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Abstract

This paper investigates the impact of exchange rate movements on the conduct of monetary policy in Australia, Canada, New Zealand and the United Kingdom. We develop and estimate a structural general equilibrium two-sector model with sticky prices and wages and limited exchange rate pass-through. Different specifications for the monetary policy rule and the real exchange rate process are examined. The results indicate that the Reserve Bank of Australia, the Bank of Canada and the Bank of England paid close attention to real exchange rate movements, whereas the Reserve Bank of New Zealand did not seem to incorporate exchange rate movements explicitly into their policy rule. With a higher degree of intrinsic inflation persistence, the central bank of New Zealand seems less concerned about future inflation pressure induced by current exchange rate movements. In addition, the structure of the shocks driving inflation and output variations in New Zealand is such that it may be sufficient for the Reserve Bank of New Zealand to only respond to exchange rate movements indirectly through stabilizing inflation and output.

JEL classification: F3, F4
Bank classification: Exchange rates; Monetary policy framework; International topics

Résumé

L'auteure étudie l'incidence des mouvements du taux de change sur la conduite de la politique monétaire en Australie, au Canada, en Nouvelle-Zélande et au Royaume-Uni. Elle élabore et estime un modèle structurel d'équilibre général à deux secteurs dans lequel les prix et les salaires sont rigides et les variations du taux de change se répercutent de façon limitée. L'auteure examine différentes spécifications pour la règle de politique monétaire et l'équation de taux de change réel. Les résultats indiquent que la Banque de réserve d'Australie, la Banque du Canada et la Banque d'Angleterre prêtent une attention particulière aux mouvements du taux de change réel, alors que la Banque de réserve de Nouvelle-Zélande ne semble pas les prendre en compte de manière explicite dans sa règle de politique monétaire. Le degré de persistance intrinsèque de l'inflation étant plus élevé en Nouvelle-Zélande, la banque centrale de ce pays est apparemment moins préoccupée des pressions inflationnistes futures que pourraient induire les variations actuelles du taux de change. En outre, la structure des chocs qui déterminent les fluctuations de l'inflation et de la production en Nouvelle-Zélande est telle qu'il suffit peut-être à la banque centrale de réagir de façon indirecte aux mouvements de change en stabilisant l'inflation et la production.

Classification JEL : F3, F4
Classification de la Banque : Cadre de la politique monétaire; Questions internationales; Taux de change

1 Introduction

Taylor (2001) argues that a well-functioning monetary policy regime should be based on three elements: a flexible exchange rate, an inflation target and a monetary policy rule. This trinity, however, does not imply that movements in the exchange rate can be ignored by the central bank: exchange rate movements may cause relative prices to adjust, and therefore affect the demand for domestic goods. In addition, monetary policy is partly transmitted to the real economy through its effect on the exchange rate. The critical question is to what extent central banks take into account exchange rate movements explicitly in formulating monetary policy.

There are two strands of literature on this issue. The first strand examines whether central banks should respond to exchange rate movements. There is little consensus yet on this question. Ball (1999) argues that exchange rate movements affect domestic inflation through its effect on import prices, and thus central banks should optimally react to exchange rate movements. Likewise, Svensson (2000) argues that a flexible exchange rate permits the transmission of monetary policy through additional channels, and since the exchange rate is a forward-looking variable, it improves monetary policy by incorporating expectations of future variables. Conversely, some studies suggest that there should be no role for the exchange rate in the optimal monetary policy rule. In a theoretical model, Clarida, Gali and Gertler (2001) find that when there is complete exchange rate pass-through, central banks should target domestic inflation and ignore exchange rate movements. West (2004) suggests that exchange rate stabilization may aggravate instability elsewhere.

The second strand in the literature estimates policy reaction functions to study the actual role of exchange rates in the implementation of monetary policy. For developed economies, Clarida, Gali and Gertler (1998) show that the monetary authorities in some European countries and Japan responded to exchange rate misalignments. Along the same line, Calvo and Reinhart (2002) find that many emerging economies use interest rates as the means of smoothing exchange rate fluctuations. A free floating exchange rate increases foreign exchange volatility, which may cause problems for the banking system and induce balance-sheet effects. For this reason, countries may face "fear of floating". In this context, there is some controversy as to whether this response is optimal or not.

Rather than estimating monetary policy functions in a univariate setup as in the previous literature, Lubik and Schorfheide (2007) study the role of exchange rates in monetary policy rules by estimating a general equilibrium model, which allows for an endogenous transmission mechanism. They develop a small open economy model with four endogenous equations and five exogenous shocks, and are the first to apply Bayesian estimation method to address the issue of open-economy monetary policy rules. However, the real exchange rate in their model is assumed to be exogenously specified following an autoregressive process. This is because if the terms of trade are specified endogenously, the estimation of the fully structural model is problematic. Moreover, complete pass-through of exchange rates is assumed, which leaves out a significant part of the story. With limited endogenous transmission, it might be difficult to offer structural interpretations for the empirical results. And to be able to exploit cross-equation restrictions and the links of the monetary policy rule with the rest of the economy, these are essential.

In this paper, we build upon Lubik and Schorfheide (2007) and adopt a multivariate approach of estimating a dynamic stochastic general equilibrium model to examine the role of exchange rates in monetary policy rules. We develop a small open economy two-sector model with several frictions that generate limited exchange rate pass-through in the short run. In particular, we assume that prices and wages are sticky following Calvo (1983), with partial indexation of prices and wages on lagged inflation. The non-tradable sector produces goods for consumption and investment, and provides distribution services to facilitate the sale of foreign-produced imports. Also, we allow for a data-determined combination of producer currency pricing (PCP) and local currency pricing (LCP) firms in the tradable sector. The currency of invoicing has an impact on the magnitude of the pass-through effect, which may affect the desired exchange rate volatility. Our model is estimated using the Bayesian method for different specifications of the monetary policy rule for four countries: Australia, Canada, New Zealand and the United Kingdom.

One of the findings of this paper is that the endogenous real exchange rate specification leads to much higher marginal likelihood values for all four countries than the exogenous real exchange rate specification. The estimation results suggest that for the Reserve Bank of Australia, the Bank of Canada and the Bank of England, the monetary policy rule incorporated an interest rate reaction to real exchange rate movements, whereas the Reserve Bank of New Zealand did not seem to explicitly include exchange rate movements in their policy rule, though the indirect effect of exchange rates on interest rates exists.

Our empirical results suggest the following explanations for why New Zealand is different. First, it may be related to the structure of shocks in accounting for inflation and output variations. Particularly, for New Zealand, the technology shock in the non-tradable sector does not play a significant role for inflation variation, and the risk premium shock is unimportant in explaining the forecast error variances of output. This differs from our results for Australia, Canada and the United Kingdom. The nature of the shocks and their implications for monetary policy suggest that it may not be sufficient for the central banks of Australia, Canada and the UK to respond to real exchange rate variation only indirectly through targeting inflation rate and stabilizing output levels. Second, the degree of partial price indexation is estimated to be much larger for New Zealand, which suggests that current inflation depends more on past inflation and less on expected future inflation. Therefore, when the Reserve Bank of New Zealand responds to current inflation, it is less concerned about future inflation pressure caused by real exchange rate movements. We assess the robustness of the benchmark results to alternative sample lengths and other specifications of the monetary policy rule. The main results remain largely unchanged.

The remainder of this paper is organized as follows. Section 2 presents the theoretical model. Section 3 describes the data and the empirical methodology to be employed. Section 4 states the main empirical results. Section 5 reports findings from robustness analysis. Finally, Section 6 concludes.

2 The Model

The model in this paper is of a small open economy, in which the foreign output, prices and interest rate are taken as exogenous. There are two sectors in the domestic economy: tradable and non-tradable. Domestic intermediate good and non-tradable good producers use capital and labor as inputs for production. Non-tradable distribution services are needed to bring foreign-produced intermediate inputs to the domestic market. Competitive final good producers use composites of both domestic- and foreign-produced differentiated intermediate goods to produce final goods for consumption and investment. Several frictions are introduced, including Calvo-type sticky prices and wages with partial indexation on lagged inflation, a combination of both PCP and LCP firms, cost of adjustment in capital accumulation, and consumption habit formation. The structure of the model is similar to Dong (2007), and shares its basic features with many recent dynamic general equilibrium models, including Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2003). We refer to Dong (2007) for more details of the model. In what follows, we simply discuss the solutions of the model.

2.1 Households

The estimation is based on the first order conditions characterizing households' utility and firms' profit maximization problems. Households derive utility from the consumption of tradable and non-tradable goods, as well as leisure. The optimal consumption path is given by:

$$\frac{(C_t - hC_{t-1})^{-\rho}}{R_t} = \beta E_t \frac{(C_{t+1} - hC_t)^{-\rho}}{\pi_{t+1}} \tag{2.1}$$

$$C_{T,t} = \alpha_T \left(\frac{P_{T,t}}{P_t}\right)^{-\varsigma} C_t \tag{2.2}$$

$$C_{N,t} = (1-\alpha_T) \left(\frac{P_{N,t}}{P_t}\right)^{-\varsigma} C_t. \tag{2.3}$$

Here, π_t is the gross consumption inflation rate, R_t is the domestic interest rate, $C_{T,t}$ and $C_{N,t}$ denote the aggregate consumption of tradable and non-tradable goods, and $P_{T,t}$ and $P_{N,t}$ represent the corresponding prices. ρ is the coefficient of relative risk aversion of households, β is the subjective discount factor, h is the habit formation coefficient, and ς is the elasticity of substitution between tradable and non-tradable consumption goods.

Households provide labor services, $L_{N,t}$, to non-tradable good producers, and $L_{T,t}$ to intermediate tradable good producers, at the wage rate W_t^i. They also own capital and rent it to producers at the rates $r_{T,t}^k$ and $r_{N,t}^k$, for tradable sector and non-tradable sectors, respectively. Optimal wage setting and capital accumulation implies that the following conditions hold:

$$W_t = \left\{ \psi_w \left[W_{t-1} \left(\frac{P_{t-1}}{P_{t-2}}\right)^{\tau_w} \right]^{1-\gamma} + (1-\psi_w)\varpi_t^{1-\gamma} \right\}^{\frac{1}{1-\gamma}} \tag{2.4}$$

$$\left[\frac{\chi(K_{T,t}-K_{T,t-1})}{K_{T,t-1}}+1\right]=\Lambda_{t,t+1}\left[\frac{\chi(K_{T,t+1}^2-K_{T,t}^2)}{2K_{T,t}^2}+1-\delta+r_{T,t+1}^k\right] \tag{2.5}$$

$$\left[\frac{\chi(K_{N,t}-K_{N,t-1})}{K_{N,t-1}}+1\right]=\Lambda_{t,t+1}\left[\frac{\chi(K_{N,t+1}^2-K_{N,t}^2)}{2K_{N,t}^2}+1-\delta+r_{N,t+1}^k\right] \tag{2.6}$$

$$\Lambda_{t,t+1}\equiv\frac{\beta E_t(C_{t+1}-hC_t)^{-\rho}}{(C_t-hC_{t-1})^{-\rho}}, \tag{2.7}$$

where ψ_w captures the extent of wage stickiness, τ_w is the degree of wage indexation, γ is the elasticity of substitution among different types of labor services, and ϖ_t^i is the optimal wage rate for labor service of type i at time t if household i is randomly selected to re-optimize in that period. Finally, δ is the depreciation rate and χ represents size of adjustment cost.

Households can hold the domestic currency bond B_t, and the foreign currency bond B_t^*. The foreign interest rate R_t^* is assumed to be exogenously given, and subject to a debt-elastic interest rate premium rp_t:[1]

$$rp_t=\exp\left[-\varphi_n\xi_t-\varphi_s\left(\frac{E_tS_{t+1}}{S_{t-1}}-1\right)+\hat{\varphi}_t\right]$$

$$\xi_t\equiv S_tB_t^*/P_tY_t,$$

where S_t is the nominal exchange rate, defined as the price of foreign currency in terms of domestic currency, and $\hat{\varphi}_t$ represents the risk premium shock, which is assumed to follow a first order autoregressive process. We assume the risk premium depends on not only the country's net foreign debt but also the expected change in the exchange rate E_tS_{t+1}/S_{t-1}, as in Adolfson et al. (2007), based on the observation of the forward premium puzzle.[2] A modified UIP condition can be derived from the model as:

$$\frac{R_t}{R_t^*rp_t}=E_t\frac{S_{t+1}}{S_t}. \tag{2.8}$$

Or, alternatively, we can simply assume that the real exchange rate follows an exogenous autoregressive process as in Lubik and Schorfheide (2007). We test the endogenous versus exogenous specifications of real exchange rates with the structural estimation.

2.2 Tradable Sector

Final goods are produced as CES aggregates of domestic intermediate inputs and imports. The demand for each type of intermediate goods thus depends on their relative prices and the elasticity of

[1] It is used as a stationarity-inducing technique to ensure the existence of a unique steady state for the small open economy. For other ways of inducing stationarity of the equilibrium dynamics for small open economy models, see Schmitt-Grohé and Uribe (2003).

