H,t} - \pi_t^* + \varepsilon_{s,t} \tag{54}$$

For the empirical analysis I add a shock to this equation, $\varepsilon_{s,t}$, to capture measurement errors.

Uncovered interest parity

Under the assumption of complete international financial markets, the following pricing equation holds,

$$E_t\{Q_{t,t+1}(R_t - R_t^*(\mathcal{E}_{t+1}/\mathcal{E}_t))\} = 0 \tag{55}$$

As before, $Q_{t,t+1}$ is the stochastic discount factor, R_t is the gross interest rate, and $\mathcal{E}_t$ is the level of the exchange rate. Linearization around the steady state implies,

$$r_t - r_t^* = E_t \Delta e_{t+1} + \varepsilon_{uip,t} \tag{56}$$

where $\varepsilon_{uip,t}$ is the uncovered interest parity shock. This shock is introduced to capture deviations from UIP, such as a time varying risk premium.

2.5 Risk sharing and the rest of the world

Under complete markets and taking into account the inclusion of a non-traded sector,[10] it can be shown that the following condition holds

$$c_t = hc_{t-1} + c_t^* - hc_{t-1}^* + \frac{(1-h)(2(1-\alpha)-1)}{\frac{2\alpha}{1-\eta} - 1} q_t \tag{57}$$

[10] For a reference see Corsetti, Dedola and Leduc (2005).

Aggregate demand in the small open economy is driven by the real exchange rate through equation (57).

Because the foreign economy is exogenous to the domestic economy, there is some flexibility in specifying the behaviour of foreign variables, y_t^*, r_t^* and π_t^*. I assume they are AR(1) processes:

$$y_t^* = \rho_{y^*} y_{t-1}^* + \varepsilon_{y^*,t} \tag{58}$$

$$\pi_t^* = \rho_{\pi^*} \pi_{t-1}^* + \varepsilon_{\pi^*,t} \tag{59}$$

$$r_t^* = \rho_{r^*} r_{t-1}^* + \varepsilon_{r^*,t} \tag{60}$$

where $\varepsilon_{i,t}$ is normally distributed with mean zero and variance $\sigma_{i,t}^2$, for $i = y^*$, r^*, and π^* respectively.

2.6 Goods market clearing condition

The market clearing condition in the domestic tradable sector is given by the loglinearized version of the following equation,

$$Y_{H,t} = C_{H,t} + C_{H,t}^* + G_{H,t} \tag{61}$$

where, $C_{H,t}$ is obtained by combining equation (6) and equation (9) and $C_{H,t}^*$ is, after some transformations, given by

$$C_{H,t}^* = \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} \left(\frac{1}{Q_t}\right)^{-\eta} C_t^* \tag{62}$$

In loglinearised terms,

$$\begin{aligned} c_{H,t} &= -\eta(p_{H,t} - p_{T,t}) - \nu(p_{T,t} - p_t) + c_t \\ &= \alpha(\nu\lambda - \eta)s_t + \nu\lambda p_{N,t} + c_t \end{aligned} \tag{63}$$

and

$$c^*_{H,t} = \eta\lambda p_{N,t} - \eta(1-\lambda)\alpha s_t + c^*_t + \eta q_t \tag{64}$$

The loglinearized version of the domestic market clearing condition is

$$\begin{aligned} y_{H,t} &= \alpha((1-\alpha)(\nu\lambda - \eta) - \eta(1-\lambda)\alpha)s_t \\ &\quad +((1-\alpha)\nu\lambda + \alpha\eta\lambda)p_{N,t} + (1-\alpha)c_t + \alpha c^*_t + \eta\alpha q_t \end{aligned} \tag{65}$$

The market clearing condition in the non-tradable sector is given by the following expression,

$$y_{N,t} = c_{N,t} + g_{N,t} \tag{66}$$

where

$$\begin{aligned} c_{N,t} &= -\nu(p_{N,t} - p_t) + c_t \\ &= -\nu(1-\lambda)\alpha s_t - \nu(1-\lambda)p_{N,t} + c_t \end{aligned} \tag{67}$$

from which I obtain the following expression,

$$y_{N,t} = -\nu(1-\lambda)\alpha s_t - \nu(1-\lambda)p_{N,t} + c_t + g_{N,t} \tag{68}$$

Then, the market clearing condition in the home economy is a weighted average of domestic tradable and domestic non-tradable output,[11]

$$y_t = (1-\lambda)y_{H,t} + \lambda y_{N,t} \tag{69}$$

2.7 Marginal cost

I obtain an expression for the loglinearized marginal cost in the traded and non-traded sectors by combining equations (20), (27), and the aggregate production function $y_t = a_t + n_t$.

$$mc_{H,t} = \sigma(c_t - hc_{t-1}) + \psi(y_t - a_t) - a_{H,t} - (p_{H,t} - p_t) \tag{70}$$

[11] This requires some assumptions. In particular, in steady state there must not be net accumulation of foreign assets. It is also useful that the price of traded and non-traded goods in the steady state are equal, given perfect labour mobility between sectors.

Similarly, I obtain an expression for the non-traded sector marginal cost

$$mc_{N,t} = \sigma(c_t - hc_{t-1}) + \psi(y_t - a_t) - a_{N,t} - (p_{N,t} - p_t) \tag{71}$$

where I have used the fact that

$$n_t = (1-\lambda)n_{H,t} + \lambda n_{N,t} \tag{72}$$

and

$$a_t = (1-\lambda)a_{H,t} + \lambda a_{N,t} \tag{73}$$

2.8 Monetary policy rules

The model is closed after specifying the monetary policy reaction function. I analyze optimal monetary policy within a family of generalised Taylor rules, where the central bank responds to inflation, output growth and movements in the nominal exchange rate.

The general reaction function is given by

$$r_t = \rho_r r_{t-1} + (1-\rho_r)(\psi_1 \tilde{y}_t + \psi_2 \pi_t + \psi_{2N}\pi_{N,t} + \psi_{2H}\pi_{H,t} + \psi_3 \Delta e_t) \tag{74}$$

This paper then discusses two variants of this monetary reaction function:

- An overall-inflation rule: $\psi_{2N} = \psi_{2H} = 0$ and $\psi_2 \neq 0$.
- A sectoral-inflation rule: $\psi_2 = 0$, $\psi_{2N} = \kappa$, $\psi_{2H} = 1-\kappa$. In this case the monetary authority explicitly takes into account the multisectoral features of the economy.

