Expenditure-Switching Effect and the Choice of Exchange Rate Regime

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Abstract

This paper investigates the quantitative importance of the expenditure-switching effect by developing and estimating a structural sticky price model nesting both PCP (Producer Currency Pricing) and LCP (Local Currency Pricing) settings. In doing so it provides empirical evidence for use in the theoretical debate for the choice of exchange rate regime, and sheds light on the magnitude of the benefits from exchange rate flexibility in terms of expenditure switching. The level of the expenditure-switching effect is determined by the degree of price stickiness, the fraction of firms employing PCP versus LCP, and the elasticity of substitution between domestic goods and foreign 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 the domestic agents is relatively small for the United Kingdom, and relatively large for Australia and Canada. This is because the majority of exporters to the UK employ LCP to set their export prices and the domestic production price is much less sticky in the UK. Both of these limit the domestic expenditure switching initiated by nominal exchange rate movements. On the other hand, the expenditure switching by the foreign distributors is comparatively small for Canada, since a larger fraction of Canadian firms adopt LCP for their export price setting. Though the degree of substitution by British final good producers is small, there is more expenditure switching between British products and local products by the foreign agents. Overall, in terms of expenditure switching, the benefits from floating rates seem to be most significant for Australia.

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1 Introduction

Few questions in international macroeconomics have aroused more debate than the one concerning the choice of exchange rate regime. Economic literature offers abundant models, theories, and propositions that attempt to answer the question of whether a country should fix its exchange rate or allow it to float. Yet little consensus has emerged.

In the early 1950s, Milton Friedman put forward a well-known hypothesis in support of the flexible exchange rate regime. He argued that a floating exchange rate regime is preferable, because when prices are sticky, nominal exchange rate movements can adjust the relative prices of home goods and foreign goods. Thus, smoother adjustment of quantities is achieved through changes in exchange rates under the flexible exchange rate regime. 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 — an increase in the trade balance. The magnitude of the expenditure-switching effect, which is defined as the adjustment of relative demands in response to nominal exchange rate movements, is therefore suggestive of the importance of exchange rate flexibility.

Since Friedman set forth his hypothesis, a number of theories have been brought forward either to confirm or to overthrow his original intuition. Among others, the work of Obstfeld and Rogoff (1995,1998,2000,2001) has offered a consistent and logical framework featuring Producer Currency Pricing (PCP), supporting the idea that 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 nontradable final consumption goods and PCP for tradable intermediate goods. Thus, although there is limited pass-through of exchange rate movements to retail prices, there is full pass-through to import prices. Therefore, when prices are sluggish, nominal exchange rate changes can induce expenditure switching at the local producers' level, an advantage often attributed to flexible exchange rate regime over fixed exchange rate regime. In that sense, 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 reexamined several problems under the Local Currency Pricing (LCP) setting. Because of the distinction of the currencies in which prices are set, they have come to different conclusions. Concerning the exchange rate regime debate, 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. When prices are sticky in the local currency, there is no expenditure-switching effect of nominal exchange rates, and therefore no benefit to exchange rate flexibility. Nominal exchange rate flexibility leads only to deviation from purchasing power parity without achieving any relative price adjustment.

At a theoretical level, it is difficult to establish an acceptable model to end the debate over exchange rate regime choice. In fact, the two streams of thought based on the leading models have even achieved the exact opposite conclusions concerning the expenditure-switching effect. Besides, the actual quantitative importance of the expenditure-switching effect is crucial to determining whether exchange rate flexibility is preferable. Therefore empirical study is needed to examine the quantitative significance of the expenditure-switching effect. Although it is hard to present a direct and simple relationship about how the degree to which central banks want to stabilize exchange rates should depend on the size of the expenditure-switching effect, the magnitude of expenditure switching matters to the choice of the exchange rate policy. Devereux and Engel (2006) examine the variability of exchange rates under optimal monetary policy and find that the variance of the optimal exchange rates falls with the elasticity of substitution between home and foreign intermediate inputs. Since the magnitude of the expenditure switching depends positively on that elasticity, in that sense, when the size of the expenditure-switching effect is small, the optimal amount of exchange rate volatility should also be small. This by no means rules out the possibility that besides the expenditure-switching effect, other aspects have impacts on the exchange rate regime choice. For example, benefits from independent monetary policy, international trade stimulation due to stable exchange rates and so on.[1] Empirical research is still needed to resolve the quantitative importance of the expenditure-switching role of nominal exchange rates.[2]

In the international macroeconomic literature, a great deal of empirical work has been done in studies of exchange rate pass-through to examine the degree to which exchange rate movements are reflected in import prices. According to the textbook definition of exchange rate pass-through, 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 the import price responds to exchange rate fluctuations.[3] 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, etc.[4] 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.[5] While their econometric techniques may differ,

[1] There's more discussion of this in the conclusion section.

[2] Not only the size of the expenditure-switching effect is important for it is relevant with respect 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. See Engel (2002) for a summary.

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

[4] See, for example, Corsetti, Dedola, and Leduc (2004).

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

these studies all focus on pass-through studies and do not go further to investigate the role of expenditure switching, which is precisely what matters as far as the exchange rate regime debate is concerned. On the other hand, other studies have examined how imports are affected by import prices, but the important link between exchange rates and relative prices is missing. Gourinchas (1998) evaluates the impact of exchange rate movements on job reallocations across and within sectors. But without a general equilibrium context, it is hard to assess his findings.

This paper seeks to gain insight into the exchange rate regime debate by directly estimating the importance of the expenditure-switching effect. If the effect turns out to be insignificant, the benefits to be had from exchange rate flexibility may not be very large. For this purpose, I have built a structural small open economy model featuring sticky prices and wages, habit formation in preference for consumption, and adjustment costs in investment. Sticky price assumption is a must for the model, because the choice of exchange rate regime would be irrelevant if prices are flexible. Habit formation in consumption and adjustment costs in investment play important roles in generating persistent and hump-shaped output response to monetary shocks with reasonable duration of price contracts. Since the empirical evidence suggests that there is partial pass-through to import prices in the short run, which does not seem to support either the pure PCP model or the pure LCP model, a general model that nests both PCP and LCP settings is developed in this paper, similar to Corsetti and Pesenti (2005) and Bergin (2006).

The model cannot be solved analytically, but the log-linearized conditions can be obtained. The magnitude of the expenditure-switching effect is influenced by the price stickiness, the fraction of firms adopting PCP versus LCP setting for their export goods, and the elasticity of substitution between domestic varieties and import varieties. The expenditure switching appears both in the domestic market and in the foreign market where the substitution between domestic goods and foreign goods occurs in response to exchange rate movements. Since there is no absolute measurement of what constitutes 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 is the smallest for the United Kingdom. Much more firms exporting to the UK price their goods in the local currency, and the domestic intermediate good price is much more flexible in the country, so exchange rate movements merely trigger moderated expenditure switching. The opposite is true for Australia and Canada. On the other hand, a larger fraction of Australian firms adopt PCP for export pricing comparing to the other two countries, so the expenditure switching by foreign agents are also larger for Australia. In that sense, the benefits from exchange rate flexibility are most significant for Australia among the three countries examined here. Though the degree to which the British substitute between domestic goods and import goods is small, since a smaller fraction of British exporting firms adopting LCP than Canadian exporting firms, the expenditure switching in the foreign market would be slightly larger for the UK than that for Canada.

The remainder of this paper is organized as follows: Section 2 presents the theoretical model. Section 3 explains the data and the empirical strategy that have been employed. The empirical results are stated in Section 4. Finally, 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 prices and the foreign interest rate are exogenous, and the economy faces a downward sloping demand curve for its exports. The economy is characterized by : (1) a continuum of infinitely lived households; (2) a continuum of final good producers; (3) a continuum of intermediate good suppliers; and (4) government and 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 labor supply.

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

where U is the instantaneous utility function, and β is the discount factor $(0 < \beta < 1)$. $a_{\beta t}$ represents the preference shock to the discount rate that affects the intertemporal substitution of households. It is assumed to follow a first-order autoregressive process given by

$$\ln a_{\beta t} = (1 - \delta_{a\beta}) \ln a_{\beta} + \delta_{a\beta} \ln a_{\beta,t-1} + \epsilon_{a\beta t} \tag{2.1}$$

where $\epsilon_{a\beta t}$ is normally distributed with zero mean and variance $\sigma^2_{\epsilon a\beta}$.

The instantaneous utility function is assumed to take the form

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

The functional form is commonly used in the New Open Economy Macroeconomics literature. Utility is assumed to be positively dependent on the consumption of goods by household i, and negatively dependent on the 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 years. This paper employs the habit formation specification to produce sluggish responses that are consistent with the empirical evidence. ρ is the coefficient of relative risk aversion of households. μ is the inverse of labor supply elasticity.

Households consume various final goods indexed by $k \in [0,1]$. Let ς be the elasticity of substitution among differentiated final consumption goods. The Dixit Stiglitz index is given by

$$C_t^i = \left[\int_0^1 C_t^i(k)^{1-\frac{1}{\varsigma}} dk \right]^{\frac{\varsigma}{\varsigma-1}}$$

This then implies that the consumption of each variety of the final good is

$$C_t^i(k) = C_t^i \left(\frac{P_t(k)}{P_t} \right)^{-\varsigma}$$

Households receive dividends D_t from the firms and get the lump sum transfer τ_t from the government. A household of type i can provide labor service to intermediate 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 an interest rate R_t^*, which is subject to exogenous shocks.

$$\ln R_t^* = (1 - \delta_{R^*}) \ln R^* + \delta_{R^*} \ln R_{t-1}^* + \epsilon_{R^*t} \tag{2.2}$$

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

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

$$C_t + I_t + AC_t + \frac{S_t B_t^*}{P_t R_t^* rp_t} + \frac{B_t}{P_t R_t} = \frac{D_t}{P_t} + \tau_t + r_t^k K_{t-1} + \frac{W_t L_t}{P_t} + \frac{S_t B_{t-1}^*}{P_{t-1}\pi_t} + \frac{B_{t-1}}{P_t}$$

π_t is the gross consumption inflation rate, and S_t is the nominal exchange rate, which is defined as the price of foreign currency in terms of domestic currency. K_t denotes capital, which is assumed to be owned by households and rented to intermediate firms at the rate of r_t^k. Investment in new capital is assumed to involve a quadratic adjustment cost AC_t, which is given by

$$AC_t = \frac{\chi}{2}\frac{(K_t - K_{t-1})^2}{K_{t-1}}$$

K_t evolves following the law of motion

$$K_t = (1-\delta)K_{t-1} + I_t \tag{2.3}$$

rp_t is a debt-elastic interest rate premium. It is a stationarity-inducing technique used here to ensure the existence of a unique steady state.[6] The risk premium is dependent on the country's net foreign debt. ϵ_{rpt} represents the risk premium shock, which is adopted because of the well-documented empirical weakness of the uncovered interest rate parity condition. The shock is assumed to be normally distributed with zero mean and variance $\sigma^2_{\epsilon rp}$.

$$\ln rp_t = -\varphi\left[\exp\left(\frac{S_t B_t^*}{P_{ht} Z_t}\right) - 1\right] + \epsilon_{rpt}$$

2.1.2 Households' Intertemporal Decisions

In the labor market, households act as price-setters and meet the demand for their particular type of labor service. Wage rates are assumed to be set in a staggered fashion, following Calvo (1983). That is, in each period, the probability that the wage rate is changed is $1-\psi_w$. Without losing generality, assume that the wage rate of type i labor is changed at time t, and ϖ_t^i is the new wage rate. With probability ψ_w^j, ϖ_t^i will still be in effect at time $t+j$. Households choose ϖ_t^i at date t 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

$$L_t^i = \int_0^1 l_t^i(s)ds$$

The first-order condition that characterizes the interior solution of the optimization problem with respect to the wage rate is

$$\begin{aligned}
&\Sigma_{j=0}^{\infty}(\psi_w\beta)^j E_t U_{L,t+j}(-\gamma)a_{\beta,t+j}\left(\frac{\varpi_t^i}{W_{t+j}}\right)^{-\gamma-1} W_{t+j}^{-1} H_{t+j} \\
&= \Sigma_{j=0}^{\infty}(\psi_w\beta)^j E_t \lambda_{t+j}(1-\gamma)a_{\beta,t+j}\left(\frac{\varpi_t^i}{W_{t+j}}\right)^{-\gamma} P_{t+j}^{-1} H_{t+j}
\end{aligned}$$

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

where $U_{L,t+j}$ is the marginal disutility of labor, and λ_{t+j} is the shadow price with $\lambda_{t+j} = U_{C,t+j}$. So the optimal value of ϖ_t^i is set according to

$$\varpi_t^i = \frac{E_t \Sigma_{j=0}^{\infty} (\psi_w \beta)^j \gamma a_{\beta,t+j} (\varpi_t^i)^{-\gamma\mu} W_{t+j}^{\gamma(1+\mu)} H_{t+j}^{1+\mu}}{E_t \Sigma_{j=0}^{\infty} (\psi_w \beta)^j (\gamma - 1) a_{\beta,t+j} W_{t+j}^{\gamma} H_{t+j} P_{t+j}^{-1} (C_{t+j} - hC_{t+j-1})^{-\rho}} = \varpi_t \tag{2.4}$$

The wage index W_t is related to ϖ_t via the relationship

$$W_t = \left[(1 - \psi_w) \Sigma_{j=0}^{\infty} \psi_w^j \varpi_{t-j}^{1-\gamma} \right]^{\frac{1}{1-\gamma}} \tag{2.5}$$

Labor market clearing requires

$$L_t = H_t \tag{2.6}$$

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

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

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

$$\begin{aligned} a_{\beta t}(C_t - hC_{t-1})^{-\rho} \left[\frac{\chi(K_t - K_{t-1})}{K_{t-1}} + 1 \right] = \\ \beta E_t a_{\beta,t+1} (C_{t+1} - hC_t)^{-\rho} \left[\frac{\chi(K_{t+1}^2 - K_t^2)}{2K_t^2} + 1 - \delta + r_{t+1}^k \right] \end{aligned} \tag{2.8}$$