[2] Adolfson et al. (2007) show that a small open economy model with a modified specification of the risk premium better matches the observed properties of Swedish data.

substitution between them — σ.

$$Y_{H,t} = \alpha_H \left(\frac{P_{H,t}}{P_{T,t}}\right)^{-\sigma} Y_{T,t} \tag{2.9}$$

$$Y_{F,t} = (1-\alpha_H) \left(\frac{P_{F,t}}{P_{T,t}}\right)^{-\sigma} Y_{T,t}. \tag{2.10}$$

Intermediate tradable good producers use capital and labor as inputs, and act as monopolistic competitors for price setting. In this paper, I assume that a proportion ϕ of intermediate firms use LCP for their export pricing, while $(1-\phi)$ use PCP, where ϕ is a structural parameter to be estimated later. Since the fraction of firms employing LCP versus PCP will have an impact on the pass-through effect of exchange rates to domestic prices, central banks may frame their policy in a way to take this into account. Let $X_{H,t}(s)$ denote the optimal price set for the home market, and $X^l_{H,t}(s)$, $X^p_{H,t}(s)$ denote the prices set for the foreign market respectively by an LCP firm and a PCP firm. The first order conditions suggest that:

$$\begin{aligned}
X_{H,t}(s) &= \frac{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} \varepsilon P^{\varepsilon}_{ht+j} Y_{ht+j} MC_{T,t+j} (P_{t+j-1}/P_{t-1})^{-\tau_d \varepsilon}}{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} (\varepsilon-1) P^{\varepsilon}_{ht+j} Y_{ht+j} (P_{t+j-1}/P_{t-1})^{-\tau_d(\varepsilon-1)}} \\
X^p_{H,t}(s) &= \frac{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} \varepsilon (P^*_{ht+j} S_{t+j})^{\varepsilon} Y^*_{ht+j} MC_{T,t+j} (P_{t+j-1}/P_{t-1})^{-\tau_d \varepsilon}}{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} (\varepsilon-1) (P^*_{ht+j} S_{t+j})^{\varepsilon} Y^*_{ht+j} (P_{t+j-1}/P_{t-1})^{-\tau_d(\varepsilon-1)}} \\
X^l_{H,t}(s) &= \frac{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} \varepsilon (P^*_{ht+j})^{\varepsilon} Y^*_{ht+j} MC_{T,t+j} (P^*_{t+j-1}/P^*_{t-1})^{-\tau_d \varepsilon}}{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} (\varepsilon-1) (P^*_{ht+j})^{\varepsilon} Y^*_{ht+j} S_{t+j} (P^*_{t+j-1}/P^*_{t-1})^{-\tau_d(\varepsilon-1)}}.
\end{aligned}$$

where the marginal cost $MC_{T,t+j}$ and the stochastic discount factor $\Gamma_{t,t+j}$ are given by:

$$\begin{aligned}
MC_{T,t+j} &= \frac{(1-\eta)^{\eta-1} (r^k_{T,t+j} P_{T,t+j})^{\eta}}{\eta^{\eta} W^{\eta-1}_{t+j} A_{T,t+j}} \\
\Gamma_{t,t+j} &= \beta^j \frac{U_{c,t+j}/P_{t+j}}{U_{c,t}/P_t}.
\end{aligned}$$

The price index for intermediate goods sold domestically, $P_{H,t}$, and the export price index, $P^*_{H,t}$, can then be expressed as:

$$P_{H,t} = \left\{ \psi_d \left[P_{H,t-1} \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\tau_d} \right]^{1-\varepsilon} + (1-\psi_d) X^{1-\varepsilon}_{H,t} \right\}^{\frac{1}{1-\varepsilon}} \tag{2.11}$$

$$P^*_{H,t} = \left\{ \psi_d \left[P^*_{H,t-1} \left(\frac{P^*_{t-1}}{P^*_{t-2}} \right)^{\tau_d} \right]^{1-\varepsilon} + (1-\psi_d) \left[\phi (X^l_{H,t})^{1-\varepsilon} + (1-\phi) \left(\frac{X^p_{H,t}}{S_t} \right)^{1-\varepsilon} \right] \right\}^{\frac{1}{1-\varepsilon}}. \tag{2.12}$$

where ε represents the elasticity of substitution among varieties produced within one country. The foreign demand for exports from the small open economy is assumed to be exogenously given by:

$$Y^*_{H,t} = \alpha_f \left(\frac{P^*_{H,t}}{P^*_t}\right)^{-\sigma_f} Y^*_t. \tag{2.13}$$

2.3 Non-tradable Sector

Similarly, non-tradable goods are also produced with capital and labor. Non-tradable goods are used for consumption, investment, and distribution services to import foreign-produced intermediate goods. The price index for non-tradable goods is given by:

$$P_{N,t} = \left\{\psi_d \left[P_{N,t-1}\left(\frac{P_{t-1}}{P_{t-2}}\right)^{\tau_d}\right]^{1-\nu} + (1-\psi_d)X^{1-\nu}_{N,t}\right\}^{\frac{1}{1-\nu}}. \tag{2.14}$$

As in Burstein, Neves and Rebelo (2003), we assume that to bring one unit of the tradable intermediate good to the domestic market, λ units of a basket of the differentiated non-tradable goods are needed. Thus, the price index for foreign-produced intermediate goods in the home market, $P_{F,t}$, and the trade balance value are given by:

$$P_{F,t}(s) = S_t P^*_t(s) + \lambda P_{N,t} \tag{2.15}$$

$$TB_t = P_{F,t}Y_{F,t} - S_t P^*_{H,t} Y^*_{H,t}. \tag{2.16}$$

2.4 Government and Monetary Authority

The government balances its budget. Aggregate government spending is assumed to be an exogenous process, with the shares on tradables and non-tradables depending on their relative prices.

$$P_t G_t + P_t \tau_t + B_{t-1} = \frac{B_t}{R_t}$$

$$G_{T,t} = \alpha_T \left(\frac{P_{T,t}}{P_t}\right)^{-\varsigma} G_t$$

$$G_{N,t} = (1-\alpha_T)\left(\frac{P_{N,t}}{P_t}\right)^{-\varsigma} G_t.$$

The monetary policy reaction function is described as a Taylor (1993) rule. Central banks take the domestic interest rate as the policy instrument to respond to the inflation rate and the output gap.

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_\pi \ln(\pi_t/\pi) + \alpha_y \ln(Y_t/Y)] + \epsilon_{rt}, \tag{i}$$

where ρ_r is a parameter capturing interest-rate smoothing, and ϵ_{rt} is a temporary monetary policy shock.[3]

[3] An alternative specification of the monetary policy reaction function is the inflation forecast-based rule, where the monetary authority adjusts the short-term interest rate based on the difference between expected inflation in the future

We are interested in investigating the role of exchange rates in the monetary policy rule, so we test the hypothesis of rule (i), in which central banks do not respond directly to exchange rate movements, against the following possible rules:

Nominal Exchange Rate Smoothing:

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_\pi \ln(\pi_t/\pi) + \alpha_y \ln(Y_t/Y) + \alpha_x \ln(S_t/S_{t-1})] + \epsilon_{rt} \quad \text{(ii)}$$

Real Exchange Rate Smoothing:

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_\pi \ln(\pi_t/\pi) + \alpha_y \ln(Y_t/Y) + \alpha_x \ln(q_t/q_{t-1})] + \epsilon_{rt} \quad \text{(iii)}$$

Risk Premium Smoothing:

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_\pi \ln(\pi_t/\pi) + \alpha_y \ln(Y_t/Y) + \alpha_x \ln(rp_t/rp_{t-1})] + \epsilon_{rt}. \quad \text{(iv)}$$

In rule (ii), in addition to reacting to the inflation and output gap, central banks also include nominal exchange rate movements in the policy rule, in order to reduce nominal exchange rate volatility. In rule (iii), central banks respond to *real* exchange rate movements, instead of *nominal* exchange rate movements. Considering that all four countries examined in this paper are fairly open economies, the central bank may want to respond to real exchange rate movements in order to smooth international relative price fluctuations that could affect their international competitiveness and have an effect on aggregate demand for domestic goods. Finally, in rule (iv), in order to maintain financial stability, central banks can react to risk premium shifts that reflect changes in the expectations of risks in financial markets. We test each of these monetary policy rules within the structural framework by estimating variants of the base model and evaluating the marginal likelihood values and posterior odds.

The model is analyzed in the log-linearized form around a non-stochastic steady state, which yields a system of equations that are linear in log deviations and can be solved using standard methods. The log-linearized equations are described in Appendix A.[4] The debt-elastic risk premium assumption ensures that the model has a steady state. The stochastic behavior of this model is driven by eight exogenous shocks, and they are assumed to evolve according to AR(1) processes. For the small open economy, all foreign variables are taken as exogenously determined:

and the inflation target, and the output gap. These types of rules are often used in central banks' projection models. The major critique of the Taylor rule is that it is not forward-looking. Nevertheless, the Taylor rule concisely captures some of the key judgements that policymakers must confront, its performance is robust across various economic models, and it generally fits the data remarkably well. In addition, in the policy making process, central banks usually do not strictly adhere to the suggested interest rate setting derived from projection models and may deviate from it temporarily if they judge it necessary (Blinder, 1998). Thus the ex post interest rate path may be represented differently. In any case, we check the robustness of the empirical findings to the alternative specification of expected inflation targeting in Section 5.

[4] In this model, real variables are assumed to be stationary. The following transformations of variables are used to achieve stationarity: $p_{T,t} = \frac{P_{T,t}}{P_t}$, $p_{N,t} = \frac{P_{N,t}}{P_t}$, $p_{H,t} = \frac{P_{H,t}}{P_t}$, $p_{F,t} = \frac{P_{F,t}}{P_t}$, $p^*_{H,t} = \frac{P^*_{H,t}}{P^*_t}$, $x_{H,t} = \frac{X_{H,t}}{P_t}$, $x^p_{H,t} = \frac{X^p_{H,t}}{P_t}$, $x^l_{H,t} = \frac{X^l_{H,t}}{P^*_t}$, $x_{N,t} = \frac{X_{N,t}}{P_t}$, $w_t = \frac{W_t}{P_t}$, $\omega_t = \frac{\varpi_t}{P_t}$, $q_t = \frac{S_t P^*_t}{P_t}$, $\pi_t = \frac{P_t}{P_{t-1}}$, $\pi^*_t = \frac{P^*_t}{P^*_{t-1}}$, $b^*_t = \frac{B^*_t}{P^*_t}$.

$$\ln R_t^* = (1 - \rho_{R^*}) \ln R^* + \rho_{R^*} \ln R_{t-1}^* + \epsilon_{R^*t}$$

$$\ln A_{T,t} = (1 - \rho_{AT}) \ln A_T + \rho_{AT} \ln A_{T,t-1} + \epsilon_{ATt}$$

$$\ln A_{N,t} = (1 - \rho_{AN}) \ln A_N + \rho_{AN} \ln A_{N,t-1} + \epsilon_{ANt}$$

$$\ln Y_t^* = (1 - \rho_{y^*}) \ln Y^* + \rho_{y^*} \ln Y_{t-1}^* + \epsilon_{y^*t}$$

$$\ln P_t^* = \phi^*(\ln(P_{l,t}^*/S_t)) + (1 - \phi^*) \ln P_{p,t}^*$$

$$\ln(P_{l,t}^*/P_{l,t-1}^*) = (1 - \rho_{p^*}) \ln(\pi_l^*) + \rho_{p^*} \ln(P_{l,t-1}^*/P_{l,t-2}^*) + \epsilon_{p^*t}$$

$$\ln(P_{p,t}^*/P_{p,t-1}^*) = \ln(P_{l,t}^*/P_{l,t-1}^*)$$

$$\ln G_t = (1 - \rho_g) \ln G + \rho_g \ln G_{t-1} + \epsilon_{gt}$$

$$\ln \hat{\varphi}_t = (1 - \rho_\varphi) \ln \hat{\varphi} + \rho_\varphi \ln \hat{\varphi}_{t-1} + \epsilon_{\varphi t}.$$

3 Empirical Approach

3.1 Data

The structural model is estimated using the Bayesian method. We use data on the following macroeconomic series for the estimation: the real wage rate, output, real exchange rate, short term interest rate, and the trade balance value over steady state exports.[5] These variables help to capture the roles of the exchange rate, trade, technology, prices and interest rate, as well as the explanatory factors arising outside of the small open economy. The foreign variables for the domestic small open economy are constructed as geometric weighted averages of the G-7 countries, excluding the domestic country under consideration. The time-varying weights are based on each country's share of total real GDP.[6]

The model is taken to the data for four countries: Australia, Canada, New Zealand and the United Kingdom. The data are seasonally adjusted quarterly series, and are HP filtered. The period covered for our estimation is different across countries due to their specific histories. For Australia, our dataset starts at 1984:1. This point is chosen because the Australian dollar was floated in December 1983, most exchange controls were abolished then, and financial system deregulation took place. Our dataset for Canada covers the period 1970:1 to 2006:4, in light of its floating exchange rate since 1970. The starting point for New Zealand is 1985:2, when the fixed exchange rate with respect to a trade-weighted basket of currencies was abolished. Major financial sector policy reforms were also carried out in 1984. The case of the United Kingdom is more complicated due to the UK's membership in the Exchange Rate Mechanism (ERM) of the European Monetary System between 1990 and 1992. The United Kingdom

[5] Note that the information on prices has been captured in the real wage series.

[6] In addition, data on government consumption, foreign output, and foreign interest rates are collected and constructed to pre-estimate the observable exogenous processes for G_t, R_t^* and Y_t^*.

finally left the ERM in 1992, which could be an appropriate starting point. However, the dataset might be too short to deliver reliable estimation results. So in the benchmark case, we select 1979:3 as the starting point, when an anti-inflation policy was in place. For the sensitivity analysis, we re-estimate the model for the UK over 1992:4 to 2006:4 to see if the results are robust to the choice of sample period.

3.2 Bayesian Method

We estimate the structural model using Bayesian technique. The advantage of the system-based approach is that it provides a consistent way to update researchers' beliefs about parameter values based on the data that are actually observed. Priors on the parameters are assigned, based on results from past studies and information outside the data set, to measure the *ex ante* plausibility of parameter values. The time series are then brought in to revise the parameter values, based on information from the data series, to get posterior estimates.[7] The Bayesian approach also provides a framework to compare and choose models on the basis of the marginal likelihood values. The marginal likelihood of a model M is defined as:

$$L = \int_\theta p(\theta|M)p(Y|\theta, M)d\theta,$$

where θ represents the parameter vector and Y denotes the observable data series. $p(\theta|M)$ is the prior density of the parameters, and $p(Y|\theta, M)$ is the likelihood function. The marginal density indicates the likelihood of the model given the data. As a Bayesian alternative to hypothesis testing, the Bayes factor between model i and j can be computed as:

$$B_{i,j} = \frac{L_i}{L_j}.$$

Let p_i denote the prior probability assigned to model i, the posterior probability that model i is likely is then given by:

$$pp_i = \frac{p_i L_i}{\Sigma_j p_j L_j}.$$

The posterior odds is defined as the ratio of the posterior probability that model i is plausible over the probability that it is not:

$$PO_i = \frac{pp_i}{1 - pp_i}.$$

The Bayes factor and the posterior odds are used to compare models in this paper, in order to test which specification is more plausible in terms of the central banks' response to exchange rate movements.

