BANK OF CANADA
BANQUE DU CANADA

Working Paper/Document de travail
2007-54

Expenditure-Switching Effect and the Choice of Exchange Rate Regime

by Wei Dong

www.bank-banque-canada.ca

Bank of Canada Working Paper 2007-54

November 2007

Expenditure-Switching Effect and the Choice of Exchange Rate Regime

by

Wei Dong

International Department
Bank of Canada
Ottawa, Ontario, Canada K1A 0G9
wdong@bankofcanada.ca

ISSN 1701-9397

Acknowledgements

I am indebted to Charles Engel for his invaluable advice, support, and intellectual guidance in my economic research in general, and in my preparation of this paper specifically. I thank Kenneth West, Menzie Chinn, Bruce Hansen, Larry Schembri, Don Coletti, Robert Lafrance, James Nason, Michael Devereux, Eric Santor, Ali Dib, and numerous seminar participants for helpful comments.

Abstract

The author investigates the quantitative importance of the expenditure-switching effect by developing and estimating a structural sticky-price model nesting both producer currency pricing (PCP) and local currency pricing (LCP) settings. The author aims to provide empirical evidence of the magnitude of the benefits to be gained from exchange rate flexibility in terms of expenditure switching, and to contribute to the ongoing debate regarding the optimal exchange rate regime. In the author's model, the size of the expenditure-switching effect is determined by the degree of price stickiness, the fraction of firms employing PCP versus LCP, the distribution margin, and the elasticity of substitution between domestic and foreign tradable goods. The model is estimated for three small open economies: Australia, Canada, and the United Kingdom. The empirical results suggest that, among the three countries, the magnitude of the expenditure switching by domestic agents is relatively small for the United Kingdom, and comparatively large for Canada; the distribution margin in the United Kingdom is exceptionally high, which limits the degree of domestic expenditure switching initiated by nominal exchange rate movements. Moreover, expenditure switching by foreign distributors is comparatively small for Australia and Canada, since a larger fraction of Australian and Canadian firms adopt LCP for their export price-setting.

JEL classification: F3, F4
Bank classification: Exchange rate regimes; International topics

Résumé

L'auteure s'attache à mesurer l'ampleur des transferts de dépenses imputables aux variations du taux de change. Pour ce faire, elle élabore et estime un modèle structurel à prix rigides autorisant une facturation dans la monnaie des pays producteurs et dans celle des pays importateurs. Elle s'efforce de recueillir des indications empiriques sur la valeur des avantages que procureraient les régimes de changes flottants en favorisant des transferts de dépenses. Elle entend prendre ainsi part au débat en cours sur le choix d'un régime de change optimal. Dans le modèle, la taille des transferts de dépenses dépend du degré de rigidité des prix, de la proportion des entreprises qui fixent leurs prix dans la monnaie de leur pays d'attache plutôt que dans celle de leurs clients étrangers, de la marge de distribution et du niveau de substituabilité des biens échangeables produits localement et importés. L'auteure estime son modèle pour trois petites économies ouvertes : l'Australie, le Canada et le Royaume-Uni. Selon les résultats empiriques, les transferts de dépenses des agents nationaux sont plutôt faibles au Royaume-Uni, mais relativement importants au Canada; la marge de distribution étant particulièrement élevée au Royaume-Uni, l'ampleur des transferts de dépenses attribuables aux variations du taux de change nominal s'y trouve limitée. En Australie et au Canada, les transferts dont sont responsables les distributeurs étrangers sont plutôt modestes, car une bonne partie des entreprises résidentes facturent leurs exportations dans la monnaie des pays importateurs.

Classification JEL : F3, F4
Classification de la Banque : Régimes de taux de change; Questions internationales

1 Introduction

Few questions in international macroeconomics have aroused more debate than the choice of exchange rate regime. While the economic literature offers many models, theories and propositions, little consensus has yet to emerge on how to answer the question of whether a country should adopt a fixed or flexible exchange rate regime.

In 1953, Milton Friedman put forward a well known hypothesis in support of flexible exchange rate regimes. He argued that when prices are sticky, a floating exchange rate regime is preferable, because nominal exchange rate movements can adjust the relative prices of home goods and foreign goods, allowing for a smoother adjustment of quantities through changes in exchange rates. For example, an initial current account deficit in the home country will tend to depreciate the home currency, which then induces a decline in the relative price of its output. This relative price movement eventually leads to a switch in expenditure towards home products — and hence an increase in the trade balance. The magnitude of the expenditure-switching effect, which is defined as the adjustment of relative demand in response to nominal exchange rate movements, therefore suggests the quantitative importance of the benefits from exchange rate flexibility.

Since Friedman set forth his hypothesis, several theories have been brought forward to either confirm or challenge his original intuition. Among others, the work of Obstfeld and Rogoff (1995, 1998, 2000) has offered a consistent and logical framework featuring producer currency pricing (PCP), which supports the idea that a floating exchange rate regime is desirable. Obstfeld (2001) models import goods as intermediate products, and allows final good producers to substitute between imports and domestically produced alternatives. The model combines local currency invoicing for non-tradable final consumption goods and PCP for tradable intermediate goods. This implies that there is limited pass-through of exchange rate movements to retail prices, but full pass-through to import prices. When prices are sluggish, nominal exchange rate changes can induce expenditure switching at the local producers' level, an advantage often attributed to a flexible exchange rate regime over a fixed exchange rate regime. In this sense, a flexible exchange rate regime is optimal.

On the other hand, quite a few papers in the international macroeconomics literature, beginning with the work of Betts and Devereux (1996), have re-examined these issues under a local currency pricing (LCP) setting and have come to different conclusions. Regarding the optimal exchange rate regime, for example, Devereux and Engel (2003) have examined monetary policy under the LCP setting, and concluded that the optimal monetary policy leads to a fixed exchange rate. Put simply, when prices are sticky in the local currency, there is no expenditure-switching effect from changes in the nominal exchange rate, and therefore there is no benefit to exchange rate flexibility. Instead, nominal exchange rate flexibility leads only to deviation from purchasing power parity without achieving any relative price adjustment.

It is difficult to establish an acceptable model with this variety of opinion, to resolve the debate over exchange rate regime choice. The two leading models have come to exact opposite conclusions about the expenditure-switching effect. But, it is the actual quantitative importance of the expenditure-switching effect that is crucial for determining whether exchange rate flexibility is preferable. For example, Devereux and Engel (2006) examine the variability of exchange rates under the optimal monetary policy and find that the variance of the optimal exchange rate falls with the elasticity of substitution between home and foreign intermediate inputs. Since the magnitude of expenditure switching depends positively on that elasticity, when the size of the expenditure-switching effect is small, the optimal amount of exchange rate volatility should also be small.[1] Therefore, empirical study is needed to examine the quantitative significance of the expenditure-switching effect. It is hard to layout a direct and simple relationship showing how the degree to which central banks want to stabilize exchange rates should depend on the size of the expenditure-switching effect. But the magnitude of expenditure switching matters to the choice of exchange rate policy.

In the international macroeconomic literature, many studies have also examined exchange rate pass-through, the degree to which exchange rate movements are reflected in changes in import prices. Exchange rate pass-through is defined as the percentage change in local currency import prices resulting from a one percent change in the exchange rate. A typical pass-through regression estimates how import prices respond to exchange rate fluctuations.[2] But since exchange rate changes also have feedback effects on domestic prices through marginal cost adjustment, some pass-though studies estimate an equation in which the relative price is a function of the exchange rate, cost factors, et al.[3] In this case, costs, and thus errors in cost measurements, will influence the ratio only when there is a difference in the demand elasticity of the two markets.[4] While their econometric techniques may differ, these studies all focus on pass-through effects. They do not go further to investigate the role of expenditure switching, which is precisely what matters in the exchange rate regime debate.[5]

This paper seeks to gain insight into the exchange rate regime debate by directly estimating the quantitative importance of the expenditure-switching effect. If the effect turns out to be insignificant, the benefits to be gained from exchange rate flexibility may not be large. For this purpose, I have developed a structural small open economy model featuring sticky prices and wages, distribution services, and a combination of PCP and LCP. The sticky price assumption is a must for the model, since the choice of exchange rate regime would be irrelevant if prices were flexible. The distribution sector is also key, since it allows me to study the impact of the distribution wedge on quantity adjustments in response to exchange rate movements. The empirical evidence suggests that there is partial pass-through to import prices in the short run. That does not seem to support either the pure PCP model or the pure LCP model. Similar to Corsetti and Pesenti (2005) and Bergin (2006), I have developed a general model that nests both PCP and LCP settings in this paper.

In the model, the magnitude of the expenditure-switching effect is influenced by the degree of price stickiness, the fraction of firms adopting PCP instead of LCP for their export goods, the distribution

[1] This by no means rules out the possibility that other aspects than the expenditure-switching effect have impacts on the exchange rate regime choice, for example, benefits from independent monetary policy and international trade stimulation due to stable exchange rates.

[2] See, for example, Campa and Goldberg (2005).

[3] See, for example, Corsetti, Dedola, and Leduc (2005).

[4] For extended surveys of the theory of exchange rate pass-through, see Goldberg and Knetter (1997).

[5] Other studies have examined how imports are affected by import prices, but the important link between exchange rates and relative prices is missing. Gourinchas (1999) evaluates the impact of exchange rate movements on job reallocations within and across sectors. But without a general equilibrium context, it is hard to assess his findings.

margin, and the elasticity of substitution between domestic varieties and import varieties. Expenditure switching appears both in domestic markets and in foreign markets where the substitution between domestic- and foreign-produced tradable goods occurs in response to exchange rate movements. Since there is no absolute measurement of what is a significant expenditure-switching effect, the model is taken to the data for several countries for comparison. The model is estimated using the Bayesian maximum likelihood estimation method for three countries: Australia, Canada, and the United Kingdom. The empirical results indicate that, among the three countries, the magnitude of the domestic expenditure-switching effect seems to be comparatively small for the United Kingdom. Although a somewhat smaller fraction of firms exporting to the UK price their goods in the local currency, the distribution margin in that country is exceptionally high, so exchange rate movements trigger only moderate expenditure switching. The opposite is true for Canada and Australia. On the other hand, a smaller fraction of UK firms adopt LCP for export pricing compared to Australian and Canadian firms, so expenditure switching by foreign agents is actually larger for the UK. To sum up, the benefits from exchange rate flexibility, in the sense of expenditure switching, are most significant for Canada in the domestic market; while for the UK, considerable substitution between domestic- and foreign-produced goods is in markets outside the country.

The remainder of this paper is organized as follows. Section 2 presents the theoretical model. Section 3 describes the data and the empirical strategy to be employed. Section 4 states he empirical results. Section 5 concludes the paper.

2 The Model

In this section, the basic model is described. The economy considered here is a small open economy, in the sense that the foreign price and the foreign interest rate are exogenous, and there is a downward sloping demand curve for its exports. The economy is characterized by : (1) a continuum of infinitely lived households; (2) competitive final tradable good producers; (3) a continuum of intermediate tradable good producers; (4) intermediate tradable good importers; (5) a continuum of non-tradable good producers; and (6) government and the monetary authority.

2.1 Households

2.1.1 Preferences

Households maximize expected utility discounted at the rate of time preference. Households are indexed by $i \in (0, 1)$. The lifetime utility is a function of consumption and labour supply.

$$U_t = E_t \Sigma_{t=0}^{\infty} \beta^t U(C_t^i, L_t^i),$$

where U is the instantaneous utility function, and β is the discount factor $(0 < \beta < 1)$.

The instantaneous utility function is assumed to take the form[6]

$$U = \frac{1}{1-\rho}(C_t^i - hC_{t-1})^{1-\rho} - \frac{1}{1+\mu}(L_t^i)^{1+\mu}.$$

Utility is assumed to depend positively on the consumption of goods by household i, and depend negatively on aggregate past consumption. The concept that consumers form habits in their consumption patterns has intuitive appeal and produces hump-shaped responses of consumption to exogenous shocks. In reality, consumption does not respond instantly to news, but instead demonstrates a gradual response to shocks over the course of several years. Finally, ρ is the coefficient of relative risk aversion of households, and μ is the inverse of labour supply elasticity.

The full consumption basket, C_t, is defined by the CES aggregate of consumption of tradable goods, $C_{T,t}$, and non-tradable goods, $C_{N,t}$, at the elasticity of substitution ς, and thus:

$$C_t = \left[\alpha_T^{\frac{1}{\varsigma}} C_{T,t}^{1-\frac{1}{\varsigma}} + (1-\alpha_T)^{\frac{1}{\varsigma}} C_{N,t}^{1-\frac{1}{\varsigma}}\right]^{\frac{\varsigma}{\varsigma-1}}. \tag{2.1}$$

The price index for the consumption bundle is:

$$P_t = \left[\alpha_T P_{T,t}^{1-\varsigma} + (1-\alpha_T) P_{N,t}^{1-\varsigma}\right]^{\frac{1}{1-\varsigma}}. \tag{2.2}$$

Households receive dividends D_t from the firms and a lump sum transfer τ_t from the government. A household of type i can provide labour service, $L_{N,t}$, to non-tradable good producers, and $L_{T,t}$ to intermediate tradable good producers, at the wage rate W_t^i. Households can purchase the domestic currency bond B_t, which pays a nominal domestic interest rate R_t. In addition, households can hold a noncontingent nominal bond denominated in foreign currency — B_t^*. This pays a gross interest rate R_t^*, which is subject to exogenous shocks:

$$\ln R_t^* = (1-\rho_{R^*}) \ln R^* + \rho_{R^*} \ln R_{t-1}^* + \epsilon_{R^*t}, \tag{2.3}$$

where ϵ_{R^*t} is normally distributed with zero mean and variance $\sigma_{R^*}^2$.

The representative household's budget constraint can then be expressed as:

$$\begin{aligned} C_t + \frac{P_{T,t}I_{T,t}}{P_t} + \frac{P_{N,t}I_{N,t}}{P_t} + \frac{P_{T,t}AC_{T,t}}{P_t} + \frac{P_{N,t}AC_{N,t}}{P_t} + \frac{S_tB_t^*}{P_tR_t^*rp_t} + \frac{B_t}{P_tR_t} = \\ \frac{D_t}{P_t} + \tau_t + \frac{r_{T,t}^k P_{T,t}K_{T,t-1}}{P_t} + \frac{r_{N,t}^k P_{N,t}K_{N,t-1}}{P_t} + \frac{W_tL_{T,t}}{P_t} + \frac{W_tL_{N,t}}{P_t} + \frac{S_tB_{t-1}^*}{P_{t-1}\pi_t} + \frac{B_{t-1}}{P_t}, \end{aligned}$$

where π_t is the gross consumption inflation rate, and S_t is the nominal exchange rate, defined as the price of foreign currency in terms of domestic currency. Capital is assumed to be sector-specific. $K_{T,t}$ denotes capital stock in the tradable sector, which is assumed to be owned by households and rented to intermediate firms at the rate $r_{T,t}^k$. $K_{N,t}$ denotes capital stock in the non-tradable sector, and the

[6] The functional form is commonly used in the New Open Economy Macroeconomics literature.

rental rate is $r^k_{N,t}$. Investment in new capital is assumed to involve quadratic adjustment costs given by:

$$
\begin{aligned}
AC_{T,t} &= \frac{\chi}{2}\frac{(K_{T,t}-K_{T,t-1})^2}{K_{T,t-1}} \\
AC_{N,t} &= \frac{\chi}{2}\frac{(K_{N,t}-K_{N,t-1})^2}{K_{N,t-1}},
\end{aligned}
$$

and $K_{T,t}$ and $K_{N,t}$ evolves following the law of motion:

$$
\begin{aligned}
K_{T,t} &= (1-\delta)K_{T,t-1} + I_{T,t} \\
K_{N,t} &= (1-\delta)K_{N,t-1} + I_{N,t}.
\end{aligned}
\tag{2.4}
$$

rp_t is a debt-elastic interest rate premium, and is used as a stationarity-inducing technique to ensure the existence of a unique steady state.[7] The risk premium depends on the country's net foreign debt and the expected change in the exchange rate E_tS_{t+1}/S_{t-1}, following Adolfson et al. (2007). This is based on the observation of the forward premium puzzle, which suggests a negative correlation between the risk premium and the expected changes in exchange rates. If the domestic currency is expected to appreciate (depreciate) consecutively, domestic investors will require a higher (lower) return on their foreign bond holdings. 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. Finally, $\hat{\varphi}_t$ represents the risk premium shock, which is adopted due to the well documented empirical weakness of the uncovered interest rate parity condition. The shock is assumed to follow an AR(1) process, with the error term $\epsilon_{\varphi t}$ normally distributed with zero mean and variance σ^2_{φ}, and:

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

where $\xi_t \equiv S_tB^*_t/P_tY_t$.