A simple arbitrage argument yields

$$\frac{R_t}{R_t^* rp_t} = E_t \frac{S_{t+1}}{S_t} \tag{2.9}$$

2.2 Final Good Producers

Final goods are differentiated. Final good producers are assumed to be monopolistically competitive. Each of them uses composites of various intermediate goods to produce its own variety of the consumption good, which is assumed to be nontradable. The technology is given by a CES production function

$$Z_t(k) = \left[\alpha^{\frac{1}{\sigma}} Y_{ht}(k)^{1-\frac{1}{\sigma}} + (1 - \alpha)^{\frac{1}{\sigma}} Y_{ft}(k)^{1-\frac{1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{2.10}$$

where $Y_{ht}(k)$ denotes the amount of home-variety intermediate goods used in the small open economy's final good production by firm k. Correspondingly, $Y_{ft}(k)$ denotes the amount of foreign-variety intermediate goods imported for final good production by firm k. The elasticity of substitution between domestic and foreign intermediate goods is assumed to be σ, and that the elasticity of substitution between varieties within one country is ε. Let $s \in [0,1]$ be the index of intermediate good varieties, so that $Y_{ht}(k)$ and $Y_{ft}(k)$ are defined as

$$Y_{ht}(k) = \left[\int_0^1 y_{ht}(k,s)^{1-\frac{1}{\varepsilon}} ds\right]^{\frac{\varepsilon}{\varepsilon-1}}$$
$$Y_{ft}(k) = \left[\int_0^1 y_{ft}(k,s)^{1-\frac{1}{\varepsilon}} ds\right]^{\frac{\varepsilon}{\varepsilon-1}}$$

where $y_{ht}(k,s)$ denotes the amount of home-produced intermediate good of variety s used by the final good producer k. Similarly, $y_{ft}(k,s)$ denotes the amount of foreign-produced intermediate good of variety s used by the final good producer k. The aggregation technologies imply the following demands of domestic and imported intermediate goods[7]

$$y_{ht}(k,s) = Y_{ht}(k)\left(\frac{P_{ht}(s)}{P_{ht}}\right)^{-\varepsilon} \tag{2.11}$$

$$y_{ft}(k,s) = Y_{ft}(k)\left(\frac{P_{ft}(s)}{P_{ft}}\right)^{-\varepsilon} \tag{2.12}$$

Taking the prices of intermediate good composites as given, final good producers solve the profit maximization problem and set the prices. The consumption good prices are assumed to be sticky, following Calvo (1983). We assume that final firms are not allowed to change the prices unless they receive a random signal, and that the probability that they will receive a signal in each period is $1-\psi_c$. Let $X_{ct}(k)$ be the price firm k chooses if it is selected to reset the price at time t. Since, with probability ψ_c^j, this price will still be valid at time $t+j$, the profit function of the final good producer k is

$$E_t\Sigma_{j=0}^{\infty}\psi_c^j\Gamma_{t,t+j}\left[X_{ct}(k)Z_{t+j}(k) - P_{ht+j}Y_{ht+j}(k) - P_{ft+j}Y_{ft+j}(k)\right]$$

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

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

The solution of the profit maximization problem yields

[7] P_{ht} denotes the price index of home-produced intermediate goods, and P_{ft} denotes the import price index of foreign-produced intermediate goods.

$$Y_{ht}(k) = Z_t(k)\left[\alpha^{\frac{1}{\sigma}} + (1-\alpha)\alpha^{\frac{1-\sigma}{\sigma}}\left(\frac{P_{ft}}{P_{ht}}\right)^{1-\sigma}\right]^{\frac{\sigma}{1-\sigma}} \quad (2.13)$$

$$Y_{ft}(k) = Z_t(k)\left(\frac{1-\alpha}{\alpha}\right)\left[\alpha^{\frac{1}{\sigma}}\left(\frac{P_{ft}}{P_{ht}}\right)^{\sigma-1} + (1-\alpha)\alpha^{\frac{1-\sigma}{\sigma}}\right]^{\frac{\sigma}{1-\sigma}} \quad (2.14)$$

$$X_{ct}(k) = \frac{E_t\Sigma_{j=0}^{\infty}\psi_c^j\Gamma_{t,t+j}\varsigma Z_{t+j}P_{t+j}^{\varsigma}\left[\alpha P_{ht+j}^{1-\sigma} + (1-\alpha)P_{ft+j}^{1-\sigma}\right]^{\frac{1}{1-\sigma}}}{E_t\Sigma_{j=0}^{\infty}\psi_c^j\Gamma_{t,t+j}(\varsigma-1)Z_{t+j}P_{t+j}^{\varsigma}} = X_{ct} \quad (2.15)$$

Since, in period t, a fraction $(1-\psi_c)\psi_c^j$ of domestic final good producers are posting prices that were actually set in period $t-j$, the price index for the consumption goods, P_t, can be expressed as

$$P_t = \left[(1-\psi_c)\Sigma_{j=0}^{\infty}\psi_c^j X_{ct-j}^{1-\varsigma}\right]^{\frac{1}{1-\varsigma}} \quad (2.16)$$

The optimal price choice is the same for every final good producer, as the solution from the profit maximization problem indicates that the value of X_{ct} is only dependent on the aggregate prices and quantities and thus does not vary with k. Therefore, the price index is also independent of k. Final goods are used for consumption and investment by households, and for consumption by the government. The final good market clearing condition implies that

$$Z_t = C_t + I_t + G_t + AC_t \quad (2.17)$$

2.3 Intermediate Good Suppliers

There are two types of monopolistically competitive intermediate good suppliers in the small open economy's market. 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.

2.3.1 Intermediate Good Producers

Each intermediate good producer produces its differentiated good with capital and labor as the inputs; and the elasticity of substitution among varieties of labor types is γ. For the representative intermediate firm, the Cobb Douglas technology is given by

$$Y_t(s) = A_t K_{t-1}(s)^{\eta} H_t(s)^{1-\eta} \quad (2.18)$$

$$H_t(s) = \left[\int_0^1 l_t^i(s)^{1-\frac{1}{\gamma}} di \right]^{\frac{\gamma}{\gamma-1}}$$

where A_t is the technology shock, H_t is the aggregate labor input, and $l_t^i(s)$ is the amount of type i labor used in variety s intermediate good production. A_t is assumed to follow a stochastic process as

$$\ln A_t = (1 - \delta_A) \ln A + \delta_A \ln A_{t-1} + \epsilon_{At} \tag{2.19}$$

where ϵ_{At} is normally distributed with zero mean and variance $\sigma_{\epsilon A}^2$.

The demand curve for $l_t^i(s)$ is given by

$$l_t^i(s) = H_t(s) \left(\frac{W_t^i}{W_t} \right)^{-\gamma} \tag{2.20}$$

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

$$\frac{W_t H_t(s)}{P_t r_t^k K_{t-1}(s)} = \frac{1-\eta}{\eta} \tag{2.21}$$

The market clearing condition implies that

$$Y_t(s) = Y_{ht}(s) + Y_{ht}^*(s) \tag{2.22}$$

where $Y_{ht}^*(s)$ denotes the amount of home-produced intermediate goods of variety s exported to foreign countries.

A hybrid case is considered here where some intermediate firms use PCP while others use LCP to set their export prices. Both intermediate good prices set in the domestic market and in the foreign market are assumed to be sticky. We assume the probability that intermediate firms will change the prices in each period is $1-\psi_d$, and the proportion of firms using LCP to set a new price at each period is constant and equal to ϕ. Recent studies have debated whether the 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 particular step down in the pass-through coefficient around the year of 1997 with the reduced from regressions. But the evidence is mixed for other countries as Campa and Goldberg (2006) suggest. They conducted tests based on similar approach for fifteen countries and find it is difficult to make a case that the exchange rate pass-through into import prices has systematically declined. In addition, Bouakez and Rebei (2005) address the pass-through declining question for Canada with a dynamic stochastic general equilibrium framework and conclude that the pass-through to

Canadian import prices has been rather 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 the fraction ϕ of exporters adopting LCP to be constant.

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

$$Y_{ht}^* = \alpha_f \left(\frac{P_{ht}^*}{P_t^*}\right)^{-\sigma_f} Y_t^* \tag{2.23}$$

where P_{ht}^* 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

$$\ln Y_t^* = (1-\delta_{y^*}) \ln Y^* + \delta_{y^*} \ln Y_{t-1}^* + \epsilon_{y^*t} \tag{2.24}$$

$$\ln P_t^* = \phi^*(\ln(P_t^{*l}/S_t)) + (1-\phi^*) \ln P_t^{*p} \tag{2.25}$$

$$\ln(P_t^{*l}/P_{t-1}^{*l}) = (1-\delta_{pl}) \ln(\pi^{*l}) + \delta_{pl} \ln(P_{t-1}^{*l}/P_{t-2}^{*l}) + \epsilon_{plt} \tag{2.26}$$

$$\ln(P_t^{*p}/P_{t-1}^{*p}) = (1-\delta_{pp}) \ln(\pi^{*p}) + \delta_{pp} \ln(P_{t-1}^{*p}/P_{t-2}^{*p}) + \epsilon_{ppt} \tag{2.27}$$

where ϕ^* is the proportion of firms using LCP to set export prices at each period in the foreign countries; P_t^{*l} is the foreign LCP price index; P_t^{*p} is the foreign PCP price index; and ϵ_{y^*t}, ϵ_{plt}, and ϵ_{ppt} are normally distributed with zero means and variances $\sigma^2_{\epsilon y^*}$, $\sigma^2_{\epsilon pl}$ and $\sigma^2_{\epsilon pp}$.

Now, consider a PCP intermediate good producer in the small open economy who is randomly selected to set new prices at time t. Let $X_{ht}(s)$ and $X_{ht}^p(s)$ 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

$$Y_{ht+j}(s) = Y_{ht+j} \left(\frac{X_{ht}(s)}{P_{ht+j}}\right)^{-\varepsilon} \tag{2.28}$$

$$Y_{ht+j}^p(s) = Y_{ht+j}^* \left(\frac{X_{ht}^p(s)/S_{t+j}}{P_{ht+j}^*}\right)^{-\varepsilon} \tag{2.29}$$

Since the probability that $X_{ht}(s)$ and $X_{ht}^p(s)$ are still in effect at date $t+j$ is ψ_d^j, the firm chooses $X_{ht}(s)$ and $X_{ht}^p(s)$ to maximize the present discounted value of profits

$$E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} \Bigg\{ X_{ht}(s) Y_{ht+j}(s) + X_{ht}^p(s) Y_{ht+j}^p(s)$$
$$- \frac{1}{1-\eta} W_{t+j} A_{t+j}^{-1} \left[Y_{ht+j}(s) + Y_{ht+j}^p(s) \right] \left[\frac{(1-\eta) r_{t+j}^k P_{t+j}}{\eta W_{t+j}} \right]^{\eta} \Bigg\}$$

Plug (2.28) and (2.29) into the profit function and get first-order conditions. The solution to this problem is

$$X_{ht}(s) = \frac{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} \varepsilon P_{ht+j}^{\varepsilon} W_{t+j}^{1-\eta} A_{t+j}^{-1} Y_{ht+j} (1-\eta)^{\eta-1} (r_{t+j}^k)^{\eta} P_{t+j}^{\eta}}{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} (\varepsilon - 1) P_{ht+j}^{\varepsilon} Y_{ht+j} \eta^{\eta}} = X_{ht}$$
$$X_{ht}^p(s) = \frac{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} \varepsilon (P_{ht+j}^* S_{t+j})^{\varepsilon} W_{t+j}^{1-\eta} A_{t+j}^{-1} Y_{ht+j}^* (1-\eta)^{\eta-1} (r_{t+j}^k)^{\eta} P_{t+j}^{\eta}}{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} (\varepsilon - 1) (P_{ht+j}^* S_{t+j})^{\varepsilon} Y_{ht+j}^* \eta^{\eta}} = X_{ht}^p$$

Next, consider a domestic LCP intermediate good producer who is randomly selected to set new prices at time t. Let $X_{ht}^l(s)$ 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

$$Y_{ht+j}^l(s) = Y_{ht+j}^* \left(\frac{X_{ht}^l(s)}{P_{ht+j}^*} \right)^{-\varepsilon} \tag{2.30}$$

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

$$E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} \Bigg\{ X_{ht}(s) Y_{ht+j}(s) + X_{ht}^l(s) S_{t+j} Y_{ht+j}^l(s)$$
$$- \frac{1}{1-\eta} W_{t+j} A_{t+j}^{-1} \left[Y_{ht+j}(s) + Y_{ht+j}^l(s) \right] \left(\frac{(1-\eta) r_{t+j}^k P_{t+j}}{\eta W_{t+j}} \right)^{\eta} \Bigg\}$$

The solution of $X_{ht}^l(s)$ is

$$X_{ht}^l(s) = \frac{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} \varepsilon (P_{ht+j}^*)^{\varepsilon} W_{t+j}^{1-\eta} A_{t+j}^{-1} Y_{ht+j}^* (1-\eta)^{\eta-1} (r_{t+j}^k)^{\eta} P_{t+j}^{\eta}}{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} (\varepsilon - 1) (P_{ht+j}^*)^{\varepsilon} Y_{ht+j}^* S_{t+j} \eta^{\eta}} = X_{ht}^l$$

The optimal price choices for intermediate good producers are only contingent on

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

aggregate prices and quantities, thus are not dependent on the intermediate good variety s. The price index for intermediate goods sold domestically, P_{ht}, and the export price index, P^*_{ht}, can then be expressed as

$$P_{ht} = \left[(1-\psi_d)\Sigma_{j=0}^{\infty}\psi_d^j X_{ht-j}^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \tag{2.31}$$

$$P^*_{ht} = \left\{(1-\psi_d)\Sigma_{j=0}^{\infty}\psi_d^j \left[\phi(X^l_{ht-j})^{1-\varepsilon} + (1-\phi)(X^p_{ht-j}/S_t)^{1-\varepsilon}\right]\right\}^{\frac{1}{1-\varepsilon}} \tag{2.32}$$

2.3.2 Intermediate Good Importers

Being monopolistically competitive, the intermediate good importers choose a resale price P_{ft} to maximize their profits. We assume this price is also sticky, following Calvo's type. However, the stickiness parameter ψ_f is different from the one for the domestic intermediate good producers. The profit function is given by

$$E_t\Sigma_{j=0}^{\infty}\psi_f^j\Gamma_{t,t+j}\left[X_{ft}(s) - S_{t+j}P^*_{t+j}\right]Y_{ft+j}(s)$$

where

$$Y_{ft+j}(s) = Y_{ft+j}\left(\frac{X_{ft}(s)}{P_{ft+j}}\right)^{-\varepsilon} \tag{2.33}$$

P^*_t is the price index in foreign currency for intermediate goods in the foreign market. By solving this profit maximization problem, we have

$$X_{ft}(s) = \frac{E_t\Sigma_{j=0}^{\infty}\psi_f^j\Gamma_{t,t+j}\varepsilon S_{t+j}P^*_{t+j}(P_{ft+j})^{\varepsilon}Y_{ft+j}}{E_t\Sigma_{j=0}^{\infty}\psi_f^j\Gamma_{t,t+j}(\varepsilon-1)(P_{ft+j})^{\varepsilon}Y_{ft+j}} = X_{ft}$$

Thus the price index for foreign-produced intermediate goods in the home market, P_{ft}, can be expressed as

$$P_{ft} = \left[(1-\psi_f)\Sigma_{j=0}^{\infty}\psi_f^j(X_{ft-j})^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \tag{2.34}$$

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 simply adjust the lump sum transfer in each period to balance the budget constraint. Government spending, G_t, is assumed to follow a first-order autoregressive process, which is given by

$$\ln G_t = (1 - \delta_g) \ln G + \delta_g \ln G_{t-1} + \epsilon_{gt} \tag{2.35}$$

where ϵ_{gt} is normally distributed with zero mean and variance $\sigma^2_{\epsilon g}$.