[7]The model is estimated using a numerical optimization procedure provided by Dynare. Dynare is a collection of MATLAB routines which study the transitory dynamics of non-linear models. More information can be found at: *http://www.cepremap.cnrs.fr/dynare/*.

Probability statements about the parameters are made before observing the data. Since the estimation algorithm is computationally very intensive, some parameters are fixed by calibration. The subjective discount factor β is given a standard value of 0.99 for quarterly data. The relative risk aversion parameter ρ is set to 4, and is consistent with the estimation results of Ambler, Dib and Rebei (2003) based on Canadian data. The inverse of labor supply elasticity μ is set equal to 2. The weight of tradable goods in the consumption basket, α_T, takes a value of 0.5. The elasticity of substitution between tradables and non-tradables — ς, is given a value of 0.6, which is selected based on the available estimates.[8] The elasticity of substitution among different types of labor services γ is assumed to be 6, consistent with micro estimates. The quarterly capital depreciation rate, δ, is set to 0.025.

For Canada, the share of capital in tradable good production, η, is set to 0.37, and the share of capital in non-tradable good production, θ, is set to 0.28. These calibrated values are based on the estimation results of a two-sector small open economy model for Canada by Ortega and Rebei (2006). For Australia, New Zealand and the United Kingdom, the corresponding capital shares are set to $\eta = 0.36$, $\theta = 0.32$. The average fraction of labor effort in the tradable good sector, L_T/L, is inferred from the data on the distribution of civilian employment by economic sector for several industrialized countries.[9] A simple approximation of the service sector to represent the non-tradable sector is used. The fraction L_T/L is on average approximately 0.27 for Australia, 0.29 for Canada, 0.30 for New Zealand and 0.31 for the United Kingdom, during their respective estimation periods.

The priors for the structural parameters to be estimated are displayed along with the posterior results. There are 25 parameters to be estimated, including parameters capturing the degree of price stickiness and partial indexation, proportions of PCP versus LCP firms, elasticities of substitution and monetary policy rule coefficients. For most of them, priors with wide standard deviations are used, with means centered at values commonly regarded as reasonable. With respect to the priors for the fraction of firms employing LCP versus PCP for their exports, inferences are drawn from *International Merchandise Trade: Featured Article* published by the Australian Bureau of Statistics, survey results for Canada from Murray, Powell, and Lafleur (2003), as well as publications by the ECU Institute.[10] Based on these, the prior means for ϕ and ϕ^* are set at 0.73 and 0.31 for Australia, 0.76 and 0.3 for Canada, 0.7 and 0.3 for New Zealand, and respectively 0.3, 0.4 for the UK.[11]

[8] Stockman and Tesar (1995) estimate the elasticity to be 0.44 for an "average" industrialized country out of the G7 countries. Mendoza (1991) estimates it to be 0.74.

[9] The time series data covering 1960-2006 is from the *Bureau of Labor Statistics* website.

[10] On average, the Australian dollar accounted for 27% of exports and 31% of imports from March quarter 2002 to March quarter 2003. The survey results conducted by the Bank of Canada in 2002 show that 24% of Canadian firms quote export prices in Canadian dollars. The ECU institute reports that the percentages of exports and imports denominated in home currency for the UK during the year of 1992 are 62% and 43%.

[11] Recent studies have debated whether exchange rate pass-through into import prices may have declined in recent years in industrialized countries. The evidences are still mixed so far: Marazzi and Sheets (2007) document a sustained decline in exchange rate pass-through to US import prices; Campa and Goldberg (2005), on the other hand, find that pass-through declines were statistically significant only in 4 of the the 23 OECD countries they study and the United States is not one of the four. Over time, the proportion of exports and imports invoiced in the domestic currency may change slightly. However, as the International Merchandise trade article pointed out, in Australia's case, this was largely caused by changes in exports or imports of a small number of commodities invoiced mainly in Australian dollars. In other words, the modest movements of the invoice currency fractions are due to adjustments in export or import structure, rather than the invoice currency switching by firms. Overall, it seems reasonable to assume that the fractions ϕ and ϕ^* of firms adopting LCP are approximately constant.

Priors on the policy coefficients are chosen to match values generally associated with the Taylor rule. The prior mean for the coefficient on the lagged interest rate term ρ_r is set at 0.8, with a standard deviation of 0.1. The coefficient on the inflation rate α_π is given a prior mean of 1.6. The prior mean for the coefficient on the output gap is set at 0.5. A large standard deviation of 0.2 is given, since the empirical evidence on the value of this parameter is diverse. With respect to the coefficient on exchange rates or risk premium movements, whenever it is applicable, a prior mean of 0.25 is specified. For the parameters of the shocks, little guidance is provided by the literature, so loose priors, which are not very informative, are specified.

4 Empirical Results

In this section, we report the empirical results of our estimation. Specifically, we fit various versions of the structural model to the data and assess their empirical performance. We then compare the implied marginal densities and discuss the parameter estimates. Finally, we present the impulse response and variance decomposition results.

4.1 Model Assessment

We estimate the model under different exchange rate and monetary policy reaction function specifications. To assess the conformity of the model to the data, unconditional second moments are computed and reported in Table 1-4 for the four countries in the benchmark case.[12] The first block reports the statistics of the data, and the second block presents the corresponding estimates implied by the model, which are computed from 1,000 random draws in the posterior distributions of the structural parameters. The median from the simulated distribution of moments are reported, together with the 10th and 90th percentiles.

As shown in the tables, in all cases, we see that the standard deviations and autocorrelations of the observable series are very well matched with their counterparts derived from simulations of the model. The data moments fall within the corresponding model confidence intervals. In particular, for all countries, the persistence and excess volatility of real exchange rates and trade balances are well captured by the simulated model. The model also provides generally good characterizations of the cross correlation properties. In most cases, the data values lie within the error bands implied by the model. The confidence intervals, however, are usually large, which implies that there is a large degree of uncertainty about the model-based correlations. Overall, the model does a reasonably good job of matching properties of the data, though there certainly may be room for improvement in the future.

[12] The benchmark model is the one where the real exchange rate is assumed to be endogenously determined and the central bank includes real exchange rate movements in the monetary policy rule, in addition to inflation and output gap.

4.2 Marginal Likelihood Values

The estimation results for the benchmark case are reported in Table 5-8 for Australia, Canada, New Zealand and the United Kingdom. The parameter estimates for the absence of exchange rate response case are also presented in Table 9 for New Zealand. For the sake of brevity, the parameter estimation results for other cases are not reported, but the log marginal likelihood values are shown in Table 10. As can be seen from this table, the endogenous real exchange rate specification generally leads to much larger marginal likelihood values than the exogenous real exchange rate specification.[13] Since Lubik and Schorfheide (2007) assume the real exchange rate to be exogenously given, their results could potentially be biased.

Given that the endogenous q_t specification leads to much higher marginal likelihood values, we now turn to the comparison of different forms of monetary policy rules with the real exchange rate determined endogenously. We consider the four alternative monetary policy rules (i) – (iv) described in Section 2. The central bank can potentially respond to nominal exchange rates fluctuations, real exchange rates movements, or risk premium shifts, in addition to the inflation rate and output gap. We also estimate the model under the restriction $\alpha_x = 0$, in which case central banks are assumed not to respond to any exchange rate movement. The Bayes factors and posterior odds are computed and presented in Table 11.

For Australia, the log marginal data density associated with $\alpha_x = 0$ is larger than that of the central bank responding to Δs_t or Δrp_t case. But the marginal data density of the benchmark model is 8.3343 larger on a log-scale than the $\alpha_x = 0$ model.[14] The values of Bayes factor and posterior odds clearly show that the benchmark model is preferred when compared to the other models. This leads us to favor the view that the Reserve Bank of Australia explicitly responded to real exchange rate movements in the past two decades. For Canada, the marginal likelihood value of responding to Δs_t model is larger than that of the $\alpha_x = 0$ model. The log marginal density of the benchmark model, though, is still the largest among all of them, which seems to suggest that the Bank of Canada also paid close attention to real exchange rate movements. The Bayes factor is at most 0.0043 for the other models compared to the benchmark, and the posterior odds of the benchmark is around 231.56. The UK's case is similar to Australia's case. The log marginal likelihood of the benchmark model is 1.8899 larger on a log-scale than the absence of exchange rate response model. The benchmark model is preferred over other models. Our estimation results suggest that the Bank of England directly responded to real exchange rate movements over the sample period. The case for New Zealand, however, is different. The marginal data density is the largest for the absence of exchange rate response case. The Bayes factor

[13] It is worth noting that the numbers in Table 10 are log marginal likelihood values, so the difference between any two marginal likelihood values is actually in the scale of the log difference to the power of e.

[14] We note that there is generally considerable difference in the marginal likelihood values associated with the central banks reacting to real versus nominal exchange rate movements. This may seem puzzling at a first glance, since we know real exchange rates move closely with nominal exchange rates. However, the transmission mechanism between interest rates and *real* versus *nominal* exchange rates is different. For example, in the extreme case where prices are fully flexible, the nominal exchange rate appreciates or depreciates reacting to interest rate shifts. Nevertheless, the real exchange rate won't react, because prices adjust right away to offset whatever changes that might occur to the nominal exchange rate. Thus the monetary policy response to the *real* versus *nominal* exchange rate movements would be very different. Now that in the model, the prices are not fully flexible, yet not completely fixed either, we should still see the difference in the adjustment mechanism, only to a lesser degree.

for $\alpha_x = 0$ model is 8.4014 against the benchmark. The Reserve Bank of New Zealand did not seem to explicitly include exchange rate variation into their policy rule over the past twenty years.

Our result on New Zealand is consistent with Huang, Margaritis and Mayes' (2001) finding that what appears to be a closed economy policy rule closely describes the actions of the Reserve Bank of New Zealand for the period of 1989 to 1998. However, this should not be regarded as the Reserve Bank of New Zealand paid no attention to exchange rate movements. Rather as pointed out by Taylor (2001), although the monetary policy rule does not appear to involve an interest rate reaction to exchange rate movements, it implies such a reaction through inflation targeting and output stabilization.

4.3 Parameter Estimates

The posterior estimates are reported in Table 5-9. The first three columns in each table give an overview of the prior distributions specified for the parameters. The next two columns present the estimated posterior mode from directly maximizing the log of the posterior distributions, given the priors and the likelihood based on the data. We also report the corresponding standard errors computed from the inverse Hessian. The last three columns report the mean and the 90% confidence interval of the posterior distributions obtained by using the Monte Carlo Metropolis Hastings algorithm. It is subject to 1,000,000 draws, and the first 500,000 draws are dropped.

The Calvo stickiness parameters ψ_d for domestic producer prices and ψ_w for wage rates are estimated to be around 0.68 to 0.74 for all countries, which implies that, on average, prices and wages are reset approximately once every three to four quarters. These estimated lengths of price and wage contracts are in line with the macro literature. Lubik and Schorfheide (2006) report estimates of the price stickiness parameter ranging from 0.74 to 0.78 in their two-country structural model. Ambler, Dib, and Rebei (2003) estimate the Calvo adjustment parameter to be 0.68 for Canada. Microeconomic evidence, however, tends to suggest less sticky prices. For all countries, prices are estimated to be less sticky than wage rates.[15]

When firms and households are not allowed to adjust prices and wage rates, they index the current price levels by past inflation. The parameters τ_d and τ_w capture the degree of this indexation. In the benchmark case, they are estimated to be 0.27 and 0.33 for Australia , 0.28 and 0.24 for Canada, 0.25 and 0.15 for the UK. The corresponding estimates for New Zealand in the absence of exchange rate response case are 0.47 and 0.30. The standard errors associated with these estimates are in similar scale and in the neighborhood of 0.1. The estimated degree of price indexation for Australia, Canada and the UK is close to 0.25, which corresponds to the weight on the lagged inflation term to be about 0.2, and the weight on the expected future inflation term to be about 0.8 in the New Keynesian Phillips Curve. For New Zealand, however, the estimated degree of price indexation is 0.47, which implies a weight of 0.32 on the lagged inflation rate and 0.68 on the expected future inflation rate. In the model, central banks are assumed to respond directly to current inflation. The fact that the current inflation depends less on the expected future inflation in New Zealand may provide a case for the Reserve Bank of New

[15] As emphasized by Christiano, Eichenbaum and Evans (2005) , sticky wages play an important role in allowing the model to generate reasonable price stickiness.

Zealand to be less concerned about the future inflation pressure induced by exchange rate movements.[16]

The proportions of domestic and foreign firms using LCP to set export prices, ϕ and ϕ^*, are estimated to be 0.78 and 0.29 for Australia, 0.81 and 0.25 for Canada, 0.74 and 0.24 for New Zealand, and 0.34 and 0.24 for the United Kingdom. For the first three countries, LCP is dominant for its own exports, but PCP is dominant for other countries' exports to them. While for the UK, in either case, invoicing in the producers' currency is more frequent. The elasticity of substitution between domestic and foreign varieties in the domestic market and in the foreign market, σ and σ_f, are estimated to be around 1.4 to 2.0, which are in the upper half of the range of macro estimates. The distribution margin ϱ measures the fraction of the import price accounted for by distribution costs.[17] It is estimated to be 0.72 for Australia, 0.56 for Canada, 0.59 for New Zealand, and much larger at 0.82 for the UK. Berger et al. (2007) analyze retail prices and at-the-dock prices of specific items in the Bureau of Labor Statistics' CPI and IPP databases and find the overall distribution margin for the United States to be around 50% to 70%, which is much larger than people generally expected.