2.1.2 Households' Intertemporal Decisions

In the labour market, households act as price-setters and meet the demand for their particular type of labour service. Wage rates are assumed to be set in a staggered fashion, following Calvo (1983). That is, in each period, only those households who receive random signals to change their wage rates can optimally adjust their nominal wages. The probability that households receive such a signal is constant and equal to $1-\psi_w$. In addition, we allow partial indexation for households not receiving such signals in each period to index their wages rates to past inflation according to:

[7] For other ways of inducing stationarity of the equilibrium dynamics for small open economy models, see Schmitt-Grohé and Uribe (2003).

$$W_t^i = \left(\frac{P_{t-1}}{P_{t-2}}\right)^{\tau_w} W_{t-1}^i, \tag{2.5}$$

where τ_w is the degree of wage indexation. Let ϖ_t^i be the new wage rate for labour service of type i at time t. Households choose ϖ_t^i to maximize the lifetime utility subject to the budget constraint holding in all periods as well as meeting the demand for type i labor service, such that:

$$L_t^i = L_{T,t}^i + L_{N,t}^i.$$

The optimal value of ϖ_t^i is set according to:

$$\varpi_t^i = \frac{E_t \Sigma_{j=0}^{\infty} (\psi_w \beta)^j \gamma (\varpi_t^i)^{-\gamma\mu} W_{t+j}^{\gamma(1+\mu)} L_{t+j}^{1+\mu} (P_{t+j-1}/P_{t-1})^{-\tau_w \gamma(1+\mu)}}{E_t \Sigma_{j=0}^{\infty} (\psi_w \beta)^j (\gamma - 1) W_{t+j}^{\gamma} L_{t+j} P_{t+j}^{-1} (C_{t+j} - hC_{t+j-1})^{-\rho} (P_{t+j-1}/P_{t-1})^{-\tau_w(\gamma-1)}} = \varpi_t.$$

The wage index W_t is related to ϖ_t via the relationship:

$$W_t = \left\{ \psi_w \left[W_{t-1} \left(\frac{P_{t-1}}{P_{t-2}}\right)^{\tau_w} \right]^{1-\gamma} + (1 - \psi_w) \varpi_t^{1-\gamma} \right\}^{\frac{1}{1-\gamma}}. \tag{2.6}$$

The first-order condition characterizing the optimal consumption path is given by Euler's equation:

$$\frac{(C_t - hC_{t-1})^{-\rho} S_t}{R_t^* rp_t} = \beta E_t \frac{(C_{t+1} - hC_t)^{-\rho} S_{t+1}}{\pi_{t+1}}. \tag{2.7}$$

The demand for tradable and non-tradable goods are given by:

$$C_{T,t} = \alpha_T \left(\frac{P_{T,t}}{P_t}\right)^{-\varsigma} C_t \tag{2.8}$$

$$C_{N,t} = (1 - \alpha_T) \left(\frac{P_{N,t}}{P_t}\right)^{-\varsigma} C_t. \tag{2.9}$$

Capital accumulation is set so that the cost is equal to the expected benefit of holding capital stock:

$$\left[\frac{\chi(K_{T,t} - K_{T,t-1})}{K_{T,t-1}} + 1\right] = \Lambda_{t,t+1} \left[\frac{\chi(K_{T,t+1}^2 - K_{T,t}^2)}{2K_{T,t}^2} + 1 - \delta + r_{T,t+1}^k\right] \tag{2.10}$$

$$\left[\frac{\chi(K_{N,t} - K_{N,t-1})}{K_{N,t-1}} + 1\right] = \Lambda_{t,t+1} \left[\frac{\chi(K_{N,t+1}^2 - K_{N,t}^2)}{2K_{N,t}^2} + 1 - \delta + r_{N,t+1}^k\right], \tag{2.11}$$

where $\Lambda_{t,t+1} = \dfrac{\beta E_t (C_{t+1} - hC_t)^{-\rho}}{(C_t - hC_{t-1})^{-\rho}}$. A simple arbitrage argument yields:

$$\frac{R_t}{R_t^* rp_t} = E_t \frac{S_{t+1}}{S_t}. \tag{2.12}$$

2.2 Tradable Sector

2.2.1 Final Good Producers

Competitive final good producers use composites of differentiated intermediate tradable goods to produce final goods for consumption and investment. The technology is given by a CES production function:

$$Y_{T,t}(k) = \left[\alpha_H^{\frac{1}{\sigma}} Y_{H,t}^{1-\frac{1}{\sigma}} + (1-\alpha_H)^{\frac{1}{\sigma}} Y_{F,t}^{1-\frac{1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \tag{2.13}$$

where $Y_{H,t}(k)$ denotes the amount of home-variety intermediate goods used in the small open economy's final good production by firm k. Correspondingly, $Y_{F,t}(k)$ denotes the amount of foreign-variety intermediate goods imported for the final good production by firm k. The elasticity of substitution between domestic and foreign intermediate goods is assumed to be σ. The elasticity of substitution between varieties within one country is assumed to be ε.

Profit maximization by final good producers entails:

$$Y_{H,t} = \alpha_H \left(\frac{P_{H,t}}{P_{T,t}}\right)^{-\sigma} Y_{T,t} \tag{2.14}$$

$$Y_{F,t} = (1-\alpha_H) \left(\frac{P_{F,t}}{P_{T,t}}\right)^{-\sigma} Y_{T,t} \tag{2.15}$$

$$P_{T,t} = \left[\alpha_H P_{H,t}^{1-\sigma} + (1-\alpha_H) P_{F,t}^{1-\sigma}\right]^{\frac{1}{1-\sigma}}. \tag{2.16}$$

Final tradable goods are used for consumption and investment by households, and for consumption by the government. The final good market clearing condition implies that:

$$Y_{T,t} = C_{T,t} + I_{T,t} + G_{T,t} + AC_{T,t}. \tag{2.17}$$

2.2.2 Intermediate Good Suppliers

There are two types of intermediate good suppliers in the small open economy. The first type produces the intermediate goods to supply the home market and to export to foreign countries. The second type imports the intermediate goods produced by foreign firms for resale in the domestic market.

Intermediate Good Producers

Each intermediate good producer produces its differentiated good with capital and labour; and the elasticity of substitution among varieties of labour types is γ. Let $s \in [0,1]$ be the index of intermediate good varieties, and the Cobb Douglas technology is given by:

$$Z_{T,t}(s) = A_{T,t} K_{T,t-1}(s)^{\eta} L_{T,t}(s)^{1-\eta} \tag{2.18}$$

$$L_{T,t}(s) = \left[\int_0^1 l^i_{T,t}(s)^{1-\frac{1}{\gamma}} di \right]^{\frac{\gamma}{\gamma-1}},$$

where $Z_{T,t}$ denotes the intermediate tradable output, $L_{T,t}$ is the aggregate labour input into the intermediate good production, and $l^i_{T,t}(s)$ is the amount of type i labour used in variety s intermediate good production. The technology shock $A_{T,t}$ is assumed to follow a stochastic process:

$$\ln A_{T,t} = (1 - \rho_{AT}) \ln A_T + \rho_{AT} \ln A_{T,t-1} + \epsilon_{ATt}, \tag{2.19}$$

where ϵ_{ATt} is normally distributed with zero mean and variance σ^2_{AT}.

Cost minimization implies that the optimal trade-off between capital and labour depends on their relative costs:

$$\frac{W_t L_{T,t}(s)}{P_{T,t} r^k_{T,t} K_{T,t-1}(s)} = \frac{1-\eta}{\eta}. \tag{2.20}$$

The market clearing condition implies that:

$$Z_{T,t}(s) = Y_{H,t}(s) + Y^*_{H,t}(s), \tag{2.21}$$

where $Y^*_{H,t}(s)$ denotes the amount of home-produced intermediate goods of variety s exported to foreign countries.

A hybrid case is considered here in which some intermediate firms use PCP while others use LCP to set their export prices. Intermediate good prices set in both the domestic market and the foreign market are assumed to be sticky. We assume the probability that intermediate good firms will change prices in each period is $1 - \psi_d$, the degree of price indexation is τ_d, and the proportion of domestic firms using LCP to set a new price at each period is constant and equal to ϕ. Recent studies have debated whether exchange rate pass-through into import prices may have declined in recent years in industrialized countries. For the United States, Marazzi et al. (2005) estimated a significant step down in the pass-through coefficient around the year of 1997. But as Campa and Goldberg (2006) suggest, the evidence is mixed for other countries. They conducted tests based on a similar approach as Marazzi et al. (2005) for 15 countries and found that it is difficult to make a case that exchange rate pass-through into import prices has systematically declined. In addition, Bouakez and Rebei (2005) address the question of declining pass-through for Canada within a dynamic stochastic general equilibrium framework and conclude that the pass-through to Canadian import prices has been stable, while pass-through to Canadian consumer prices has declined in recent years. Even if we leave the partial equilibrium and general equilibrium methodology debate aside, overall it seems reasonable to assume that the fraction ϕ of exporters adopting LCP is constant.

Each intermediate tradable good firm acts as a monopolistic competitor, and it sets a price for its variety of good and meets the demand at that price. It is assumed that the foreign demand for exports of the small open economy is given by:

$$Y^*_{H,t} = \alpha_f \left(\frac{P^*_{H,t}}{P^*_t} \right)^{-\sigma_f} Y^*_t, \tag{2.22}$$

where $P^*_{H,t}$ is the price index for home-produced intermediate goods in the foreign market, P^*_t is the foreign price level, and Y^*_t represents foreign output. The foreign variable Y^*_t is assumed to follow a first-order autoregressive process, and the foreign variable P^*_t is defined as follows:

$$\ln Y^*_t = (1 - \rho_{y^*}) \ln Y^* + \rho_{y^*} \ln Y^*_{t-1} + \epsilon_{y^*t} \tag{2.23}$$

$$\ln P^*_t = \phi^* (\ln(P^*_{l,t}/S_t)) + (1 - \phi^*) \ln P^*_{p,t} \tag{2.24}$$

$$\ln(P^*_{l,t}/P^*_{l,t-1}) = (1 - \rho_{p^*}) \ln(\pi^*_l) + \rho_{p^*} \ln(P^*_{l,t-1}/P^*_{l,t-2}) + \epsilon_{p^*t} \tag{2.25}$$

$$\ln(P^*_{p,t}/P^*_{p,t-1}) = \ln(P^*_{l,t}/P^*_{l,t-1}), \tag{2.26}$$

where ϕ^* is the proportion of firms using LCP to set export prices at each period in the foreign country; $P^*_{l,t}$ is the foreign LCP price index; and $P^*_{p,t}$ is the foreign PCP price index. For simplicity, the log inflation rate for each price index is assumed to be the same. The error terms ϵ_{y^*t} and ϵ_{p^*t} are normally distributed with zero means and variances $\sigma^2_{y^*}$ and $\sigma^2_{p^*}$.

Now, consider a PCP intermediate good producer in the small open economy who is randomly selected to set new prices at time t. Let $X_{H,t}(s)$ and $X^p_{H,t}(s)$ denote the prices chosen by the firm in the home market and the foreign market, respectively, where the superscript p indicates PCP setting. If the price is still in effect at time $t + j$, then the firm's sales in the domestic market and the foreign market, respectively, are given by:

$$Y_{ht+j}(s) = Y_{ht+j} \left(\frac{X_{H,t}(s)(P_{t+j-1}/P_{t-1})^{\tau_d}}{P_{ht+j}} \right)^{-\varepsilon} \tag{2.27}$$

$$Y^p_{ht+j}(s) = Y^*_{ht+j} \left(\frac{X^p_{H,t}(s)(P_{t+j-1}/P_{t-1})^{\tau_d}}{S_{t+j} P^*_{ht+j}} \right)^{-\varepsilon}. \tag{2.28}$$

Since the probability that $X_{H,t}(s)$ and $X^p_{H,t}(s)$ are still in effect at date $t + j$ is ψ^j_d, the firm chooses $X_{H,t}(s)$ and $X^p_{H,t}(s)$ to maximize the present discounted value of profits:

$$E_t \Sigma^\infty_{j=0} \psi^j_d \Gamma_{t,t+j} \left\{ X_{H,t}(s) \left(\frac{P_{t+j-1}}{P_{t-1}} \right)^{\tau_d} Y_{ht+j}(s) + X^p_{H,t}(s) \left(\frac{P_{t+j-1}}{P_{t-1}} \right)^{\tau_d} Y^p_{ht+j}(s) \right.$$
$$\left. - MC_{T,t+j}[Y_{ht+j}(s) + Y^p_{ht+j}(s)] \right\},$$

where the marginal cost is given by:

$$MC_{T,t+j} = \frac{(1-\eta)^{\eta-1}(r^k_{T,t+j} P_{T,t+j})^\eta}{\eta^\eta W^{\eta-1}_{t+j} A_{T,t+j}}.$$

$\Gamma_{t,t+j}$ is the stochastic discount factor that is expressed in units of the consumption good,

$$\Gamma_{t,t+j} = \beta^j \frac{U_{c,t+j}/P_{t+j}}{U_{c,t}/P_t}.$$

Substitute (2.27) and (2.28) into the profit function and obtain the first-order conditions. The solution to this problem is:

$$X_{H,t}(s) = \frac{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} \varepsilon P_{ht+j}^{\varepsilon} Y_{ht+j} MC_{T,t+j} (P_{t+j-1}/P_{t-1})^{-\tau_d \varepsilon}}{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} (\varepsilon - 1) P_{ht+j}^{\varepsilon} Y_{ht+j} (P_{t+j-1}/P_{t-1})^{-\tau_d(\varepsilon-1)}} = X_{H,t}$$

$$X_{H,t}^p(s) = \frac{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} \varepsilon (P_{ht+j}^* S_{t+j})^{\varepsilon} Y_{ht+j}^* MC_{T,t+j} (P_{t+j-1}/P_{t-1})^{-\tau_d \varepsilon}}{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} (\varepsilon - 1) (P_{ht+j}^* S_{t+j})^{\varepsilon} Y_{ht+j}^* (P_{t+j-1}/P_{t-1})^{-\tau_d(\varepsilon-1)}} = X_{H,t}^p.$$

Next, consider a domestic LCP intermediate good producer who is randomly selected to set new prices at time t. Let $X_{H,t}^l(s)$ denote the price chosen by the firm in the foreign market, where the superscript l indicates LCP setting.[8] If the price is still in effect at time $t+j$, then the firm's sales in the foreign market are given by:

$$Y_{ht+j}^l(s) = Y_{ht+j}^* \left(\frac{X_{H,t}^l(s)(P_{t+j-1}^*/P_{t-1}^*)^{\tau_d}}{P_{ht+j}^*} \right)^{-\varepsilon}. \tag{2.29}$$

Similarly, the firm chooses $X_{H,t}^l(s)$ to maximize its present discounted value of profits:

$$E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} \Bigg\{ X_{H,t}(s) \left(\frac{P_{t+j-1}}{P_{t-1}} \right)^{\tau_d} Y_{ht+j}(s) + X_{H,t}^l(s) \left(\frac{P_{t+j-1}^*}{P_{t-1}}^* \right)^{\tau_d} S_{t+j} Y_{ht+j}^l(s)$$
$$- MC_{T,t+j}[Y_{ht+j}(s) + Y_{ht+j}^l(s)] \Bigg\}.$$