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

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\ln(\bar{\pi}_t/\pi) + \alpha_\pi(\ln(\pi_t/\pi) - \ln(\bar{\pi}_t/\pi)) + \alpha_y \ln(Z_t/Z)] + \epsilon_{rt}$$

The domestic interest rate will respond to the deviation of the inflation rate from its target value $\bar{\pi}_t$ as well as to the output gap. ρ_r is a parameter that captures the interest-rate smoothing. ϵ_{rt} is a monetary policy shock, which is assumed to be i.i.d. normal with zero mean and variance $\sigma^2_{\epsilon r}$. $\bar{\pi}_t$ is the inflation objective, which is assumed to follow a first-order autoregressive process given by

$$\ln \bar{\pi}_t = (1 - \delta_{\bar{\pi}}) \ln \bar{\pi} + \delta_{\bar{\pi}} \ln \bar{\pi}_{t-1} + \epsilon_{\bar{\pi}t} \tag{2.36}$$

The model will be analyzed in the form log-linearized around a deterministic steady state. In this small open economy model, 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 this 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 21 equations: the Euler equation (2.7); the capital accumulation optimality condition (2.8); the optimal wage setting equation (2.4); the arbitrage condition (2.9); the demand functions (2.13), (2.14), and (2.23); the optimal price setting equations; the intermediate good production function (2.18) and the capital-labor trade-off equation (2.21); the market clearing equations (2.17), (2.22), and (2.6); the foreign price specification; the risk premium equation; the capital law of motion (2.3); the monetary policy reaction function; and the budget constraint. A complete list of all the variables and parameters in this model can be found in Table 1-3.

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 the log deviations, and this system can be solved using standard methods. In this paper I use the following transformations to achieve stationarity: $x_{ct} = \frac{X_{ct}}{P_{ht}}$, $x_{ht} = \frac{X_{ht}}{P_{ht}}$, $x^p_{ht} = \frac{X^p_{ht}}{P_{ht}}$,

$x_{ft} = \frac{X_{ft}}{P_{ht}}$, $x^l_{ht} = \frac{X^l_{ht}}{P^*_t}$, $p_{ft} = \frac{P_{ft}}{P_{ht}}$, $p^*_{ht} = \frac{P^*_{ht}}{P^*_t}$, $p_t = \frac{P_t}{P_{ht}}$, $w_t = \frac{W_t}{P_{ht}}$, $\omega_t = \frac{\varpi_t}{P_{ht}}$, $q_t = \frac{S_t P^*_t}{P_{ht}}$, $\pi_{ht} = \frac{P_{ht}}{P_{ht-1}}$, $\pi^*_t = \frac{P^*_t}{P^*_{t-1}}$, $b^*_t = \frac{B^*_t}{P^*_t}$. The linearized equation system is described in Appendix A.

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

$$\hat{y}_{ht} - \hat{y}_{ft} = \sigma \hat{p}_{ft}$$

As this equation indicates, the size of the expenditure-switching effect in the domestic market is actually determined not only by the magnitude of the impact of exchange rates on the relative price, but also by the degree of substitutability between domestic and foreign intermediate 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 were small. The size of the impact on the relative price of an exchange rate movement depends, among other things, on the fraction of firms adopting LCP versus PCP for their export pricing, the fraction of firms that adjust prices each period, 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.

The expenditure switching is not only conducted by the domestic final good producers, but also by the foreign agents who import intermediate goods from the domestic country. With the small open economy model, we assume the foreign variables are exogenous. This means we assume the small open economy is too small to have any impact on the foreign economy. 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 inform what the expenditure switching between domestic intermediate goods and foreign intermediate goods is like in the rest of the world, with the rest of world taken as given.

3 Econometric Methodology

The model is estimated via Bayesian maximum likelihood estimation approach in this paper, similar to Smets and Wouters (2003) and Lubik and Schorfheide (2005). The current section discusses the data and the methodology employed for estimating the parameters.

3.1 Data

The stochastic behavior of this model is driven by ten exogenous shocks: $\hat{\pi}_t^{*l}$, $\hat{\pi}_t^{*p}$, $\hat{a}_{\beta t}$, $\hat{a}_t$, $\hat{g}_t$, $\hat{r}_t^*$, $\hat{y}_t^*$, $\hat{\bar{\pi}}_t$, ϵ_{rt}, and ϵ_{rpt}. Data on nine key macroeconomic variables are used to estimate the structural parameters of the Dynamic Stochastic General Equilibrium (DSGE) model. The nine series are for the following variables: $\hat{p}_{ft}$, $\hat{p}_{ht}^*$, $\hat{p}_t$, $\hat{w}_t$, $\hat{y}_{ft}$, $\hat{y}_{ht}^*$, $\hat{z}_t$, $\hat{q}_t$, and $\hat{r}_t$. By their definitions, they are computed from import price index, export price index, consumer price index, wage rates, imports, exports, output, nominal exchange rate, foreign price index and treasury bill rates. These variables help to capture the potentially important roles of exchange rate, trade, technology, and interest rate as well as the explanatory factors arising outside of the small open economy. Besides, the foreign output level and the foreign interest rate are used for estimates of the model's exogenous stochastic processes. The foreign output level is calculated as a geometric weighted average over 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 worked out in a similar manner. Likewise, I gathered the 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.

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 2003:2, 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 model is fitted to the data in first differences. The solution of the log-linearized model and the estimation procedure are described in Appendix B.

3.2 Bayesian Estimation Method

The model is estimated using the Bayesian maximum likelihood estimation method, which is widely used in analyzing closed economy models, also used increasingly often in analyzing open economy models. Prior distributions over the parameters are assigned first. Time series data are then 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

[9]Dynare is a collection of MATLAB routines which study the transitory dynamics of non-linear models. More information could be found at the following address: *http://www.cepremap.cnrs.fr/dynare/*.

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

Further more, 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 caused by certain set of parameter values generating the same joint distribution is less of an issue for DSGE models than for VARs, because of the usually smaller parameter set for the former. The lack of identification due to the absence of informative observations can generally be hard to detect because of the large size and the nonlinearities of the structural models. Consequently, the lack of identification can cause the likelihood function to be very flat at certain directions of the parameter space, and thus make it computationally very 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, therefore facilitating maximization.

Probability statements about the parameters are made before observing the data to measure the ex ante plausibility of the parameter values. The choices of priors are based either on the researchers' beliefs about the parameters, on results from previous studies, or from other information not contained in the data sample. Other than these factors, the choice of priors has to reflect the restrictions set on the parameters by the model, for example within $(0,1)$ interval, nonnegativity, etc.

In this paper, since the estimation algorithm is computationally intensive, a few parameters are fixed by calibration either because: they are not major parameters of interest in this paper; they no longer appear in the log-linearized model, but only affect the steady state values; or 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 equal to 4, and the inverse of labor supply elasticity μ is set equal to 2. The elasticity of substitution among domestic intermediate good varieties ε is assumed to be 8 following Amber, Dib, and Rebei (2003). The ς parameter that gives the elasticity of substitution among consumption good varieties is also set at the value of 8. The α parameter takes a value of 0.75 to reflect the home bias on domestic goods. The quarterly capital depreciation rate, δ, is set to 0.03; and the share of capital in production, η, is equal to 0.36. The ratios of consumption and investment to final goods are calibrated at $C/Z = 0.6, G/Z = 0.18$, and $I/Z = 0.22$ for all the three developed countries.

Other than those parameters, there are 27 parameters to be estimated. The priors set for them are summarized in Table 4. Generally, Beta distributions are picked 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 the final good price and the wage rate are set at 0.75. Under these priors, final production firms and households change prices and wages once every 4 quarters. A shorter price stickiness period of 3.3 quarters for intermediate good suppliers translates into the priors of $\psi_d = \psi_f = 0.70$. Consumer prices are considered to be more sticky than producer prices, because the CPI data consist of services, for which prices are more sluggish and take a longer time to adjust.

With respect to the priors for the fraction of firms employing LCP versus PCP for their exports, inferences are drawn from various sources for the three countries considered here. The Australian Bureau of Statistics published *International Merchandise Trade: Featured Article*, where the major invoice currencies used for Australia's merchandise exports and imports for the period from March quarter 2002 to March quarter 2003 are reported. 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, reference on ϕ are drawn from Murray and Powell (2003), where they report the survey result conducted by the staff in the Bank of Canada's regional offices in 2002. 326 firms were surveyed on 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. This number was 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 doesn't provide any information on the invoice currency for imports. Based on the coarse calculation that the United States accounts for 60% of Canada's imports, and the US dollar share in its export invoicing is around

95%,[10] 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 0.25 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).[11] 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 take place across the thirteen years, the UK pound remains the principle currency used for the denomination of both its exports and imports. Thus the priors for ϕ and ϕ^* are set at 0.3 and 0.4, respectively for the UK.

The prior mean for the elasticity of substitution between domestic goods and imports σ is set at 1. A large standard deviation of 0.5 is given since the empirical evidences on the value of this parameter are diverse. In particular, macro studies tend to find this elasticity to be around 0.5 to 1.5. While the estimated elasticity at a disaggregated industry level is much higher with an average number in the neighborhood of 5 to 6.[12] The parameter h that captures the consumption habit formation is given a prior mean of 0.7. 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 Tables 5-7. The first two columns in each table 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 next 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. Basically the two sets of estimates display similar results. The estimated parameter values generally fall into reasonable ranges.

The Calvo stickiness parameter ψ_c for the final consumption good is estimated

[10] 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.

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

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

to be very high at around 0.9. This implies that final good producers change prices approximately once every 10 quarters, on average. The estimated contract length for final consumption goods are very long because, in the model, final goods are assumed to be nontradable and are produced only with intermediate inputs. When a final good producer has the chance to reoptimize its price, since intermediate good prices are also sluggish, the optimization choice could remain the same. In other words, when prices for intermediate inputs are sticky, the final good prices will behave as if they were somewhat sticky even though the final good producers were assumed to set prices freely. The rigidity parameter for intermediate good prices, ψ_d, is estimated to be 0.6423 for Australia, 0.6773 for Canada, and 0.3050 for the UK. These indicate an average contract length of roughly 1.5 to 3 quarters for intermediate good producers. The tradable good prices are found to be a little less sticky than macro studies generally suggested,[13] and is more consistent with existing microeconomic evidences. In particular, 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. 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 investigates the pricing behavior of 647 UK companies. Overall, British firms on average change prices twice in the year preceding the survey. Estimates of ψ_f at around 0.63-0.80 for all three of the countries imply that the prices set by the intermediate good importers typically remain fixed for 3-5 quarters. The rigidity parameter for wages is estimated to be approximately 0.62-0.80. 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 be imposed 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.

Concerning the controversy over the choice of currency in which intermediate firms use to set their export prices, the estimate of ϕ^*, the proportion of foreign firms using LCP to set export prices, is close to 0.1729 for Australia, 0.1050 for Canada, and 0.8665 for the United Kingdom. The fact that much more firms exporting to the United Kingdom price their products in the local currency would suggest that when prices are sticky in the short run, exchange rate movements can not achieve as much the effect of relative price adjustment as in the flexible price case. There would be much smaller domestic expenditure switching over intermediate goods for the UK than for the other two countries. In addition, the Calvo stickiness parameter for domestic intermediate good producers is estimated to be much smaller for the UK, so that domestic production prices can adjust in a timely manner, and not much expenditure switching is initiated

[13] For instance, Lubik and Schorfheide (2005) report estimates of the price stickiness parameter ranging from 0.74 to 0.78 in their two-country benchmark model. Ambler, Dib, and Rebei (2003) report an estimate of the Calvo adjustment parameter at 0.68 for Canada.

by the currency appreciation or depreciation.

The estimate of ϕ, the proportion of domestic firms using LCP to set export prices, is small at around 0.1397 for Australia, and 0.2395 for the United Kingdom, which indicates that PCP is dominant for these countries' export price setting. For Canada, the estimate of ϕ is 0.4544. In this case, although invoicing in the exporter's currency is also more frequent, it is much less pronounced than in the other two cases. Therefore, in response to nominal exchange rate movements, the degree of expenditure switching between domestic intermediate goods and foreign intermediate goods in the foreign market would be smaller for Canada, compared to the other two countries. The posterior estimates of ϕ are generally smaller than the prior means specified and could reflect the missing roles of vehicle currencies and exchange rate risk hedging. When export goods are priced in the local market currency, the exchange rate risk hedging behavior of firms tend to smooth the fluctuation of prices due to exchange rate movements, reflecting as favoring PCP in the data.

The estimate of the elasticity of substitution between domestic varieties and foreign varieties σ is close to 0.6725 for Australia, 0.5535 for Canada, and 0.5829 for the United Kingdom. The estimation results here are in line with the macro estimates. For example, with a structural small open economy model, Ambler, Dib, and Rebei (2003) estimate the elasticity to be 0.55 for Canada. 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 with respect to a permanent tariff shock is around 6.2. Trade liberalization increases the extensive margin. Thus, a much larger elasticity is measured in response to a tariff shock because of the increase in trade flows from newly traded goods. The size of the expenditure-switching effect should depend on the value of σ. The estimates of the elasticity of substitution are not dramatically different across countries, though the estimate is somewhat larger for Australia. Besides, we should note that the estimates of σ for all the countries are significantly different from 1, though the priors are set at 1. The estimates of σ_f are of similar scale at around 0.57 for Australia and the United Kingdom. σ_f is estimated to be slightly larger at 0.6778 for Canada.