A slightly larger fraction of firms exporting to Australia, Canada or New Zealand price their products in the local market currency, compared to the UK. This may suggest a slightly larger expenditure-switching effect in the UK, when prices are sticky in the short run. However, as emphasized by Dong (2007), the higher ϱ is, the smaller the effect of exchange rate movements on the relative quantities. As distribution costs account for a very large share in import prices in the UK, expenditure switching over tradable goods would be much less significant. Krugman (1989) noted that exchange rate volatility might be emphasized, if the expenditure-switching effect is small. Based on this reasoning, if the expenditure-switching effect were taken into account, the Bank of England might benefit from higher exchange rate volatility. A welfare analysis can potentially provide a more thorough interpretation on this, but it is beyond the focus of this paper. Of the four countries examined, Canada and New Zealand are more open than Australia and the UK.[18] Not surprisingly, our results suggest that the degree of pass-through to consumption prices is larger for Canada and New Zealand than for the other two countries. In Canada and New Zealand, the nominal exchange rate might provide less additional information for monetary policy, since a certain part of the information is already contained in the domestic prices. The real exchange rate provides extra information on the foreign price level though.

Turning to the estimates of the coefficients in the monetary policy reaction functions, we find the interest rate to be quite persistent for all countries. All four countries respond quite aggressively to the output gap. For Australia, Canada and the United Kingdom, the estimated coefficients on real exchange rate movements are significantly different from zero. The estimates of the risk premium coefficients, the AR parameters and standard deviations for the unobserved shocks are also reported. It is worth noting that the estimated exogenous processes for these shocks differ significantly, though the same priors are given at the beginning.

[16] Robustness analysis is performed in Section 5 with respect to expected inflation targeting rules. For New Zealand, they lead to worse model fit than current inflation targeting rules in all cases.

[17] The distribution margin is defined as in: $\hat{p}_{F,t}$=(1-ϱ)$\hat{q}_t$+$\varrho\hat{p}_{N,t}$.

[18] The measure of openness data can be found at the *Penn World Table* database.

4.4 Impulse Responses

To further understand the dynamics of the model, impulse responses for Canada in the benchmark case are presented in Figure 1-2. In the figures, the impulse responses of four variables of interest to eight exogenous shocks are displayed. The four variables are output, the real exchange rate, inflation rate and interest rate. The impulse responses show the consequences of a one-unit increase in the exogenous shock for the value of variables. The responses are calculated from a random selection of 1,000 parameters out of the 500,000 draws from the posterior distributions. Together with the median response, the 10% and 90% percentiles are also shown.

As can be seen from the figures, a technology shock in the non-tradable sector drives up the aggregate domestic output. The domestic currency depreciates. Final good producers then switch from imports to domestically-produced goods. The positive technology shock increases the supply of goods, and therefore lowers inflation. Easing monetary policy in this case would further depreciate the domestic currency. Similarly, a technology shock in the tradable sector also induces a drop in inflation. But since a technology shock in the tradable sector increases the production of domestic-produced intermediate goods, the domestic currency appreciates. The central bank relaxing monetary policy contributes to the expansionary effect on output.

A risk premium shock drives up the demand for foreign currency. The demand for domestic currency declines, and the domestic currency depreciates. Monetary policy is tightened to constrain inflation, and aggregate output falls. A positive monetary policy shock means an increase in the domestic interest rate. Domestic bonds become more attractive compared to foreign bonds, so the domestic currency appreciates and the real exchange rate falls. In reaction to a government spending shock, the domestic production is driven up by demand, which increases the demand for domestic money. This puts upward pressure on the domestic interest rate. As a result, the domestic currency appreciates.

The foreign shocks have significant impacts on the small open economy. An increase in foreign prices leads to expenditure switching from foreign-produced goods to domestic-produced goods in both domestic and foreign markets. This implies an increasing demand of the domestic currency, and the domestic currency appreciates. The foreign inflation is passed through to the domestic economy. In response, the interest rate increases. Unsurprisingly, the effects of the foreign interest rate shock on the key variables are in line with those of the risk premium shock. The two shocks are identified in the model through the observed foreign interest rate series. In other words, the risk premium shock captures whatever is left unaccounted for by the observed foreign interest rate shock. Finally, responding to a foreign output shock, the demand for domestic exports increases, hence the aggregate domestic output rises. The foreign output shock suggests an ease on domestic inflation, and thus a looser monetary policy.

4.5 Variance Decomposition

To infer the role of various structural shocks in driving the movements of output, the real exchange rate, inflation and interest rates, we present the variance decomposition results for various horizons in Table 12-15 for the preferred models. Not surprisingly, we find that the foreign price shock plays an important role in accounting for the forecast error variances of the real exchange rate, since all the four countries considered here are small open economies. The technology shock in the tradable sector is generally also very important in generating variations of the key variables. When we compare the variance decomposition results for New Zealand with those for the other three countries, however, we find that they are very different.

First, for Australia, Canada and the United Kingdom, in addition to the foreign price shock, the technology shocks in both tradable and non-tradable sector account for significant percentages of inflation variation; for New Zealand, the role of the technology shock in the non-tradable sector, $A_{N,t}$, is not important. As can be seen from the impulse response figures and the earlier analysis, a positive $A_{N,t}$ shock causes the domestic currency to depreciate. Meanwhile the positive technology shock induces a drop in the inflation rate. In this case, without an active monetary policy, expenditure switching occurs from foreign- to domestic-produced intermediate goods due to the domestic currency depreciation, and all the key variables then converge to their steady state values. However, if the central bank were to respond to lower inflation without consideration on exchange rate movements, the interest rate would be reduced. This would induce a further depreciation of the domestic currency as a result, and the magnitude of the adjustment increases. Since amplified volatility in the adjustment process is undesirable, the central banks of Australia, Canada and the UK might want to directly react to exchange rate movements in addition to inflation targeting. The Reserve Bank of New Zealand, on the other hand, simply has little of this concern.

Second, for New Zealand, 99% of the forecast error variances of the output are explained by the tradable sector technology shock, $A_{T,t}$, and the foreign price shock; for the other three countries, in addition to those, the risk premium shock is as important as the $A_{T,t}$ shock, if not more. The implications of the risk premium shock, the monetary policy shock, and the foreign interest rate shock are quite different from those of other shocks. In particular, they have no direct effect on the demand for domestic-produced goods. Rather, they only work through their effects on exchange rates. In response to a positive risk premium shock, the domestic currency depreciates. Final good producers tend to substitute domestic-produced for foreign-produced goods. The demand for domestic money rises and inflation picks up. The interest rate is increased to contain inflation, and output drops. For Australia, Canada and the United Kingdom, direct response to exchange rate movements helps to reduce the impacts of the risk premium shock. For New Zealand, this is not so relevant.[19]

[19] Since New Zealand is a much smaller country in economic scale compared to other countries studied in this paper, it also seems plausible that its exchange rate might experience additional volatility due to some micro factors; while the implementation of monetary policy is based on macro judgements. Accounting for the micro level shocks is beyond the scope of this paper.

5 Robustness Checks

In this section, we assess the sensitivity of the estimation results to alternative data samples and inflation targeting rules. We find that changing data sample does not change the major empirical results. For Australia and Canada, the expected inflation targeting rule leads to better model fit. The results still suggest that the Reserve Bank of Australia, the Bank of Canada and the Bank of England explicitly reacted to real exchange rate movements and the Reserve Bank of New Zealand did not. For all the countries, the models with sectoral inflation targeting or wage inflation targeting rules, however, are inferior to models with current inflation targeting rules, as they lead to lower log marginal likelihood values.

5.1 Alternative Sample for the UK

As mentioned in Section 3, for the main estimation, we choose a starting point for the UK data series at 1979:3. However, over the 1990s, the Bank of England was committed to various degrees to the ERM, and between October 1990 and September 1992, belonged to the "hard" ERM. Since this might affect the estimation of the monetary policy reaction function, we use the post-ERM data for the United Kingdom, starting from 1992:4 to 2006:4, to re-estimate the models. The log marginal likelihood values corresponding to various specifications of monetary policy rule are shown in Table 16, and the parameter estimation results in the benchmark case are presented in Table 17.

All the major results stay the same. The marginal data density of the model, where the central bank directly responds to real exchange rate variation, is the largest. The parameter estimation results also remain essentially similar to the original estimates based on the longer data series. One exception is that the estimate of the degree of price indexation τ_d is 0.47, much larger than its original estimate of 0.25. This in principle could imply that during 1992:4 to 2006:4, the current inflation level depends less on expected future inflation and more on lagged inflation in the UK. However, the estimation results still suggest that the Bank of England explicitly included real exchange rate movements in its monetary policy rule. As we state in Section 4, the structure of shocks in accounting for inflation and output variances may help to explain this finding.

5.2 Expected Inflation Targeting

Our next robustness check is with respect to the possibility of expected inflation targeting in the monetary policy rules. Central banks are frequently generating forecasts for the economy and they are aware of policy lags. Therefore it seems that an expected inflation targeting rule is a closer description of central banks' real practices. In this section, we re-estimate the models under the assumption that central banks target the expected future inflation rather than the current inflation. The new monetary policy rules can be specified as:

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_\pi E_t \ln(\pi_{t+1}/\pi) + \alpha_y \ln(Y_t/Y)] + \epsilon_{rt}$$

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_\pi E_t \ln(\pi_{t+1}/\pi) + \alpha_y \ln(Y_t/Y) + \alpha_x \ln(S_t/S_{t-1})] + \epsilon_{rt}$$

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_\pi E_t \ln(\pi_{t+1}/\pi) + \alpha_y \ln(Y_t/Y) + \alpha_x \ln(q_t/q_{t-1})] + \epsilon_{rt}$$

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_\pi E_t \ln(\pi_{t+1}/\pi) + \alpha_y \ln(Y_t/Y) + \alpha_x \ln(rp_t/rp_{t-1})] + \epsilon_{rt}.$$

The log marginal densities from these estimations are displayed in Table 18. Comparing these values to those in the baseline cases, we see that the expected inflation targeting assumption leads to slightly larger marginal likelihood values in all cases for Australia and Canada. It suggests that it is more likely that the Reserve Bank of Australia and the Bank of Canada followed an expected inflation targeting rule. For both countries, the central bank responding to Δq_t model is still preferred among all the models. The estimates of α_π, α_y and α_x in the expected inflation targeting model are slightly smaller than the corresponding estimates in the baseline case, which suggests that the central banks of Australia and Canada may respond less aggressively to the inflation rate, output gap and real exchange rate movements than what the benchmark case indicates. For the UK, under certain policy rule specifications, expected inflation targeting leads to better fit, while under other specifications, it results in worse fit. Overall, the highest marginal likelihood value is achieved for the model, where the central bank responds to the current inflation, output gap and real exchange rate movements. Finally, for New Zealand, expected inflation targeting rules result in worse model fit in all cases than current inflation targeting rules. The estimates of the policy response coefficients are very similar to those in the baseline case.

5.3 Sectoral Inflation Targeting

The next robustness check explores sectoral inflation targeting, since the monetary authority may want to respond differently to inflation in the tradable sector, relative to inflation in the non-tradable sector. Specifically, we re-estimate the structural model for the four countries with each one of the following monetary policy rules:

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_T \ln(\pi_t^T/\pi^T) + \alpha_N \ln(\pi_t^N/\pi^N) + \alpha_y \ln(Y_t/Y)] + \epsilon_{rt}$$

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_T \ln(\pi_t^T/\pi^T) + \alpha_N \ln(\pi_t^N/\pi^N) + \alpha_y \ln(Y_t/Y) + \alpha_x \ln(S_t/S_{t-1})] + \epsilon_{rt}$$

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_T \ln(\pi_t^T/\pi^T) + \alpha_N \ln(\pi_t^N/\pi^N) + \alpha_y \ln(Y_t/Y) + \alpha_x \ln(q_t/q_{t-1})] + \epsilon_{rt}$$

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_T \ln(\pi_t^T/\pi^T) + \alpha_N \ln(\pi_t^N/\pi^N) + \alpha_y \ln(Y_t/Y) + \alpha_x \ln(rp_t/rp_{t-1})] + \epsilon_{rt}.$$

Our estimation results are displayed in Table 19. For all countries, the assumption of sectoral inflation targeting worsens model fit, compared to the benchmark CPI inflation targeting case.[20] The estimates on α_T and α_N are generally quite similar to each other, and are larger than the estimates of α_π in the baseline model. Benigno (2004) investigates how monetary policy should be conducted in a two-region model, and shows that the near-optimal policy is to give higher weight to the inflation in the region where there is higher degree of price rigidity. Ortega and Rebei (2006) analyze the welfare implications of sectoral inflation targeting rule in the context of a small open economy model for Canada. They find welfare gains in targeting exclusively the non-tradable good inflation, since prices are more sticky in the non-tradable sector. We do not find evidence supporting that, in practice, the central banks studied in this paper responded very differently to the inflation rates in different sectors.[21]

5.4 Wage Inflation Targeting

Recent studies find that the optimal monetary policy may entail targeting wage inflation when the degree of nominal inertia differs between prices and wages. For example, Erceg and Levin (2006) show that the optimal monetary policy rule can be closely approximated by a rule that targets a weighted average of wage and price inflation in the context of a two-sector general equilibrium model calibrated to match the corresponding responses from an empirical VAR. Ortega and Rebei (2006), however, find that wage inflation stabilization substantially increases almost all volatilities, and cannot improve welfare over CPI inflation targeting. In this section, we carry out our last sensitivity analysis with respect to the following hybrid rules, to see whether in actual practice the central banks responded to wage inflation.