The solution of $X_{H,t}^l(s)$ is:

$$X_{H,t}^l(s) = \frac{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} \varepsilon (P_{ht+j}^*)^{\varepsilon} Y_{ht+j}^* MC_{T,t+j} (P_{t+j-1}^*/P_{t-1}^*)^{-\tau_d \varepsilon}}{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} (\varepsilon - 1) (P_{ht+j}^*)^{\varepsilon} Y_{ht+j}^* S_{t+j} (P_{t+j-1}^*/P_{t-1}^*)^{-\tau_d(\varepsilon-1)}} = X_{H,t}^l.$$

The optimal price choices for intermediate good producers are only contingent on aggregate prices and quantities, and thus are not dependent on the intermediate good variety s. The price index for intermediate goods sold domestically, $P_{H,t}$, and the export price index, $P_{H,t}^*$, can then be expressed as:

$$P_{H,t} = \left\{ \psi_d \left[P_{H,t-1} \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\tau_d} \right]^{1-\varepsilon} + (1-\psi_d) X_{H,t}^{1-\varepsilon} \right\}^{\frac{1}{1-\varepsilon}} \tag{2.30}$$

[8] An LCP firm's choice of domestic price is the same as that of a PCP firm.

$$P^*_{H,t} = \left\{ \psi_d \left[P^*_{H,t-1} \left(\frac{P^*_{t-1}}{P^*_{t-2}} \right)^{\tau_d} \right]^{1-\varepsilon} + (1-\psi_d) \left[\phi (X^l_{H,t})^{1-\varepsilon} + (1-\phi) \left(\frac{X^p_{H,t}}{S_t} \right)^{1-\varepsilon} \right] \right\}^{\frac{1}{1-\varepsilon}}. \tag{2.31}$$

Intermediate Good Importers

The intermediate good importers purchase foreign-produced intermediate goods in the foreign market and resell them in the domestic market. We assume that bringing one unit of the tradable intermediate good to the domestic market requires λ units of a basket of the differentiated non-tradable goods,

$$\lambda = \left[\int_0^1 \lambda(n)^{1-\frac{1}{\nu}} di \right]^{\frac{\nu}{\nu-1}},$$

where $n \in [0,1]$ is the index of non-tradable good varieties, and ν is the elasticity of substitution among varieties of non-tradable goods. The import sector is perfectly competitive, so the price index for foreign-produced intermediate goods in the home market, $P_{F,t}$, is given by:

$$P_{F,t}(s) = S_t P^*_t(s) + \lambda P_{N,t}. \tag{2.32}$$

Finally, define the trade balance value as:

$$TB_t = P_{F,t} Y_{F,t} - S_t P^*_{H,t} Y^*_{H,t}. \tag{2.33}$$

2.3 Non-tradable Good Producers

The non-tradable goods are produced using capital and labour with a Cobb Douglas technology:

$$Y_{N,t}(n) = A_{N,t} K_{N,t-1}(n)^{\theta} L_{N,t}(n)^{1-\theta} \tag{2.34}$$

$$L_{N,t}(n) = \left[\int_0^1 l^i_{N,t}(n)^{1-\frac{1}{\gamma}} di \right]^{\frac{\gamma}{\gamma-1}}.$$

$A_{N,t}$ is the technology shock to the non-tradable sector, and is assumed to follow a first-order autoregressive process. Taking wages and capital rental rates as given, non-tradable good producers solve the profit maximization problem and set prices. The non-tradable good prices are also assumed to be sticky, following Calvo (1983). For simplicity, we assume the probability that non-tradable good producers reoptimize in each period is also $1-\psi_d$, and the degree of non-tradable price indexation is again τ_d. Let $X_{N,t}(n)$ be the price that firm n chooses if it is selected to reset its price at time t. The profit function of the non-tradable good producer n is:

$$E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} \left[X_{N,t}(n) \left(\frac{P_{t+j-1}}{P_{t-1}} \right)^{\tau_d} Y_{N,t+j}(n) - MC_{N,t+j} Y_{N,t+j}(n) \right],$$

where the marginal cost is given by:

$$MC_{N,t+j} = \frac{(1-\theta)^{\theta-1}(r^k_{N,t+j}P_{N,t+j})^{\theta}}{\theta^{\theta}W^{\theta-1}_{t+j}A_{N,t+j}}.$$

The solution to the profit maximization problem is:

$$X_{N,t}(n) = \frac{E_t\Sigma_{j=0}^{\infty}\psi_d^j\Gamma_{t,t+j}\nu P^{\nu}_{N,t+j}Y_{N,t+j}MC_{N,t+j}(P_{t+j-1}/P_{t-1})^{-\tau_d\nu}}{E_t\Sigma_{j=0}^{\infty}\psi_d^j\Gamma_{t,t+j}(\nu-1)P^{\nu}_{N,t+j}Y_{N,t+j}(P_{t+j-1}/P_{t-1})^{-\tau_d(\nu-1)}} = X_{N,t}.$$

The price index for non-tradable goods is given by:

$$P_{N,t} = \left\{\psi_d\left[P_{N,t-1}\left(\frac{P_{t-1}}{P_{t-2}}\right)^{\tau_d}\right]^{1-\nu} + (1-\psi_d)X^{1-\nu}_{N,t}\right\}^{\frac{1}{1-\nu}}. \tag{2.35}$$

The market clearing condition implies that:

$$Y_{N,t} = C_{N,t} + I_{N,t} + G_{N,t} + AC_{N,t} + \lambda Y_{F,t}, \tag{2.36}$$

and the aggregate output is given by:

$$P_tY_t = P_{T,t}Y_{T,t} + P_{N,t}Y_{N,t}. \tag{2.37}$$

2.4 Government and Monetary Authority

The government budget constraint is given by:

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

The government debt is Ricardian in this model, in the sense that the equilibrium is invariant to the timing of the lump sum transfer. The government could adjust the lump sum transfer in each period to balance the budget constraint. Government spending, G_t, is a combination of tradable and non-tradable goods. The weights are assumed to be symmetric to consumer behaviour. G_t is assumed to follow a first-order autoregressive process, which is given by:

$$\ln G_t = (1-\rho_g)\ln G + \rho_g \ln G_{t-1} + \epsilon_{gt}, \tag{2.38}$$

where ϵ_{gt} is normally distributed with zero mean and variance σ_g^2.

The government consumption expenditure on tradable goods and non-tradable goods respectively is assumed to be given by:

$$G_{T,t} = \alpha_T\left(\frac{P_{T,t}}{P_t}\right)^{-\varsigma}G_t \tag{2.39}$$

$$G_{N,t} = (1-\alpha_T)\left(\frac{P_{N,t}}{P_t}\right)^{-\varsigma} G_t. \tag{2.40}$$

Finally, the model is closed by adding the monetary policy reaction function following Taylor (1993) and Smets and Wouters (2003),

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

The domestic interest rate will respond to the inflation rate as well as to the output gap. ρ_r is a parameter that captures interest-rate smoothing, and ϵ_{rt} is a monetary policy shock, which is assumed to be i.i.d. normal with zero mean and variance σ_r^2.

The model is analyzed in the log-linearized form around a deterministic steady state. Importantly, domestic agents have access to a nominal foreign bond that pays interest rate R_t^*, which is subject to a debt-elastic risk premium. This assumption ensures that the model has a steady state, in the sense that transitory shocks will not have long-run effects on the state of the model. The equilibrium of the model is characterized by 34 equations: the Euler equation (2.7); the capital accumulation optimality condition (2.10) and (2.11); the optimal wage setting equation; the arbitrage condition (2.12); the demand functions (2.14), (2.15), and (2.22); the household and government consumption of tradable and non-tradable goods (2.8), (2.9), (2.39), (2.40), the optimal price setting equations (2.30), (2.31), (2.32), (2.35); the tradable and non-tradable good production functions (2.18), (2.13), (2.34), and the capital-labour trade-off equations; the market clearing equations (2.17), (2.21), (2.36), (2.37); the foreign price specification; the risk premium equation; the capital law of motion (2.4); the labour demand equations; the monetary policy reaction function; the trade balance equation (2.33), and the budget constraint. A complete list of all the variables and parameters in this model can be found in Table 1-2.

2.5 Linearized Relations

For the empirical analysis in the next section, the model is log-linearized around the nonstochastic steady state. This yields a system of equations that are linear in log deviations, and can be solved using standard methods. In this paper, I use the following transformations to achieve stationarity: $p_{T,t} = \frac{P_{T,t}}{P_t}$, $p_{N,t} = \frac{P_{N,t}}{P_t}$, $p_{H,t} = \frac{P_{H,t}}{P_t}$, $p_{F,t} = \frac{P_{F,t}}{P_t}$, $p_{H,t}^* = \frac{P_{H,t}^*}{P_t^*}$, $x_{H,t} = \frac{X_{H,t}}{P_t}$, $x_{H,t}^p = \frac{X_{H,t}^p}{P_t}$, $x_{H,t}^l = \frac{X_{H,t}^l}{P_t^*}$, $x_{N,t} = \frac{X_{N,t}}{P_t}$, $w_t = \frac{W_t}{P_t}$, $\omega_t = \frac{\varpi_t}{P_t}$, $q_t = \frac{S_t P_t^*}{P_t}$, $\pi_t = \frac{P_t}{P_{t-1}}$, $\pi_t^* = \frac{P_t^*}{P_{t-1}^*}$, $b_t^* = \frac{B_t^*}{P_t^*}$. The linearized equation system is described in Appendix A.

To study the expenditure-switching effect, we want to determine the impact of an exchange rate movement on the relative demands for home- to foreign-produced intermediate goods. It is straightforward to derive from the log-linearized equation system that:

$$\begin{aligned}\hat{y}_{H,t} - \hat{y}_{F,t} &= \sigma(\hat{p}_{F,t} - \hat{p}_{H,t}) \\ &= \sigma[(1-\varrho)\hat{q}_t + \varrho\hat{p}_{N,t} - \hat{p}_{H,t}],\end{aligned} \tag{2.41}$$

where ϱ is the distribution margin. As this equation indicates, the size of the expenditure-switching effect in the domestic market is actually determined both by the magnitude of the impact of exchange rate movements on the relative import to domestic price, and by the degree of substitutability between domestic and foreign tradable goods. The expenditure-switching effect would not be an important policy consideration if the relative price did not adjust very much in response to an exchange rate movement, or if the elasticity of substitution was small. The size of the impact on the relative price of an exchange rate movement further depends, among other things, on the fraction of firms adopting LCP instead of PCP for their export pricing, the fraction of firms that adjust prices each period, the size of the distribution margin, and fundamentally, the macro structure of the model. In particular, it is the fraction ϕ^* of foreign firms using LCP that matters for the domestic expenditure switching.

Expenditure switching is not conducted only by domestic final good producers, but also by foreign agents who import intermediate goods from the domestic country. With the small open economy model, we assume that foreign variables are exogenous. The fraction ϕ of domestic firms using LCP to set their export prices and the foreign elasticity of substitution σ_f can then be used to determine the degree of expenditure switching between domestic- and foreign-produced intermediate goods in the rest of the world, with the rest of world taken as given.

3 Econometric Methodology

The model is estimated via the Bayesian maximum likelihood estimation approach, similar to Smets and Wouters (2003) and Lubik and Schorfheide (2006). This section describes the data and the methodology employed for estimating the parameters.

3.1 Data

The stochastic behavior of this model is driven by eight exogenous shocks: $\hat{a}_{T,t}$, $\hat{a}_{N,t}$, $\hat{g}_t$, $\hat{\varphi}_t$, $\hat{r}^*_t$, $\hat{y}^*_t$, $\hat{\pi}^*_{l,t}$ and ϵ_{rt}. Data on five key macroeconomic variables are used to estimate the structural parameters of the model. The five series are for the following variables: $\hat{w}_t$, $\hat{y}_t$, $\hat{q}_t$, $\hat{r}_t$ and $\hat{tb}_t$. By their definitions, they are computed from wage rates, output, the nominal exchange rate, the consumer price index and foreign price index, treasury bill rates, the import price index and export price index, and imports and exports. These variables help to capture the potentially important roles of the exchange rate, trade, technology, and the interest rate, as well as the explanatory factors arising outside of the small open economy. Additionally, data on government consumption, the foreign output level, and the foreign interest rate are collected to estimate the observable exogenous processes for G_t, R^*_t and Y^*_t. The VAR estimation results are reported in Table 3. The foreign output series is constructed as a geometric weighted average 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. The foreign price index used to compute the real exchange rate is computed in a similar manner. Likewise, I gathered short-term interest rates, treasury bill rates, or equivalent rates, for the G-7 countries and averaged them using the same GDP weighting scheme to compute the foreign interest rate. As shown in Table 3, the foreign output and foreign interest rate series are very persistent in all three cases, while the government spending series are much less persistent, especially for Australia.

The model is estimated for three countries: Australia, Canada and the United Kingdom. The data are retrieved from the International Financial Statistics database for the period 1970:1 to 2006:4, with all variables being seasonally adjusted quarterly series. Output is measured as national GDP. Quantities are all in per capita terms and are deflated to real terms using the GDP deflator. The nominal exchange rate is an index number defined in terms of domestic currency per unit of foreign currency. The data is HP-filtered to achieve stationarity.

3.2 Bayesian Estimation Method

The model is estimated using the Bayesian maximum likelihood estimation method. Under this method, prior distributions over the parameters are assigned. Then time series data are brought in to study whether the model is consistent with the data. The views of the model parameters are then revised accordingly. In this paper, the model is estimated using a numerical optimization procedure provided by Dynare.[9]

The advantage of this system-based approach over the frequentist approach is that it provides a consistent way to update researchers' beliefs about parameter values based on the data that is actually observed. The frequentist approach views the unknown parameters as fixed, not random; and probability distributions are assigned to the data sets as they are drawn from the population. In the frequentist context, the confidence statements are based on the average behavior of statistical procedures under all possible samples that might have occurred, but didn't. The Bayesian approach, however, views the parameters as random variables and makes probability statements on them conditional on the data that actually occurred. Moreover, by using Monte Carlo methods to generate chains from posterior distributions, one can compute confidence intervals of parameters such that the intervals contain random variables with a certain posterior probability. This contrasts with the confidence intervals found by using the frequentist approach, which are derived from probability statements for the data.

Furthermore, in a complicated model like the one described in this paper, lack of identification is another potential problem. The obvious form of identification difficulty that is caused by a certain set of parameter values generating the same joint distribution is less of an issue for DSGE models than for VARs, due to the usually smaller parameter set of the former. But the lack of identification due to the absence of informative observations can generally be hard to detect because of the large size and nonlinearities common to structural models. Consequently, the lack of identification can cause

[9] 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/*.

the likelihood function to be very flat in certain directions of the parameter space, and thus make it computationally difficult to locate the maximum. By introducing prior distributions based on micro-evidence, the Bayesian method addresses this problem by adding curvature to the objective function, thus facilitating maximization.

3.3 Priors

Probability statements about the parameters are made before observing the data in order to measure the ex ante plausibility of the parameter values. The choice of priors can be based on the researcher's beliefs about the parameter values, the results from previous studies, or on other information not contained in the data sample. Other than these factors, the choice of priors has to reflect the restrictions imposed on the parameters by the model, for example, within $(0, 1)$ interval, nonnegativity, etc. In this paper, since the estimation algorithm is computationally very intensive, some parameters are fixed by calibration because: (i) they are not major parameters of interest in this paper; (ii) they no longer appear in the log-linearized model, but only affect the steady state values; or (iii) there is a consensus in the literature about their values.