According to Bharucha and Kent (1998), there is a fundamental distinction in a small open economy between aggregate inflation and non-traded inflation. These two inflations behave differently as we can observe for the New Zealand economy in Figure 3 and Figure 4. Concretely, CPI inflation is a weighted average between tradable inflation and non-tradable inflation

$$\pi_t = (1-\lambda)\pi_{T,t} + \lambda\pi_{N,t} \tag{75}$$

Tradable inflation depends on foreign inflation, domestic tradable inflation and nominal exchange rate changes according to

$$\pi_{T,t} = (1-\lambda)(1-\alpha)\pi_{H,t} + (1-\lambda)\alpha\pi_t^* + (1-\lambda)\alpha\Delta e_t \tag{76}$$

Then, tradable inflation, other things being equal, is influenced by three factors in the following way:

- Domestic tradable inflation: an increase in $\pi_{H,t}$ causes an increase in $\pi_{T,t}$.
- Foreign inflation: an increase in π_t^* causes an increase in $\pi_{T,t}$.
- Nominal exchange rate changes: an appreciation in the nominal exchange rate (a decrease in e_t) causes a decrease in $\pi_{T,t}$.

Hence, CPI inflation is given by the following expression:

$$\pi_t = (1-\lambda)(1-\alpha)\pi_{H,t} + (1-\lambda)\alpha\pi_t^* + (1-\lambda)\alpha\Delta e_t + \lambda\pi_{N,t} \tag{77}$$

Tradable inflation depends on the world price and the exchange rate, which plays a significant role in the determination of aggregate inflation. Non-traded inflation, however, is determined by domestic conditions.

I analyze the performance of both monetary policy rules, by comparing the value of the loss of the central bank under both specifications of the monetary policy rule and for different preferences.

3 Estimation

3.1 Estimation methodology

According to Geweke (1999) there are several ways to estimate a DSGE model. We can talk about a weak and a strong econometric interpretation. In the former, the parameters are estimated in such a way that selected theoretical moments given by the model match, as closely as possible, those observed in the data. This is normally done by minimising some distance function between the theoretical and the empirical moments of interest. The strong econometrics method, however, attempts to provide a full characterization of the observed data series.

One approach, within the strong econometric interpretation, is the methodology that uses classical maximum likelihood estimation. This method consists of four steps: first, solve the linear rational expectations model for the reduced form state equation in its predetermined variables. Secondly, the model is written in state-space form (it is augmented by adding a measurement equation). In a third step, the Kalman Filter is used to obtain the likelihood function. Finally, the parameters are estimated using maximum likelihood.

As alternative to this approach, I use the Bayesian estimation methodology for Dynamic Stochastic General Equilibrium models (DSGE) developed by Schorfheide (2000). The advantage is that it is a system based estimation method that allows me to incorporate additional information on parameters through the use of priors. Furthermore, the use of priors over the structural parameters makes the non-linear optimization algorithm more stable. This is very important in situations where only small samples of data are available.

The Bayesian estimation methodology consists of five steps.[12] In step one the linear rational expectations model is solved. In a second step, the model is written in state space form by adding a measurement

[12] For a detailed explanation, see Smets and Wouters (2003) and Smets and Wouters (2002).

equation. This links the observable variables to the vector of state variables. In step three the Kalman Filter is used to derive the likelihood function. This likelihood function is combined in step four with the prior distribution of the parameters to obtain the posterior density function. A numerical optimization routine is used to compute the mode of the posterior density and the inverse Hessian is obtained. Finally, the posterior distribution of the parameters is derived numerically using a Monte Carlo Markov chain (MCMC) algorithm. The specific MCMC algorithm that I use is the Metropolis-Hastings algorithm.[13] The proposal distribution is a multivariate Normal density with covariance matrix proportional to the inverse Hessian at the posterior mode. Posterior draws of impulse response functions and variance decompositions can be obtained by transforming the parameter draws accordingly.

I estimate the model for New Zealand, taking into account the features of this economy and the fact that the RBNZ is concerned about targeting headline inflation. The model is first estimated using a reaction function where the central bank responds directly to overall CPI inflation.

3.2 The choice of the prior distribution

I adopt the priors used by Lubik and Schorfheide (2003) for the New Zealand economy. The priors are presented in table 4. I choose a beta distribution for parameters that are constrained on the unit interval and a gamma distribution for parameters in $\mathbb{R}_+$. For the variances of the shocks I use an inverse gamma distribution. The discount factor, β, is considered fixed at the beginning of the simulation. This is called a very strict prior. It is calibrated to be 0.99, which implies an annual steady state interest rate of 4 percent. Other parameters that are fixed

[13]Draws from the posterior distribution of the DSGE model can only be generated numerically because the posterior does not belong to a well-known class of distributions. A random walk Metropolis algorithm is used to generate draws from the posterior.

are the proportion of non-traded goods in the economy (λ), the import share (α) and the elasticities, η and ν. The variances of the shocks are assumed to follow an inverse gamma distribution. This distribution guarantees a positive variance.

3.3 The data

I estimate the model for the New Zealand economy as the small open economy. The rest of the world is composed of the 12 main trading partners of New Zealand.

The small open economy model is fitted to data on output, tradable and non-tradable inflation, nominal interest rates, terms of trade and nominal exchange rate changes. The data are quarterly, seasonally-adjusted series that cover the period 1992:Q1 to 2004:Q4.[14] For inflation I use the consumer price index (CPI) and series for tradable and non-tradable prices. The output series is per capita real gross domestic product (GDP) and the nominal interest rate is a short term rate. For the nominal exchange rate I use a nominal trade weighted exchange rate index. Foreign output is a summary measure of the economic activity of 12 of New Zealand's major export destinations, GDP-12.[15] For foreign inflation, I use CPI-12 growth, which is calculated identically to GDP-12. Finally, for the interest rate I use a weighted 80:20 measure of US/Australia 90 day interest rates. The inflation and interest rate series are annualized. Data are detrended by eliminating a linear trend.