The estimate of the consumption habit formation coefficient turns out to be significant in all three cases. The estimation also yields reasonable results with respect to the monetary policy reaction equation. 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. The estimates of the AR coefficients and standard deviations for all the shocks are also reported.

4.2 Model Fit

To assess the conformity of the model and the data, unconditional second moments are computed and reported in Tables 8-9. The first block reports the statistics of the data, and the second block presents the corresponding estimates implied by the model. The median from the simulated distribution of moments, together with the 10th and the 90th percentiles are reported. Comparing the relative volatility of variables given by the data and implied by the model for Australia, we can see that the series volatility is generally captured by the model, though the model implies a little too much real exchange rate volatility. The misses are that the volatility of exports and imports are not big enough in the model relative to in the data. The cases for Canada and the United Kingdom are roughly similar.

Turning to the cross correlations, the model provides good characterizations of the correlation properties between the real exchange rate series and the prices series, particularly the import and export price series. This implies that the PCP versus LCP proportion estimates for the three countries are in line with what the data suggests. The problem appears to be that the correlations of the exchange rate series and the quantities series are too large in the model compared to those in the data. This is understandable since in the model, quantities are just determined by prices when all the firms are monopolistic competitors. The introduction of distribution services is a natural candidate to fix this inconsistency. In addition, this may imply that the actual expenditure switching effect would be even smaller than the model currently suggests. There certainly is room for improvements of the model in this aspect, but the model does a reasonably good job for us to proceed with the analysis of the expenditure-switching effect in terms of invoice currency denomination.

4.3 Impulse Response Analysis

The impulse responses of the domestic demand of home-produced intermediate goods, $\hat{y}_{ht}$, and the import of foreign-produced intermediate goods, $\hat{y}_{ft}$, are displayed in Figures 1-3 for the countries of Australia, Canada, and the United Kingdom. The impulse responses show the consequences of a one unit increase in the exogenous shocks for the value of the variables. The impulse responses are calculated from a random selection of 500 parameters from the 500,000 draws from the posterior distribution. Together with the median response, the 10% and 90% percentiles are also shown in the figures.

A positive technology shock to the final production sector increases both imports and domestic intermediate good production. The maximum responses of the quantities occur approximately one year after the impact of the shock for Australia and Canada. For the United Kingdom, the peak of the responses occur approximately 3 quarters after the shock. The impulse response function trails off after that in all three cases. As a “demand” shock, the government spending shock drives up both the domestic production and imports. A positive government expenditure shock increases the demand for domestic money. This places an upward pressure on the domestic interest rate, making foreign bonds less attractive. As a result, the appreciation of domestic currency represents a decline in the exchange rate. The domestic final good producers then tend to substitute from the domestic varieties to the foreign varieties. Due to the "keeping up with the Jones" assumption on households' preferences in this model, the intertemporal substitution effect of households is not as significant.

Next, turning to the two monetary policy shocks, nominal interest rate decreases as a result of the increased inflation objective, based on the estimates of the coefficients of the monetary policy reaction function. When the interest rate decreases, current consumption becomes relatively less expensive, and thus individuals will tend to substitute away from future consumption. However, a decrease in the interest rate will also decrease relative income. For all of the three countries studied in this paper, the “income effect” seems to be smaller than the “substitution effect”, so that a positive inflation objective shock leads to an increase in consumption, in addition to an increase in domestic production and imports. On the other hand, a positive temporary monetary policy shock leads to an immediate fall in production.

Since there is no absolute measurement for distinguishing big and small expenditure-switching effect, the three countries are compared for analysis. As we can see from Figures 1-3, responding to a one unit increase in the monetary policy shock, the increase in the domestic interest rate drives up the domestic currency value. The domestic final good producers then substitute away from the domestic intermediate goods towards the imported intermediate goods in response to this exchange rate movement. This is the case for Australia and Canada with the difference in the responses of $\hat{y}_{ft}$ and $\hat{y}_{ht}$ to be around 0.005 unit in the first year. For the United Kingdom, the dominant role of LCP setting for export goods to this country as well as the quicker adjustment of domestic intermediate good prices actually drives the impulse responses of $\hat{y}_{ht}$ to be larger than the response of $\hat{y}_{ft}$. The impulse responses to the inflation objective shock provide similar information. This is consistent with earlier analysis that the magnitude of the expenditure switching by the domestic final good producers is relatively big for Australia and Canada and small for the United Kingdom, 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 from the early 80's, the UK authorities have implicit preferences for exchange rate stability. In 1990, the preferences became explicit by the UK committing to the European Exchange Rate Mechanism (ERM) until the sterling was suspended in 1992. Such preferences affected the interest rate policy; thus, the exchange rate moved more smoothly during that period of time than it otherwise would have. What's more, the financial market reactions to monetary policy announcements seem to be less pronounced in the UK possibly due to the Bank of England was only granted operational independence with respect to the implementation of monetary policy in 1997. All of these frictions limited the movements of the exchange rate, and thus the magnitude of the expenditure switching when we examine the impulse responses to the monetary policy shock for the United Kingdom. The variables respond to the foreign shocks (foreign price shocks, foreign interest rate shock, and foreign output shock) gradually, indicating that the transmission of foreign shocks to a small open economy takes time.

4.4 Variance Decompositions

To infer the role of various structural shocks in driving the movements of the demands of domestic intermediate goods and foreign intermediate goods, the relative import price and some other important variables, the variance decomposition results for various horizons are presented in Tables 10-15 for the three countries. The reported forecast error variances are attributed to ten structural shocks.

First, let us focus on Australia. The relative import price variation is primarily driven by the preference shock and the foreign price shocks. The risk premium shock also account for nonnegligible percent of the short-term forecast error variance of the relative price. The foreign PCP shock and the risk premium shock in addition play important roles in explaining the domestic production and the import quantity movements in the short run.[14] This is compatible with the estimation result that the majority of exporters to Australia price their products in their own currency. The foreign PCP shock accounts for roughly 22% of the forecast error variances of $\hat{y}_{ht}$ and $\hat{y}_{ft}$ in the short run. Real exchange rate deviations are mostly driven by the risk premium shock in the short run. The medium and long term forecast error variances are attributed to the foreign price shocks and the preference shock. The foreign PCP shock, the risk premium shock together with the monetary policy shock account for most of the output variations.

For the country of Canada, the results are similar to those of Australia in that the risk premium shock plays a significant role. The foreign price shocks and the preference shock account for a significant percentage in explaining the relative price variations. About 8% of the forecast error variance of the output is explained by the foreign PCP shock, and roughly 12% of the variance is explained by the government spending shock and the monetary policy shock. The foreign price shocks get more weights in the medium to long run. The risk premium shock generates most of the fluctuations in the real exchange rate, and actually implies too much volatility of the real exchange rate generated by the model. If we shut down the risk premium shock, then real exchange rate variations would be mainly driven by the foreign price shocks, particularly the foreign PCP

[14] The foreign PCP shock denotes the shock to the foreign PCP inflation rate, $\hat{\pi}_t^{*p}$, which is the rate of change in the foreign export prices that are set in producer currency.

shock. The significane of the risk premium shock shows strong empirical evidence against the standard uncovered interest rate parity (UIP) condition. Introducing the modified UIP condition by accounting for the forward premium puzzle as in Adolfson, Laséen and Lindé (2007) might allow the model to better match the properties of the data.

The variance decomposition results for the country of the United Kingdom are quite different. It is the foreign LCP shock that accounts for most of the forecast error variances of the intermediate good demands.[15] This shock accounts for about 59% of the forecast error variances of $\hat{y}_{ht}$ and $\hat{y}_{ft}$ in the short run. The risk premium shock explains another 25% of the variations. The foreign LCP shock in addition accounts for most of the variations in the relative price, the real exchange rate and the output. The foreign PCP shock also accounts for nonnegligible percentages of the variations of the relative price and the real exchange rate.

In all three countries' cases, 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 shocks have significant impacts on the small open economy. Justiniano and Preston (2006) proposed a caveat of fitting open economy DSGE models about the lack of transmission of foreign shocks onto domestic variables. The current work seems to suggest that with a different pricing structure, the small open economy model can account for the influences of foreign prices shocks. For Australia, 23% of the forecast error variance of output is explained by the foreign PCP shock in the short run. For the United Kingdom, 64% of the variance of output at four quarter horizon is explained by the foreign LCP shock.

5 Conclusion

This paper develops a structural model of a small open economy with sticky prices and wages plus a mixture of PCP and LCP settings. The Bayesian estimation procedure is applied 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 the expenditure switching in the domestic market depends on the rigidity of domestic intermediate good prices, the fraction of foreign firms employing PCP versus LCP for their export pricing, and the elasticity of substitution between domestic goods and imports. The empirical results suggest that among the three countries examined in this paper, the domestic expenditure switching is relatively small for the country of the United Kingdom. The majority of exporters to the UK price their goods in the local currency. In addition, the intermediate good prices are much more flexible in the country. So the domestic expenditure switching resulted from exchange rate vari-

[15] The foreign LCP shock denotes the shock to the foreign LCP inflation rate, $\hat{\pi}_t^{*l}$, which is the rate of change in the foreign export prices that are set in local currency.

ation is relatively minor. The expenditure switching by domestic final good producers is larger for Australia and Canada. On the other hand, the proportion of domestic firms adopting LCP to set export prices is estimated to be the smallest for Australia. Thus the expenditure switching by foreign agents would also be relatively large for Australia. While since a smaller proportion of UK firms employ LCP for their export pricing than Canadian firms, the expenditure switching in the foreign market should be somewhat larger for the UK. The estimates of the domestic and foreign elasticity of substitution are not very different across countries; and they are significantly different from zero. These results suggest that the benefits from exchange rate flexibility in terms of expenditure switching are most significant for Australia. Comparing to Canada, though the degree of substitution by the UK domestic final good producers is quite small, the foreign distributors substitute more between British products and local products.

Our conclusions on 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. 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 the 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 the exchange rate regime depends on the balance of these two goals under several different specifications. Recently, Obstfeld (2006) assumes the existence of both traded and nontraded goods, and develops the view that even when the expenditure-switching role of exchange rates is trivial, exchange rate flexibility is still desirable due to the interest rate responses. This also emphasizes the desire to obtain international risk sharing. 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 the achievement of international risk sharing. The current model in this paper abstract from the presence of nontradable intermediate goods because it is not relevant for estimating the importance of expenditure switching. The introduction of nontradable goods would reinforce the case for exchange rate flexibility.

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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

$$\begin{aligned}
\hat{x}_{ct} &= (1-\psi_c\beta)E_t\Sigma_{j=0}^{\infty}(\psi_c\beta)^j[\alpha_m\hat{p}_{ft+j} + (1-\alpha_m)\hat{p}_{ht+j} - \hat{p}_{ht}] \\
&= \psi_c\beta E_t\hat{x}_{ct+1} + \psi_c\beta\hat{\pi}_{ht+1} + (1-\psi_c\beta)\alpha_m\hat{p}_{ft} \\
\alpha_m &= \frac{(1-\alpha)(P_f/P_h)^{1-\sigma}}{\alpha + (1-\alpha)(P_f/P_h)^{1-\sigma}} \\
\hat{x}_{ht} &= (1-\psi_d\beta)E_t\Sigma_{j=0}^{\infty}(\psi_d\beta)^j[(1-\eta)\hat{w}_{t+j} + \hat{p}_{ht+j} - \hat{p}_{ht} - \hat{a}_{t+j} + \eta\hat{r}^k_{t+j} + \eta\hat{p}_{t+j}] \\
&= \psi_d\beta E_t\hat{x}_{ht+1} + \psi_d\beta\hat{\pi}_{ht+1} + (1-\psi_d\beta)[(1-\eta)\hat{w}_t - \hat{a}_t + \eta\hat{r}^k_t + \eta\hat{p}_t] \\
\hat{x}^p_{ht} &= \hat{x}_{ht} \\
\hat{x}^l_{ht} &= (1-\psi_d\beta)E_t\Sigma_{j=0}^{\infty}(\psi_d\beta)^j[(1-\eta)\hat{w}_{t+j} - \hat{a}_{t+j} + \hat{p}_{ht+j} - \hat{s}_{t+j} - \hat{p}^*_t + \eta\hat{r}^k_{t+j} + \eta\hat{p}_{t+j}] \\
&= \psi_d\beta E_t\hat{x}^l_{ht+1} + \psi_d\beta\hat{\pi}^*_{t+1} + (1-\psi_d\beta)[(1-\eta)\hat{w}_t - \hat{a}_t - \hat{q}_t + \eta\hat{r}^k_t + \eta\hat{p}_t] \\
\hat{x}_{ft} &= (1-\psi_f\beta)E_t\Sigma_{j=0}^{\infty}(\psi_f\beta)^j(\hat{s}_{t+j} + \hat{p}^*_{t+j} - \hat{p}_{ht}) \\
&= \psi_f\beta E_t\hat{x}_{ft+1} + \psi_f\beta\hat{\pi}_{ht+1} + (1-\psi_f\beta)\hat{q}_t \\
\hat{p}_t &= \psi_c\hat{p}_{t-1} - \psi_c\hat{\pi}_{ht} + (1-\psi_c)\hat{x}_{ct} \\
0 &= (1-\psi_d)\hat{x}_{ht} - \psi_d\hat{\pi}_{ht} \\
\hat{p}_{ft} &= \psi_f\hat{p}_{ft-1} + (1-\psi_f)\hat{x}_{ft} - \psi_f\hat{\pi}_{ht} \\
\hat{p}^*_{ht} &= \psi_d\hat{p}^*_{ht-1} - \psi_d\hat{\pi}^*_t + (1-\psi_d)[\phi\hat{x}^l_{ht} + (1-\phi)(\hat{x}^p_{ht} - \hat{q}_t)] \\
\hat{\pi}^*_t &= \phi^*(\hat{\pi}^{*l}_t + \hat{q}_{t-1} - \hat{q}_t + \hat{\pi}^*_t - \hat{\pi}_{ht}) + (1-\phi^*)\hat{\pi}^{*p}_t
\end{aligned}$$