The subjective discount factor β is given a standard value of 0.99. The relative risk aversion parameter ρ is set to equal 4, and is consistent with the estimation results of Ambler, Dib and Rebei (2003) based on Canadian data, and is generally in line with macro findings for Australia and the United Kingdom. The inverse of labour supply elasticity μ is set equal to 2, following Smets and Wouters (2003). The weight of traded goods in the consumption basket, α_T, takes a value of 0.5, which implies that the shares of tradable and non-tradable goods in the consumption basket are both approximately 50%. Regarding the elasticity of substitution between tradables and non-tradables, Stockman and Tesar (1995) estimate it to be 0.44 for an "average" industrialized country out of the G7 countries. On the other hand, Mendoza (1991) estimates this elasticity to be 0.74. Here a value of 0.6 is adopted for ς. The elasticity of substitution among different types of labour services γ is assumed to be 6, corresponding to estimates from micro data.[10] The quarterly capital depreciation rate, δ, is set to 0.025.

The share of capital in tradable good production, η, is set to 0.28 for Canada. This implies that the steady state share of labour income in tradable output is 72%. The share of capital in non-tradable good production, θ, is set to 0.37. These calibrated values for η and θ are based on the estimation results of a two-sector small open economy model for Canada by Ortega and Rebei (2006). Slight adjustments are made so that the capital share in production at an aggregate level is around 0.3, consistent with Mendoza's (1991) parameterizations to rationalize postwar Canadian business fluctuations. For Australia and the United Kingdom, the corresponding values are set to $\eta = 0.36$, $\theta = 0.32$, following usual simulation practices, which is consistent with the observation that in general, tradable sectors are more capital-intensive than non-tradable sectors.[11] The fraction of labour effort in the tradable good sector is inferred from the data on the distribution of civilian

[10] See, for example, Griffin (1992).

[11] Valentinyi and Herrendorf (2007) measure the U.S. income shares of capital and labour for five sectors. Their results indicate that the capital shares of tradables and non-tradables are correspondingly 0.36 and 0.32.

employment by economic sector for several industrialized countries.[12] This share is approximately 0.31 for Australia, 0.29 for Canada and 0.34 for the United Kingdom.

Other than these parameters, there are 24 parameters to be estimated. Generally, Beta distributions are chosen for parameters that are constrained in the unit interval; Gamma distributions are set for parameters defined in $\mathbb{R}^+$; and inverse Gamma distributions are selected for standard deviations.

The prior means for the Calvo adjustment parameters of prices and wage rates are set at 0.7. Under these priors, domestic producers and households change prices and wages once every 3.3 quarters. The index parameters of prices and wages are given a prior mean of 0.5, with a standard deviation of 0.15.

With respect to the priors for the fraction of firms employing LCP versus PCP for their exports, inferences are drawn from several sources for the three countries considered here. The Australian Bureau of Statistics publishes *International Merchandise Trade: Featured Article*, which reports major invoice currencies used for Australia's merchandise exports and imports for the period from March quarter 2002 to March quarter 2003. The article indicates that, on average, the Australian dollar accounted for 27% of exports and 31% of imports during that period of time. Based on this information, the prior means are set at 0.73 for ϕ and 0.31 for ϕ^* for Australia. Over time, the proportion of exports and imports invoiced in the Australian dollar changed slightly. However, as the article pointed out, 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.

For Canada, references on ϕ are drawn from Murray, Powell, and Lafleur (2003), where they report the survey results conducted by the staff in the Bank of Canada's regional offices in 2002. In this survey, 326 firms were asked whether they quoted prices to foreign consumers in a currency other than the Canadian dollar. The results show that 24% of Canadian firms in the survey quote export prices in Canadian dollars, a number much higher than many observers would have expected. Accordingly, the prior of the parameter ϕ for Canada is centered around 0.76. Unfortunately, this survey does not provide any information on the invoice currency for imports. Based on the coarse calculation that the United States accounts for roughly 60% of Canada's imports, and the US dollar share in its export invoicing is around 95%,[13] chances are 57% of Canadian imports are priced in US dollars. Considering the role of other currencies and measurement errors, ϕ^* is given a prior mean of 0.3 for Canada.

The ECU Institute (1995) reports the percentages of exports denominated in home currency for selected countries during the years of 1980 and 1992: UK (76,62), Germany (83,77), and France (61,55).[14] The percentages of imports denominated in home currency for those two years are reported as: UK (38,43), Germany (43,56), and France (37,47). For the United Kingdom, although changes occur across the 13 years, the UK pound remains the principal currency used for the denomination of both its exports and its imports. Thus the priors for ϕ and ϕ^* are set at 0.3 and 0.4 respectively for the UK.

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

[13] Goldberg and Tille (2005) report the US dollar share in export invoicing and import invoicing for 24 countries. The 95% number is recorded for the US dollar share in the United States export invoicing in 2003, using confidential data from the US Bureau of Economic Analysis.

[14] The first number refers to the share in the year 1980. The second number refers to the share in the year 1992.

The prior mean for the elasticity of substitution between domestic goods and imports σ is set at 1.5. A large standard deviation of 0.25 is given, since the empirical evidence on the value of this parameter is diverse. In particular, macro studies tend to find this elasticity to be around 0.5 to 1.5.[15] The estimated elasticity at a disaggregated industry level is much higher, with an average number in the neighbourhood of 5 to 6.[16] The same prior is assigned to the parameter σ_f. With respect to the distribution margin ϱ, which measures the share of distribution costs in import prices, a prior mean of 0.4 is specified. Priors on the policy coefficients are chosen to match values generally associated with the Taylor rule. Finally, 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

4.1 Parameter Values

The estimation results for the three countries — Australia, Canada and the United Kingdom — are reported in Table 4-6. 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, and 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. Generally, the two sets of estimates display similar results. The estimation results are summarized visually in Figure 1-3, where both the prior and posterior distributions are plotted. The estimated parameter values generally fall into reasonable ranges.

The Calvo stickiness parameter ψ_d for domestic producer prices is estimated to be around 0.69 for Australia and Canada, and 0.72 for the United Kingdom, which implies that domestic producers, on average, change prices approximately once every 3-4 quarters. The estimated length of price contracts for domestic producers is in line with the literature. For instance, Lubik and Schorfheide (2006) report estimates of the price stickiness parameter ranging from 0.74 to 0.78 in their two-country benchmark model, while Ambler, Dib, and Rebei (2003) report an estimate of the Calvo adjustment parameter at 0.68 for Canada. Microeconomic evidence, however, tends to suggest less sticky prices. Amirault, Kwan, and Wilkinson (2006) report the survey results conducted by the Bank of Canada's regional offices on 170 Canadian firms for their views on price dynamics. The survey evidence suggests that more than 50 percent of firms change their prices more than four times a year. Hall, Walsh, and Yates (2000) report the results of a survey conducted by the Bank of England in 1995, which investigated the pricing behavior of 647 UK companies. Overall, British firms, on average, changed prices twice in the year preceding the survey. The estimate of ψ_w, the rigidity parameter for wages, is around 0.74

[15] For example, with a structural small open economy model, Ambler, Dib, and Rebei (2003) estimate the elasticity to be 0.55 for Canada. Adolfson et al. (2007) found the elasticity of substitution over domestically produced goods and imported products to be 1.525 in the modified UIP case.

[16] See, for example, Lai and Trefler (2002).

for Australia, 0.71 for Canada, and 0.77 for the United Kingdom. Thus wage rates set by households typically remain fixed for about 4 quarters. Sticky wages play an important role in allowing the model to generate reasonable price stickiness. As Christiano, Eichenbaum, and Evans (2005) emphasize, wage rigidity is the crucial requirement to impose on a model of the economy with optimizing agents and a richly specified environment in order to obtain the same response to a monetary policy shock as observed in a simple description of the data. The estimated price and wage indexation parameters are all smaller than 0.5 for the three countries examined here, though the priors are set at 0.5. In particular, the estimated degree of price indexation for Canada is close to 0.3, which corresponds to the weight on lagged inflation in the New Keynesian Phillips Curve to be about 0.23. This is in line with the general estimate of this coefficient to be around 0.2-0.3.

Concerning the controversy over the choice of currency in which tradable good producers set their export prices, the estimate of ϕ^*, the proportion of foreign firms using LCP to set export prices, is close to 0.31 for Australia and Canada, and only 0.23 for the United Kingdom. The fact that a slightly larger fraction of firms exporting to Australia or Canada price their products in the local market currency would suggest that when prices are sticky in the short run, exchange rate movements can't achieve as much of the effect of relative price adjustment as in the UK. In addition, the Calvo stickiness parameter for domestic producer prices is estimated to be a bit smaller for Australia and Canada. So production prices can adjust more quickly, and not much expenditure switching would be initiated by currency appreciation or depreciation. Based on this, then, there would be somewhat smaller domestic expenditure switching over tradable goods for Australia and Canada than for the UK. However, the estimation results also indicate that the distribution margin ϱ is estimated to be 0.66 for Australia, 0.59 for Canada, and as high as 0.84 for the UK. From equation (2.41), we can see that the higher ϱ is, the smaller the effect of exchange rate movements on the relative quantities. The distribution margin measures the fraction of the import price accounted for by distribution costs. The estimates on the distribution margin suggest that $(1 - \varrho)$ for Canada is more than twice as large as $(1 - \varrho)$ for the UK. When distribution costs account for a very large share in import prices, expenditure switching over tradable goods would be much more insignificant. ϱ is estimated to be quite high for the UK, possibly due to the relatively high non-tradable good prices in the country.

The estimate of ϕ, the proportion of domestic tradable good producers using LCP to set export prices, is around 0.79 for Australia, and 0.81 for Canada, which indicates that LCP is dominant for these countries' export price setting. For the United Kingdom, the estimate of ϕ is about 0.28. In the UK's case, invoicing in the producers' currency is more frequent. Therefore, in response to nominal exchange rate movements, the degree of expenditure switching between domestic- and foreign-produced tradable goods in the foreign market would be more significant for the UK, compared to the other two countries.

The estimate of the elasticity of substitution between domestic and foreign varieties, σ, is close to 1.7 for Australia and Canada, and 2.4 for the United Kingdom. The estimation results here are in the upper half of the range of macro estimates, and are closer to micro estimates. On the reconciliation of macro and micro estimates of the trade elasticity of substitution, Ruhl (2005) provides a framework to accommodate both. In his model, the true elasticity in response to temporary shocks is close to 1.4;

while the elasticity in response to a permanent tariff shock is around 6.2. Trade liberalization increases the extensive margin: a much larger elasticity is measured in response to a tariff shock because of the increase in trade flows from newly traded goods. As seen in equation (2.41), the size of the expenditure-switching effect depends on the value of σ. The estimates of the elasticity of substitution are not dramatically different across countries, though the estimate is a bit larger for the UK. The estimates of σ_f are of similar scale for all three countries.

Our estimation also yields reasonable results on the monetary policy reaction equation, as there is a fair amount of interest rate inertia in every country investigated in this paper. The coefficient for the inflation rate is greater than 1; thus the Taylor principle is satisfied. A modified UIP condition is introduced to reflect the negative correlation between the risk premium and the expected change in nominal exchange rates. The coefficient φ_s is estimated to be significantly different from zero for all three countries. However, unlike Adolfson et al. (2007)'s results on Swedish data,[17] even though a prior mean of 0.45 is assigned, we found the posterior of φ_s is only around 0.3 for Australia, Canada and the United Kingdom, compared to 0.6 in their estimation. Our results suggest that though the negative correlation exists and the modified UIP specification allows for a lower persistence in the risk premium shock needed to capture the autocorrelation observed in the real exchange rate series,[18] it may not be enough to generate a VAR-type humped-shaped impulse response for the real exchange rate, at least for the three countries examined here. This is confirmed later by studying the impulse response figures, where the response of the real exchange rate to a monetary policy shock is not a complete spike, in the sense that we can see some gradual responses at early periods, but it is nevertheless far from hump-shaped. The estimates of the AR coefficients and standard deviations for the unobserved shocks are also reported. We notice that the estimated exogenous processes for these shocks differ significantly, though the same priors are given at the beginning.

4.2 Model Fit

To assess the conformity of the model to the data, unconditional second moments are computed and reported in Table 7-9. 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. Generally, 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, suggesting that the model is able to mimic those properties of the data. For all three countries, the persistence and volatility of real exchange rates and trade balances are well captured by the simulated model.

Turning to the cross correlations, the model generally provides good characterizations of the cor-

[17] It is worth noticing that Sweden went from a fixed exchange rate regime to a managed floating exchange rate regime in December 1992.

[18] It is important to understand that the empirical relevance of these parameters is identified through the macro model. For details, please refer to Adolfson et al. (2007).

relation properties. The confidence intervals are large, which suggests a large degree of uncertainty about the model-based correlations. Since the data series are HP filtered, quite a few of the data cross-correlations are actually very small in scale and close to zero, in which case the signs for those values are not as important. Looking more closely, it seems that the correlations with interest rates are least satisfactory, though for two-thirds of them the data value still lies within the error bands implied by the model. This appears to be a general problem of sticky price models, as pointed out by Smets and Wouters (2003). The volatility and persistence of interest rates though, are very well captured by the model. There certainly may be room for improvements of the model, but it does a reasonably good job for us to proceed with the analysis of the quantitative importance of the expenditure-switching effect.

4.3 Impulse Response Analysis

The impulse responses are displayed in Figure 4-6 for Australia, Canada and the United Kingdom, for four variables of major interest: the domestic demand for home-produced intermediate goods, $\hat{y}_{ht}$; imports of foreign-produced goods, $\hat{y}_{ft}$; exports of domestically produced tradable goods, $\hat{y}^*_{ht}$; and the real exchange rate, $\hat{q}_t$. 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 in the figures.

A technology shock in the tradable sector increases domestic production and exports, and reduces imports through the substitution effect. The maximum response of $\hat{y}_{ht}$ occurs approximately 8 quarters after the impact of the shock for Australia and Canada. For the UK, the peak of the response occurs approximately 1 year upon the shock. As the foreign currency depreciates, domestic imports improve, since for all three countries $\phi^* < 0.5$ and thus PCP is dominant for foreign firms' export price setting. On the other hand, a technology shock in the non-tradable sector increases imports through the effect on distribution services, reducing the demand for domestically-produced tradable goods. As the domestic currency depreciates, final tradable good producers switch expenditure from imports to domestically-produced goods. Exports increase immediately in response to the non-tradable technology shock due to the expansion in domestic final tradable good production. Then $\hat{y}^*_{ht}$ drops over time. The expenditure-switching effect in the foreign market, induced by foreign currency appreciation, will lead to an increase in $\hat{y}^*_{ht}$. But it is of second-order importance for Australia and Canada, because the proportion of domestic firms employing LCP to set export prices, ϕ, is estimated to be 0.79 and 0.81 respectively. In both cases, LCP is dominant for domestic firms' export pricing.

A positive risk premium shock drives up the demand for foreign currency. The foreign currency then appreciates, leading to an immediate drop in imports and an increase in the real exchange rate. A positive monetary policy shock does a similar trick, but turn things the other way around. An increase in the nominal interest rate drives the domestic currency up. Then, imports should increase and the real exchange rate should decline. However, when the domestic interest rate rises, current consumption becomes relatively more expensive, so individuals tend to substitute away from consumption. Thus a positive monetary policy shock will lead to a decline in consumption, in addition to a drop in domestic production and imports.

As a "demand" shock, the government spending shock drives up both domestic production and imports, and crowds out exports. A positive government expenditure shock increases the demand for domestic money. This puts upward pressure on the domestic interest rate, making foreign bonds less attractive. As a result, the domestic currency appreciates and the nominal exchange rate declines. Domestic final good producers then tend to substitute foreign for domestic varieties.

In response to the foreign price shock, domestic exports are driven up by demand, and the real exchange rate drops. As the demand for foreign currency grows, the foreign currency appreciates. Expenditure switching then leads to a decline in imports and a rise in $\hat{y}_{ht}$. Since there is no absolute measurement for distinguishing a big or small expenditure-switching effect, the three countries are compared for analysis. As we can see from Figure 4-6, responding to a one-unit increase in the foreign price shock, the expenditure switching from $\hat{y}_{ft}$ to $\hat{y}_{ht}$ is the largest for Canada, as the distance between the two response lines is the smallest. Australia is second, trailed by the UK. This is consistent with earlier analysis that the magnitude of expenditure switching by domestic final tradable good producers is relatively big for Canada, and relatively small for the UK, based on the estimated parameter values. An additional concern is that the monetary regime in the United Kingdom may also have an impact on this outcome. Starting in the early 80's, the UK authorities had implicit preferences for exchange rate stability. In 1990, the preferences became explicit when the UK committed itself to the European Exchange Rate Mechanism (ERM), until the pound sterling was suspended in 1992. The exchange rate moved more smoothly during that period of time than it otherwise would have. This may also have limited the magnitude of expenditure switching.