[14] The series were obtained from the 'Reserve Bank of New Zealand Aremos database'. The choice of the period 1992 to 2004 as my sample period is based on the adoption of inflation targeting in New Zealand (1990), but eliminating the first 2 years of transition (1990 to 1991), during which the economy moved from a period of high to stable inflation.

[15]GDP components are obtained from Datastream (they are seasonally adjusted, quarterly data).

3.4 Estimation results

In this section, I discuss the estimation results of the model.

Priors and posteriors

Figures 5 to 7 represent the prior and posterior distributions of the parameters. The grey solid lines represent the prior distributions; the solid black and dashed grey lines are the posterior distributions and their modes respectively. As can be seen, there are discrepancies between the priors motivated by micro data and the posteriors that are influenced by macro data; see for example the habit persistence parameter, the parameter indicating the proportion of firms that exhibit backward-looking behaviour, and the degree of interest rate smoothing. In the rest of the cases, with some exceptions, the data are not very informative and the prior mode coincides with the posterior mode. In cases where the posterior distribution of the parameters is much sharper (narrower) than the prior distribution, the data are very informative.

Parameter estimates

When I combine the joint prior distribution with the likelihood function, I get a posterior density that cannot be evaluated analytically. In order to sample from the posterior, I employ a random walk chain Metropolis-Hasting algorithm where the proposal density is a multivariate normal. I generate $150,000$ draws from the posterior distribution, which is obtained using the Kalman filter.

The parameter estimates are presented in table 7 in appendix B. As we can see, there is a very high degree of price stickiness in both sectors, being higher in the home traded sector than in the non-traded sector. These results suggest that the degree of price rigidity is more important in New Zealand than in the standard closed and large economies.

The autoregresive coefficients of the shocks are high, suggesting an important degree of persistence driving the economy.

With respect to the parameters in the consumer's utility function, the posterior estimates for the inverse of the elasticity of substitution, σ, and the inverse of the labour elasticity, ψ, are both lower than those typically found for large economies. The parameter representing habit persistence is around 0.94, from which we can infer that consumers are more concerned about consumption growth in the utility function than about the level.

The results do not suggest significant backward-looking behaviour in the Phillips curve of both sectors. The relevant parameter, ω, is not significant, being around 0.07 (this suggests that the proportion of firms who behave in a backward-looking fashion is about 7 percent).[16]

If we analyze the value of the parameters in the reaction function, the response coefficient on inflation is 1.724. This implies that if inflation increases by 1 percent, ceteris paribus, the Reserve Bank increases its interest rate by approximately 1.7 percent. The coefficient in front of the nominal exchange rate appreciation or depreciation is very small, around 0.10. This suggests that the RBNZ does not react strongly to exchange rate movements. The estimated coefficient for the reaction to output growth is 0.36, coherent with estimates in the literature. Lastly, the coefficient indicating interest rate smoothing is around 0.364, lower than the prior mean.

I perform a posterior odds test, which shows that the model with a direct response to overall inflation is better. I compare a model where the RBNZ responds to overall inflation with one where the RBNZ responds to non-tradable inflation. The posterior odds ratio is the ratio of the posterior model probabilities.[17] The log data density from the estimation is 1298.3.

[16]Note that I have assumed in the estimation procedure that the proportion of backward-looking firms is the same in both sectors, ie $\omega_H = \omega_N = \omega$.

[17]More detail can be found in Koop (2003).

Consider the two models: M_i for $i =$'o', 'n', where 'o' refers to the null of responding to overall inflation and 'n' refers to the reaction function that embodies a response to non-traded inflation. In this case,

$$PO_{o,n} = \frac{p(M_o|y)}{p(M_n|y)} = \frac{p(y|M_o)p(M_o)}{p(y|M_n)p(M_n)} \tag{78}$$

where $p(y|M_i)$ is the marginal likelihood and $p(M_i)$ is the prior model probability. If we assign the same prior probability to both models, the odds ratio is the ratio of the marginal likelihoods and is known as the Bayes factor

$$BF_{o,n} = \frac{p(y|M_o)}{p(y|M_n)} \tag{79}$$

The greater the Bayes factor, the higher the support for M_o. In the paper, $BF_{o,n} > 1$. This means that the reaction function that responds to overall inflation is supported by the evidence.

Impulse response analysis

The impulse responses are generated from the reduced form representation of the model. They represent the responses of the endogenous variables to one-standard deviation shocks. Parameter uncertainty is incorporated in impulse-response analysis by constructing confidence intervals for the model's response to a shock. A full Bayesian impulse response function (IRF) analysis is presented.

In section B.6, I present the Bayesian impulse response functions corresponding to the shocks of the economy. The confidence intervals span 95 percent of the probability mass. Figure 8 depicts a shock to the traded goods sector. As we should expect, output increases and inflation in both sectors decreases (note that the reduction in inflation is higher in the sector that experiences the productivity improvement, the traded sector). The RBNZ reacts with an expansionary monetary policy and the nominal exchange rate depreciates. The terms of trade

fall, given the improvement in domestic productivity. Note the persistence of output, and that it returns to the steady state level, as we should expect.

Figure 9 represents a productivity improvement in the non-traded goods sector. Again, output increases and inflation falls in both sectors. In contrast to the previous case, non-traded inflation declines more than in the traded sector, consistent with higher productivity in the non-traded sector. The nominal exchange rate depreciates, given that the response of output is larger. The central bank is reacting more to output growth than to deviations of inflation from the target.

Figure 10 describes a domestic fiscal shock. This shock increases output and inflation in both sectors. The monetary authority contracts the economy and the terms of trade increase, reflecting lower domestic productivity. The higher interest rate appreciates the nominal exchange rate.

A shock to the terms of trade is described in figure 11. This shock causes an initial depreciation of the nominal exchange rate that decreases output and inflation in both sectors. In contrast to what we would expect, the monetary authority reacts by tightening the economy, increasing the interest rate.

Figure 12 presents a contractionary domestic monetary policy shock. Output and inflation fall and the nominal exchange rate appreciates, as we should expect. The terms of trade increase initially, representing a worsening in domestic competitiveness.