For the wage rate, log-linearize equation (2.4), (2.5) to get

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

A.2 Output, Capital and Employment

Intermediate goods demand

$$\hat{y}_{ht} = \hat{z}_t + (1-\alpha)\alpha^{\frac{1-\sigma}{\sigma}}(P_f/P_h)^{1-\sigma}(Y_h/Z)^{\frac{\sigma-1}{\sigma}}\sigma\hat{p}_{ft}$$
$$\hat{y}_{ft} = \hat{z}_t - \alpha(1-\alpha)^{\frac{1-\sigma}{\sigma}}(P_f/P_h)^{\sigma-1}(Y_f/Z)^{\frac{\sigma-1}{\sigma}}\sigma\hat{p}_{ft}$$
$$\hat{y}^*_{ht} = \hat{y}^*_t - \sigma^f\hat{p}^*_{ht}$$

Capital and labor demand

$$\hat{h}_t = \hat{y}_t - \hat{a}_t + \eta\hat{r}^k_t - \eta\hat{w}_t + \eta\hat{p}_t$$
$$\hat{k}_{t-1} = \hat{y}_t - \hat{a}_t - (1-\eta)\hat{r}^k_t + (1-\eta)\hat{w}_t - (1-\eta)\hat{p}_t$$

Euler's equation

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

Optimal capital accumulation

$$(\hat{a}_{\beta t} - E_t\hat{a}_{\beta,t+1}) - \frac{\rho}{1-h}[(1+h)\hat{c}_t - h\hat{c}_{t-1} - E_t\hat{c}_{t+1}] - \beta\chi(\hat{k}_{t+1} - \hat{k}_t) + \chi(\hat{k}_t - \hat{k}_{t-1}) - \beta r^k\hat{r}^k_{t+1} = 0$$

Arbitrage condition

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

Risk premium equation

$$\hat{rp}_t = -\varphi\frac{qb^*}{Y}(\hat{q}_t + \hat{b}^*_t - \hat{z}_t)$$

Capital law of motion

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

Labor market clearing condition

$$\hat{l}_t = \hat{h}_t$$

Intermediate good market clearing condition

$$\hat{y}_t = \theta \hat{y}_{ht} + (1-\theta)\hat{y}^*_{ht}$$
$$\theta = Y_h/Y$$

Final good market clearing condition

$$\hat{z}_t = \varphi_1 \hat{c}_t + \varphi_2 \hat{g}_t + (1-\varphi_1-\varphi_2)\hat{i}_t$$
$$\varphi_1 = C/Z \qquad \varphi_2 = G/Z$$

Budget constraint

$$G\hat{g}_t + I\hat{i}_t + C\hat{c}_t + \frac{qb^*}{pR^*rp}(\hat{q}_t + \hat{b}^*_t - \hat{p}_t - \hat{r}^*_t - \hat{rp}_t) =$$
$$\frac{wL}{p}(\hat{w}_t + \hat{l}_t - \hat{p}_t) + d\hat{d}_t + \frac{qb^*}{p}(\hat{q}_t + \hat{b}^*_{t-1} - \hat{p}_t - \hat{\pi}^*_t) + r_k K(\hat{r}^k_t + \hat{k}_{t-1})$$

where

$$d\hat{d}_t = Z\hat{z}_t + \frac{qp^*_h Y^*_h}{p}(\hat{q}_t + \hat{p}^*_{ht} - \hat{p}_t + \hat{y}^*_{ht})$$
$$- \frac{qY_f}{p}(\hat{q}_t - \hat{p}_t + \hat{y}_{ft}) - \frac{wH}{p}(\hat{w}_t + \hat{h}_t - \hat{p}_t) - r_k K(\hat{r}^k_t + \hat{k}_{t-1})$$

Taylor's Rule

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

A.3 Stochastic Shocks

$$\hat{\pi}^{*l}_t = \delta_{pl}\hat{\pi}^{*l}_{t-1} + \epsilon_{plt}$$
$$\hat{\pi}^{*p}_t = \delta_{pp}\hat{\pi}^{*p}_{t-1} + \epsilon_{ppt}$$
$$\hat{a}_{\beta t} = \delta_{a\beta}\hat{a}_{\beta,t-1} + \epsilon_{a\beta t}$$
$$\hat{a}_t = \delta_A \hat{a}_{t-1} + \epsilon_{At}$$
$$\hat{g}_t = \delta_g \hat{g}_{t-1} + \epsilon_{gt}$$
$$\hat{r}^*_t = \delta_{R^*}\hat{r}^*_{t-1} + \epsilon_{R^*t}$$
$$\hat{y}^*_t = \delta_{y^*}\hat{y}^*_{t-1} + \epsilon_{y^*t}$$
$$\hat{\bar{\pi}}_t = \delta_{\bar{\pi}}\hat{\bar{\pi}}_{t-1} + \epsilon_{\bar{\pi}t}$$

B Empirical Model

The linearized DSGE model characterizes the equilibrium relationship of the 21 variables and ten exogenous shocks. Let $\mathcal{X}_t = [\ \hat{p}_{ft}\ \ \hat{p}^*_{ht}\ \ \hat{p}_t\ \ \hat{w}_t\ \ \hat{y}_{ft}\ \ \hat{y}^*_{ht}\ \ \hat{z}_t\ \ \hat{q}_t\ \ \hat{r}_t\ \ \hat{\pi}^*_t\ \ \hat{\pi}_{ht}\ \ \hat{c}_t\ \ \hat{y}_t\ \ \hat{i}_t\ \ \hat{y}_{ht}\ \ \hat{h}_t\ \ \hat{l}_t\ \ \hat{rp}_t\ \ \hat{b}^*_t\ \ \hat{k}_t\ \ \hat{r}^k_t\ ]'$, $\mathcal{Z}_t = [\ \hat{\pi}^{*l}_t\ \ \hat{\pi}^{*p}_t\ \ \hat{a}_{\beta t}\ \ \hat{a}_t\ \ \hat{g}_t\ \ \hat{r}^*_t\ \ \hat{y}^*_t\ \ \hat{\bar{\pi}}_t\ \ \epsilon_{rt}\ \ \epsilon_{rpt}\ ]'$, and the 31-equation system can be written in a matrix form as

$$
\begin{aligned}
&E_t[\alpha_1 \mathcal{X}_{t+1} + \alpha_2 \mathcal{X}_t + \alpha_3 \mathcal{X}_{t-1} + \alpha_4 \mathcal{Z}_t] = 0 \\
&\mathcal{Z}_t = \mathcal{J} \mathcal{Z}_{t-1} + \epsilon_t
\end{aligned} \tag{B.1}
$$

where $\epsilon_t = [\ \epsilon_{plt}\ \ \epsilon_{ppt}\ \ \epsilon_{a\beta t}\ \ \epsilon_{alt}\ \ \epsilon_{At}\ \ \epsilon_{gt}\ \ \epsilon_{R^*t}\ \ \epsilon_{y^*t}\ \ \epsilon_{\bar{\pi}t}\ \ \epsilon_{rt}\ ]'$. The coefficient matrices α_1, α_2, α_3, and α_4 can be easily derived from the linearized equations.

Equation system (B.1) characterizes the equilibrium relationship among the variables of interest. The method of undetermined coefficients described by Uhlig (1999) can be applied to this linear difference model under rational expectations to solve for the recursive equilibrium law of motion.[16]

$$
\begin{aligned}
\mathcal{X}_t &= \mathcal{P} \mathcal{X}_{t-1} + \mathcal{Q} \mathcal{Z}_t \\
\mathcal{Z}_t &= \mathcal{J} \mathcal{Z}_{t-1} + \epsilon_t
\end{aligned} \tag{B.2}
$$

Let $\mathcal{X}_{1t} = [\ \hat{p}_{ft}\ \ \hat{p}^*_{ht}\ \ \hat{p}_t\ \ \hat{w}_t\ \ \hat{y}_{ft}\ \ \hat{y}^*_{ht}\ \ \hat{z}_t\ \ \hat{q}_t\ \ \hat{r}_t]'$, $\mathcal{X}_{2t} = [\ \hat{\pi}^*_t\ \ \hat{\pi}_{ht}\ \ \hat{c}_t\ \ \hat{y}_t\ \ \hat{i}_t\ \ \hat{y}_{ht}\ \ \hat{h}_t\ \ \hat{l}_t\ \ \hat{rp}_t\ \ \hat{b}^*_t\ \ \hat{k}_t\ \ \hat{r}^k_t\ ]'$, then the solution (B.2) can be written equivalently as

$$
\begin{aligned}
\mathcal{Y}_t &= \mathcal{G} \mathcal{Y}_{t-1} + \mathcal{H} \mathcal{K}_t \\
\mathcal{K}_{t+1} &= \mathcal{F} \mathcal{K}_t + \mathcal{B} \mathcal{Y}_{t-1} + \mathrm{v}_t
\end{aligned} \tag{B.3}
$$

where $\mathcal{Y}_t = \mathcal{X}_{1t}$, $\mathcal{K}_t = \begin{bmatrix} \mathcal{X}_{2t-1} \\ \mathcal{Z}_t \end{bmatrix}$, $\mathrm{v}_t = \begin{bmatrix} \mathbf{0} \\ \epsilon_{t+1} \end{bmatrix}$, $E(\mathrm{v}_t \mathrm{v}_s') = \begin{cases} \mathsf{Q} & t = s \\ \mathbf{0} & t \neq s \end{cases}$.

The state space representation (B.3) can then be used to construct the Kalman filter. The vector $\mathcal{K}_t$ is known as the unobservable state vector; $\mathcal{Y}_{t-1}$ is a vector of predetermined variables; and $\mathcal{Y}_t$ denotes a vector of endogenous variables observed at date t.

Define

[16] For technical details, refer to Uhlig (1999).

$$\begin{aligned}
\hat{\mathcal{K}}_{t+1|t} &= \widehat{E}(\mathcal{K}_{t+1}|\mathcal{Y}_t, \mathcal{Y}_{t-1}, \ldots) \\
\hat{\mathcal{Y}}_{t+1|t} &= \widehat{E}(\mathcal{Y}_{t+1}|\mathcal{Y}_t, \mathcal{Y}_{t-1}, \ldots) \\
&= \mathcal{G}\mathcal{Y}_t + \mathcal{H}\hat{\mathcal{K}}_{t+1|t} \\
\mathsf{P}_{t+1|t} &= E(\mathcal{K}_{t+1} - \hat{\mathcal{K}}_{t+1|t})(\mathcal{K}_{t+1} - \hat{\mathcal{K}}_{t+1|t})'
\end{aligned}$$

The Kalman filter calculates these forecasts recursively beginning with $\hat{\mathcal{K}}_{1|0}$ and $\mathsf{P}_{1|0}$, which are given by the mean and covariance matrix of the unconditional distribution of the state vector, since the transition equation is stationary.

Let e_t be the forecast error

$$\begin{aligned}
\mathsf{e}_t &= \mathcal{Y}_t - \hat{\mathcal{Y}}_{t|t-1} \\
&= \mathcal{H}(\mathcal{K}_t - \hat{\mathcal{K}}_{t|t-1})
\end{aligned}$$

which by construction is Gaussian and serially uncorrelated with

$$E(\mathsf{e}_t\mathsf{e}_t') = \mathcal{H}\mathsf{P}_{t|t-1}\mathcal{H}' \tag{B.4}$$

Thus, the model's log-likelihood function can be calculated as

$$\mathcal{L} = -\frac{9T}{2}log(2\pi) - \frac{1}{2}\Sigma_{t=1}^{T} log|\mathcal{H}\mathsf{P}_{t|t-1}\mathcal{H}'| - \frac{1}{2}\Sigma_{t=1}^{T}\mathsf{e}_t'(\mathcal{H}\mathsf{P}_{t|t-1}\mathcal{H}')^{-1}\mathsf{e}_t \tag{B.5}$$

Table 1: A List of Variables and Parameters

Variables or Parameters	Description
Z_t	Domestic production of final goods
C_t	Domestic aggregate consumption of final goods
L_t	Labor service supplied by domestic households
K_t	Capital stock
I_t	Investment
S_t	Nominal exchange rate
H_t	Aggregate labor input into intermediate good production
$l_t^i(s)$	The demand for type i labor by intermediate good producer s
τ_t	Domestic lump sum transfer
D_t	Domestic dividends
W_t	Domestic wage rate
R_t	Domestic interest rate
R_t^*	World interest rate
rp_t	Risk premium
r_t^k	Capital rental rate
G_t	Government consumption
B_t	Domestic bond
B_t^*	Foreign bond
AC_t	Investment adjustment cost
λ_t	Shadow price
$\Gamma_{t,t+j}$	The stochastic discount factor
Y_t	Aggregate intermediate goods produced in the small country
Y_t^*	Foreign output
Y_{ht}	The amount of aggregate home variety intermediate goods used in the home country's final good production sector
Y_{ht}^*	The amount of aggregate home variety intermediate goods used in the foreign country's final good production sector
Y_{ft}	The amount of aggregate foreign variety intermediate goods imported for the home country's final good production
$y_{ht}(k,s)$	The amount of home-produced intermediate goods of variety s used by the home country's final good producer k
$y_{ft}(k,s)$	The amount of foreign-produced intermediate goods of variety s imported for the home country's final good producer k
P_{ht}	Price index of home-produced intermediate goods in the home market
P_{ht}^*	Price index of home-produced intermediate goods in the foreign market
P_{ft}	Price index of foreign-produced intermediate goods in the home market