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_\pi \ln(\pi_t/\pi) + \alpha_w \ln(\pi_t^W/\pi^W) + \alpha_y \ln(Y_t/Y)] + \epsilon_{rt}$$

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_\pi \ln(\pi_t/\pi) + \alpha_w \ln(\pi_t^W/\pi^W) + \alpha_y \ln(Y_t/Y) + \alpha_x \ln(S_t/S_{t-1})] + \epsilon_{rt}$$

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_\pi \ln(\pi_t/\pi) + \alpha_w \ln(\pi_t^W/\pi^W) + \alpha_y \ln(Y_t/Y) + \alpha_x \ln(q_t/q_{t-1})] + \epsilon_{rt}$$

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_\pi \ln(\pi_t/\pi) + \alpha_w \ln(\pi_t^W/\pi^W) + \alpha_y \ln(Y_t/Y) + \alpha_x \ln(rp_t/rp_{t-1})] + \epsilon_{rt}.$$

The marginal likelihood values derived from the estimations are shown in Table 20. In almost all cases, a combination of price and wage inflation targeting leads to lower marginal densities than in the CPI inflation targeting case. The only exception is the central bank responding to Δs_t rule for the UK, in which case the marginal likelihood value associated with the hybrid rule is 2.3611 larger in log scale

[20] We also check the monetary policy rule specification of further breaking down the inflation rates to the intermediate tradable sector, the import sector and the non-tradable sector. The model fit is even worse in that case.

[21] It is worth noting that, in this paper, although the Calvo stickiness parameter ψ_d is assumed to be the same for the intermediate tradable good producers and the non-tradable good producers, the degree of price stickiness for final goods and for non-tradable goods are different. This is because the final goods are assumed to be composites of both domestically produced intermediate goods and imports.

than with the CPI inflation targeting rule. Overall, however, for the UK, the marginal density is still the largest for the model with the specification of the central bank responding to the CPI inflation, output gap and real exchange rate movements. The estimation results here do not seem to support that these central banks included wage inflation targeting into their monetary policy rules.

6 Conclusion

In this paper, we develop and estimate a structural model with limited exchange rate pass-through for Australia, Canada, New Zealand and the United Kingdom, to study whether and how exchange rate movements were incorporated in the formulation of monetary policy. Our main finding is that the Reserve Bank of Australia, the Bank of Canada and the Bank of England directly responded to real exchange rate movements in the past, while the Reserve Bank of New Zealand did not seem to incorporate exchange rate movements explicitly into their monetary policy rule. This, however, does not imply that the Reserve Bank of New Zealand paid no attention to the exchange rate. Instead, the central bank of New Zealand responded to exchange rate movements indirectly, because in our model, the exchange rate, inflation and output are all endogenously determined. What might appear to be a closed economy rule actually implies an interest rate reaction to exchange rate movements through inflation and output stabilization.

Our results also reveal the potential explanations for the indirect reaction of the central bank of New Zealand as follows. First, the structure of shocks accounting for inflation and output variations is different for New Zealand than for the other three countries. In particular, in Australia, Canada and the UK, the technology shock in the non-tradable sector is important in explaining the forecast error variances of inflation, and the risk premium shock plays a role in driving output variation. Since the central bank solely responding to inflation shifts driven by the non-tradable technology shock would amplify volatilities in the adjustment path, and the risk premium shock only has impacts on the domestic economy through exchange rate movements, the central banks of Australia, Canada and the UK might want to respond to real exchange rate variation directly, although this is not of concern for New Zealand. Second, in New Zealand, current inflation seems to reflect less expected future inflation, and contains more information on past inflation. So the central bank of New Zealand might be less concerned about future inflation pressure caused by current exchange rate movements.

Our paper contributes to the literature of open economy monetary policy rules by extending Lubik and Schorfheide (2007) to allow for endogenous exchange rate specification and to accommodate limited exchange rate pass-through. We adopt a full-information approach to study the conduct of monetary policy and deliver insights into the monetary transmission mechanism in open economies. In any case, whether the central banks' responses are optimal or not is a different question, and further research is needed to address that.

A The Linearized Equation System

Prices and Wages:

$$
\begin{aligned}
&0 = \alpha_T \left(\frac{P_T}{P}\right)^{1-\varsigma} \hat{p}_{T,t} + (1-\alpha_T)\left(\frac{P_N}{P}\right)^{1-\varsigma} \hat{p}_{N,t} \\
&\hat{p}_{T,t} = \alpha_H \left(\frac{P_H}{P_T}\right)^{1-\sigma} \hat{p}_{H,t} + (1-\alpha_H)\left(\frac{P_F}{P_T}\right)^{1-\sigma} \hat{p}_{F,t} \\
&\hat{x}_{H,t} = \psi_d \beta E_t \hat{x}_{H,t+1} + \psi_d \beta \hat{\pi}_{t+1} - \psi_d \beta \tau_d \hat{\pi}_t + (1-\psi_d\beta)[(1-\eta)\hat{w}_t - \hat{a}_{T,t} + \eta \hat{r}^k_{T,t}] \\
&\hat{x}^p_{H,t} = \hat{x}_{H,t} \\
&\hat{x}^l_{H,t} = \psi_d \beta E_t \hat{x}^l_{H,t+1} + \psi_d \beta \hat{\pi}^*_{t+1} - \psi_d \beta \tau_d \hat{\pi}^*_t + (1-\psi_d\beta)[(1-\eta)\hat{w}_t - \hat{a}_{T,t} - \hat{q}_t + \eta \hat{r}^k_{T,t}] \\
&\hat{x}_{N,t} = \psi_d \beta E_t \hat{x}_{N,t+1} + \psi_d \beta \hat{\pi}_{t+1} - \psi_d \beta \tau_d \hat{\pi}_t + (1-\psi_d\beta)[(1-\theta)\hat{w}_t - \hat{a}_{N.t} + \theta \hat{r}^k_{N,t}] \\
&\hat{p}_{H,t} = \psi_d \hat{p}_{H,t-1} - \psi_d \hat{\pi}_t + \psi_d \tau_d \hat{\pi}_{t-1} + (1-\psi_d)\hat{x}_{H,t} \\
&\hat{p}_{N,t} = \psi_d \hat{p}_{N,t-1} - \psi_d \hat{\pi}_t + \psi_d \tau_n \hat{\pi}_{t-1} + (1-\psi_d)\hat{x}_{N,t} \\
&\hat{p}^*_{H,t} = \psi_d \hat{p}^*_{H,t-1} - \psi_d \hat{\pi}^*_t + \psi_d \tau_d \hat{\pi}^*_{t-1} + (1-\psi_d)[\phi \hat{x}^l_{H,t} + (1-\phi)(\hat{x}^p_{H,t} - \hat{q}_t)] \\
&\hat{p}_{F,t} = \frac{SP^*}{P_f}\hat{q}_t + \frac{\lambda P_N}{P_f}\hat{p}_{N,t} \\
&\hat{\pi}^*_t = \phi^*(\hat{\pi}^*_{l,t} + \hat{q}_{t-1} - \hat{q}_t + \hat{\pi}^*_t - \hat{\pi}_t) + (1-\phi^*)\hat{\pi}^*_{p,t} \\
&\hat{\omega}_t = \psi_w \beta E_t \hat{\omega}_{t+1} + \psi_w \beta \hat{\pi}_{t+1} - \psi_w \beta \tau_w \hat{\pi}_t + \frac{1-\psi_w\beta}{1+\gamma\mu}\left[\mu \hat{l}_t + \gamma\mu\hat{w}_t + \frac{\rho}{1-h}(\hat{c}_t - h\hat{c}_{t-1})\right] \\
&\hat{w}_t = \psi_w \hat{w}_{t-1} - \psi_w \hat{\pi}_t + \psi_w \tau_w \hat{\pi}_{t-1} + (1-\psi_w)\hat{\omega}_t
\end{aligned}
$$

Output, Capital and Employment:

$$
\begin{aligned}
&\hat{y}_{H,t} = \hat{y}_{T,t} - \sigma(\hat{p}_{H,t} - \hat{p}_{T,t}) \\
&\hat{y}_{F,t} = \hat{y}_{T,t} - \sigma(\hat{p}_{F,t} - \hat{p}_{T,t}) \\
&\hat{y}^*_{H,t} = \hat{y}^*_t - \sigma^f \hat{p}^*_{H,t} \\
&\hat{k}_{T,t-1} = \hat{z}_t - \hat{a}_{T,t} - (1-\eta)\hat{r}^k_{T,t} + (1-\eta)\hat{w}_t - (1-\eta)\hat{p}_{T,t} \\
&\hat{k}_{N,t-1} = \hat{y}_{N,t} - \hat{a}_{N,t} - (1-\theta)\hat{r}^k_{N,t} + (1-\theta)\hat{w}_t - (1-\theta)\hat{p}_{N,t} \\
&\hat{l}_{T,t} = \hat{z}_t - \hat{a}_{T,t} + \eta \hat{r}^k_{T,t} - \eta\hat{w}_t + \eta\hat{p}_{T,t} \\
&\hat{l}_{N,t} = \hat{y}_{N,t} - \hat{a}_{N,t} + \theta \hat{r}^k_{N,t} - \theta\hat{w}_t + \theta\hat{p}_{N,t} \\
&\hat{k}_{T,t} = (1-\delta)\hat{k}_{T,t-1} + \delta\hat{i}_{T,t} \\
&\hat{k}_{N,t} = (1-\delta)\hat{k}_{N,t-1} + \delta\hat{i}_{N,t} \\
&\frac{\rho}{1-h}[(1+h)\hat{c}_t - h\hat{c}_{t-1} - E_t\hat{c}_{t+1}] = \chi(\hat{k}_{T,t} - \hat{k}_{T,t-1}) - \beta\chi E_t(\hat{k}_{T,t+1} - \hat{k}_{T,t}) - \beta r^k_T \hat{r}^k_{T,t+1} \\
&\frac{\rho}{1-h}[(1+h)\hat{c}_t - h\hat{c}_{t-1} - E_t\hat{c}_{t+1}] = \chi(\hat{k}_{N,t} - \hat{k}_{N,t-1}) - \beta\chi E_t(\hat{k}_{N,t+1} - \hat{k}_{N,t}) - \beta r^k_N \hat{r}^k_{N,t+1}
\end{aligned}
$$

Euler's equation:

$$(\hat{q}_t - E_t\hat{q}_{t+1} + \hat{\pi}^*_{t+1}) - \hat{r}^*_t - \hat{rp}_t = \frac{\rho}{1-h}[(1+h)\hat{c}_t - h\hat{c}_{t-1} - E_t\hat{c}_{t+1}]$$

Arbitrage condition:

$$\begin{aligned}
&\hat{r}_t - \hat{r}^*_t - \hat{rp}_t = E_t\hat{q}_{t+1} - \hat{q}_t - \hat{\pi}^*_{t+1} + \hat{\pi}_{t+1} \\
&\hat{rp}_t = -\varphi_s(E_t\hat{q}_{t+1} - \hat{q}_{t-1} - \hat{\pi}^*_{t+1} - \hat{\pi}^*_t + \hat{\pi}_{t+1} + \hat{\pi}_t) - \tilde{\varphi}_n\hat{\xi}_t + \hat{\varphi}_t
\end{aligned}$$

Market clearing conditions:

$$\begin{aligned}
\hat{l}_t &= \frac{L_T}{L}\hat{l}_{T,t} + \frac{L_N}{L}\hat{l}_{N,t} \\
\hat{z}_t &= \frac{Y_H}{Z}\hat{y}_{H,t} + \frac{Y^*_H}{Z}\hat{y}^*_{H,t} \\
\hat{y}_{T,t} &= \frac{C_T}{Y_T}\hat{c}_{T,t} + \frac{G_T}{Y_T}\hat{g}_{T,t} + \frac{I_T}{Y_T}\hat{i}_{T,t} \\
\hat{y}_{N,t} &= \frac{C_N}{Y_N}\hat{c}_{N,t} + \frac{G_N}{Y_N}\hat{g}_{N,t} + \frac{I_N}{Y_N}\hat{i}_{N,t} + \frac{\lambda Y_F}{Y_N}\hat{y}_{F,t} \\
\hat{y}_t &= \frac{P_T Y_T}{PY}(\hat{p}_{T,t} + \hat{y}_{T,t}) + \frac{P_N Y_N}{PY}(\hat{p}_{N,t} + \hat{y}_{N,t})
\end{aligned}$$

Consumption:

$$\begin{aligned}
\hat{c}_{T,t} &= \hat{c}_t - \varsigma\hat{p}_{T,t} & \hat{c}_{N,t} &= \hat{c}_t - \varsigma\hat{p}_{N,t} \\
\hat{g}_{T,t} &= \hat{g}_t - \varsigma\hat{p}_{T,t} & \hat{g}_{N,t} &= \hat{g}_t - \varsigma\hat{p}_{N,t}
\end{aligned}$$

Budget constraint:

$$\begin{aligned}
C\hat{c}_t + G\hat{g}_t + &\frac{P_T I_T}{P}(\hat{p}_{T,t} + \hat{i}_{T,t}) + \frac{P_N I_N}{P}(\hat{p}_{N,t} + \hat{i}_{N,t}) + \frac{SB^*}{PR^*rp}(\hat{q}_t + \hat{b}^*_t - \hat{r}^*_t - \hat{rp}_t) \\
&= d\hat{d}_t + \frac{WL}{P}(\hat{w}_t + \hat{l}_t) + \frac{SB^*}{P}(\hat{q}_t + \hat{b}^*_{t-1} - \hat{\pi}^*_t) \\
&\quad + \frac{r_k P_T K_T}{P}(\hat{r}^k_{T,t} + \hat{k}_{T,t-1} + \hat{p}_{T,t}) + \frac{r_k P_N K_N}{P}(\hat{r}^k_{N,t} + \hat{k}_{N,t-1} + \hat{p}_{N,t})
\end{aligned}$$

where:

$$\begin{aligned}
d\hat{d}_t = Y\hat{y}_t &+ \frac{SP^*_h Y^*_h}{P}(\hat{q}_t + \hat{p}^*_{H,t} + \hat{y}^*_{H,t}) - \frac{P_F Y_f}{P}(\hat{p}_{F,t} + \hat{y}_{F,t}) - \frac{WL}{P}(\hat{w}_t + \hat{l}_t) \\
&- \frac{r_k P_T K_T}{P}(\hat{r}^k_{T,t} + \hat{k}_{T,t-1} + \hat{p}_{T,t}) - \frac{r_k P_N K_N}{P}(\hat{r}^k_{N,t} + \hat{k}_{N,t-1} + \hat{p}_{N,t})
\end{aligned}$$