A negative foreign economy shock represented by a shock to foreign output (figure 13) or foreign inflation (figure 14) reduces domestic output. The negative foreign shock reduces the demand of domestically produced goods and this reduces domestic output. In both cases, the central bank reacts by expanding the economy. In contrast, a contractionary foreign monetary policy shock increases domestic output initially and induces contractionary domestic monetary policy.

3.5 Comparison of empirical and model-based cross-covariances

Following the procedure used in Smets and Wouters (2003), I validate the model by comparing the model-based variances and cross-covariances with those in the data. I calculate the cross-covariances between the six observed data series implied by the model and compare them with empirical cross-covariances. The empirical cross-covariances are based on a VAR(2) estimated on the data sample covering the period 1992:Q1 to 2004:Q4. The model cross-covariances are also calculated by estimating a VAR(2) on $10,000$ random samples of the observations generated by the DSGE model. Generally the data covariances, for most of the 6 lags considered, fall within the error bands, suggesting that the model is able to mimic the cross-covariances of the data. The errors bands are very large: this suggests that there exists a large amount of uncertainty surrounding the model-based cross-covariances. More detailed results and figures are available from the author upon request.

4 Alternative monetary policies

In the previous section, I estimated the model for the monetary policy regime followed by New Zealand, where the central bank responds directly to overall CPI inflation. In this section, I simulate the model under two alternative monetary policy regimes, and for different preferences of the central bank, and identify which reaction function minimises the central bank's loss function. The parameters are calibrated at the posterior mean of the estimated parameters in the previous section. The alternative reaction functions are:

$$r_t^o = \gamma_1^o \pi_t + \gamma_2^o \Delta y_t + \gamma_3^o r_{t-1} \quad (80)$$

$$r_t^{NT} = \gamma_1^{NT} \pi_{N,t} + \gamma_2^{NT} \Delta y_t + \gamma_3^{NT} r_{t-1} \quad (81)$$

The former invokes a direct response to overall inflation, whereas the latter responds to non-tradables inflation.

To analyze the performance of the different monetary regimes, I follow two procedures. First, I compare the volatility implied by the different monetary policy regimes on the variables that enter in the reaction function. Second, I simulate the model under both monetary policy regimes for different preferences of the central bank.

4.1 Volatility analysis

We can see in table 1 that responding to non-traded inflation generates lower variability in the terms of trade, interest rates, and inflation in the non-traded sector. In contrast, responding to overall inflation results in marginally lower volatility in consumption and output; moderately lower exchange rate volatility; and substantially lower volatility in tradable and overall CPI.

Table 1
Volatilities of simulated variables

	overall π reaction fn.	Non-traded π reaction fn.
Variable	Std. Deviation	Std. Deviation
c	**0.096**	0.157
y	**0.292**	0.294
e	1.568	**1.489**
q	**1.023**	1.235
s	1.549	**1.178**
r	0.358	**0.269**
π	**0.290**	0.370
π_H	**0.368**	0.686
π_N	0.386	**0.203**

Note: Bold values indicate the regime under which a volatility is lower.

4.2 Should the RBNZ respond to non-traded inflation?

The volatility comparison above assumed that the central bank's preferences were of a particular form. It is apparent from the volatility comparisons that the overall losses associated with the two reaction functions will depend on the weights applied to the various volatilities.

This subsection examines how the performance of the two reaction functions vary depending on the central bank's preferences across inflation, output, and interest rates. This experiment is a little different to the direct comparison of volatilities because the reaction coefficients are optimised for the central bank's preferences. Given that the coefficient on the exchange rate is small in the estimated reaction function, I set this coefficient to zero in the simulation.

The coefficients γ_i^j, for $i = 1 \ldots 3$ and $j = o, NT$, are chosen to minimize the central bank loss function[18]

$$L_t = \lambda var(\pi_t) + (1-\lambda)var(y_t) + \frac{\lambda}{4}var(\Delta r_t) \tag{82}$$

I repeat the minimization problem and simulation for every possible specification of the central bank's preferences, ie by varying $\lambda \in [0, 1]$. In other words, I apply the two reaction functions and store the resulting loss function values for both for each λ. This comparison enables me to identify which reaction functions perform well for which preferences.

4.3 Results from comparing reaction functions

As we can see in figure 1, whenever $\lambda \in [0, 0.6]$ the value of the loss function is smaller under a reaction function where the central bank

[18]The central bank is concerned about stabilizing the output gap, inflation and changes in the interest rate. This is a standard loss function in the literature on monetary policy.

Table 2
overall inflation reaction function losses

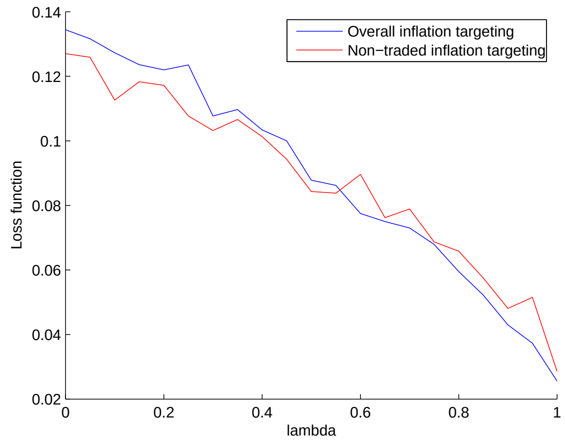
λ	Loss Value	γ_1	γ_2	γ_3
0	0.134	1.56	0.86	0.60
0.05	0.132	1.23	0.86	0.60
0.10	0.127	1.12	0.95	1
0.15	0.124	1.01	0.95	0.53
0.20	0.122	1.56	0.76	0.67
0.25	0.124	1.23	0.86	0.67
0.30	0.108	1.12	0.86	1
0.35	0.110	1.23	0.86	0.93
0.40	0.103	1.12	0.95	1
0.45	0.100	1.12	0.57	0.80
0.50	0.088	1.67	0.76	1
0.55	0.086	1.56	0.95	0.87
0.60	0.078	1.01	0.57	0.73
0.65	0.075	1.56	0.95	0.93
0.70	0.073	1.23	0.48	0.87
0.75	0.068	1.12	0.76	1
0.80	0.060	1.01	0.38	1
0.85	0.052	1.12	0.48	1
0.90	0.043	1.23	0.38	1
0.95	0.037	1.23	0.29	1
1	0.026	1.23	0.10	0.93