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

Variables or Parameters	Description
P_t	Price index for final consumption good in the home market
P_t^*	The foreign price level
π_t	Gross domestic consumption inflation rate
π_{ht}	Gross domestic production inflation rate
π^*	Gross foreign inflation rate
P_t^{*l}	LCP price index of intermediate goods produced by foreign producers
P_t^{*p}	PCP price index of intermediate goods produced by foreign producers
X_{ct}	Price chosen by the final good production firm that is randomly selected to set new prices at time t
X_{ht}	Price in the home market chosen by the domestic intermediate firm that is randomly selected to set new prices at time t
$X_{ht}^p(X_{ht}^l)$	PCP(LCP) price in foreign market chosen by the domestic intermediate firm selected to set new prices at time t
ϖ_t	The new wage rate set by domestic household that receives a signal to change the wage rate at time t
$\bar{\pi}_t$	Inflation target
$a_{\beta t}$	Preference shock
A_t	Technology shock
ϵ_{rt}	Monetary policy shock
ϵ_{rpt}	Risk Premium shock
δ_{pl}	The AR coefficient of $\hat{\pi}_t^{*l}$
δ_{pp}	The AR coefficient of $\hat{\pi}_t^{*p}$
$\delta_{a\beta}$	The AR coefficient of $\hat{a}_{\beta t}$
δ_A	The AR coefficient of $\hat{a}_t$
δ_{R^*}	The AR coefficient of $\hat{r}_t^*$
δ_{y^*}	The AR coefficient of $\hat{y}_t^*$
δ_g	The AR coefficient of $\hat{g}_t$
$\delta_{\bar{\pi}}$	The AR coefficient of $\hat{\bar{\pi}}_t$
β	Subjective discount rate
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
θ	The fraction of goods sold in the domestic market in the total intermediate good production
χ	Investment adjustment cost coefficient
φ	Parameter in the risk premium equation

Table 3: A List of Variables and Parameters (Continued)

Variables or Parameters	Description
ψ_c	The probability that a final firm will not receive a signal to change its price
ψ_d	The probability that an intermediate firm will not receive a signal to change its price
ψ_f	The probability that an intermediate importer 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 rates
h	Habit formation coefficient
ϕ	The proportion of domestic intermediate firms using LCP to set a new price at each period
ϕ^*	The proportion of foreign intermediate firms using LCP to set a new price at each period
γ	Elasticity of substitution among varieties of labor types
μ	Constant relative risk aversion coefficient of labor
ρ	Constant relative risk aversion coefficient of consumption
α	Weighting parameter in the intermediate input bundle
ς	The elasticity of substitution between varieties of final consumption goods
σ	The elasticity of substitution between domestic and foreign varieties
ε	The elasticity of substitution between varieties within one country
η	Cobb-Douglas coefficient in intermediate good production function
δ	Depreciation rate
α_f	Weighting parameter of foreign demand
σ_f	Elasticity parameter of foreign demand

Table 4: Prior Distribution

Parameters	Distribution	Mean	Std
ψ_c	Beta	0.75	0.10
ψ_d	Beta	0.70	0.10
ψ_f	Beta	0.70	0.10
ψ_w	Beta	0.75	0.10
h	Beta	0.70	0.10
σ	Gamma	1.00	0.50
σ_f	Gamma	0.50	0.15
φ	Gamma	0.05	0.01
ρ_r	Beta	0.80	0.10
α_π	Gamma	1.40	0.10
α_y	Beta	0.60	0.10
ϕ	Beta	0.73	0.10
ϕ^*	Beta	0.31	0.10
δ_{pl}	Beta	0.80	0.10
δ_{pp}	Beta	0.80	0.10
$\delta_{a\beta}$	Beta	0.80	0.10
δ_{al}	Beta	0.80	0.10
δ_a	Beta	0.80	0.10
δ_g	Beta	0.80	0.10
$\delta_{\bar{\pi}}$	Beta	0.80	0.10
$\sigma_{\epsilon pl}$	Inv Gamma	0.1	2
$\sigma_{\epsilon pp}$	Inv Gamma	0.1	2
$\sigma_{\epsilon a\beta}$	Inv Gamma	0.1	2
$\sigma_{\epsilon al}$	Inv Gamma	0.1	2
$\sigma_{\epsilon a}$	Inv Gamma	0.1	2
$\sigma_{\epsilon g}$	Inv Gamma	0.1	2
$\sigma_{\epsilon \bar{\pi}}$	Inv Gamma	0.1	2
$\sigma_{\epsilon r}$	Inv Gamma	0.1	2

Note: 1. For Canada, the priors of ϕ and ϕ^* are set at 0.76 and 0.25. For the UK, the priors of ϕ and ϕ^* are set at 0.30 and 0.40.
2. For the Inverse Gamma distribution, degree of freedom is indicated instead of standard deviations.

Table 5: Parameter Estimates: Australia

	Australia				
	Posterior Maximization		Posterior Distribution		
Parameters	Mode	Std Error	Mean	10%	90%
ψ_c	0.9349	0.0083	0.9483	0.9390	0.9584
ψ_d	0.6423	0.0261	0.7256	0.6960	0.7565
ψ_f	0.5579	0.0383	0.5760	0.5294	0.6220
ψ_w	0.6254	0.0332	0.7441	0.7219	0.7674
ϕ	0.1397	0.0393	0.1893	0.1197	0.2600
ϕ^*	0.1729	0.0601	0.1080	0.0675	0.1477
h	0.9274	0.0100	0.9381	0.9255	0.9507
σ	0.6725	0.0244	0.6293	0.5945	0.6612
σ_f	0.5694	0.0273	0.5033	0.4609	0.5449
φ	0.0213	0.0011	0.0197	0.0180	0.0213
ρ_r	0.9374	0.0059	0.9176	0.9051	0.9292
α_π	1.6685	0.0748	1.5897	1.4686	1.7009
α_y	0.3612	0.0704	0.6356	0.4967	0.7725
δ_{pl}	0.3597	0.0621	0.6787	0.5688	0.7888
δ_{pp}	0.9533	0.0061	0.9576	0.9504	0.9658
$\delta_{a\beta}$	0.9665	0.0609	0.6673	0.5826	0.7566
δ_A	0.7891	0.0620	0.6839	0.5936	0.7759
δ_g	0.9457	0.0195	0.5378	0.4437	0.6290
$\delta_{\bar{\pi}}$	0.9408	0.0075	0.9226	0.9088	0.9364
$\sigma_{\epsilon pl}$	1.4728	0.5412	0.8933	0.4973	1.2509
$\sigma_{\epsilon pp}$	0.1094	0.0132	0.0945	0.0767	0.1120
$\sigma_{\epsilon g}$	0.6858	0.0589	0.6444	0.5589	0.7290
$\sigma_{\epsilon r}$	0.0121	0.0008	0.0106	0.0092	0.0118
$\sigma_{\epsilon a\beta}$	1.0066	0.0028	1.3363	1.2509	1.4442
$\sigma_{\epsilon A}$	0.0997	0.0159	0.1646	0.1206	0.2093
$\sigma_{\epsilon\bar{\pi}}$	0.0812	0.0130	0.0881	0.0572	0.1176
$\sigma_{\epsilon rp}$	0.7996	0.0907	0.6260	0.5348	0.7092

Table 6: Parameter Estimates: Canada

	Canada				
	Posterior Maximization		Posterior Distribution		
Parameters	Mode	Std Error	Mean	10%	90%
ψ_c	0.9334	0.0073	0.9299	0.9181	0.9434
ψ_d	0.6773	0.0327	0.6727	0.6214	0.7301
ψ_f	0.6611	0.0229	0.6557	0.6175	0.6951
ψ_w	0.8042	0.0186	0.8060	0.7775	0.8358
ϕ	0.4544	0.0746	0.4226	0.2712	0.5677
ϕ^*	0.1050	0.0299	0.1081	0.0566	0.1554
h	0.9291	0.0095	0.9280	0.9127	0.9437
σ	0.5535	0.0156	0.5552	0.5286	0.5812
σ_f	0.6778	0.0377	0.6866	0.6266	0.7479
φ	0.0389	0.0076	0.0426	0.0298	0.0553
ρ_r	0.9531	0.0061	0.9530	0.9434	0.9634
α_π	1.7984	0.1539	1.7954	1.5377	2.0554
α_y	0.6891	0.0823	0.7061	0.5671	0.8426
δ_{pl}	0.5664	0.0689	0.5529	0.4341	0.6708
δ_{pp}	0.9431	0.0068	0.9399	0.9285	0.9514
$\delta_{a\beta}$	0.9110	0.0117	0.9110	0.8907	0.9299
δ_A	0.4920	0.1047	0.5650	0.3465	0.7809
δ_g	0.8357	0.0103	0.8355	0.8184	0.8521
$\delta_{\bar{\pi}}$	0.9116	0.0099	0.9118	0.8962	0.9284
$\sigma_{\epsilon pl}$	1.4921	0.5045	1.6642	0.7206	2.6246
$\sigma_{\epsilon pp}$	0.0947	0.0098	0.0984	0.0808	0.1139
$\sigma_{\epsilon g}$	0.7041	0.0577	0.7245	0.6219	0.8242
$\sigma_{\epsilon r}$	0.0089	0.0006	0.0091	0.0080	0.0101
$\sigma_{\epsilon a\beta}$	0.9693	0.1764	1.0122	0.7174	1.3112
$\sigma_{\epsilon A}$	0.1878	0.0431	0.1809	0.1086	0.2611
$\sigma_{\epsilon\bar{\pi}}$	0.0933	0.0195	0.1034	0.0690	0.1363
$\sigma_{\epsilon rp}$	0.8385	0.0704	0.8600	0.7371	0.9728

Table 7: Parameter Estimates: United Kingdom

	United Kingdom				
	Posterior Maximization		Posterior Distribution		
Parameters	Mode	Std Error	Mean	10%	90%
ψ_c	0.9370	0.0055	0.9362	0.9284	0.9435
ψ_d	0.3050	0.0213	0.2971	0.2699	0.3243
ψ_f	0.8037	0.0107	0.7994	0.7823	0.8171
ψ_w	0.6166	0.0326	0.6239	0.5718	0.6736
ϕ	0.2395	0.0725	0.2580	0.1379	0.3722
ϕ^*	0.8665	0.0253	0.8613	0.8370	0.8895
h	0.9868	0.0035	0.9863	0.9816	0.9914
σ	0.5829	0.0147	0.5815	0.5584	0.6041
σ_f	0.5795	0.0277	0.5820	0.5498	0.6154
φ	0.0724	0.0119	0.0742	0.0579	0.0915
ρ_r	0.9819	0.0040	0.9826	0.9797	0.9855
α_π	1.6385	0.1043	1.6582	1.5141	1.7978
α_y	0.1550	0.0258	0.1603	0.1165	0.2004
δ_{pl}	0.9792	0.0002	0.9773	0.9755	0.9792
δ_{pp}	0.8515	0.0143	0.8515	0.8320	0.8707
$\delta_{a\beta}$	0.9938	0.0013	0.9927	0.9893	0.9976
δ_A	0.6232	0.0607	0.6127	0.5145	0.7086
δ_g	0.8434	0.0258	0.8407	0.7996	0.8837
$\delta_{\bar{\pi}}$	0.5471	0.1073	0.5561	0.3911	0.7174
$\sigma_{\epsilon pl}$	0.1894	0.0147	0.1992	0.1740	0.2228
$\sigma_{\epsilon pp}$	1.5546	0.3818	1.5754	1.1940	1.9729
$\sigma_{\epsilon g}$	0.8180	0.1021	0.8126	0.6462	0.9771
$\sigma_{\epsilon r}$	0.0139	0.0013	0.0141	0.0123	0.0159
$\sigma_{\epsilon a\beta}$	0.9571	0.1363	1.0307	0.6507	1.4591
$\sigma_{\epsilon A}$	0.0631	0.0090	0.0638	0.0515	0.0755
$\sigma_{\epsilon\bar{\pi}}$	0.0180	0.0075	0.0413	0.0082	0.1008
$\sigma_{\epsilon rp}$	0.9755	0.0798	1.0159	0.8962	1.1379

Table 8: Unconditional Second Moments: Australia

Variables	Relative Volatility to $\Delta ln(p_t)$	Correlation with $\Delta ln(q_t)$	Correlation with $\Delta ln(y_{ft})$
		Australia	
		Data	
$\Delta ln(p_t)$	1.0000	0.1678	-0.0450
$\Delta ln(p_{ft})$	3.7234	0.7092	0.2749
$\Delta ln(p^*_{ht})$	4.5000	-0.7583	-0.1003
$\Delta ln(q_t)$	5.0745	1.0000	0.2063
$\Delta ln(r_t)$	1.0426	-0.0536	0.2038
$\Delta ln(w_t)$	1.2872	0.1070	0.0397
$\Delta ln(y_{ft})$	7.7660	0.2063	1.0000
$\Delta ln(y^*_{ht})$	7.5638	0.2818	0.4999
$\Delta ln(z_t)$	1.3298	0.0120	0.3451
		Model	
$\Delta ln(p_t)$	1.0000	0.2663	-0.1044
		(0.2040,0.3343)	(-0.1438,-0.0701)
$\Delta ln(p_{ft})$	2.7662	0.6388	0.1999
	(2.4276,3.2552)	(0.5948,0.7002)	(0.0881,0.3250)
$\Delta ln(p^*_{ht})$	2.4164	-0.6873	-0.2825
	(2.0169,2.9538)	(-0.7085,-0.6697)	(-0.3765,-0.1818)
$\Delta ln(q_t)$	8.4247	1.0000	0.7667
	(6.4954,11.509)		(0.6951,0.8196)
$\Delta ln(r_t)$	0.2953	0.4227	0.2400
	(0.2594,0.3584)	(0.3689,0.4700)	(0.1413,0.3437)
$\Delta ln(w_t)$	0.5079	0.2892	0.0028
	(0.4558,0.5742)	(0.2333,0.3465)	(-0.0559,0.0686)
$\Delta ln(y_{ft})$	3.2713	0.7667	1.0000
	(2.4711,4.4659)	(0.6951,0.8196)	
$\Delta ln(y^*_{ht})$	1.2322	0.6664	0.2719
	(1.0197,1.5010)	(0.6463,0.6899)	(0.1777,0.3702)
$\Delta ln(z_t)$	3.3184	0.7981	0.9979
	(2.4973,4.5407)	(0.7316,0.8436)	(0.9970,0.9987)