Trade balance value:

$$\hat{tb}_t = \hat{p}_{F,t} - \hat{q}_t - \hat{p}^*_{H,t} + \hat{y}_{F,t} - \hat{y}^*_{H,t}$$

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Table 1: Unconditional Second Moments: Australia (Benchmark Case)

Variables	Std Deviation	Autocorrelation	Correlation with $\hat{y}_t$	Correlation with $\hat{q}_t$	Correlation with $\hat{tb}_t$
			Australia		
			Data		
$\hat{w}_t$	0.0106	0.7156	-0.1416	0.0711	0.2066
$\hat{y}_t$	0.0111	0.7852	1.0000	-0.1471	0.3462
$\hat{q}_t$	0.0748	0.8349	-0.1471	1.0000	-0.3984
$\hat{r}_t$	0.0041	0.8182	0.4692	-0.0561	0.1879
$\hat{tb}_t$	0.1216	0.7959	0.3462	-0.3984	1.0000
			Model		
$\hat{w}_t$	0.0264	0.9127	0.4577	-0.3936	0.1794
	(0.0179, 0.0405)	(0.7731, 0.9865)	(0.2156, 0.6572)	(-0.6566, -0.0855)	(-0.0957, 0.4401)
$\hat{y}_t$	0.0155	0.7386	1.0000	-0.3703	0.3039
	(0.0125, 0.0194)	(0.6063, 0.8439)		(-0.6088, -0.1152)	(0.0461, 0.5366)
$\hat{q}_t$	0.0764	0.8667	-0.3703	1.0000	-0.4988
	(0.0601, 0.0984)	(0.7628, 0.9334)	(-0.6088, -0.1152)		(-0.6945, -0.2153)
$\hat{r}_t$	0.0122	0.9523	-0.4760	0.4050	-0.0874
	(0.0075, 0.0193)	(0.8111,1.0000)	(-0.6574, -0.2793)	(0.1078, 0.6440)	(-0.3609, 0.1814)
$\hat{tb}_t$	0.1243	0.8242	0.3039	-0.4988	1.0000
	(0.0979, 0.1584)	(0.7055, 0.9059)	(0.0461, 0.5366)	(-0.6945, -0.2153)	

Table 2: Unconditional Second Moments: Canada (Benchmark Case)

Variables	Std Deviation	Autocorrelation	Correlation with $\hat{y}_t$	Correlation with $\hat{q}_t$	Correlation with $\hat{tb}_t$
			Canada		
			Data		
$\hat{w}_t$	0.0109	0.7987	-0.3104	-0.0016	-0.0361
$\hat{y}_t$	0.0142	0.8578	1.0000	0.2099	-0.0870
$\hat{q}_t$	0.0314	0.8428	0.2099	1.0000	0.1868
$\hat{r}_t$	0.0039	0.8131	0.5087	-0.0884	-0.1493
$\hat{tb}_t$	0.0442	0.5975	-0.0870	0.1868	1.0000
			Model		
$\hat{w}_t$	0.0169	0.8593	0.2732	-0.5547	0.0342
	(0.0116, 0.0267)	(0.6462, 0.9916)	(-0.1132, 0.6017)	(-0.8106, -0.1396)	(-0.3155, 0.3509)
$\hat{y}_t$	0.0136	0.7199	1.0000	-0.1143	0.1370
	(0.0105, 0.0172)	(0.5219, 0.8653)		(-0.4891, 0.2875)	(-0.2156, 0.4474)
$\hat{q}_t$	0.0381	0.8657	-0.1143	1.0000	-0.0524
	(0.0268, 0.0553)	(0.6650, 0.9843)	(-0.4891, 0.2875)		(-0.3822, 0.3003)
$\hat{r}_t$	0.0086	0.9008	-0.3287	0.5279	0.0200
	(0.0051, 0.0151)	(0.6656, 1.0000)	(-0.5991, 0.0280)	(0.0507, 0.8234)	(-0.3242, 0.3683)
$\hat{tb}_t$	0.0556	0.7219	0.1370	-0.0524	1.0000
	(0.0432, 0.0703)	(0.5202, 0.8492)	(-0.2156, 0.4474)	(-0.3822, 0.3003)	

Table 3: Unconditional Second Moments: New Zealand (Benchmark Case)

Variables	Std Deviation	Autocorrelation	Correlation with $\hat{y}_t$	Correlation with $\hat{q}_t$	Correlation with $\hat{tb}_t$
	New Zealand				
	Data				
$\hat{w}_t$	0.0129	0.6948	0.0413	-0.1959	-0.0877
$\hat{y}_t$	0.0169	0.8117	1.0000	-0.6145	0.0569
$\hat{q}_t$	0.0893	0.8720	-0.6145	1.0000	-0.2713
$\hat{r}_t$	0.0037	0.6647	0.2056	-0.3512	0.1140
$\hat{tb}_t$	0.0909	0.4679	0.0569	-0.2713	1.0000
	Model				
$\hat{w}_t$	0.0361	0.9336	0.5846	-0.5076	0.1794
	(0.0245, 0.0528)	(0.8053, 0.9983)	(0.3593, 0.7472)	(-0.7299, -0.1946)	(-0.0740, 0.3961)
$\hat{y}_t$	0.0238	0.7809	1.0000	-0.4857	0.2269
	(0.0191, 0.0297)	(0.6586, 0.8765)		(-0.6812, -0.1899)	(-0.0349, 0.4678)
$\hat{q}_t$	0.0964	0.9060	-0.4857	1.0000	-0.2391
	(0.0725, 0.1275)	(0.7955, 0.9703)	(-0.6812, -0.1899)		(-0.4742, 0.0420)
$\hat{r}_t$	0.0115	0.9387	-0.5612	0.2064	-0.0606
	(0.0079, 0.0175)	(0.7990, 1.0000)	(-0.7148, -0.3610)	(-0.1682, 0.5370)	(-0.2916, 0.1608)
$\hat{tb}_t$	0.1318	0.7055	0.2269	-0.2391	1.0000
	(0.1083, 0.1655)	(0.5845, 0.8128)	(-0.0349, 0.4678)	(-0.4742, 0.0420)	

Table 4: Unconditional Second Moments: United Kingdom (Benchmark Case)

Variables	Std Deviation	Autocorrelation	Correlation with $\hat{y}_t$	Correlation with $\hat{q}_t$	Correlation with $\hat{tb}_t$
			United Kingdom		
			Data		
$\hat{w}_t$	0.0083	0.7545	0.1810	-0.1294	0.1466
$\hat{y}_t$	0.0121	0.8672	1.0000	0.0172	0.4606
$\hat{q}_t$	0.0706	0.8079	0.0172	1.0000	-0.0495
$\hat{r}_t$	0.0032	0.8200	0.2384	-0.1496	0.1534
$\hat{tb}_t$	0.0395	0.6282	0.4606	-0.0495	1.0000
			Model		
$\hat{w}_t$	0.0310	0.9546	0.5088	-0.7108	0.0158
	(0.0209, 0.0474)	(0.8320, 1.0000)	(0.2311, 0.7200)	(-0.8614, -0.4598)	(-0.2243, 0.2453)
$\hat{y}_t$	0.0137	0.7841	1.0000	-0.3100	0.1555
	(0.0111, 0.0169)	(0.6705, 0.8676)		(-0.5855, -0.0389)	(-0.0921, 0.3671)
$\hat{q}_t$	0.0928	0.8974	-0.3100	1.0000	-0.1024
	(0.0687, 0.1255)	(0.7869, 0.9645)	(-0.5855, -0.0389)		(-0.3371, 0.1439)
$\hat{r}_t$	0.0104	0.9650	-0.4917	0.6971	-0.0048
	(0.0067, 0.0160)	(0.8440, 1.0000)	(-0.6924, -0.2687)	(0.4179, 0.8592)	(-0.2392, 0.2281)
$\hat{tb}_t$	0.0641	0.8166	0.1555	-0.1024	1.0000
	(0.0509, 0.0813)	(0.7153, 0.8965)	(-0.0921, 0.3671)	(-0.3371, 0.1439)	

Table 5: Parameter Estimates: Australia (Benchmark Case)

	Australia							
	Prior Distribution			Posterior Maximization		Posterior Distribution		
Parameters	Distribution	Mean	Std	Mode	Std Error	Mean	10%	90%
ψ_d	Beta	0.70	0.10	0.6832	0.0399	0.6893	0.6261	0.7533
ψ_w	Beta	0.70	0.10	0.7361	0.0455	0.7361	0.6655	0.8092
τ_d	Beta	0.50	0.15	0.2730	0.0815	0.2936	0.1633	0.4236
τ_w	Beta	0.50	0.15	0.3270	0.0963	0.3333	0.1845	0.4829
ϕ	Beta	0.73	0.10	0.7755	0.0987	0.7482	0.5998	0.9044
ϕ^*	Beta	0.31	0.10	0.2883	0.0978	0.2995	0.1489	0.4437
σ	Gamma	1.50	0.25	1.5082	0.2552	1.5745	1.1385	1.9942
σ_f	Gamma	1.50	0.25	2.0388	0.1849	2.0478	1.7416	2.3396
ρ_r	Beta	0.80	0.10	0.9270	0.0122	0.9274	0.9080	0.9472
α_π	Gamma	1.60	0.10	1.3992	0.0911	1.4118	1.2596	1.5589
α_y	Gamma	0.50	0.20	1.2094	0.2447	1.2678	0.8629	1.6764
α_x	Gamma	0.25	0.10	0.3414	0.0844	0.3501	0.2067	0.4853
φ_s	Gamma	0.45	0.20	0.3322	0.0454	0.3409	0.2733	0.4115
φ_n	Gamma	0.01	0.005	0.0211	0.0047	0.0222	0.0146	0.0301
χ	Gamma	10.0	2.00	14.742	2.2565	15.134	11.352	18.637
ϱ	Beta	0.40	0.10	0.7224	0.0525	0.7071	0.6252	0.7987
ρ_p	Beta	0.80	0.10	0.5386	0.0913	0.5517	0.4072	0.6899
ρ_{AT}	Beta	0.85	0.05	0.9664	0.0120	0.9605	0.9401	0.9823
ρ_{AN}	Beta	0.80	0.10	0.2967	0.0660	0.2930	0.1882	0.3982
ρ_φ	Beta	0.80	0.10	0.8110	0.0714	0.8007	0.6901	0.9172
σ_p	Inv Gamma	0.01	4.00	0.0836	0.0178	0.0848	0.0562	0.1110
σ_r	Inv Gamma	0.01	4.00	0.0027	0.0002	0.0027	0.0024	0.0031
σ_{AT}	Inv Gamma	0.01	4.00	0.0225	0.0049	0.0256	0.0164	0.0344
σ_{AN}	Inv Gamma	0.01	4.00	0.0718	0.0204	0.0834	0.0456	0.1202
σ_φ	Inv Gamma	0.01	4.00	0.0141	0.0032	0.0155	0.0100	0.0211

Table 6: Parameter Estimates: Canada (Benchmark Case)

	Canada							
	Prior Distribution			Posterior Maximization		Posterior Distribution		
Parameters	Distribution	Mean	Std	Mode	Std Error	Mean	10%	90%
ψ_d	Beta	0.70	0.10	0.7107	0.0367	0.7175	0.6564	0.7828
ψ_w	Beta	0.70	0.10	0.7379	0.0358	0.7392	0.6804	0.7978
τ_d	Beta	0.50	0.15	0.2768	0.0688	0.2976	0.1841	0.4098
τ_w	Beta	0.50	0.15	0.2442	0.0819	0.2607	0.1279	0.3867
ϕ	Beta	0.76	0.10	0.8121	0.0968	0.7796	0.6324	0.9307
ϕ^*	Beta	0.30	0.10	0.2533	0.0922	0.2648	0.1254	0.4060
σ	Gamma	1.50	0.25	1.6387	0.2781	1.6926	1.2112	2.1424
σ_f	Gamma	1.50	0.25	1.8888	0.1412	1.8906	1.6610	2.1181
ρ_r	Beta	0.80	0.10	0.9330	0.0107	0.9346	0.9178	0.9509
α_π	Gamma	1.60	0.10	1.2550	0.0940	1.2736	1.1236	1.4261
α_y	Gamma	0.50	0.20	0.9104	0.2188	0.9810	0.6138	1.3420
α_x	Gamma	0.25	0.10	0.5809	0.1359	0.5925	0.3619	0.8197
φ_s	Gamma	0.45	0.20	0.3458	0.0307	0.3538	0.3035	0.4028
φ_n	Gamma	0.01	0.005	0.0346	0.0070	0.0353	0.0239	0.0465
χ	Gamma	10.0	2.00	17.121	2.3311	17.468	13.619	21.263
ϱ	Beta	0.40	0.10	0.5558	0.0630	0.5470	0.4423	0.6504
ρ_p	Beta	0.80	0.10	0.5433	0.0660	0.5593	0.4500	0.6675
ρ_{AT}	Beta	0.85	0.05	0.9839	0.0064	0.9805	0.9694	0.9922
ρ_{AN}	Beta	0.80	0.10	0.3523	0.0659	0.3449	0.2362	0.4489
ρ_φ	Beta	0.80	0.10	0.7626	0.0797	0.7433	0.6150	0.8743
σ_p	Inv Gamma	0.01	4.00	0.0641	0.0131	0.0647	0.0441	0.0852
σ_r	Inv Gamma	0.01	4.00	0.0022	0.0001	0.0022	0.0020	0.0025
σ_{AT}	Inv Gamma	0.01	4.00	0.0217	0.0047	0.0242	0.0153	0.0327
σ_{AN}	Inv Gamma	0.01	4.00	0.0603	0.0179	0.0705	0.0343	0.1063
σ_φ	Inv Gamma	0.01	4.00	0.0076	0.0014	0.0082	0.0058	0.0106

Table 7: Parameter Estimates: New Zealand (Benchmark Case)