Table 3
Non-tradable inflation reaction function losses

λ	Loss Value	γ_1	γ_2	γ_3
0	0.127	1.89	0.95	0.53
0.05	0.126	1.12	0.95	0.73
0.10	0.113	1.56	0.76	0.87
0.15	0.118	1.45	0.95	0.60
0.20	0.117	1.12	0.95	0.80
0.25	0.108	1.23	0.67	0.73
0.30	0.103	1.12	0.95	1.00
0.35	0.107	1.67	0.95	0.87
0.40	0.101	1.89	0.71	0.87
0.45	0.094	1.56	0.76	0.67
0.50	0.084	1.12	0.76	0.80
0.55	0.084	1.45	0.95	0.93
0.60	0.090	1.34	0.95	0.87
0.65	0.076	1.34	0.57	1.00
0.70	0.079	1.78	0.67	0.08
0.75	0.069	1.45	0.48	0.73
0.80	0.066	1.12	0.38	0.67
0.85	0.058	1.01	0.29	0.80
0.90	0.048	1.45	0.38	0.87
0.95	0.052	1.12	0.48	0.67
1	0.029	1.12	0.10	0.87

responds to non-traded inflation. However for values of λ greater than 0.6, responding to overall inflation is better.

Figure 1
Loss function under alternative monetary policy regimes



As the central bank becomes more concerned about output variability (reflecting a 'flexible' approach to inflation targeting), the central bank is better off responding to non-traded inflation instead of overall inflation. When λ is around 0.6, responding directly to overall inflation results in better monetary policy. These results are consistent with the ones obtained by Svensson (2000), where a model of a small open economy is used to compare CPI inflation and domestic inflation reaction functions. What Svensson finds in his paper is that Taylor-type policy rules that respond to non-traded inflation perform better than those that respond to overall inflation.

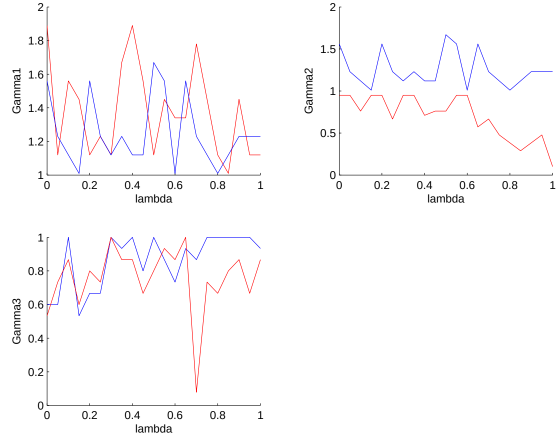
The intuition behind these results is that when the central bank responds to overall CPI inflation, it attempts to offset the direct effects of exchange rate movements, which are largely temporary in nature.

When the exchange rate depreciates, the perfect pass-through causes CPI inflation to rise over the very short-term. In response, monetary policy increases interest rates, which causes the exchange rate to appreciate and a fall in CPI inflation. Monetary policy then has to contend with the indirect exchange rate impact via the exchange rate effect on the output gap. In contrast, when the central bank responds directly to non-traded inflation, it ignores the direct exchange rate impact on CPI and instead focuses on the direct effect via the output gap.[19]

All these results are reinforced in figure 2. As we can see in the right upper graph, representing the coefficients of the reaction functions, the central bank reacts more strongly to deviations of overall inflation from its desired level than when the central bank is responding to non-traded inflation. The opposite happens with the output gap (left upper graph). In the case of interest rate smoothing, neither reaction function dominates when $\lambda \leq 0.6$. Nevertheless, for values of $\lambda \geq 0.6$, the loss is lower when the central bank responds directly to non-traded inflation rather than overall inflation.

[19]These results were found by Conway, Drew, Hunt and Scott (1998) who address the same question with a less structural model.

Figure 2
Comparison of coefficients in the reaction function



5 Conclusions

Should the central bank of a small open economy respond to overall CPI inflation? Or should it take into account the multisectoral structure of the economy? To respond to those questions, I have analysed a structural general equilibrium model of a small open economy with two sectors: a traded sector and a non-traded sector. The model shares the characteristics of the new open economy models, adapted to represent the features of the New Zealand economy. In particular, I assume a loss function where the central bank is concerned about inflation, output growth and exchange rate movements.

From the estimation of the model, I obtain the characteristics of the New Zealand economy, given by the posterior means of the parameters. New Zealand is an economy characterized by a high degree of price stickiness, low inverse elasticities of intertemporal and intratemporal substitution in the utility function, and a very high degree of habit persistence. The evidence suggests that the central bank responds directly to overall CPI inflation (cf non-tradable inflation) and that the direct reaction to exchange rate movements is not very important.

Taking into account these characteristics, I have obtained conditions under which the central bank would minimize losses by following a reaction function with a direct response to non-traded inflation, instead of the actual policy rule of responding to overall CPI inflation. The results in the paper show that the choice of reaction function depends on the central bank's preferences. In particular, if preferences are relatively biased towards inflation stabilization, responding directly to overall inflation is better. If instead the central bank places relatively more weight on output stabilization, responding directly to non-traded inflation is a better strategy. These results, however, do not take into account uncertainty in the parameters. This uncertainty should be taken into account in future research, by introducing Bayesian calibration in the simulation of the different monetary policy regimes.

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Appendices

A Motivation

The following table presents variance, covariance and correlation coefficients of non-traded inflation and overall inflation for Canada, Australia and New Zealand (period 1989:Q1 to 2004:Q4).