The effects of the foreign interest rate shock on the variables are not surprisingly in line with those of the risk premium shock. The two shocks are identified in the model through the observed foreign interest rate series. The risk premium shock captures whatever is left unaccounted for by the observed foreign interest rate shock. An increase in the foreign output level drives up domestic exports. Domestic imports also improve due to the foreign production boom. This appreciates the foreign currency. Then imports decline and $\hat{y}_{ht}$ increases.

4.4 Variance Decompositions

To infer the role of structural shocks in driving the movements of trade balance, real exchange rate and output level, the variance decomposition results for various horizons are presented in Table 10-12 for the three countries. The reported forecast error variances are attributed to the eight structural shocks.

First, let us focus on Australia. The trade balance and real exchange rate variations are primarily driven by the foreign price shock, which explains more than 60% of their forecast error variances. The risk premium shock accounts for nonnegligible percentages of their short-term forecast error variances. The technology shock in the tradable sector alone accounts for roughly 50% of the forecast error variances of $\hat{y}_t$ in the short to medium run.

For Canada and the United Kingdom, the results are similar to those of Australia, in that the foreign price shock plays a significant role in all cases. For these two countries though, the role of the risk premium shock in accounting for the real exchange rate and output variations is not as significant. The foreign price shock explains most of their variances. The technology shock in the tradable sector still explains over 30% of the forecast error variance of output for Canada.

For all three countries, the foreign interest rate shock and the foreign output shock do not seem to play much of a role in the variance decomposition. But the foreign price shock has significant impacts on the small open economy. Justiniano and Preston (2006) proposed a caveat of fitting open economy DSGE models, in that the small open economy model is unable to account for the transmission of foreign shocks to the domestic economy. The current work seems to suggest that with a different pricing structure, the small open economy model can account for the influences of foreign price shocks. For Australia, 32% of the forecast error variance of output is explained by the foreign price shock in the short run. For Canada, over 65% of the variance of output at the four-quarter horizon is explained by the foreign price shock.

5 Conclusion

This paper develops a structural model of a small open economy with sticky prices and wages, and a mixture of PCP and LCP settings. The Bayesian estimation procedure is used to estimate the model using data from three small open economies — Australia, Canada, and the United Kingdom — to study the expenditure-switching effect empirically. The level of expenditure switching in the domestic market depends on the rigidity of domestic producer prices, the fraction of foreign firms employing PCP versus LCP for their export pricing, the distribution margin, and the elasticity of substitution between domestic goods and imports. The empirical results suggest that among the three countries examined in this paper, domestic expenditure switching is relatively small for the United Kingdom. This is mainly because the distribution margin in the UK is very high. So in the short run, expenditure switching resulting from exchange rate variation in the domestic market is relatively minor. On the other hand, the proportion of domestic firms adopting LCP to set export prices is estimated to be much smaller for the UK. Expenditure switching by foreign agents would be less significant for Australia and Canada. The estimates of the domestic and foreign elasticity of substitution are not very different among the three countries. These results suggest that the benefits from exchange rate flexibility in terms of expenditure switching seem to be most significant for Canada in the domestic market, while the benefits to the UK are mainly through the substitution effect in markets outside the country.

Our conclusions regarding the benefits of exchange rate flexibility in terms of expenditure switching by no means rule out the presence of other factors that have impacts on the fixed-versus-floating choice. The expenditure-switching effect is one very important factor, but not the only factor, in the matter of optimal exchange rate regime consideration. Devereux and Engel (2006) have proposed that the optimal exchange rate policy is determined by the trade-off between the size of the terms-of-trade effect and the desire to achieve international risk sharing. On the one hand, nominal exchange rate flexibility can bring desirable changes to relative producer prices when these prices are sticky and set in PCP.

On the other hand, nominal exchange rate movements will also induce changes to the real exchange rate, which will then lead to inefficient consumption allocation. Devereux and Engel (2006) show that the optimal choice of exchange rate regime depends on the balance of these two goals in several different specifications. Obstfeld (2004) assumes the existence of both traded and nontraded goods, and develops the view that exchange rate flexibility is also desirable because of interest rate responses. By examining the interest rate responses to the productivity shock, he arrives at the conclusion that there is a need for exchange rate flexibility, because when an idiosyncratic shock has disproportionate effects on home consumption and foreign consumption, divergent interest rate movements are necessary to achieve international risk sharing. Interesting as the theoretical inferences are, empirical research is still needed to resolve the quantitative importance of the expenditure-switching role of nominal exchange rates, because the extent to which exchange rates alter relative quantities is important for determining the desirability of exchange rate flexibility. In addition, the size of the expenditure-switching effect is important not only for its relevance to the choice of exchange rate regime. It also matters for the magnitude of exchange rate volatility and the transmission of business cycles across countries.[19]

[19]See Engel (2003) for more details.

Reference:

Adolfson, M., S. Laséen, J. Lindé, and M. Villani. 2007. "Evaluating An Estimated New Keynesian Small Open Economy Model." Sveriges Riksbank Working Paper No. 203.

Ambler, S., A. Dib, and N. Rebei. 2003. "Nominal Rigidities and Exchange Rate Pass-Through in a Structural Model of a Small Open Economy." Bank of Canada Working Paper No. 2003-29.

Amirault, D., C. Kwan, and G. Wilkinson. 2006. "Survey of Price-Setting Behavior of Canadian Companies." Bank of Canada Working Paper No. 2006-35.

Bergin, P. R. 2006. "How Well Can the New Open Economy Macroeconomics Explain the Exchange Rate and Current Account?" *Journal of International Money and Finance* 25(5): 675–701.

Betts, C. and M. B. Devereux. 1996. "The Exchange Rate in a Model of Pricing-to-Market." *European Economic Review* 40(3-5): 1007–21.

Bouakez, H. and N. Rebei. 2005. "Has Exchange Rate Pass-Through Really Declined in Canada?" Bank of Canada Working Paper No. 2005-29.

Calvo, G. A. 1983. "Staggered Prices in a Utility Maximization Framework." *Journal of Monetary Economics* 12(3): 383–98.

Campa, J. M. and L. S. Goldberg. 2005. "Exchange Rate Pass-Through into Import Prices." *Review of Economics and Statistics* 87(4): 679–90.

——. 2006. "Pass Through of Exchange Rates to Consumption Prices: What Has Changed and Why?" National Bureau of Economic Research (NBER) Working Paper No. 12547.

Christiano, L. J., M. Eichenbaum, and C. L. Evans. 2005. "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." *Journal of Political Economy* 113(1) 1–45.

Corsetti, G., L. Dedola, and S. Leduc. 2005. "DSGE Models of High Exchange-Rate Volatility and Low Pass-Through." Federal Reserve Board International Finance Discussion Papers No. 845.

Corsetti, G. and P. Pesenti. 2005. "International Dimensions of Optimal Monetary Policy." *Journal of Monetary Economics* 52(2): 281–305.

Devereux, M. B. and C. Engel. 2003. "Monetary Policy in the Open Economy Revisited: Price Setting and Exchange-Rate Flexibility." *Review of Economic Studies* 70(4): 765–83.

——. 2006. "Expenditure Switching versus Real Exchange Rate Stabilization: Competing Objectives for Exchange Rate Policy." *Journal of Monetary Economics.* Forthcoming.

ECU Institute. 1995. *International Currency Competition and the Future Role of the Single European Currency.* Final report of the "European Monetary Union — international monetary system" working group. London: Kluwer Law International.

Engel, C. 2003. "Expenditure Switching and Exchange-Rate Policy." In *NBER Macroeconomics Annual 2002*, 231–72, edited by B. S. Bernanke and K. S. Rogoff.

Friedman, M. 1953. "The Case for Flexible Exchange Rates." In *Essays in Positive Economics*, 157–203. Chicago: University of Chicago Press.

Goldberg, L. S. and C. Tille. 2005. "Vehicle Currency Use in International Trade." Federal Reserve Bank of New York Staff Report No. 200.

Goldberg, P. K. and M. M. Knetter. 1997. "Good Prices and Exchange Rates: What Have We Learned?" *Journal of Economic Literature* 35(3): 1243–72.

Gourinchas, P.-O. 1999. "Exchange Rates and Jobs: What Do We Learn from Job Flows?" In *NBER Macroeconomics Annual 1998*, 153-208, edited by B. S. Bernanke and J. J. Rotemberg.

Griffin, P. 1992. "The Impact of Affirmative Action on Labor Demand: A Test of Some Implications of the Le Chatelier Principle." *Review of Economics and Statistics* 74(2): 251–60.

Hall, S., M. Walsh, and A. Yates. 2000. "Are UK Companies' Prices Sticky?" *Oxford Economic Papers* 52(3): 425–46.

Justiniano, A. and B. Preston. 2006. "Can Structural Small Open Economy Models Account for the Influence of Foreign Disturbances?" Society for Economic Dynamics Meeting Paper No. 479.

Lai, H. and D. Trefler. 2002. "The Gains from Trade with Monopolistic Competition: Specification, Estimation, and Mis-Specification." National Bureau of Economic Research (NBER) Working Paper No. 9169.

Lubik, T. and F. Schorfheide. 2006. "A Bayesian Look at New Open Economy Macroeconomics." *NBER Macroeconomics Annual 2005*, 313–66, edited by D. Acemoglu, K. Rogoff and M. Woodford.

Marazzi, M., N. Sheets, R. Vigfusson, J. Faust, J. Gagnon, J. Marquez, R. Martin, T. Reeve, and J. Rogers. 2005. "Exchange Rate Pass-Through to U.S. Import Prices: Some New Evidence." Federal Reserve Board International Finance Discussion Paper No. 833.

Mendoza, E. G. 1991. "Real Business Cycles in a Small Open Economy." *American Economic Review* 81(4): 797–818.

Murray, J., J. Powell, and L.-R. Lafleur. 2003. "Dollarization in Canada: An Update." *Bank of Canada Review* (Summer): 29–34.

Obstfeld, M. 2001. "International Macroeconomics: Beyond the Mundell-Fleming Model." Mundell-Fleming Lecture. *IMF Staff Papers* 47: 1–39.

——. 2006. "Pricing-to-Market, the Interest-Rate Rule, and the Exchange Rate." Prepared for the Conference in Honour of Guillermo A. Calvo, International Monetary Fund, 15-16 April.

Obstfeld, M. and K. Rogoff. 1995. "Exchange Rate Dynamics Redux." *Journal of Political Economy*

103(3): 624–60.

——. 1998. "Risk and Exchange Rates." National Bureau of Economic Research (NBER) Working Paper No. 6694.

——. 2000. "New Directions for Stochastic Open Economy Models." *Journal of International Economics* 50(1): 117–53.

Ortega, E. and N. Rebei. 2006. "The Welfare Implications of Inflation versus Price-Level Targeting in a Two-Sector, Small Open Economy." Bank of Canada Working Paper No. 2006-12.

Ruhl, K. J. 2005. "The Elasticity Puzzle in International Economics." Draft.

Schmitt-Grohé, S. and M. Uribe. 2003. "Closing Small Open Economy Models." *Journal of International Economics* 61(1): 163–85.

Smets F. and R. Wouters. 2003. "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area." *Journal of the European Economic Association* 1(5): 1123–75.

Stockman, A. C. and L. L. Tesar. 1995. "Tastes and Technology in a Two-Country Model of the Business Cycle: Explaining International Comovements." *American Economic Review* 85(1): 168–85.

Taylor, J. B. 1993. "Discretion versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy* 39: 195–214.

Valentinyi, Á. and B. Herrendorf. 2007. "Measuring Factor Income Shares at the Sector Level — A Primer." Centre for Economic Policy Research (CEPR) Discussion Paper No. 6271.

A The Linearized Equation System

For any variable ι_t, denote by ι its steady state value and by $\hat{\iota}_t$ its log deviation from its steady state value:

$$\hat{\iota}_t = \ln \iota_t - \ln \iota$$

The deviation $\hat{\iota}_t$ can thus be interpreted as the percent deviation of the variable from its steady state.

A.1 Prices

$$\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} &= (1-\psi_d\beta)E_t\Sigma_{j=0}^{\infty}(\psi_d\beta)^j[(1-\eta)\hat{w}_{t+j} + \hat{p}_{t+j} - \hat{a}_{T,t+j} + \eta\hat{r}^k_{T,t+j} \\
&\qquad\qquad - \hat{p}_t - \tau_d\hat{p}_{t+j-1} + \tau_d\hat{p}_{t-1}] \\
&= \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} &= (1-\psi_d\beta)E_t\Sigma_{j=0}^{\infty}(\psi_d\beta)^j[(1-\eta)\hat{w}_{t+j} + \hat{p}_{t+j} - \hat{a}_{T,t+j} - \hat{s}_{t+j} + \eta\hat{r}^k_{T,t+j} \\
&\qquad\qquad - \hat{p}^*_t - \tau_d\hat{p}^*_{t+j-1} + \tau_d\hat{p}^*_{t-1}] \\
&= \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} &= (1-\psi_d\beta)E_t\Sigma_{j=0}^{\infty}(\psi_d\beta)^j[(1-\theta)\hat{w}_{t+j} + \hat{p}_{t+j} - \hat{a}_{N,t+j} + \theta\hat{r}^k_{N,t+j} \\
&\qquad\qquad - \hat{p}_t - \tau_d\hat{p}_{t+j-1} + \tau_d\hat{p}_{t-1}] \\
&= \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}
\end{aligned}$$

For the wage rate, log-linearize the equations to get:

$$
\begin{aligned}
\hat{\omega}_t = & \frac{1-\psi_w\beta}{1+\gamma\mu} E_t \Sigma_{j=0}^{\infty} (\psi_w\beta)^j \Big[\mu \hat{l}_{t+j} + \gamma\mu\hat{w}_{t+j} + (1+\gamma\mu)\hat{p}_{t+j} + \frac{\rho}{1-h}(\hat{c}_{t+j} - h\hat{c}_{t+j-1}) \\
& - (1+\gamma\mu)\hat{p}_t - \tau_w(1+\gamma\mu)\hat{p}_{t+j-1} + \tau_w(1+\gamma\mu)\hat{p}_{t-1}\Big] \\
= & \psi_w\beta E_t\hat{\omega}_{t+1} + \psi_w\beta\hat{\pi}_{t+1} - \psi_w\beta\tau_w\hat{\pi}_t + \frac{1-\psi_w\beta}{1+\gamma\mu}\Big[\mu\hat{l}_t + \gamma\mu\hat{w}_t + \frac{\rho}{1-h}(\hat{c}_t - h\hat{c}_{t-1})\Big] \\
\hat{w}_t = & \psi_w\hat{w}_{t-1} - \psi_w\hat{\pi}_t + \psi_w\tau_w\hat{\pi}_{t-1} + (1-\psi_w)\hat{\omega}_t
\end{aligned}
$$

A.2 Output, Capital and Employment

Intermediate goods demand:

$$
\begin{aligned}
\hat{y}_{H,t} &= \hat{y}_{T,t} - \sigma(\hat{p}_{H,t} - \hat{p}_{T,t}) \\
\hat{y}_{F,t} &= \hat{y}_{T,t} - \sigma(\hat{p}_{F,t} - \hat{p}_{T,t}) \\
\hat{y}^*_{H,t} &= \hat{y}^*_t - \sigma^f \hat{p}^*_{H,t}
\end{aligned}
$$