Table 9: Unconditional Second Moments: Canada and the United Kingdom

Variables	Canada		United Kingdom	
	Relative Volatility to $\Delta ln(p_t)$	Correlation with $\Delta ln(q_t)$	Relative Volatility to $\Delta ln(p_t)$	Correlation with $\Delta ln(q_t)$
		Data		
$\Delta ln(p_t)$	1.0000	0.1600	1.0000	0.2707
$\Delta ln(p_{ft})$	4.1475	0.4219	2.4206	0.5687
$\Delta ln(p^*_{ht})$	7.2295	-0.7473	4.3016	-0.9148
$\Delta ln(q_t)$	6.5902	1.0000	4.8333	1.0000
$\Delta ln(r_t)$	1.5902	0.0138	0.7698	0.0401
$\Delta ln(w_t)$	1.6230	0.2062	1.0079	0.2323
$\Delta ln(y_{ft})$	13.951	0.1967	4.8095	0.4069
$\Delta ln(y^*_{ht})$	14.557	0.1545	6.6349	0.2294
$\Delta ln(z_t)$	1.5574	-0.0030	0.7857	0.0507
		Model		
$\Delta ln(p_t)$	1.0000	0.1087	1.0000	0.7686
		(0.0891,0.1320)		(0.6940,0.8251)
$\Delta ln(p_{ft})$	3.8314	0.6417	2.2342	0.8903
	(3.1245,4.7990)	(0.5435,0.7218)	(2.0758,2.4213)	(0.8515,0.9222)
$\Delta ln(p^*_{ht})$	5.2858	-0.7628	3.0312	-0.9698
	(3.8576,6.7881)	(-0.8156,-0.7142)	(2.6626,3.5255)	(-0.9778,-0.9571)
$\Delta ln(q_t)$	24.631	1.0000	2.8747	1.0000
	(18.796,31.136)		(2.5530,3.3306)	
$\Delta ln(r_t)$	0.4794	0.4125	0.1393	0.2193
	(0.3944,0.5834)	(0.3453,0.4676)	(0.1159,0.1681)	(0.0533,0.3837)
$\Delta ln(w_t)$	0.6704	0.1665	0.4068	-0.1591
	(0.5588,0.7931)	(0.1220,0.2148)	(0.3605,0.4615)	(-0.2653,-0.0597)
$\Delta ln(y_{ft})$	10.318	0.8871	3.5544	-0.2413
	(7.6284,13.256)	(0.8502,0.9161)	(2.8228,4.6697)	(-0.2992,-0.1868)
$\Delta ln(y^*_{ht})$	3.7108	0.7465	1.7678	0.9659
	(2.5752,4.8744)	(0.6923,0.8028)	(1.5548,2.0396)	(0.9528,0.9749)
$\Delta ln(z_t)$	10.458	0.8954	3.5344	-0.1971
	(7.7557,13.477)	(0.8619,0.9230)	(2.8024,4.6528)	(-0.2544,-0.1443)

Figure 1: Impulse Responses: Australia

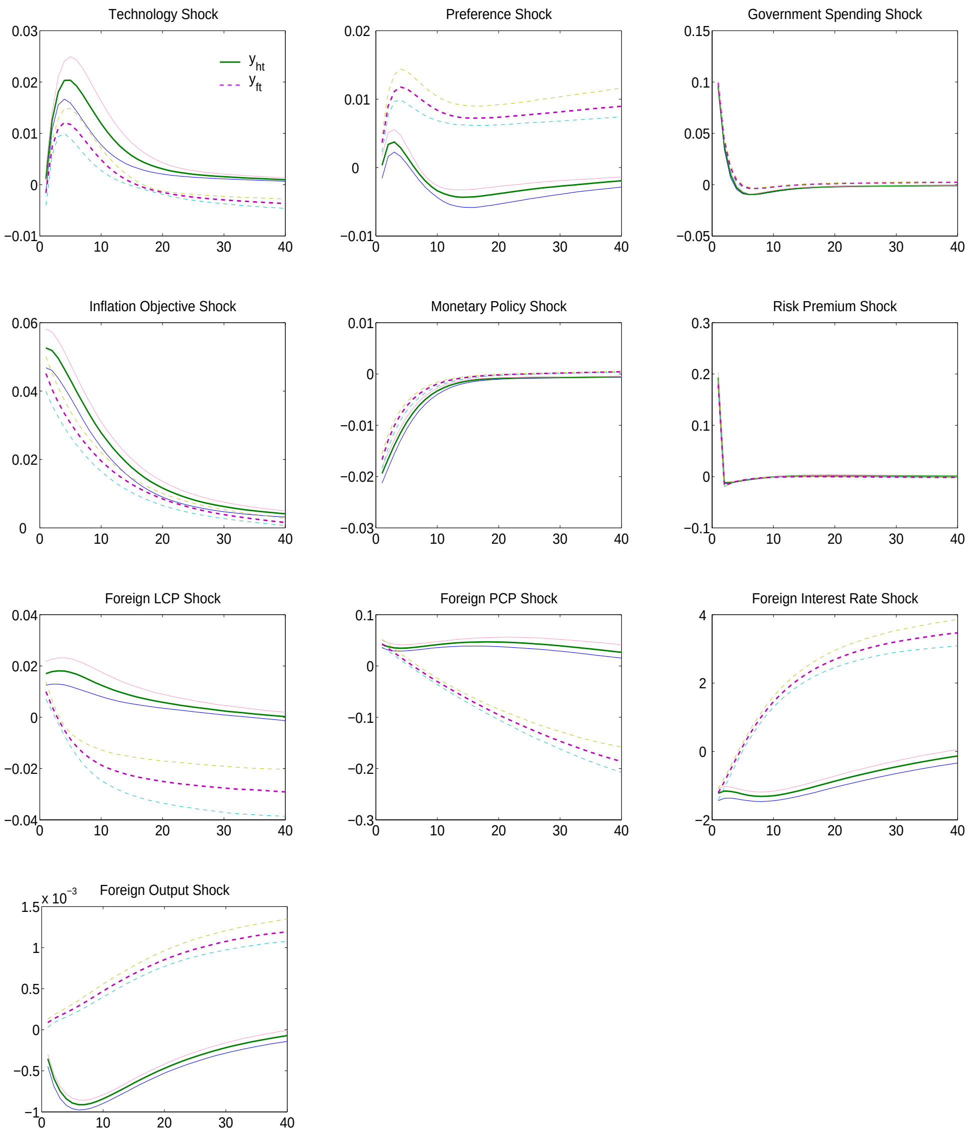

Figure 2: Impulse Responses: Canada

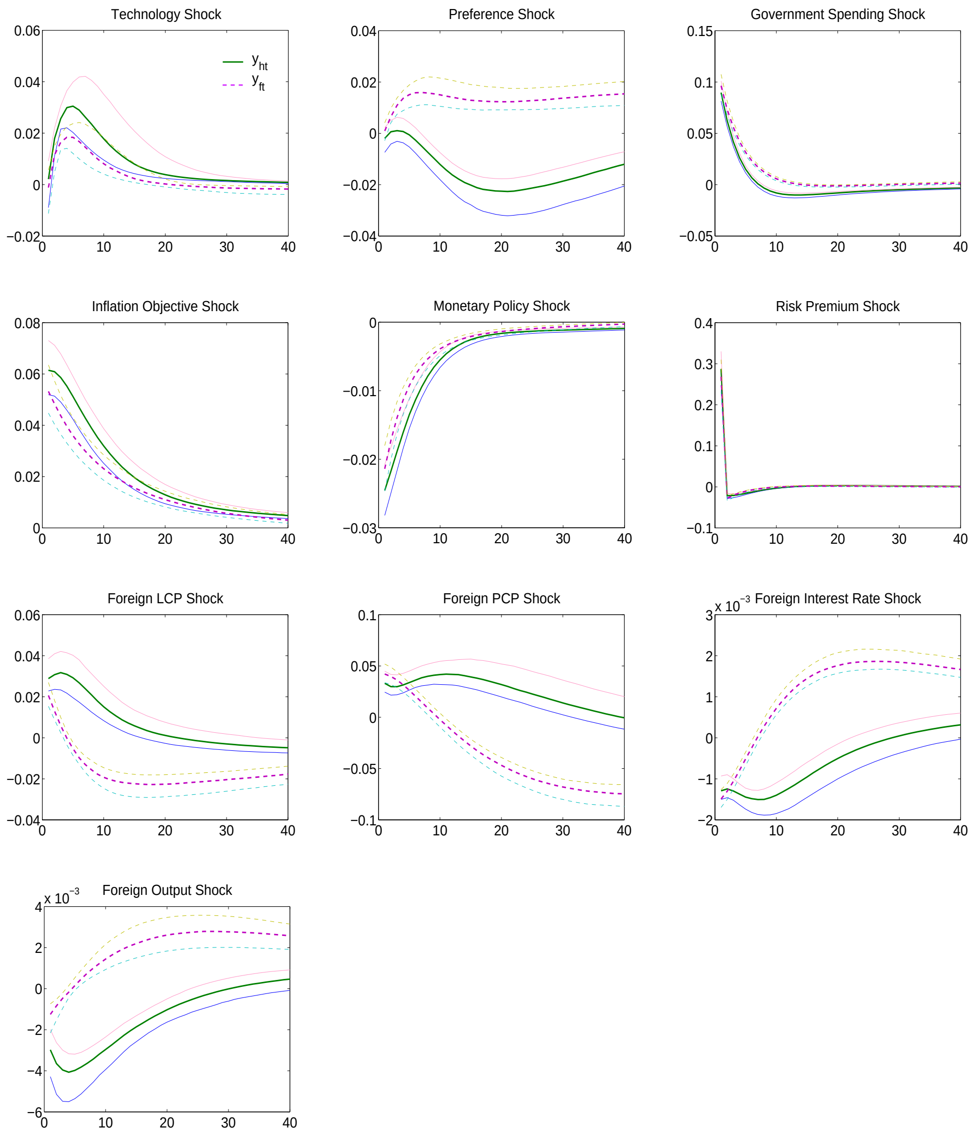

Figure 3: Impulse Responses: United Kingdom

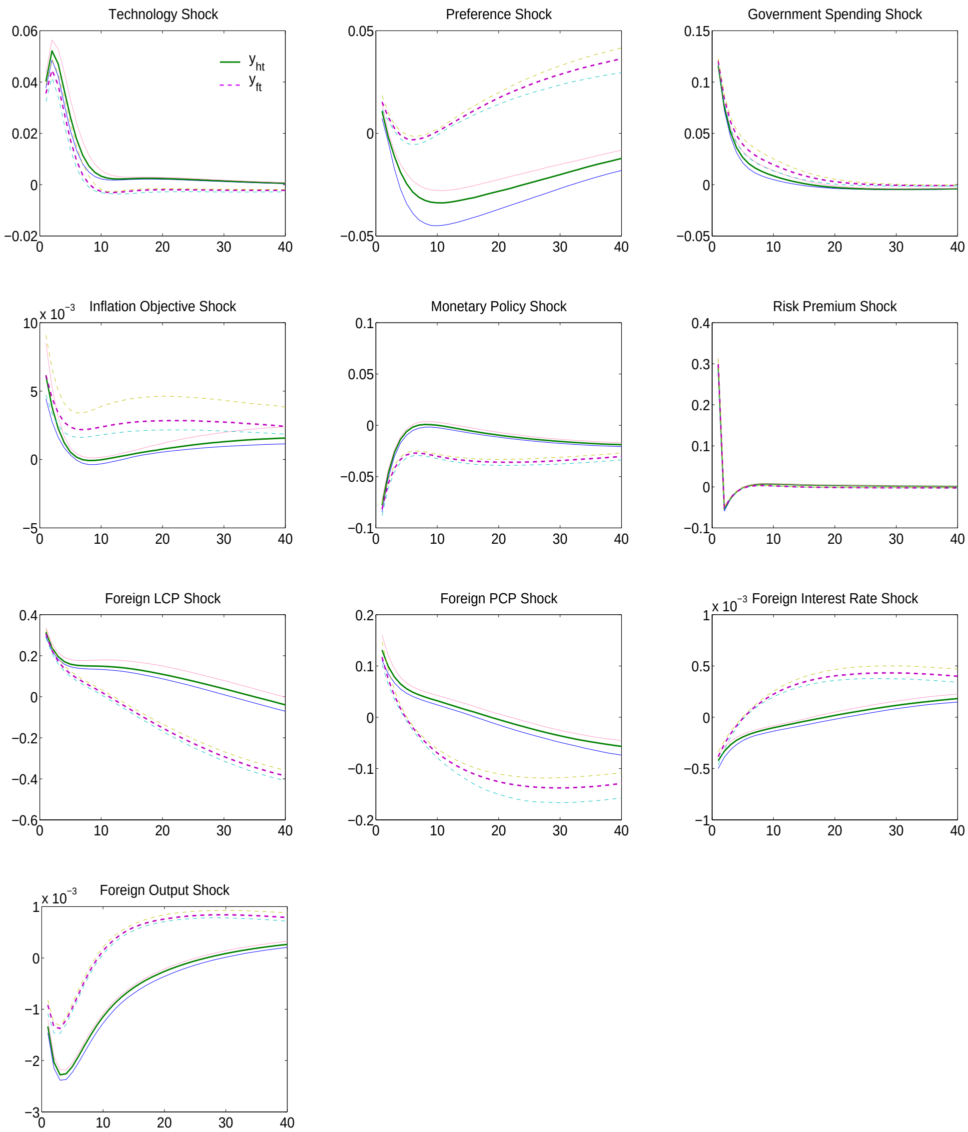

Table 10: Variance Decompositions: Australia

	Period	$\hat{p}_{ft}$	$\hat{y}_{ht}$	$\hat{y}_{ft}$	$\hat{q}_t$	$\hat{z}_t$
		Australia				
Technology shock	1	1.6883	0.1926	0.0896	0.3713	0.1378
	4	2.5289	1.1354	0.5559	1.1982	0.8358
	8	1.6412	1.2371	0.5463	1.0320	0.8799
	12	1.1075	1.2445	0.5154	0.8458	0.8698
	20	0.7011	1.2538	0.4478	0.6431	0.8320
	40	0.4500	1.2236	0.3303	0.4614	0.6989
	∞	0.3720	0.4622	0.2015	0.3781	0.3045
Preference shock	1	29.263	4.7813	2.6737	11.828	3.6858
	4	23.419	4.7544	2.6719	10.379	3.4713
	8	16.547	4.7340	3.0262	9.5338	3.5271
	12	13.150	4.7361	3.4878	8.9390	3.6906
	20	11.165	4.7359	4.2460	8.8319	3.9447
	40	11.160	4.6976	5.7503	9.7802	4.5887
	∞	19.132	15.520	10.334	23.074	12.002
Government Spending shock	1	9.9975	3.2495	5.6446	5.9643	4.3488
	4	4.9019	3.0598	5.3075	4.5741	4.1122
	8	2.5987	3.0396	5.0413	3.5697	4.0530
	12	1.7907	3.0573	4.7542	2.9084	4.0035
	20	1.2504	3.0783	4.1235	2.1977	3.8265
	40	0.9676	2.9988	2.9459	1.5819	3.2278
	∞	1.9757	6.4217	7.1393	5.0595	7.1871
Inflation Objective shock	1	0.3838	0.1459	0.2466	0.2243	0.1923
	4	0.1953	0.1377	0.2299	0.1716	0.1812
	8	0.1048	0.1368	0.2182	0.1341	0.1784
	12	0.0723	0.1375	0.2057	0.1095	0.1762
	20	0.0504	0.1383	0.1784	0.0831	0.1684
	40	0.0386	0.1347	0.1269	0.0602	0.1418
	∞	0.0736	0.2663	0.2865	0.1776	0.2926
Foreign LCP shock	1	28.470	3.0551	1.3703	12.005	2.1548
	4	53.394	4.3076	1.5899	28.179	2.2592
	8	57.160	4.5865	3.3813	35.649	2.4107
	12	53.551	4.6279	5.6331	37.881	2.8684
	20	47.798	4.6423	10.119	38.612	4.3933
	40	41.376	5.5262	18.096	37.086	9.6391
	∞	31.079	4.4491	14.724	25.903	9.0320