Table 4
Moments of inflation series (part A)

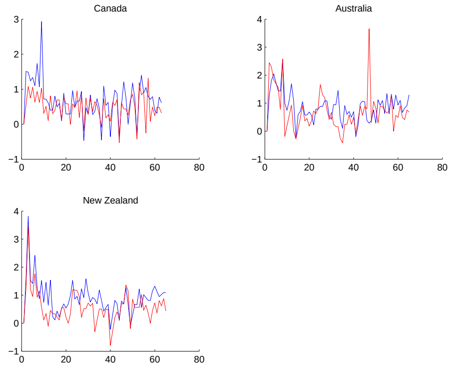
Country	Canada	Australia	New Zealand
Variance Non-tradable CPI	0.306	0.252	0.351
Variance CPI	0.1410	0.509	0.330
Covariance	0.136	0.172	0.259
Correlation Coefficient	0.654	0.500	0.760

The following table presents variance, covariance and correlation coefficients of non-traded inflation and overall inflation for Canada, Australia and New Zealand (period 2001:Q2 to 2004:Q4).

Table 5
Moments of inflation series (part B)

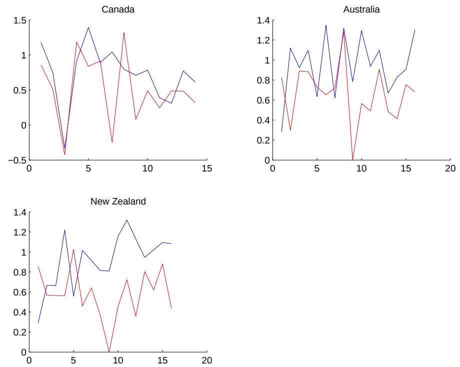
Country	Canada	Australia	New Zealand
Variance Non-tradable CPI	0.173	0.092	0.074
Variance CPI	0.250	0.086	0.061
Covariance	0.115	0.016	-0.016
Correlation Coefficient	0.556	0.178	-0.237

Figure 3
Non-traded inflation vs overall inflation (1989:Q1-2004:Q4)



Note: Quarter on quarter inflation rates

Figure 4
Non-traded inflation vs Overall inflation (2001:Q2-2004:Q4)



Note: Quarter on quarter inflation rates

B Estimation

B.1 Observable variables

$y_t, \pi_{N,t}, \pi_{T,t}, \Delta e_t, y_t^*, \pi_T^*, r, r^*$

B.2 Shocks

Structural shocks

1. Productivity shocks: ε_H, ε_N
2. Government expenditure shocks: ε_g
3. Monetary policy shock: ε_r
4. Foreign shocks: ε_{y^*}, ε_{π^*},ε_{r^*}

Measurement errors

1. Uncovered interest parity shock: ε_{uip}
2. Terms of trade shock: ε_s

B.3 Endogenous variables

$y_t, \pi_{H,t}, \pi_{N,t}, \pi_t, mc_{H,t}, mc_{N,t}\ g_t, a_{H,t}, a_{N,t}, c_t\ \Delta e_t, q_t, s_t, p_{NT,t}, y_t^*, r_t, r_t^*, \pi_t^*$

B.4 Equations

Domestic tradable sector

$$\begin{aligned} y_{H,t} = {} & \alpha(\nu(1-\alpha)-\eta)s_t - \nu(1-\alpha)(p_{H,t}-p_t) \\ & +(1-\alpha)c_t + \alpha c_t^* + \eta\alpha q_t + g_{H,t} \end{aligned} \tag{83}$$

Domestic non-tradable sector

$$y_{N,t} = -\nu(p_{N,t}-p_t) + c_t + g_{N,t} \tag{84}$$

Output

$$y_t = (1-\lambda)y_{H,t} + \lambda y_{N,t} \tag{85}$$

Consumption

$$c_t = \frac{h}{1+h}c_{t-1} - \frac{1-h}{\sigma(1+h)}(r_t - E_t\pi_{t+1}) + \frac{1}{1+h}E_t c_{t+1} \tag{86}$$

Domestic tradable inflation

$$\pi_{H,t} = \lambda_H mc_{H,t} + \gamma_{H,f}E_t\pi_{H,t+1} + \gamma_{H,b}\pi_{H,t-1} \tag{87}$$

where

$$\begin{aligned} \lambda_H &= (1-\omega)(1-\theta_H)(1-\beta\theta_H)\phi^{-1} \\ \gamma_{H,f} &= \beta\theta_H\phi^{-1} \\ \gamma_{H,b} &= \omega\phi^{-1} \\ \phi &= \theta_H + \omega(1-\theta_H(1-\beta)) \end{aligned}$$

Domestic non-tradable inflation

$$\pi_{N,t} = \lambda_N mc_{N,t} + \gamma_{N,f} E_t \pi_{N,t+1} + \gamma_{N,b} \pi_{N,t-1} \tag{88}$$

where

$$\lambda_N = (1-\omega)(1-\theta_N)(1-\beta\theta_N)\phi^{-1}$$
$$\gamma_{N,f} = \beta\theta_N \phi^{-1}$$
$$\gamma_{N,b} = \omega\phi^{-1}$$
$$\phi = \theta_N + \omega(1-\theta_N(1-\beta))$$

Domestic tradable marginal cost

$$mc_{H,t} = \frac{\sigma}{1-h}(c_t - hc_{t-1}) + \psi y_t - (\psi(1-\lambda)+1)a_{H,t} - \psi\lambda a_{N,t} - (p_{H,t} - p_t) \tag{89}$$

Domestic non-tradable marginal cost

$$mc_{N,t} = \frac{\sigma}{1-h}(c_t - hc_{t-1}) + \psi y_t - (\psi(1-\lambda))a_{H,t} - (\psi\lambda+1)a_{N,t} - (p_{N,t} - p_t) \tag{90}$$

Price ratios

$$p_{H,t} - p_t = (1-\lambda)\alpha s_t - \lambda p_{N,t} \tag{91}$$

$$p_{N,t} - p_t = (1-\lambda)\alpha s_t + (1-\lambda)p_{N,t} \tag{92}$$

Domestic tradad sector productivity

$$a_{H,t} = \rho_H a_{H,t-1} + \varepsilon_{aH,t} \tag{93}$$

Domestic non-tradable productivity

$$a_{N,t} = \rho_H a_{N,t-1} + \varepsilon_{aN,t} \tag{94}$$

Fiscal policy

$$g_t = \rho_H g_{t-1} + \varepsilon_{g,t} \tag{95}$$

International risk sharing condition

$$c_t = hc_{t-1} + c_t^* - hc_{t-1}^* + \frac{(1-h)(2(1-\alpha)-1)}{\frac{2\alpha}{1-\eta} - 1} q_t \tag{96}$$