Capital and labour demand:

$$
\begin{aligned}
\hat{k}_{T,t-1} &= \hat{z}_t - \hat{a}_{T,t} - (1-\eta)\hat{r}^k_{T,t} + (1-\eta)\hat{w}_t - (1-\eta)\hat{p}_{T,t} \\
\hat{k}_{N,t-1} &= \hat{y}_{N,t} - \hat{a}_{N,t} - (1-\theta)\hat{r}^k_{N,t} + (1-\theta)\hat{w}_t - (1-\theta)\hat{p}_{N,t} \\
\hat{l}_{T,t} &= \hat{z}_t - \hat{a}_{T,t} + \eta\hat{r}^k_{T,t} - \eta\hat{w}_t + \eta\hat{p}_{T,t} \\
\hat{l}_{N,t} &= \hat{y}_{N,t} - \hat{a}_{N,t} + \theta\hat{r}^k_{N,t} - \theta\hat{w}_t + \theta\hat{p}_{N,t}
\end{aligned}
$$

Euler's equation:

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

Optimal capital accumulation:

$$
\begin{aligned}
\frac{\rho}{1-h}[(1+h)\hat{c}_t - h\hat{c}_{t-1} - E_t\hat{c}_{t+1}] &= \chi(\hat{k}_{T,t} - \hat{k}_{T,t-1}) - \beta\chi E_t(\hat{k}_{T,t+1} - \hat{k}_{T,t}) - \beta r^k_T \hat{r}^k_{T,t+1} \\
\frac{\rho}{1-h}[(1+h)\hat{c}_t - h\hat{c}_{t-1} - E_t\hat{c}_{t+1}] &= \chi(\hat{k}_{N,t} - \hat{k}_{N,t-1}) - \beta\chi E_t(\hat{k}_{N,t+1} - \hat{k}_{N,t}) - \beta r^k_N \hat{r}^k_{N,t+1}
\end{aligned}
$$

Arbitrage condition:

$$
\hat{r}_t - \hat{r}^*_t - \hat{rp}_t = E_t\hat{q}_{t+1} - \hat{q}_t - \hat{\pi}^*_{t+1} + \hat{\pi}_{t+1}
$$

Risk premium equation:

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

Capital law of motion:

$$\hat{k}_{T,t} = (1-\delta)\hat{k}_{T,t-1} + \delta\hat{i}_{T,t}$$
$$\hat{k}_{N,t} = (1-\delta)\hat{k}_{N,t-1} + \delta\hat{i}_{N,t}$$

Labour market clearing condition:

$$\hat{l}_t = \frac{L_T}{L}\hat{l}_{T,t} + \frac{L_N}{L}\hat{l}_{N,t}$$

Intermediate tradable market clearing condition:

$$\hat{z}_t = \frac{Y_H}{Z}\hat{y}_{H,t} + \frac{Y^*_H}{Z}\hat{y}^*_{H,t}$$

Final tradable and non-tradable market clearing condition:

$$\hat{y}_{T,t} = \frac{C_T}{Y_T}\hat{c}_{T,t} + \frac{G_T}{Y_T}\hat{g}_{T,t} + \frac{I_T}{Y_T}\hat{i}_{T,t}$$
$$\hat{y}_{N,t} = \frac{C_N}{Y_N}\hat{c}_{N,t} + \frac{G_N}{Y_N}\hat{g}_{N,t} + \frac{I_N}{Y_N}\hat{i}_{N,t} + \frac{\lambda Y_F}{Y_N}\hat{y}_{F,t}$$

Consumption:

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

Aggregate output:

$$\hat{y}_t = \frac{P_T Y_T}{PY}(\hat{p}_{T,t} + \hat{y}_{T,t}) + \frac{P_N Y_N}{PY}(\hat{p}_{N,t} + \hat{y}_{N,t})$$

Budget constraint:

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

where:

$$
\begin{aligned}
d\hat{d}_t = Y\hat{y}_t + \frac{SP_h^*Y_h^*}{P}(\hat{q}_t + \hat{p}_{H,t}^* + \hat{y}_{H,t}^*) - \frac{P_FY_f}{P}(\hat{p}_{F,t} + \hat{y}_{F,t}) - \frac{WL}{P}(\hat{w}_t + \hat{l}_t) \\
- \frac{r_kP_TK_T}{P}(\hat{r}_{T,t}^k + \hat{k}_{T,t-1} + \hat{p}_{T,t}) - \frac{r_kP_NK_N}{P}(\hat{r}_{N,t}^k + \hat{k}_{N,t-1} + \hat{p}_{N,t})
\end{aligned}
$$

Trade balance value:

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

Taylor's Rule:

$$
\hat{r}_t = \rho_r\hat{r}_{t-1} + (1-\rho_r)(\alpha_\pi\hat{\pi}_t + \alpha_y\hat{y}_t) + \epsilon_{rt}
$$

A.3 Stochastic Shocks

$$
\begin{aligned}
\hat{a}_{T,t} &= \rho_{AT}\hat{a}_{T,t-1} + \epsilon_{ATt} \\
\hat{a}_{N,t} &= \rho_{AN}\hat{a}_{N,t-1} + \epsilon_{ANt} \\
\hat{g}_t &= \rho_g\hat{g}_{t-1} + \epsilon_{gt} \\
\hat{\varphi}_t &= \rho_\varphi\hat{\varphi}_{t-1} + \epsilon_{\varphi t} \\
\hat{r}_t^* &= \rho_{R^*}\hat{r}_{t-1}^* + \epsilon_{R^*t} \\
\hat{y}_t^* &= \rho_{y^*}\hat{y}_{t-1}^* + \epsilon_{y^*t} \\
\hat{\pi}_{l,t}^* &= \rho_{p^*}\hat{\pi}_{l,t-1}^* + \epsilon_{p^*t}
\end{aligned}
$$

Table 1: A List of Variables and Parameters

Variables or Parameters	Description
C_t	Domestic aggregate consumption
$C_{T,t}$	Consumption of tradable goods
$C_{N,t}$	Consumption of non-tradable goods
L_t	Aggregate Labour service supplied by households
$L_{T,t}$	Labour input into the tradable good sector
$L_{N,t}$	Labour input into the non-tradable good sector
$K_{T,t}$	Tradable capital stock
$K_{N,t}$	Non-tradable capital stock
$I_{T,t}$	Investment in the tradable sector
$I_{N,t}$	Investment in the non-tradable sector
S_t	Nominal exchange rate
τ_t	Government lump sum transfer
D_t	Aggregate dividends
W_t	Wage rate
R_t	Domestic nominal interest rate
R_t^*	World interest rate
rp_t	Risk premium
ξ_t	Foreign asset position
$r_{T,t}^k$	Capital rental rate in the tradable sector
$r_{N,t}^k$	Capital rental rate in the non-tradable sector
G_t	Aggregate government consumption
$G_{T,t}$	Government consumption on tradable goods
$G_{N,t}$	Government consumption on non-tradable goods
B_t	Domestic currency denominated bond
B_t^*	Foreign currency denominated bond
$AC_{T,t}$	Investment adjustment cost in the tradable sector
$AC_{N,t}$	Investment adjustment cost in the non-tradable sector
λ_t	Shadow price
$\Gamma_{t,t+j}$	Stochastic discount factor
Y_t	Domestic aggregate output
Y_t^*	Foreign output
Z_t	Intermediate tradable good production
$Y_{T,t}$	Final tradable good production
$Y_{N,t}$	Non-tradable good production
$Y_{H,t}$	Home-produced intermediate tradable goods sold in the domestic market
$Y_{H,t}^*$	Home-produced intermediate tradable goods exported to the foreign market
$Y_{F,t}$	Foreign-produced intermediate tradable goods imported to the domestic market
$A_{T,t}$	Technology shock in the tradable sector
$A_{N,t}$	Technology shock in the non-tradable sector
TB_t	Trade balance value
P_t	Price index of aggregate consumption good
P_t^*	Foreign price level
$P_{T,t}$	Price index of tradable goods
$P_{N,t}$	Price index of non-tradable goods
$P_{H,t}$	Price index of home-produced intermediate goods in the domestic market
$P_{H,t}^*$	Price index of home-produced intermediate goods in the foreign market
$P_{F,t}$	Price index of foreign-produced intermediate goods in the domestic market
π_t	Gross domestic consumption inflation rate
π^*	Gross foreign inflation rate

Table 2: A List of Variables and Parameters (Continued)

Variables or Parameters	Description
$P^*_{l,t}$	LCP price index of foreign-produced intermediate goods
$P^*_{p,t}$	PCP price index of foreign-produced intermediate goods
$X_{N,t}$	Optimal price chosen by non-tradable good producers
$X_{H,t}$	Optimal price chosen by domestic tradable intermediate firms
$X^p_{H,t}(X^l_{H,t})$	PCP(LCP) price chosen by domestic tradable intermediate firms
ϖ_t	Optimal wage rate set by domestic households
ϵ_{rt}	Monetary policy shock
$\hat{\varphi}_t$	Risk Premium shock
ρ_{p^*}	The AR coefficient of foreign price shocks
ρ_{AT}	The AR coefficient of tradable sector technology shock
ρ_{AN}	The AR coefficient of non-tradable sector technology shock
ρ_{R^*}	The AR coefficient of world interest rate shock
ρ_{y^*}	The AR coefficient of foreign output shock
ρ_g	The AR coefficient of government expenditure shock
ρ_φ	The AR coefficient of risk premium shock
β	Subjective discount rate
h	Habit formation coefficient
ρ_r	Interest-rate smoothing coefficient
α_π	Inflation coefficient in monetary policy reaction function
α_y	Output gap coefficient in monetary policy reaction function
χ	Capital adjustment cost coefficient
φ_n	Parameter for foreign asset position in the risk premium equation
φ_s	Parameter for change in exchange rates in the risk premium equation
ψ_d	The probability that a producer will not receive a signal to change its price
ψ_w	The probability that a household will not receive a signal to change its wage rate
τ_d	Price indexation
τ_w	Wage indexation
ϕ	The proportion of domestic tradable firms using LCP for export price setting
ϕ^*	The proportion of foreign firms using LCP for export price setting
γ	Elasticity of substitution among varieties of labour types
δ	Depreciation rate
μ	Constant relative risk aversion coefficient of labour
ρ	Constant relative risk aversion coefficient of consumption
α_T	Weighting parameter in the consumption aggregate function
α_H	Weighting parameter in the tradable good aggregate function
ς	The elasticity of substitution between tradable and non-tradable goods
σ	The elasticity of substitution between domestic and foreign tradable goods
ε	The elasticity of substitution among varieties produced within one country
ν	The elasticity of substitution among non-tradable goods
η	Cobb-Douglas coefficient for tradable good production
θ	Cobb-Douglas coefficient for non-tradable good production
α_f	Weighting parameter of foreign demand
σ_f	Elasticity parameter of foreign demand
λ	Amount of non-tradable good required for distribution service
ϱ	Distribution margin

Table 3: First-step Estimates of the Stochastic Processes: VAR

Exogenous Processes	AR Coefficient	Std Deviation	t-statistics	Std Error of Shock
		Australia		
Government Spending	0.3887	0.0761	5.1066	0.0151
Foreign Output	0.8454	0.0444	19.047	0.0057
Foreign Interest Rate	0.8682	0.0395	21.963	0.0014
		Canada		
Government Spending	0.6423	0.0629	10.214	0.0084
Foreign Output	0.8265	0.0467	17.682	0.0063
Foreign Interest Rate	0.8649	0.0403	21.449	0.0014
		United Kingdom		
Government Spending	0.5444	0.0695	7.8315	0.0082
Foreign Output	0.8332	0.0459	18.137	0.0060
Foreign Interest Rate	0.8541	0.0415	20.561	0.0014

Table 4: Parameter Estimates: Australia

	Australia							
	Prior Distribution			Posterior Maximization		Posterior Distribution		
Parameters	Distribution	Mean	Std	Mode	Std Error	Mean	10%	90%
ψ_d	Beta	0.70	0.10	0.6918	0.0312	0.6970	0.6473	0.7467
ψ_w	Beta	0.70	0.10	0.7353	0.0356	0.7360	0.6781	0.7921
τ_d	Beta	0.50	0.15	0.2110	0.0593	0.2243	0.1244	0.3192
τ_w	Beta	0.50	0.15	0.2499	0.0785	0.2623	0.1361	0.3849
ϕ	Beta	0.73	0.10	0.7872	0.0946	0.7612	0.6165	0.9115
ϕ^*	Beta	0.31	0.10	0.3030	0.0879	0.3071	0.1691	0.4400
σ	Gamma	1.50	0.25	1.6311	0.2660	1.7102	1.2603	2.1653
σ_f	Gamma	1.50	0.25	2.1519	0.1670	2.1436	1.8712	2.4015
ρ_r	Beta	0.80	0.10	0.9504	0.0080	0.9502	0.9372	0.9631
α_π	Gamma	1.40	0.10	1.1919	0.0897	1.1975	1.0479	1.3403
α_y	Gamma	0.50	0.20	1.5179	0.2825	1.5546	1.0773	2.0069
φ_s	Gamma	0.45	0.20	0.3028	0.0348	0.3089	0.2528	0.3676
φ_n	Gamma	0.01	0.005	0.0312	0.0062	0.0326	0.0223	0.0424
χ	Gamma	10.0	2.00	15.128	2.1460	15.486	12.004	18.982
ϱ	Beta	0.40	0.10	0.6655	0.0544	0.6555	0.5685	0.7470
ρ_{AT}	Beta	0.80	0.05	0.9517	0.0129	0.9458	0.9237	0.9693
ρ_{AN}	Beta	0.80	0.10	0.2220	0.0511	0.2214	0.1395	0.3005
ρ_p	Beta	0.80	0.10	0.5213	0.0608	0.5278	0.4284	0.6312
ρ_φ	Beta	0.80	0.10	0.8311	0.0479	0.8232	0.7442	0.9022
σ_r	Inv Gamma	0.01	4.00	0.0024	0.0001	0.0024	0.0022	0.0027
σ_{AT}	Inv Gamma	0.01	4.00	0.0274	0.0054	0.0304	0.0206	0.0403
σ_{AN}	Inv Gamma	0.01	4.00	0.1041	0.0247	0.1155	0.0719	0.1573
σ_p	Inv Gamma	0.01	4.00	0.0696	0.0122	0.0710	0.0512	0.0896
σ_φ	Inv Gamma	0.01	4.00	0.0136	0.0027	0.0147	0.0100	0.0190

Table 5: Parameter Estimates: Canada

	Canada							
	Prior Distribution			Posterior Maximization		Posterior Distribution		
Parameters	Distribution	Mean	Std	Mode	Std Error	Mean	10%	90%
ψ_d	Beta	0.70	0.10	0.6897	0.0369	0.6984	0.6430	0.7586
ψ_w	Beta	0.70	0.10	0.7126	0.0359	0.7160	0.6587	0.7744
τ_d	Beta	0.50	0.15	0.2688	0.0691	0.2924	0.1752	0.4033
τ_w	Beta	0.50	0.15	0.2371	0.0816	0.2575	0.1225	0.3837
ϕ	Beta	0.76	0.10	0.8096	0.0977	0.7794	0.6385	0.9305
ϕ^*	Beta	0.30	0.10	0.3066	0.1060	0.3125	0.1525	0.4631
σ	Gamma	1.50	0.25	1.7011	0.2888	1.7606	1.2636	2.2251
σ_f	Gamma	1.50	0.25	1.8737	0.1408	1.8725	1.6506	2.0861
ρ_r	Beta	0.80	0.10	0.9298	0.0144	0.9313	0.9109	0.9511
α_π	Gamma	1.40	0.10	1.0743	0.0986	1.0995	0.9580	1.2255
α_y	Gamma	0.50	0.20	0.9202	0.2773	1.0033	0.5814	1.4121
φ_s	Gamma	0.45	0.20	0.3485	0.0308	0.3575	0.3084	0.4059
φ_n	Gamma	0.01	0.005	0.0387	0.0076	0.0393	0.0274	0.0510
χ	Gamma	10.0	2.00	17.209	2.3696	17.402	13.425	21.137
ϱ	Beta	0.40	0.10	0.5908	0.0611	0.5845	0.4869	0.6842
ρ_{AT}	Beta	0.80	0.05	0.9727	0.0086	0.9683	0.9562	0.9832
ρ_{AN}	Beta	0.80	0.10	0.3651	0.0666	0.3536	0.2460	0.4573
ρ_p	Beta	0.80	0.10	0.5463	0.0653	0.5637	0.4604	0.6724
ρ_φ	Beta	0.80	0.10	0.7969	0.0664	0.7813	0.6726	0.8927
σ_r	Inv Gamma	0.01	4.00	0.0022	0.0001	0.0023	0.0020	0.0025
σ_{AT}	Inv Gamma	0.01	4.00	0.0225	0.0051	0.0256	0.0165	0.0344
σ_{AN}	Inv Gamma	0.01	4.00	0.0520	0.0145	0.0604	0.0338	0.0872
σ_p	Inv Gamma	0.01	4.00	0.0636	0.0135	0.0644	0.0435	0.0840
σ_φ	Inv Gamma	0.01	4.00	0.0082	0.0015	0.0088	0.0063	0.0113