Table 11: Variance Decompositions: Australia (Continued)

	Australia					
	Period	$\hat{p}_{ft}$	$\hat{y}_{ht}$	$\hat{y}_{ft}$	$\hat{q}_t$	$\hat{z}_t$
Foreign PCP shock	1	10.095	22.848	22.474	4.6704	22.725
	4	9.5132	23.769	25.937	4.0817	25.026
	8	18.841	23.845	27.428	10.142	25.785
	12	28.281	23.822	28.467	17.691	26.042
	20	37.756	23.833	31.640	27.477	27.241
	40	45.202	24.786	38.884	37.745	31.992
	∞	46.786	58.840	58.254	39.613	59.323
Monetary Policy shock	1	0.1368	6.6783	8.0915	0.0957	7.3712
	4	0.2324	6.3932	7.5288	0.1991	7.0321
	8	0.1563	6.3577	7.1306	0.1677	6.9295
	12	0.1068	6.3500	6.7243	0.1361	6.8372
	20	0.0686	6.3398	5.8146	0.1007	6.5322
	40	0.0453	6.1649	3.9976	0.0686	5.4478
	∞	0.0333	1.4259	1.0631	0.0395	1.2960
Risk Premium shock	1	19.933	59.037	59.399	64.827	59.372
	4	5.7746	56.431	56.168	51.199	57.070
	8	2.9021	56.051	53.215	39.744	56.225
	12	1.8887	56.013	50.197	31.457	55.500
	20	1.1594	55.967	43.411	22.017	53.048
	40	0.7133	54.455	29.841	13.176	44.245
	∞	0.5089	12.601	7.9743	5.7206	10.544
Foreign interest rate shock	1	0.0042	0.0104	0.0103	0.0001	0.0103
	4	0.0188	0.0098	0.0110	0.0066	0.0102
	8	0.0341	0.0097	0.0127	0.0170	0.0105
	12	0.0399	0.0098	0.0147	0.0239	0.0109
	20	0.0420	0.0098	0.0186	0.0302	0.0123
	40	0.0407	0.0106	0.0254	0.0339	0.0170
	∞	0.0335	0.0115	0.0216	0.0266	0.0163
Foreign output shock	1	0.0279	0.0021	0.0007	0.0132	0.0013
	4	0.0222	0.0025	0.0007	0.0118	0.0013
	8	0.0154	0.0026	0.0009	0.0106	0.0013
	12	0.0119	0.0026	0.0012	0.0095	0.0014
	20	0.0091	0.0026	0.0017	0.0083	0.0015
	40	0.0070	0.0026	0.0027	0.0069	0.0021
	∞	0.0066	0.0025	0.0025	0.0080	0.0022

Table 12: Variance Decompositions: Canada

	Canada					
	Period	$\hat{p}_{ft}$	$\hat{y}_{ht}$	$\hat{y}_{ft}$	$\hat{q}_t$	$\hat{z}_t$
Technology shock	1	2.6289	0.1470	0.0756	0.1792	0.0960
	4	4.6349	1.1083	0.5900	0.9111	0.7422
	8	3.0129	1.3357	0.6606	0.9570	0.8603
	12	2.1014	1.3513	0.6516	0.9037	0.8611
	20	1.4008	1.3571	0.6266	0.8297	0.8481
	40	1.0107	1.3641	0.5772	0.7620	0.8104
	∞	0.8226	0.8230	0.3417	0.6549	0.4703
Preference shock	1	10.196	0.1450	0.0224	0.1745	0.0500
	4	23.012	1.2012	0.1439	2.2230	0.3738
	8	22.620	2.1390	0.1827	3.8810	0.5608
	12	19.078	2.2572	0.2606	4.2596	0.5715
	20	14.940	2.2685	0.4978	4.5131	0.6544
	40	13.087	2.3077	0.8412	5.2061	0.7627
	∞	16.331	2.8246	1.1552	7.4747	1.1309
Government Spending shock	1	9.3304	6.9046	8.9289	1.5062	8.2598
	4	6.9799	7.0519	8.8174	1.4696	8.2333
	8	3.5037	7.0056	8.7197	1.3444	8.2028
	12	2.3376	6.9958	8.5812	1.2568	8.1643
	20	1.5452	7.0042	8.2583	1.1493	8.0410
	40	1.1369	7.0119	7.5739	1.0524	7.6822
	∞	1.6013	12.612	13.187	2.4407	13.417
Inflation Objective shock	1	0.6951	0.1509	0.2224	0.1267	0.1982
	4	0.3991	0.1527	0.2165	0.1107	0.1940
	8	0.1811	0.1501	0.2135	0.1006	0.1923
	12	0.1196	0.1499	0.2101	0.0940	0.1914
	20	0.0810	0.1513	0.2024	0.0862	0.1889
	40	0.0636	0.1526	0.1857	0.0793	0.1806
	∞	0.1505	0.4872	0.5819	0.3366	0.5683
Foreign LCP shock	1	19.800	2.0633	1.3380	0.82996	1.5542
	4	43.546	2.9099	1.3347	5.9583	1.6324
	8	41.142	3.1973	1.6552	8.7143	1.6730
	12	37.656	3.2428	2.1962	10.105	1.8589
	20	33.459	3.2468	3.2392	11.662	2.3274
	40	29.450	3.2973	5.1283	13.032	3.4494
	∞	23.598	2.7177	4.3015	11.347	3.1516

Table 13: Variance Decompositions: Canada (Continued)

	Canada					
	Period	$\hat{p}_{ft}$	$\hat{y}_{ht}$	$\hat{y}_{ft}$	$\hat{q}_t$	$\hat{z}_t$
Foreign PCP shock	1	1.4399	7.3003	8.5342	2.0915	8.1356
	4	6.5206	6.9711	8.5578	3.5677	8.0350
	8	22.174	6.8832	9.1531	6.8926	8.2125
	12	33.787	6.9753	9.9609	10.453	8.4801
	20	45.292	7.0420	11.978	15.952	9.3154
	40	52.907	7.1083	16.717	22.567	12.009
	∞	55.530	35.525	43.823	34.200	40.910
Monetary Policy shock	1	0.1581	3.6935	4.1715	0.0372	4.0187
	4	0.2819	3.6007	4.1091	0.0923	3.9591
	8	0.1711	3.5460	4.0616	0.0899	3.9359
	12	0.1148	3.5353	3.9961	0.0839	3.9153
	20	0.0739	3.5283	3.8439	0.0759	3.8522
	40	0.0515	3.5194	3.5250	0.0675	3.6790
	∞	0.0428	2.0087	1.8686	0.0539	1.9745
Risk Premium shock	1	55.137	79.564	79.688	94.958	77.665
	4	14.097	76.969	76.212	85.568	76.808
	8	6.8267	75.707	75.332	77.914	76.340
	12	4.4956	75.456	74.118	72.733	75.934
	20	2.9449	75.366	71.322	65.613	74.746
	40	2.0631	75.202	65.406	57.108	71.393
	∞	1.6720	42.926	34.683	43.248	38.321
Foreign interest rate shock	1	0.0003	0.0079	0.0089	0.0061	0.0086
	4	0.0324	0.0079	0.0089	0.0061	0.0086
	8	0.0627	0.0083	0.0096	0.0208	0.0084
	12	0.0730	0.0085	0.0109	0.0258	0.0089
	20	0.0773	0.0085	0.0138	0.0316	0.0101
	40	0.0761	0.0086	0.0194	0.0371	0.0134
	∞	0.0655	0.0157	0.0239	0.0416	0.0200
Foreign output shock	1	0.6146	0.0237	0.0100	0.0909	0.0138
	4	0.4960	0.0276	0.0104	0.0864	0.0135
	8	0.3055	0.0278	0.0124	0.0852	0.0139
	12	0.2368	0.0278	0.0148	0.0856	0.0149
	20	0.1865	0.0277	0.0188	0.0868	0.0167
	40	0.1536	0.0279	0.0264	0.0878	0.0212
	∞	0.1862	0.0601	0.0345	0.2029	0.0370

Table 14: Variance Decompositions: United Kingdom

	United Kingdom					
	Period	$\hat{p}_{ft}$	$\hat{y}_{ht}$	$\hat{y}_{ft}$	$\hat{q}_t$	$\hat{z}_t$
Technology shock	1	2.7206	0.5079	0.4321	6.0568	0.4584
	4	1.7385	0.5110	0.4235	2.8618	0.4535
	8	0.5517	0.5098	0.4227	1.3629	0.4533
	12	0.2596	0.5112	0.4133	0.9077	0.4502
	20	0.1263	0.5134	0.3812	0.5527	0.4357
	40	0.0769	0.5039	0.2917	0.3295	0.3703
	∞	0.0591	0.0667	0.0522	0.1984	0.0571
Preference shock	1	10.267	0.1776	0.1076	2.8595	0.1306
	4	9.1308	0.2698	0.1296	1.8676	0.1707
	8	3.5891	0.2695	0.1615	0.9447	0.1831
	12	1.8039	0.2691	0.1876	0.6912	0.1953
	20	0.9256	0.2715	0.2305	0.5225	0.2205
	40	0.6072	0.2907	0.3062	0.4495	0.2807
	∞	1.7355	0.5432	0.3382	2.0506	0.3919
Government Spending shock	1	5.6679	4.9329	5.0777	5.4133	5.0265
	4	3.8484	4.1210	4.2278	2.9302	4.1900
	8	1.1005	4.1061	4.2004	1.3853	4.1820
	12	0.4590	4.1044	4.1068	0.9107	4.1542
	20	0.1854	4.1077	3.7874	0.5441	4.0233
	40	0.0930	4.0278	2.8848	0.3177	3.4215
	∞	0.0992	1.1676	1.1124	0.3722	1.1433
Inflation Objective shock	1	0.0002	0.0005	0.0005	0.0006	0.0005
	4	0.0001	0.0004	0.0004	0.0003	0.0004
	8	0.0000	0.0004	0.0004	0.0002	0.0004
	12	0.0000	0.0004	0.0004	0.0001	0.0004
	20	0.0000	0.0004	0.0004	0.0001	0.0004
	40	0.0000	0.0004	0.0003	0.0000	0.0004
	∞	0.0000	0.0001	0.0000	0.0000	0.0000
Foreign LCP shock	1	49.832	58.314	59.552	55.797	59.117
	4	17.512	63.806	63.854	61.118	63.884
	8	34.891	63.844	63.537	63.876	63.790
	12	51.897	63.859	63.369	65.828	63.695
	20	65.598	63.857	63.796	69.682	63.754
	40	74.612	63.892	67.143	74.812	65.650
	∞	80.199	93.344	92.856	85.820	93.173

Table 15: Variance Decompositions: United Kingdom (Continued)

	United Kingdom					
	Period	$\hat{p}_{ft}$	$\hat{y}_{ht}$	$\hat{y}_{ft}$	$\hat{q}_t$	$\hat{z}_t$
Foreign PCP shock	1	27.293	8.0263	7.0195	0.7699	7.3712
	4	65.344	6.9980	7.0712	11.079	6.9861
	8	59.288	7.0519	7.5263	22.661	7.0981
	12	45.243	7.0667	8.3115	25.165	7.3792
	20	32.898	7.0680	10.038	24.760	8.2171
	40	24.355	7.6272	12.798	21.757	10.445
	∞	17.671	2.8329	3.7580	10.593	3.2766
Monetary Policy shock	1	0.2946	2.4006	2.3763	2.3286	2.3852
	4	0.2013	1.9490	1.9560	1.1401	1.9553
	8	0.0576	1.9410	1.9427	0.5386	1.9515
	12	0.0250	1.9383	1.8994	0.3534	1.9381
	20	0.0113	1.9372	1.7513	0.2098	1.8760
	40	0.0071	1.8956	1.3336	0.1203	1.5942
	∞	0.0071	0.1638	0.1510	0.0489	0.1571
Risk Premium shock	1	3.8769	25.639	25.433	26.732	25.510
	4	2.1875	22.343	22.337	18.985	22.360
	8	0.5021	22.276	22.208	9.2222	23.340
	12	0.3052	22.249	21.711	6.1367	22.186
	20	0.2516	22.243	20.014	3.7243	21.471
	40	0.2463	21.761	15.241	2.2109	18.237
	∞	0.2270	1.8812	1.7315	0.9131	1.8006
Foreign interest rate shock	1	0.0001	0.0001	0.0001	0.0004	0.0001
	4	0.0006	0.0001	0.0001	0.0003	0.0001
	8	0.0007	0.0001	0.0001	0.0004	0.0001
	12	0.0005	0.0001	0.0001	0.0004	0.0001
	20	0.0004	0.0001	0.0001	0.0003	0.0001
	40	0.0003	0.0001	0.0001	0.0003	0.0001
	∞	0.0002	0.0000	0.0000	0.0002	0.0000
Foreign output shock	1	0.0478	0.0013	0.0008	0.0413	0.0010
	4	0.0371	0.0014	0.0008	0.0184	0.0010
	8	0.0141	0.0014	0.0009	0.0093	0.0010
	12	0.0070	0.0014	0.0009	0.0065	0.0010
	20	0.0035	0.0014	0.0009	0.0043	0.0010
	40	0.0021	0.0014	0.0009	0.0029	0.0009
	∞	0.0017	0.0004	0.0003	0.0032	0.0003