Uncovered interest parity

$$r_t - r_t^* = E_t \Delta e_{t+1} + \varepsilon_{uip,t} \tag{97}$$

Evolution of the terms of trade

$$s_t = s_{t-1} + \pi_t - \pi_t^* - \Delta e_t + \varepsilon_{s,t} \tag{98}$$

Relationship between terms of trade and real exchange rate

$$q_t = ((1-\lambda)\alpha - 1)s_t - \lambda p_N \tag{99}$$

Overall inflation

$$\pi_t = (1-\lambda)\pi_{h,t} + \lambda\pi_{N,t} - (1-\lambda)\alpha s_t \tag{100}$$

Monetary policy rule

$$r_t = \rho_r r_{t-1} + (1-\rho_r)(\psi_1 \tilde{y}_t + \psi_2 \pi_t + \psi_{2N} \pi_{N,t} + \psi_{2H} \pi_{H,t} + \psi_3 \Delta e_t) \quad (101)$$

Foreign economy

$$y_t^* = \rho_y y_{t-1}^* + \varepsilon_{y*,t} \quad (102)$$

$$\pi_t^* = \rho_{\pi^*} \pi_{t-1}^* + \varepsilon_{\pi*,t} \quad (103)$$

$$r_t^* = \rho_{r^*} r_{t-1}^* + \varepsilon_{r*,t} \quad (104)$$

Table 6
Prior specification

Parameters		Distribution	Mean	Std Dev.
σ	Consumption ut.	Gamma	1	0.5
ψ	Labour ut.	Gamma	2	0.5
h	Habit	Beta	0.7	0.15
θ_H	Calvo: traded sector	Beta	0.75	0.15
θ_N	Calvo: non-traded sector	Beta	0.75	0.15
p	Backward-loofing firms	Beta	0.4	0.15
ρ_{aH}	Traded productivity	Beta	0.85	0.1
ρ_{aN}	Non-traded productivity	Beta	0.85	0.1
ρ_g	Fiscal policy	Beta	0.75	0.1
ρ_{y^*}	Foreign output	Beta	0.8	0.1
ρ_{π^*}	Foreign inflation	Beta	0.8	0.2
ρ_{r^*}	Foreign monetary policy	Beta	0.6	0.2
ψ_1	monetary policy, y	Gamma	1.5	0.5
ψ_2	monetary policy, π	Gamma	0.25	0.125
ψ_3	monetary policy, Δe	Gamma	0.1	0.05
ρ_r	interest smoothing	Beta	0.7	0.2
σ_{aH}	traded productivity shock	Inv-Gamma	1.25	0.66
σ_{aN}	non-traded productivity shock	Inv-Gamma	1.25	0.66
σ_g	Fiscal shock	Inv-Gamma	1.25	0.66
σ_{uip}	UIP shock	Inv-Gamma	1.25	0.66
σ_s	TOT shock	Inv-Gamma	1.25	0.66
σ_r	Monetary policy shock	Inv-Gamma	1.25	0.66
σ_{y^*}	Foreign output shock	Inv-Gamma	1.25	0.66
σ_{π^*}	Foreign inflation shock	Inv-Gamma	1.25	0.66
σ_{r^*}	Foreign monetary policy shock	Inv-Gamma	1.25	0.66
Fixed parameters				
β	Discount factor	0.99		
η	Intrat. elast. subst.	1		
ν	Intert. elast. subst.	1		
α	Import share	0.3		
λ	Share non-traded goods	0.4		

Table 7
Estimation results

Parameters	Posterior mean	90% probability interval	
θ_H	0.816	[0.772,	0.861]
θ_N	0.880	[0.855,	0.903]
p	0.070	[0.016,	0.126]
h	0.946	[0.912,	0.982]
σ	1.134	[0.392,	1.796]
ψ	1.192	[0.729,	1.629]
ρ_{aH}	0.676	[0.563,	0.790]
ρ_{aN}	0.788	[0.709,	0.870]
ρ_g	0.922	[0.869,	0.974]
ρ_r	0.364	[0.290,	0.432]
ρ_{r^*}	0.699	[0.644,	0.757]
ρ_{y^*}	0.859	[0.771,	0.947]
ρ_{π^*}	0.382	[0.174,	0.595]
ψ_1	1.721	[1.213,	2.262]
ψ_2	0.360	[0.088,	0.643]
ψ_3	0.132	[0.033,	0.229]
Log. data density $= -1298.295$			