	New Zealand							
	Prior Distribution			Posterior Maximization		Posterior Distribution		
Parameters	Distribution	Mean	Std	Mode	Std Error	Mean	10%	90%
ψ_d	Beta	0.70	0.10	0.6878	0.0428	0.7000	0.6329	0.7721
ψ_w	Beta	0.70	0.10	0.7250	0.0493	0.7314	0.6506	0.8109
τ_d	Beta	0.50	0.15	0.4662	0.0836	0.4727	0.3385	0.6072
τ_w	Beta	0.50	0.15	0.2988	0.1157	0.3409	0.1410	0.5350
ϕ	Beta	0.70	0.10	0.7403	0.1007	0.7227	0.5721	0.8766
ϕ^*	Beta	0.30	0.10	0.2336	0.0880	0.2511	0.1160	0.3854
σ	Gamma	1.50	0.25	1.6328	0.2674	1.6986	1.2448	2.1314
σ_f	Gamma	1.50	0.25	2.0040	0.1747	2.0141	1.7436	2.2826
ρ_r	Beta	0.80	0.10	0.9304	0.0125	0.9303	0.9106	0.9508
α_π	Gamma	1.60	0.10	1.4858	0.0952	1.4958	1.3368	1.6535
α_y	Gamma	0.50	0.20	0.8649	0.2042	0.9024	0.5599	1.2298
α_x	Gamma	0.25	0.10	0.1381	0.0554	0.1590	0.0634	0.2498
φ_s	Gamma	0.45	0.20	0.4309	0.0381	0.4265	0.3752	0.4782
φ_n	Gamma	0.01	0.005	0.0260	0.0052	0.0265	0.0177	0.0347
χ	Gamma	10.0	2.00	15.346	2.2065	15.880	12.216	19.494
ϱ	Beta	0.40	0.10	0.5768	0.0575	0.5678	0.4690	0.6618
ρ_p	Beta	0.80	0.10	0.7520	0.1085	0.7392	0.5975	0.8854
ρ_{AT}	Beta	0.85	0.05	0.9494	0.0194	0.9393	0.9053	0.9745
ρ_{AN}	Beta	0.80	0.10	0.3073	0.0690	0.3010	0.1927	0.4079
ρ_φ	Beta	0.80	0.10	0.7767	0.1028	0.7652	0.6208	0.9101
σ_p	Inv Gamma	0.01	4.00	0.1508	0.0310	0.1477	0.1005	0.1953
σ_r	Inv Gamma	0.01	4.00	0.0033	0.0003	0.0033	0.0029	0.0038
σ_{AT}	Inv Gamma	0.01	4.00	0.0361	0.0090	0.0425	0.0248	0.0590
σ_{AN}	Inv Gamma	0.01	4.00	0.0842	0.0255	0.1020	0.0517	0.1522
σ_φ	Inv Gamma	0.01	4.00	0.0154	0.0036	0.0166	0.0108	0.0223

Table 8: Parameter Estimates: United Kingdom (Benchmark Case)

	United Kingdom							
	Prior Distribution			Posterior Maximization		Posterior Distribution		
Parameters	Distribution	Mean	Std	Mode	Std Error	Mean	10%	90%
ψ_d	Beta	0.70	0.10	0.7239	0.0345	0.7446	0.6865	0.7986
ψ_w	Beta	0.70	0.10	0.7396	0.0380	0.7355	0.6729	0.7982
τ_d	Beta	0.50	0.15	0.2529	0.0620	0.2745	0.1726	0.3771
τ_w	Beta	0.50	0.15	0.1496	0.0648	0.1689	0.0633	0.2682
ϕ	Beta	0.30	0.10	0.3358	0.1194	0.3502	0.1690	0.5303
ϕ^*	Beta	0.40	0.10	0.2435	0.0662	0.2517	0.1469	0.3553
σ	Gamma	1.50	0.25	1.4729	0.2693	1.6615	1.1481	2.1858
σ_f	Gamma	1.50	0.25	2.3015	0.2023	2.3073	1.9828	2.6310
ρ_r	Beta	0.80	0.10	0.9443	0.0092	0.9439	0.9290	0.9593
α_π	Gamma	1.60	0.10	1.4162	0.0938	1.4401	1.2866	1.5965
α_y	Gamma	0.50	0.20	1.0989	0.2268	1.1503	0.7640	1.5188
α_x	Gamma	0.25	0.10	0.2137	0.0633	0.2266	0.1203	0.3322
φ_s	Gamma	0.45	0.20	0.2983	0.0308	0.3096	0.2569	0.3655
φ_n	Gamma	0.01	0.005	0.0307	0.0076	0.0324	0.0203	0.0446
χ	Gamma	10.0	2.00	18.035	2.5806	18.108	13.846	22.246
ϱ	Beta	0.40	0.10	0.8202	0.0315	0.8111	0.7580	0.8646
ρ_p	Beta	0.80	0.10	0.6228	0.0486	0.6325	0.5448	0.7231
ρ_{AT}	Beta	0.85	0.05	0.9817	0.0093	0.9661	0.9370	0.9928
ρ_{AN}	Beta	0.80	0.10	0.3507	0.0702	0.3307	0.2189	0.4418
ρ_φ	Beta	0.80	0.10	0.8197	0.0668	0.7990	0.6890	0.9126
σ_p	Inv Gamma	0.01	4.00	0.0471	0.0090	0.0450	0.0320	0.0578
σ_r	Inv Gamma	0.01	4.00	0.0019	0.0001	0.0020	0.0017	0.0022
σ_{AT}	Inv Gamma	0.01	4.00	0.0340	0.0080	0.0459	0.0240	0.0685
σ_{AN}	Inv Gamma	0.01	4.00	0.0578	0.0178	0.0811	0.0375	0.1206
σ_φ	Inv Gamma	0.01	4.00	0.0127	0.0025	0.0142	0.0098	0.0187

Table 9: Parameter Estimates: New Zealand ($\alpha_x = 0$)

	New Zealand							
	Prior Distribution			Posterior Maximization		Posterior Distribution		
Parameters	Distribution	Mean	Std	Mode	Std Error	Mean	10%	90%
ψ_d	Beta	0.70	0.10	0.6897	0.0424	0.7028	0.6367	0.7725
ψ_w	Beta	0.70	0.10	0.7372	0.0483	0.7458	0.6679	0.8222
τ_d	Beta	0.50	0.15	0.4699	0.0850	0.4788	0.3387	0.6111
τ_w	Beta	0.50	0.15	0.3017	0.1183	0.3482	0.1464	0.5485
ϕ	Beta	0.70	0.10	0.7414	0.1004	0.7218	0.5673	0.8742
ϕ^*	Beta	0.30	0.10	0.2439	0.0909	0.2633	0.1237	0.4008
σ	Gamma	1.50	0.25	1.6280	0.2673	1.6930	1.2472	2.1366
σ_f	Gamma	1.50	0.25	1.9838	0.1712	1.9954	1.7283	2.2757
ρ_r	Beta	0.80	0.10	0.9285	0.0128	0.9274	0.9065	0.9480
α_π	Gamma	1.60	0.10	1.4763	0.0952	1.4820	1.3261	1.6349
α_y	Gamma	0.50	0.20	0.8231	0.1968	0.8418	0.5145	1.1542
φ_s	Gamma	0.45	0.20	0.4260	0.0394	0.4220	0.3702	0.4772
φ_n	Gamma	0.01	0.005	0.0264	0.0053	0.0271	0.0185	0.0357
χ	Gamma	10.0	2.00	15.067	2.1771	15.526	11.868	18.950
ϱ	Beta	0.40	0.10	0.5926	0.0562	0.5878	0.4933	0.6804
ρ_p	Beta	0.80	0.10	0.7371	0.1093	0.7253	0.5813	0.8751
ρ_{AT}	Beta	0.85	0.05	0.9520	0.0184	0.9420	0.9093	0.9758
ρ_{AN}	Beta	0.80	0.10	0.3131	0.0695	0.3070	0.1964	0.4141
ρ_φ	Beta	0.80	0.10	0.7936	0.0946	0.7812	0.6482	0.9213
σ_p	Inv Gamma	0.01	4.00	0.1481	0.0311	0.1442	0.0965	0.1911
σ_r	Inv Gamma	0.01	4.00	0.0032	0.0003	0.0032	0.0028	0.0037
σ_{AT}	Inv Gamma	0.01	4.00	0.0365	0.0090	0.0433	0.0256	0.0615
σ_{AN}	Inv Gamma	0.01	4.00	0.0834	0.0248	0.1009	0.0523	0.1524
σ_φ	Inv Gamma	0.01	4.00	0.0154	0.0036	0.0167	0.0109	0.0224

Table 10: Log Marginal Likelihood Values

Log Marginal Data Density	Country **Australia**	**Canada**	**United Kingdom**	**New Zealand**
Exogenous q_t ($\alpha_x \cdot \Delta q_t$)	1219.3182	2324.0028	1594.3603	1075.0426
Exogenous q_t ($\alpha_x \cdot \Delta s_t$)	1218.0107	2316.8426	1595.3912	1071.8586
Exogenous q_t ($\alpha_x = 0$)	1217.4712	2321.0081	1597.8804	1079.0370
Endogenous q_t ($\alpha_x \cdot \Delta q_t$)	1261.0284	2325.9086	1659.2395	1120.2250
Endogenous q_t ($\alpha_x \cdot \Delta s_t$)	1252.5516	2320.4496	1643.8093	1120.9483
Endogenous q_t ($\alpha_x \cdot \Delta rp_t$)	1248.7088	2310.5528	1651.9486	1119.8444
Endogenous q_t ($\alpha_x = 0$)	1252.6941	2314.7133	1657.3496	1122.3534

Table 11: Bayes Factor and Posterior Odds

	Country **Australia**	**Canada**	**United Kingdom**	**New Zealand**
			Bayes Factor	
Endogenous q_t ($\alpha_x \cdot \Delta q_t$)	1.0000	1.0000	1.0000	1.0000
Endogenous q_t ($\alpha_x \cdot \Delta s_t$)	0.0002	0.0043	0.0000	2.0612
Endogenous q_t ($\alpha_x \cdot \Delta rp_t$)	0.0000	0.0000	0.0001	0.6835
Endogenous q_t ($\alpha_x = 0$)	0.0002	0.0000	0.1511	8.4014
			Posterior Odds	
Endogenous q_t ($\alpha_x \cdot \Delta q_t$)	2499.0	231.56	6.6161	0.0897
Endogenous q_t ($\alpha_x \cdot \Delta s_t$)	0.0002	0.0043	0.0000	0.2044
Endogenous q_t ($\alpha_x \cdot \Delta rp_t$)	0.0000	0.0000	0.0001	0.0597
Endogenous q_t ($\alpha_x = 0$)	0.0002	0.0000	0.1510	2.2436

Table 12: Variance Decompositions: Australia (Benchmark Case)

		Australia			
		$\hat{q}_t$	$\hat{y}_t$	$\hat{\pi}_t$	$\hat{r}_t$
Tradable technology shock	1	22.467	3.1036	41.741	88.944
	4	9.6759	7.6476	44.695	84.327
	8	8.7875	8.4854	44.529	80.731
	12	8.7492	9.5310	44.380	78.138
Non-tradable technology shock	1	0.3787	0.1919	42.271	0.0031
	4	0.2852	8.4524	31.617	0.4638
	8	0.2515	9.4378	31.456	0.4818
	12	0.2591	9.3024	30.444	0.6278
Risk premium shock	1	22.654	26.226	0.1197	5.2198
	4	9.1217	32.672	6.4224	6.4723
	8	8.2607	31.525	6.8485	7.5662
	12	8.1530	31.338	7.7268	8.3027
Monetary policy shock	1	0.0935	1.4956	0.0108	2.4559
	4	0.0402	1.0726	0.0323	2.2955
	8	0.0283	1.0235	0.0390	2.1533
	12	0.0262	1.0062	0.0391	2.0586
Government spending shock	1	0.0000	3.7558	0.0064	0.0150
	4	0.0003	2.6604	0.0049	0.0139
	8	0.0004	2.5367	0.0049	0.0131
	12	0.0004	2.4938	0.0047	0.0125
Foreign price shock	1	54.149	65.210	15.850	3.2480
	4	80.765	47.318	17.125	6.2920
	8	82.570	46.816	17.012	8.9159
	12	82.711	46.152	17.288	10.718
Foreign interest rate shock	1	0.2469	0.0076	0.0001	0.1137
	4	0.1025	0.1704	0.1034	0.1341
	8	0.0944	0.1689	0.1088	0.1361
	12	0.0947	0.1701	0.1148	0.1401
Foreign output shock	1	0.0108	0.0096	0.0009	0.0002
	4	0.0088	0.0069	0.0010	0.0016
	8	0.0070	0.0067	0.0018	0.0023
	12	0.0066	0.0066	0.0020	0.0025

Table 13: Variance Decompositions: Canada (Benchmark Case)

		Canada			
		$\hat{q}_t$	$\hat{y}_t$	$\hat{\pi}_t$	$\hat{r}_t$
Tradable technology shock	1	5.1914	10.347	18.272	66.608
	4	1.9933	4.7231	24.989	37.988
	8	2.3273	5.4077	21.113	33.360
	12	2.3440	5.7784	21.290	33.007
Non-tradable technology shock	1	0.3695	0.0342	58.139	0.0321
	4	0.2658	1.6453	33.108	0.1370
	8	0.2391	1.5716	27.087	0.1393
	12	0.2411	1.5363	26.093	0.2186
Risk premium shock	1	3.6453	12.770	3.0656	0.7467
	4	1.3200	6.1700	6.2706	0.8094
	8	1.3806	5.1894	5.3194	1.1837
	12	1.3829	5.1548	5.4396	1.3449
Monetary policy shock	1	0.0778	0.2504	0.1156	3.6382
	4	0.0274	0.1095	0.1133	2.0518
	8	0.0217	0.0887	0.0960	1.7346
	12	0.0211	0.0866	0.0926	1.6975
Government spending shock	1	0.0000	1.1899	0.0189	0.0381
	4	0.0006	0.4601	0.0121	0.0216
	8	0.0007	0.3726	0.0101	0.0184
	12	0.0007	0.3636	0.0097	0.0180
Foreign price shock	1	90.395	74.592	20.100	28.793
	4	96.255	86.462	34.946	58.854
	8	95.892	87.003	45.882	63.400
	12	95.871	86.714	46.570	63.536
Foreign interest rate shock	1	0.2387	0.7616	0.1275	0.1436
	4	0.0887	0.3884	0.4376	0.1106
	8	0.0989	0.3306	0.3758	0.1354
	12	0.1000	0.3312	0.3916	0.1501
Foreign output shock	1	0.0824	0.0544	0.1611	0.0001
	4	0.0492	0.0412	0.1231	0.0282
	8	0.0400	0.0363	0.1167	0.0284
	12	0.0390	0.0356	0.1136	0.0285