Table 6: Parameter Estimates: United Kingdom

Parameters	United Kingdom							
	Prior Distribution			Posterior Maximization		Posterior Distribution		
	Distribution	Mean	Std	Mode	Std Error	Mean	10%	90%
ψ_d	Beta	0.70	0.10	0.7202	0.0308	0.7293	0.6748	0.7826
ψ_w	Beta	0.70	0.10	0.7692	0.0389	0.7781	0.7094	0.8446
τ_d	Beta	0.50	0.15	0.2636	0.0585	0.2642	0.1662	0.3608
τ_w	Beta	0.50	0.15	0.1009	0.0436	0.1174	0.0456	0.1886
ϕ	Beta	0.30	0.10	0.2767	0.1064	0.2974	0.1348	0.4597
ϕ^*	Beta	0.40	0.10	0.2307	0.0649	0.2517	0.1446	0.3603
σ	Gamma	1.50	0.25	2.3912	0.3549	2.4409	1.8677	3.0162
σ_f	Gamma	1.50	0.25	2.0740	0.1677	2.0447	1.7699	2.2930
ρ_r	Beta	0.80	0.10	0.9395	0.0105	0.9391	0.9224	0.9564
α_π	Gamma	1.40	0.10	1.2301	0.0920	1.2384	1.0875	1.3871
α_y	Gamma	0.50	0.20	1.1768	0.2326	1.2000	0.8160	1.5798
φ_s	Gamma	0.45	0.20	0.3510	0.0274	0.3561	0.3102	0.4034
φ_n	Gamma	0.01	0.005	0.0464	0.0089	0.0484	0.0336	0.0631
χ	Gamma	10.0	2.00	14.091	2.2317	14.512	10.711	18.090
ϱ	Beta	0.40	0.10	0.8363	0.0363	0.8362	0.7808	0.8952
ρ_{AT}	Beta	0.80	0.05	0.8706	0.0422	0.8465	0.7761	0.9176
ρ_{AN}	Beta	0.80	0.10	0.2515	0.0532	0.2535	0.1675	0.3375
ρ_p	Beta	0.80	0.10	0.6888	0.0545	0.6920	0.5971	0.7853
ρ_φ	Beta	0.80	0.10	0.8298	0.0599	0.8154	0.7158	0.9201
σ_r	Inv Gamma	0.01	4.00	0.0022	0.0001	0.0023	0.0020	0.0025
σ_{AT}	Inv Gamma	0.01	4.00	0.0991	0.0210	0.1145	0.0746	0.1526
σ_{AN}	Inv Gamma	0.01	4.00	0.0885	0.0216	0.1005	0.0575	0.1423
σ_p	Inv Gamma	0.01	4.00	0.0555	0.0080	0.0546	0.0417	0.0676
σ_φ	Inv Gamma	0.01	4.00	0.0156	0.0028	0.0174	0.0124	0.0224

Table 7: Unconditional Second Moments: Australia

	Australia				
Variables	Std Deviation	Autocorrelation	Correlation with $\hat{y}_t$	Correlation with $\hat{q}_t$	Correlation with $\hat{tb}_t$
			Data		
$\hat{w}_t$	0.0145	0.6946	-0.0116	0.0799	0.1969
$\hat{y}_t$	0.0133	0.6914	1.0000	-0.2078	0.2667
$\hat{q}_t$	0.0662	0.8557	-0.2078	1.0000	-0.3722
$\hat{r}_t$	0.0039	0.8299	0.3993	-0.1737	0.2729
$\hat{tb}_t$	0.0998	0.7945	0.2667	-0.3722	1.0000
			Model		
$\hat{w}_t$	0.0250	0.8251	0.2940	-0.4206	0.2143
	(0.0169, 0.0377)	(0.5930, 0.9707)	(-0.0368, 0.5747)	(-0.7096, -0.0034)	(-0.2477, 0.5729)
$\hat{y}_t$	0.0167	0.6876	1.0000	-0.2898	0.3175
	(0.0132, 0.0212)	(0.4817, 0.8360)		(-0.5929, 0.0552)	(-0.0371, 0.5973)
$\hat{q}_t$	0.0663	0.8431	-0.2898	1.0000	-0.4355
	(0.0491, 0.0901)	(0.6557, 0.9589)	(-0.5929, 0.0552)		(-0.7295, -0.0601)
$\hat{r}_t$	0.0075	0.9081	-0.2402	0.3289	-0.0631
	(0.0047, 0.0120)	(0.6661, 1.0000)	(-0.4973, 0.0386)	(-0.1177, 0.6602)	(-0.4641, 0.3712)
$\hat{tb}_t$	0.1025	0.8334	0.3175	-0.4355	1.0000
	(0.0769, 0.1405)	(0.6369, 0.9534)	(-0.0371, 0.5973)	(-0.7295, -0.0601)	

Table 8: Unconditional Second Moments: Canada

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		
$\hat{w}_t$	0.0179	0.8717	0.2061	-0.5714	0.0457
	(0.0121, 0.0271)	(0.6692, 0.9952)	(-0.1496, 0.5321)	(-0.8199, -0.1518)	(-0.3077, 0.3982)
$\hat{y}_t$	0.0131	0.6888	1.0000	-0.0709	0.1446
	(0.0103, 0.0168)	(0.4797, 0.8480)		(-0.4327, 0.3136)	(-0.1592, 0.4621)
$\hat{q}_t$	0.0424	0.8751	-0.0709	1.0000	-0.0431
	(0.0301, 0.0632)	(0.6716, 0.9850)	(-0.4327, 0.3136)		(-0.4070, 0.2827)
$\hat{r}_t$	0.0074	0.9008	-0.2534	0.4212	-0.0172
	(0.0045, 0.0118)	(0.6622, 1.0000)	(-0.5359, 0.0532)	(-0.1164, 0.7725)	(-0.3444, 0.3228)
$\hat{tb}_t$	0.0554	0.7146	0.1446	-0.0431	1.0000
	(0.0433,0.0699)	(0.5313, 0.8493)	(-0.1592, 0.4621)	(-0.4070, 0.2827)	

Table 9: Unconditional Second Moments: United Kingdom

Variables	Std Deviation	Autocorrelation	Correlation with $\hat{y}_t$	Correlation with $\hat{q}_t$	Correlation with $\hat{tb}_t$
	United Kingdom				
	Data				
$\hat{w}_t$	0.0143	0.7610	0.1562	-0.1891	0.1056
$\hat{y}_t$	0.0144	0.8047	1.0000	-0.0653	0.3170
$\hat{q}_t$	0.0776	0.8589	-0.0653	1.0000	0.0083
$\hat{r}_t$	0.0040	0.8472	0.1859	-0.2431	0.1645
$\hat{tb}_t$	0.0349	0.6216	0.3170	0.0083	1.0000
	Model				
$\hat{w}_t$	0.0268	0.8869	0.3958	-0.5934	-0.0175
	(0.0187, 0.0386)	(0.6698, 1.0000)	(0.0705, 0.6626)	(-0.8271, -0.1632)	(-0.3313, 0.3495)
$\hat{y}_t$	0.0144	0.6777	1.0000	-0.1990	0.1281
	(0.0115, 0.0179)	(0.4750, 0.8195)		(-0.5154, 0.1660)	(-0.1827, 0.4404)
$\hat{q}_t$	0.0892	0.8794	-0.1990	1.0000	-0.0710
	(0.0631, 0.1234)	(0.6817, 0.9880)	(-0.5154, 0.1660)		(-0.4226, 0.2668)
$\hat{r}_t$	0.0052	0.8671	-0.3051	0.2699	-0.0106
	(0.0036, 0.0076)	(0.6398, 0.9866)	(-0.5546, -0.0397)	(-0.2481, 0.6661)	(-0.3458, 0.3296)
$\hat{tb}_t$	0.0549	0.7598	0.1281	-0.0710	1.0000
	(0.0417, 0.0711)	(0..5889, 0.8895)	(-0.1827, 0.4404)	(-0.4226, 0.2668)	

Table 10: Variance Decompositions: Australia

		Australia		
		$\hat{tb}_t$	$\hat{q}_t$	$\hat{y}_t$
Tradable technology shock	1	6.4124	1.1694	51.137
	4	8.0690	0.6060	46.786
	8	7.5399	0.9055	47.462
	12	7.1149	0.9947	47.676
Non-tradable technology shock	1	0.0349	2.4363	0.2652
	4	0.0528	1.5544	2.6745
	8	0.0968	1.2372	2.6976
	12	0.0951	1.1814	2.6984
Risk premium shock	1	29.706	25.134	14.775
	4	28.420	8.5193	15.111
	8	28.988	7.7512	15.355
	12	27.635	7.6118	15.602
Monetary policy shock	1	0.0182	0.1323	0.1907
	4	0.0183	0.0432	0.1807
	8	0.0187	0.0302	0.1736
	12	0.0179	0.0279	0.1707
Government spending shock	1	0.0897	0.0001	1.2847
	4	0.0641	0.0007	1.1510
	8	0.0534	0.0009	1.1026
	12	0.0505	0.0009	1.0829
Foreign price shock	1	63.177	70.729	32.156
	4	62.842	89.132	33.897
	8	62.780	89.946	33.005
	12	64.589	90.057	32.561
Foreign interest rate shock	1	0.4239	0.3496	0.1897
	4	0.4025	0.1190	0.1975
	8	0.4158	0.1102	0.2020
	12	0.3970	0.1090	0.2066
Foreign output shock	1	0.1376	0.0500	0.0008
	4	0.1306	0.0249	0.0024
	8	0.1076	0.0186	0.0026
	12	0.1015	0.0174	0.0027

Table 11: Variance Decompositions: Canada

		Canada		
		$\hat{tb}_t$	$\hat{q}_t$	$\hat{y}_t$
Tradable technology shock	1	68.334	18.654	45.770
	4	67.762	7.6812	31.526
	8	68.872	7.5204	31.043
	12	68.318	7.4974	31.887
Non-tradable technology shock	1	0.0047	0.5764	0.0170
	4	0.0232	0.4421	0.3752
	8	0.0315	0.3836	0.3578
	12	0.0328	0.3804	0.3647
Risk premium shock	1	10.318	3.8541	2.9838
	4	9.6549	1.5829	2.2404
	8	9.4775	1.6043	2.2448
	12	9.4058	1.6040	2.2877
Monetary policy shock	1	0.0306	0.0837	0.0673
	4	0.0290	0.0330	0.0515
	8	0.0284	0.0261	0.0464
	12	0.0284	0.0254	0.0456
Government spending shock	1	0.0497	0.0000	0.3301
	4	0.0379	0.0005	0.2126
	8	0.0311	0.0006	0.1896
	12	0.0308	0.0006	0.1858
Foreign price shock	1	20.531	76.598	50.711
	4	21.751	90.144	65.490
	8	20.881	90.354	66.011
	12	21.511	90.381	65.119
Foreign interest rate shock	1	0.4219	0.1473	0.1208
	4	0.4009	0.0624	0.0911
	8	0.4041	0.0670	0.0938
	12	0.4013	0.0677	0.0967
Foreign output shock	1	0.3096	0.0868	0.0006
	4	0.3415	0.0541	0.0132
	8	0.2741	0.0443	0.0134
	12	0.2715	0.0431	0.0132

Table 12: Variance Decompositions: United Kingdom

		United Kingdom		
		$\hat{tb}_t$	$\hat{q}_t$	$\hat{y}_t$
Tradable technology shock	1	8.6798	4.5686	3.7471
	4	5.6566	4.3511	3.1868
	8	5.1986	4.3323	3.2160
	12	5.1806	4.3321	3.2300
Non-tradable technology shock	1	0.0664	0.7639	0.1561
	4	0.2669	0.6085	0.8774
	8	0.3508	0.5897	0.9388
	12	0.3751	0.5941	0.9384
Risk premium shock	1	87.251	9.6293	0.6000
	4	62.118	4.4440	0.5841
	8	63.916	4.5485	0.5940
	12	63.727	4.5158	0.5982
Monetary policy shock	1	0.0858	0.0643	0.0425
	4	0.0626	0.0247	0.0344
	8	0.0630	0.0214	0.0332
	12	0.0629	0.0212	0.0332
Government spending shock	1	0.0931	0.0005	0.0629
	4	0.0567	0.0008	0.0502
	8	0.0504	0.0008	0.0485
	12	0.0502	0.0008	0.0484
Foreign price shock	1	2.4160	84.828	95.386
	4	30.709	90.496	95.261
	8	29.337	90.436	95.164
	12	29.524	90.465	95.146
Foreign interest rate shock	1	0.7688	0.0846	0.0048
	4	0.5533	0.0395	0.0048
	8	0.5745	0.0408	0.0049
	12	0.5728	0.0406	0.0049
Foreign output shock	1	0.6394	0.0611	0.0004
	4	0.5770	0.0359	0.0009
	8	0.5091	0.0309	0.0009
	12	0.5073	0.0306	0.0009