B.5 Prior and posteriors

Figure 5
Priors and posteriors

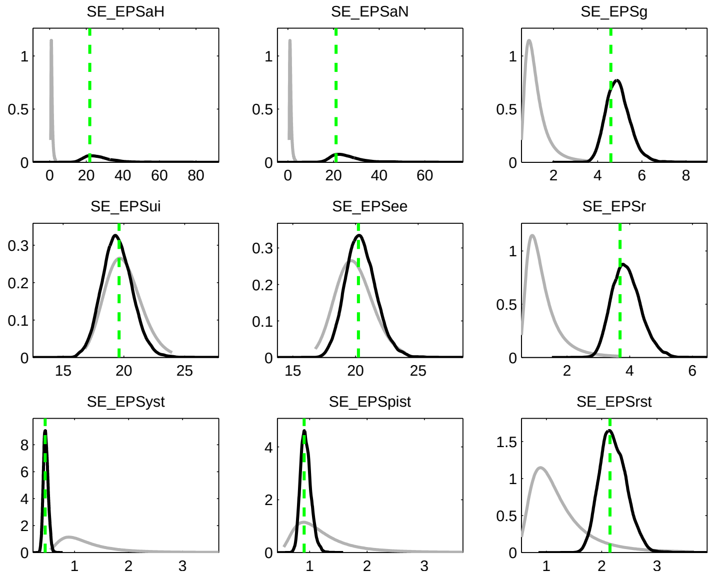


Figure 6
Priors and posteriors

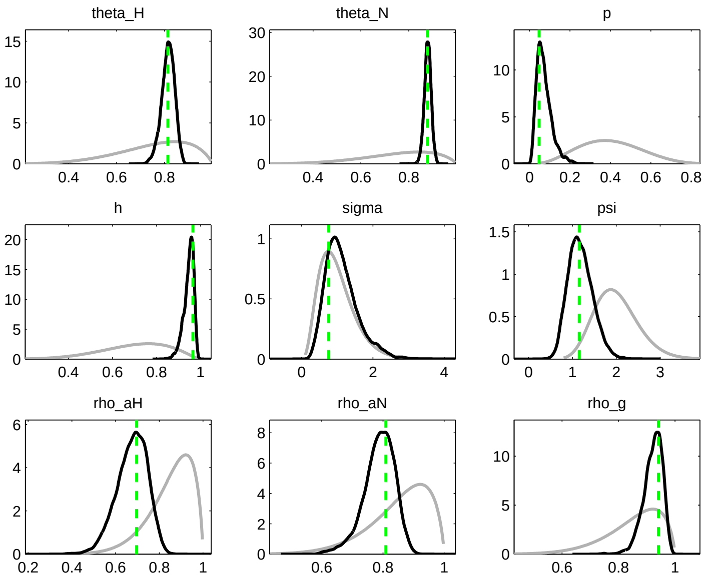
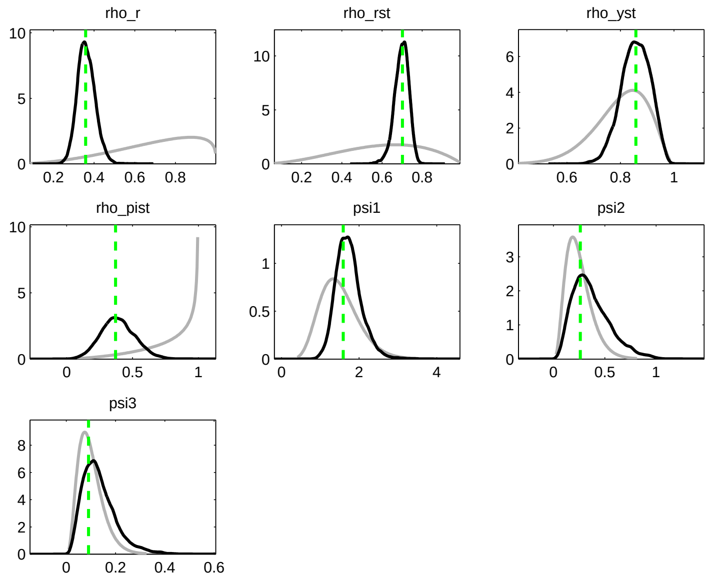


Figure 7
Priors and posteriors



B.6 Bayesian impulse response functions

Figure 8
Traded sector productivity shock

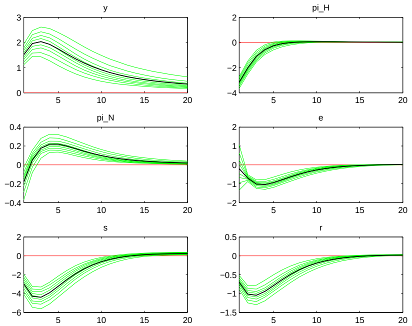


Figure 9
Non-traded sector productivity shock

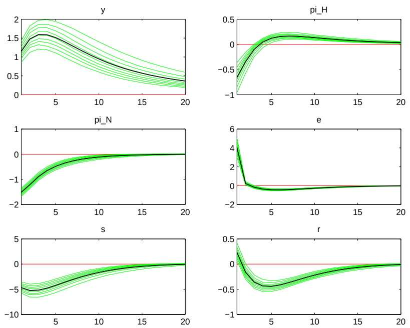


Figure 10
Domestic fiscal shock

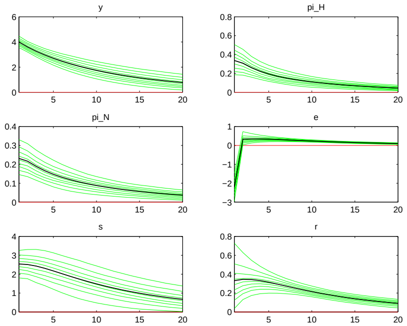


Figure 11
Terms of trade shock

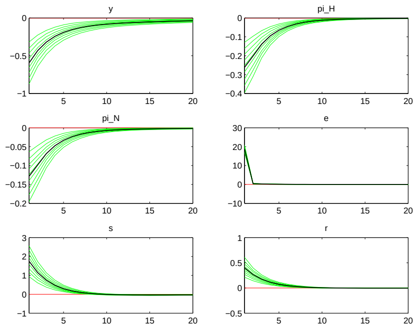


Figure 12
Domestic monetary policy shock

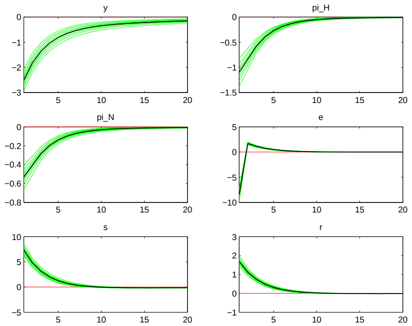


Figure 13
Foreign output shock

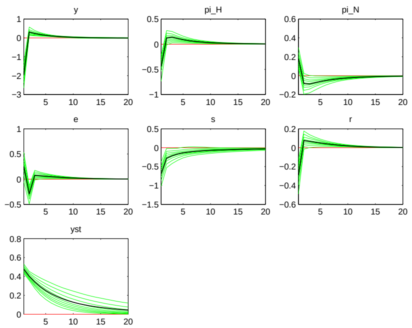


Figure 14
Foreign inflation shock

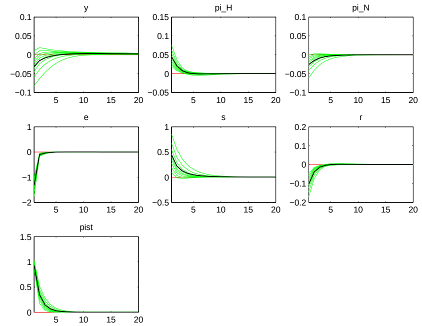


Figure 15
Foreign monetary policy shock