Table 14: Variance Decompositions: New Zealand ($\alpha_x = 0$)

		New Zealand			
		$\hat{q}_t$	$\hat{y}_t$	$\hat{\pi}_t$	$\hat{r}_t$
Tradable technology shock	1	10.495	58.424	61.663	28.504
	4	15.895	54.543	61.838	60.655
	8	18.858	55.383	74.622	66.160
	12	18.988	55.600	73.213	64.545
Non-tradable technology shock	1	0.3275	0.0001	4.8767	0.1892
	4	0.2369	0.0406	3.3527	0.0908
	8	0.2246	0.0438	1.6771	0.0838
	12	0.2331	0.0449	1.3312	0.1064
Risk premium shock	1	2.1720	0.2871	0.1737	0.0024
	4	0.7845	0.3166	0.3098	0.1347
	8	1.0895	0.3569	0.2565	0.2991
	12	1.1289	0.3718	0.2996	0.2888
Monetary policy shock	1	0.0380	0.0037	0.0043	0.8157
	4	0.0135	0.0042	0.0081	0.3885
	8	0.0111	0.0041	0.0051	0.1966
	12	0.0110	0.0040	0.0040	0.1502
Government spending shock	1	0.0001	0.0368	0.0019	0.0058
	4	0.0005	0.0338	0.0016	0.0027
	8	0.0005	0.0327	0.0008	0.0014
	12	0.0005	0.0325	0.0006	0.0011
Foreign price shock	1	86.961	41.245	33.280	70.483
	4	83.065	45.058	34.489	38.726
	8	79.809	44.175	23.436	33.255
	12	79.631	43.943	25.148	34.904
Foreign interest rate shock	1	0.0040	0.0037	0.0001	0.0002
	4	0.0026	0.0035	0.0002	0.0028
	8	0.0054	0.0039	0.0022	0.0045
	12	0.0058	0.0040	0.0031	0.0045
Foreign output shock	1	0.0032	0.0000	0.0002	0.0002
	4	0.0023	0.0001	0.0003	0.0002
	8	0.0020	0.0001	0.0002	0.0001
	12	0.0020	0.0001	0.0002	0.0001

Table 15: Variance Decompositions: United Kingdom (Benchmark Case)

		United Kingdom			
		$\hat{q}_t$	$\hat{y}_t$	$\hat{\pi}_t$	$\hat{r}_t$
Tradable technology shock	1	6.3697	3.0971	44.256	74.589
	4	2.3353	3.2202	40.084	70.704
	8	2.1928	3.9360	39.847	69.969
	12	2.1275	4.0505	39.799	69.757
Non-tradable technology shock	1	0.3859	0.0384	32.936	0.0246
	4	0.3050	1.5747	26.641	0.2059
	8	0.2615	1.7927	26.578	0.2253
	12	0.2589	1.7938	26.516	0.3126
Risk premium shock	1	18.352	4.7439	0.3548	0.9746
	4	6.4047	4.7234	2.9242	1.1440
	8	5.6713	4.5550	3.0308	1.4761
	12	5.5346	4.5597	3.2285	1.6716
Monetary policy shock	1	0.0790	0.1474	0.0053	1.8857
	4	0.0261	0.1194	0.0154	1.7879
	8	0.0194	0.1145	0.0175	1.7650
	12	0.0185	0.1140	0.0183	1.7605
Government spending shock	1	0.0001	0.4970	0.0051	0.0129
	4	0.0004	0.4007	0.0041	0.0122
	8	0.0004	0.3844	0.0041	0.0121
	12	0.0004	0.3826	0.0041	0.0120
Foreign price shock	1	74.644	91.442	22.439	22.506
	4	90.863	89.927	30.309	26.137
	8	91.798	89.184	30.499	26.541
	12	92.005	89.066	30.408	26.473
Foreign interest rate shock	1	0.1336	0.0347	0.0027	0.0067
	4	0.0466	0.0345	0.0212	0.0079
	8	0.0411	0.0333	0.0219	0.0103
	12	0.0401	0.0333	0.0233	0.0117
Foreign output shock	1	0.0355	0.0000	0.0010	0.0002
	4	0.0194	0.0003	0.0014	0.0011
	8	0.0151	0.0003	0.0017	0.0013
	12	0.0145	0.0003	0.0017	0.0013

Table 16: Log Marginal Likelihood Values: UK 92:4–06:4

Log Marginal Data Density	**United Kingdom**
Endogenous q_t ($\alpha_x \cdot \Delta q_t$)	964.9776
Endogenous q_t ($\alpha_x \cdot \Delta s_t$)	958.4531
Endogenous q_t ($\alpha_x \cdot \Delta rp_t$)	958.4522
Endogenous q_t ($\alpha_x = 0$)	961.4617

Table 17: Parameter Estimates: United Kingdom, 1992Q4–2006Q4

	United Kingdom							
	Prior Distribution			Posterior Maximization		Posterior Distribution		
Parameters	Distribution	Mean	Std	Mode	Std Error	Mean	10%	90%
ψ_d	Beta	0.70	0.10	0.6081	0.0535	0.6412	0.5441	0.7394
ψ_w	Beta	0.70	0.10	0.7756	0.0495	0.7707	0.6862	0.8577
τ_d	Beta	0.50	0.15	0.4727	0.0994	0.4867	0.3203	0.6539
τ_w	Beta	0.50	0.15	0.2613	0.1009	0.2828	0.1216	0.4371
ϕ	Beta	0.30	0.10	0.3061	0.1115	0.3270	0.1559	0.4966
ϕ^*	Beta	0.40	0.10	0.3224	0.0864	0.3350	0.1980	0.4692
σ	Gamma	1.50	0.25	1.5614	0.2616	1.6335	1.1812	2.0549
σ_f	Gamma	1.50	0.25	1.9874	0.1780	1.9955	1.7019	2.2797
ρ_r	Beta	0.80	0.10	0.9168	0.0158	0.9160	0.8888	0.9425
α_π	Gamma	1.60	0.10	1.5296	0.0960	1.5413	1.3804	1.7027
α_y	Gamma	0.50	0.20	0.9555	0.2390	0.9965	0.5770	1.3864
α_x	Gamma	0.25	0.10	0.1169	0.0455	0.1340	0.0549	0.2077
φ_s	Gamma	0.45	0.20	0.3696	0.0366	0.3723	0.3116	0.4349
φ_n	Gamma	0.01	0.005	0.0250	0.0066	0.0269	0.0154	0.0379
χ	Gamma	10.0	2.00	13.049	2.0516	13.544	10.151	17.009
ϱ	Beta	0.40	0.10	0.7765	0.0471	0.7475	0.6590	0.8351
ρ_p	Beta	0.80	0.10	0.6466	0.0760	0.6333	0.5015	0.7661
ρ_{AT}	Beta	0.85	0.05	0.9385	0.0253	0.9151	0.8649	0.9665
ρ_{AN}	Beta	0.80	0.10	0.4732	0.0802	0.4420	0.3078	0.5729
ρ_φ	Beta	0.80	0.10	0.7721	0.0935	0.7510	0.6103	0.8940
σ_p	Inv Gamma	0.01	4.00	0.0487	0.0116	0.0458	0.0277	0.0624
σ_r	Inv Gamma	0.01	4.00	0.0014	0.0002	0.0015	0.0012	0.0017
σ_{AT}	Inv Gamma	0.01	4.00	0.0234	0.0060	0.0295	0.0162	0.0428
σ_{AN}	Inv Gamma	0.01	4.00	0.0201	0.0064	0.0296	0.0125	0.0493
σ_φ	Inv Gamma	0.01	4.00	0.0098	0.0025	0.0111	0.0069	0.0154

Table 18: Log Marginal Likelihood Values: Expected Inflation Targeting

	Country			
Log Marginal Data Density	**Australia**	**Canada**	**United Kingdom**	**New Zealand**
Endogenous q_t $(\alpha_x \cdot \Delta q_t)$	1261.6177	2326.7813	1658.5019	1115.4667
Endogenous q_t $(\alpha_x \cdot \Delta s_t)$	1253.9685	2325.0873	1651.5374	1119.7415
Endogenous q_t $(\alpha_x \cdot \Delta rp_t)$	1251.6252	2311.5038	1658.5931	1115.8417
Endogenous q_t $(\alpha_x = 0)$	1255.6925	2316.3575	1651.9159	1118.5223

Table 19: Log Marginal Likelihood Values: Sectoral Inflation Targeting

	Country			
Log Marginal Data Density	**Australia**	**Canada**	**United Kingdom**	**New Zealand**
Endogenous q_t $(\alpha_x \cdot \Delta q_t)$	1228.6918	2284.9469	1640.7986	1116.6667
Endogenous q_t $(\alpha_x \cdot \Delta s_t)$	1228.3615	2269.4721	1643.9991	1118.5154
Endogenous q_t $(\alpha_x \cdot \Delta rp_t)$	1214.8495	2262.5347	1642.9832	1116.4205
Endogenous q_t $(\alpha_x = 0)$	1221.8707	2242.7252	1638.2943	1119.7792

Table 20: Log Marginal Likelihood Values: Wage Inflation Targeting

	Country			
Log Marginal Data Density	**Australia**	**Canada**	**United Kingdom**	**New Zealand**
Endogenous q_t $(\alpha_x \cdot \Delta q_t)$	1232.7349	2290.8191	1643.5816	1112.0690
Endogenous q_t $(\alpha_x \cdot \Delta s_t)$	1236.3383	2314.9504	1646.1704	1119.5378
Endogenous q_t $(\alpha_x \cdot \Delta rp_t)$	1234.6392	2265.5657	1632.9093	1113.1133
Endogenous q_t $(\alpha_x = 0)$	1228.8551	2285.1957	1638.9422	1113.6355

Figure 1: Impulse Responses: Canada

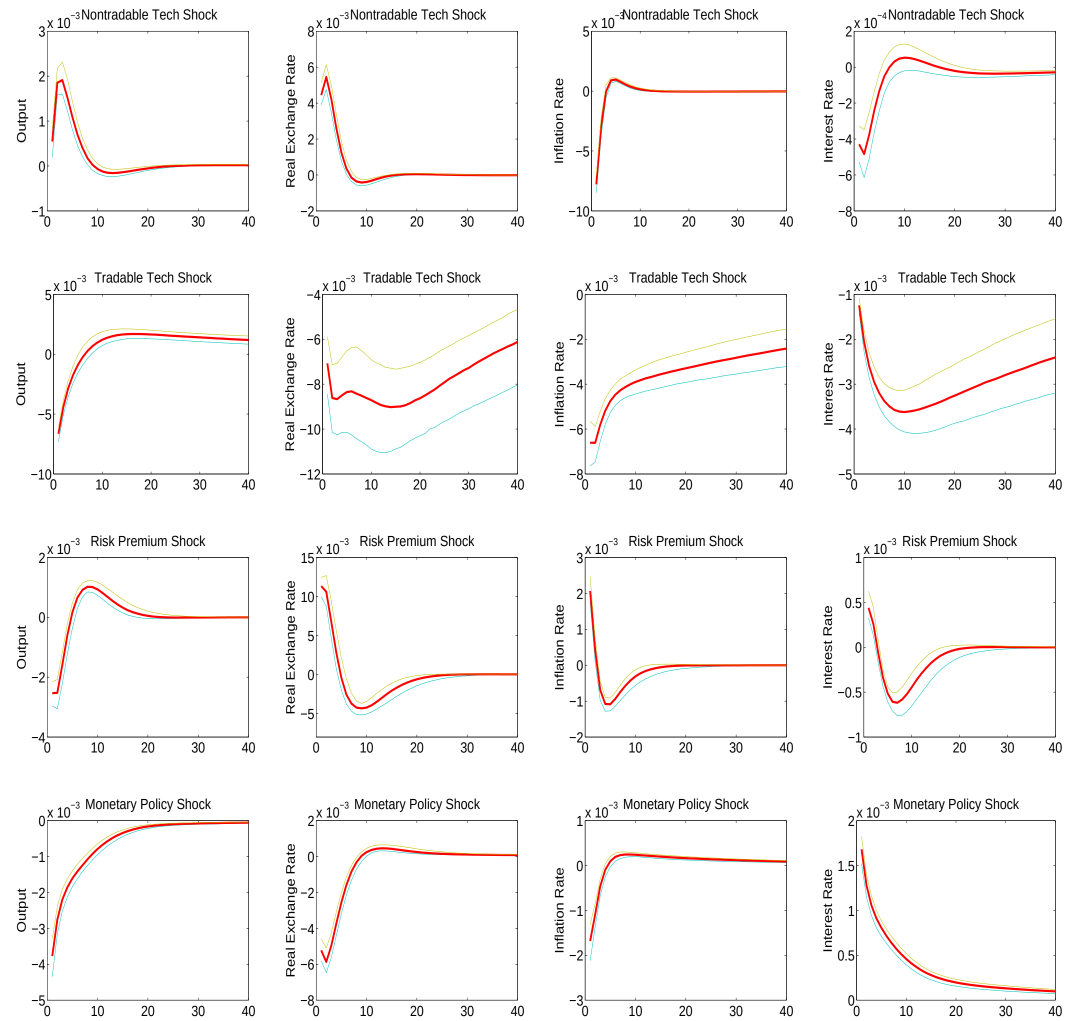

Figure 2: Impulse Responses: Canada