Figure 1: Estimated Parameter Distributions: Australia

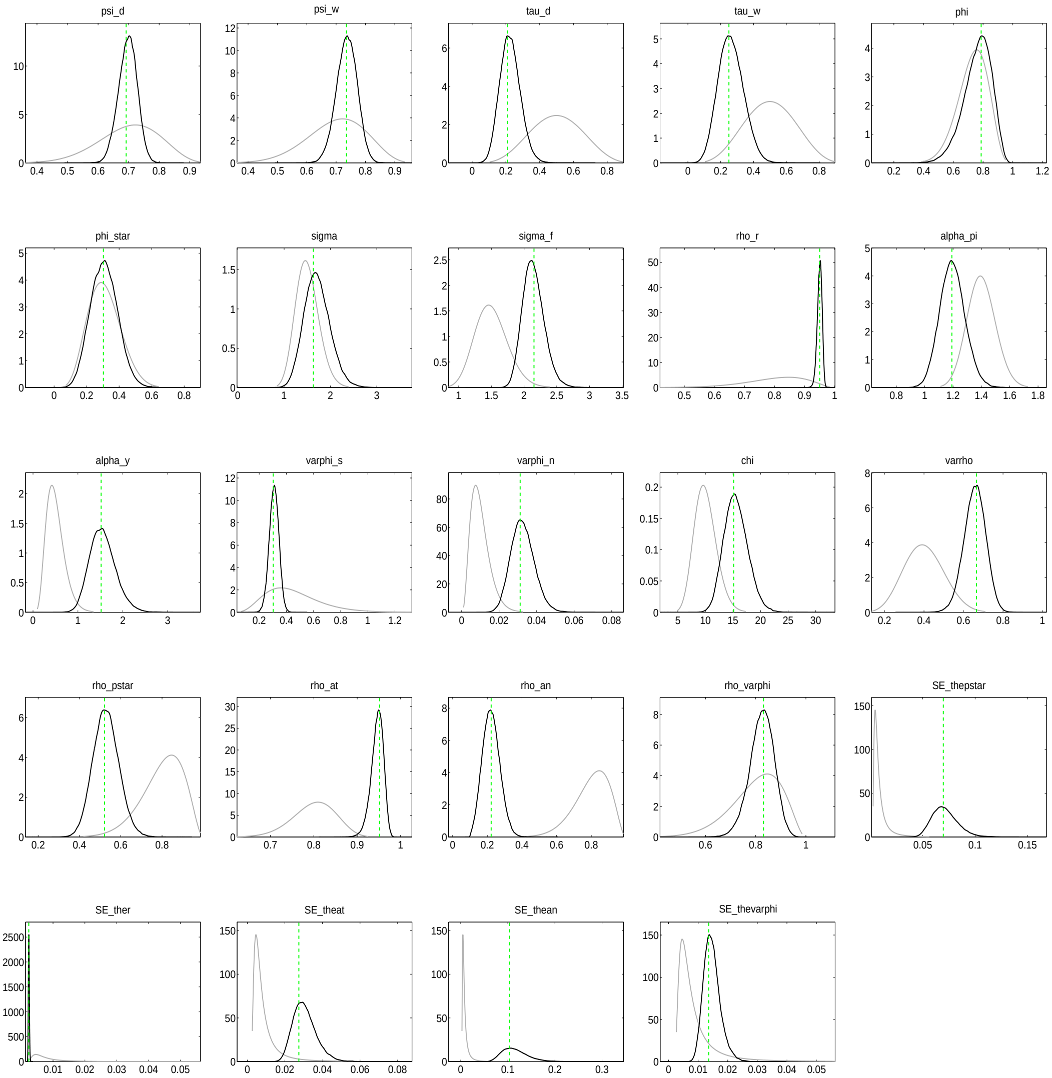

Figure 2: Estimated Parameter Distributions: Canada

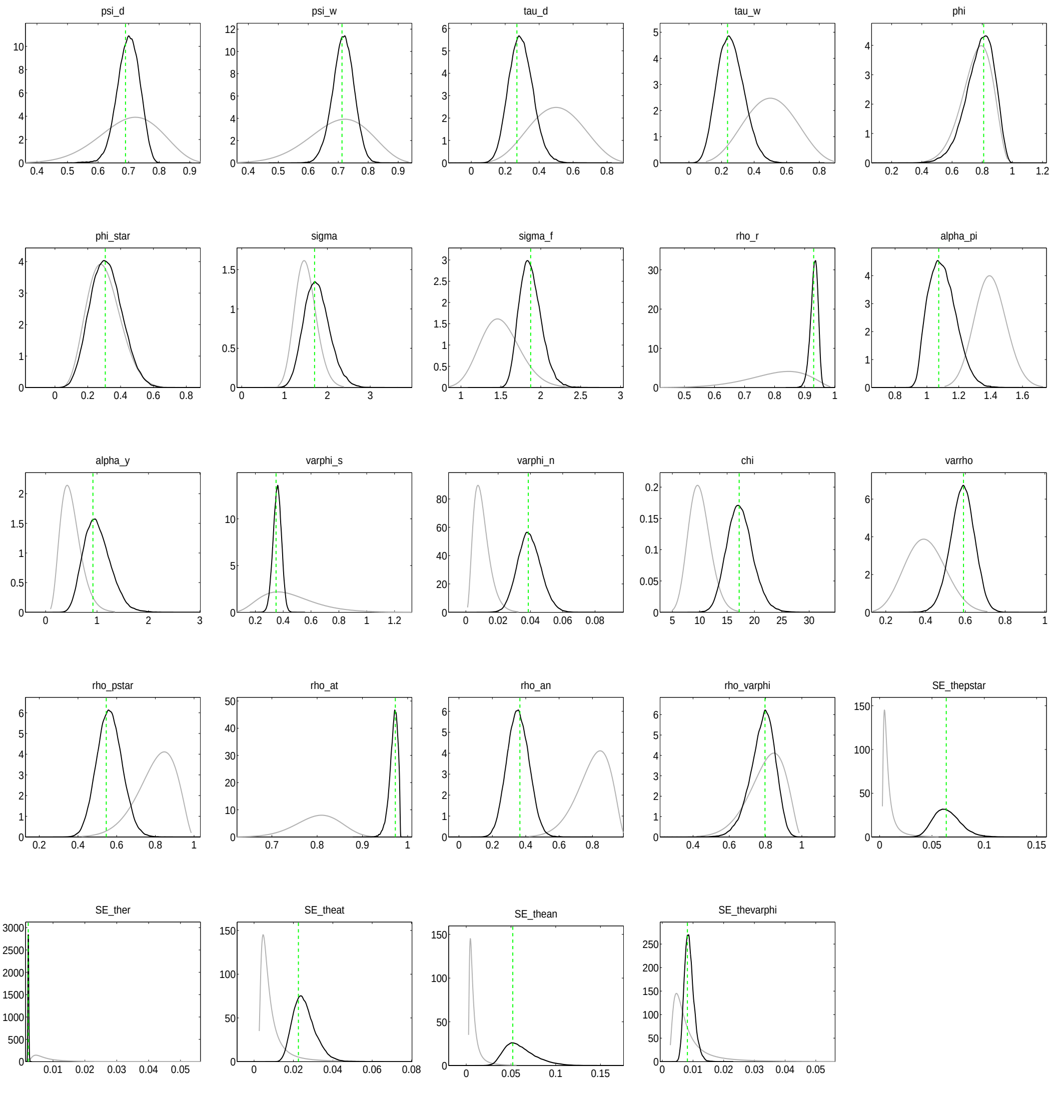

Figure 3: Estimated Parameter Distributions: United Kingdom

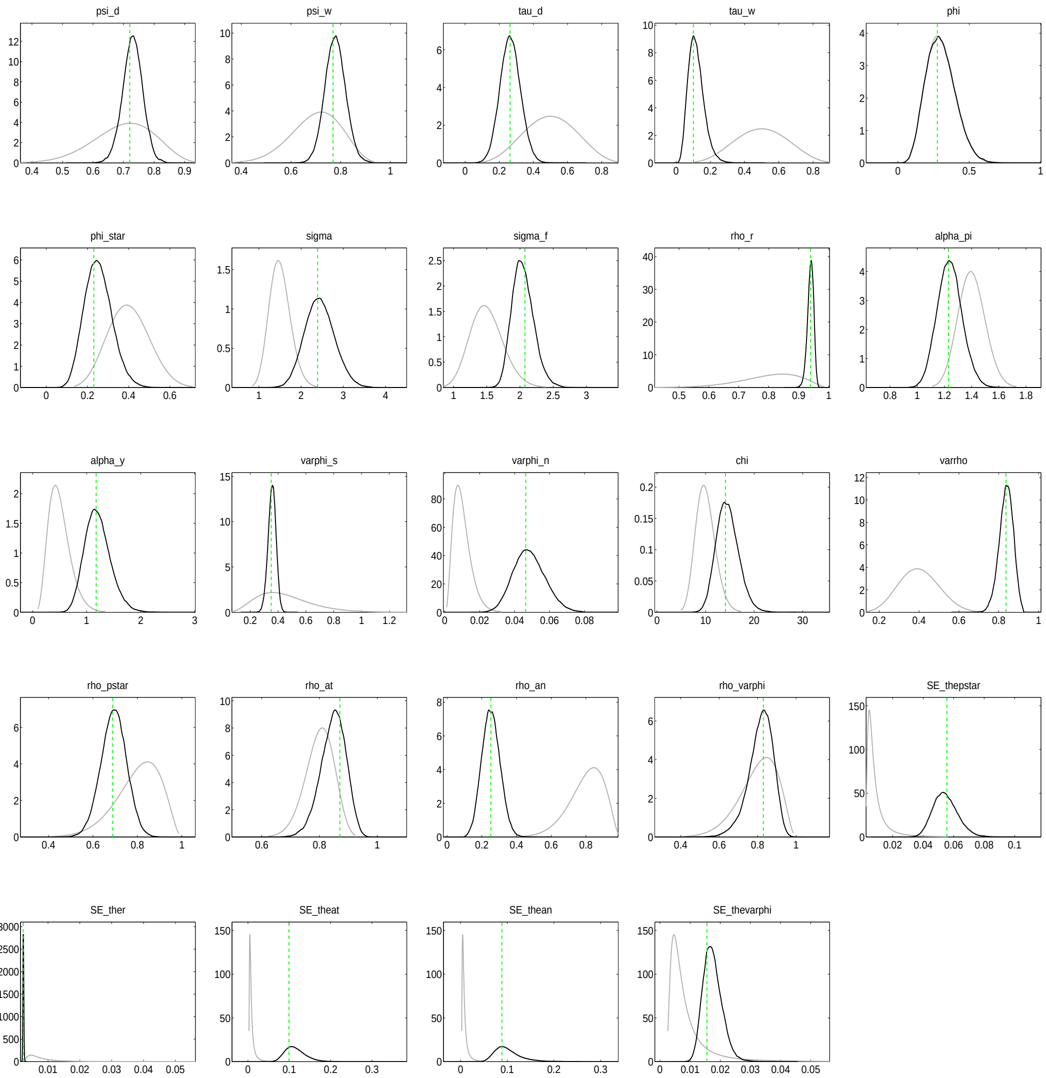

Figure 4: Impulse Responses: Australia

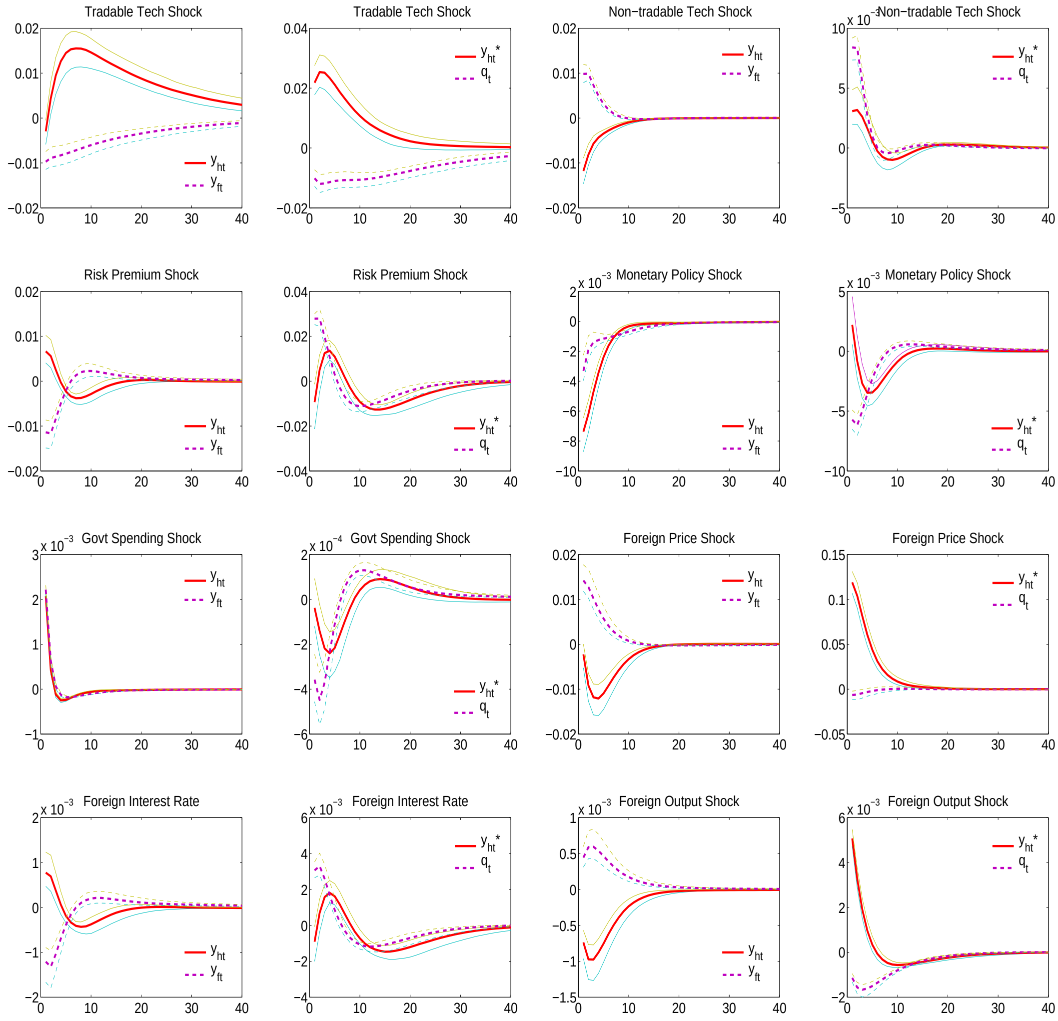

Figure 5: Impulse Responses: Canada

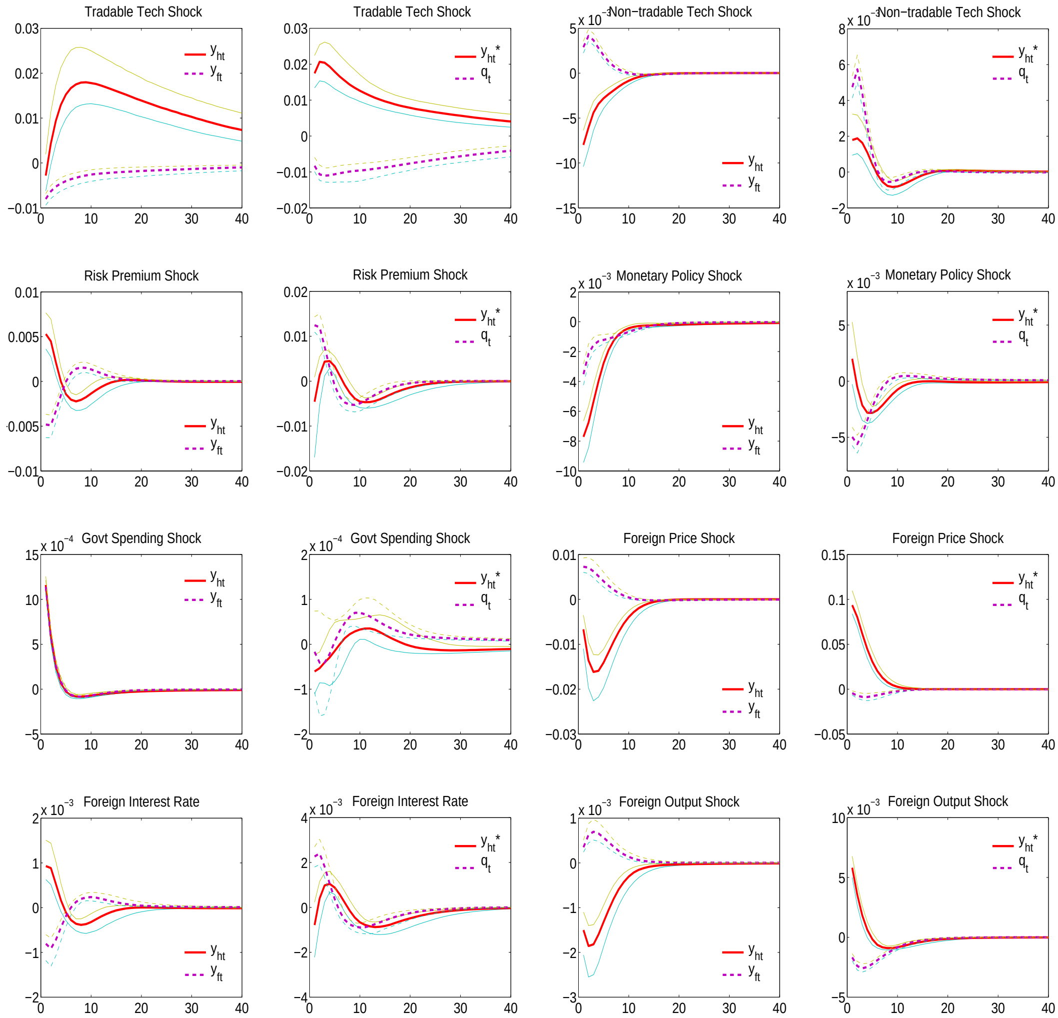

Figure 6: Impulse Responses: United Kingdom