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Assessing the fit of small open economy DSGEs*

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Abstract

We describe a simple extension of the Monacelli (2005) small open economy model that incorporates a non-tradable good, habit persistence and price indexation. The empirical fit of eight different specifications of this model is then tested in a Bayesian framework using data for three small open economies: Australia, Canada, and New Zealand. The results show that the model with a non-tradable good fits the data better than the one-good model across all specifications considered. In contrast to Rabanal and Rubio-Ramarez (2005), we find that adding price indexation to either the one- or two-good model deteriorates overall empirical fit.

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1 Introduction

Much recent work in macroeconomics has been on the development of Dynamic Stochastic General Equilibrium (DSGE) models for the analysis of monetary policy. Indeed, there is mounting evidence that these models are capable of matching business cycle dynamics as well as purely statistical models, such as VARs (Smets and Wouters 2004). Accordingly, central banks have begun to move towards models with strong microeconomic foundations, away from the older-generation models developed in the 1990s.[1] Central bank modellers are thus being confronted with a variety of questions relating to the design of DSGE models, such as how to model the real exchange rate and whether or not to include habit formation and price indexation.

This paper takes a step back from the more complicated DSGEs currently being developed by academics and central banks, and aims to assess the empirical fit of a comparatively simple small open economy DSGE model. Specifically, we aim to assess whether adding a non-tradable good, habit formation, and price indexation to a small open economy DSGE improves its overall empirical fit.

Differences between the behaviour of tradable and non-tradable prices have been shown to be important in determining real exchange rate dynamics (De Gregorio *et al* 1994; Engel 1999; Burnstein *et al* 2005). There is also empirical evidence suggesting that modelling tradable and non-tradable prices separately can improve the forecasting performance of the Phillips curve (Matheson 2006). Hence, the non-tradable sector is a key feature of some recent open economy DSGEs, such as those of Laxton and Pesenti (2003) and Devereux *et al* (2005).

Habit formation and price indexation have also been found to be important in fitting DSGEs (Smets and Wouters 2004; Christiano *et al* 2005), and these mechanisims have become standard features of the models being developed by many central banks (see, for example, Murchison and Rennison 2006).

Since Gali and Gertler (1999) developed their popular New Keynesian DSGE for the analysis of monetary policy in a closed economy, the model has been extended to the small open economy by Gali and Monacelli (2005), and augmented further by allowing for deviations from the law of one price by Monacelli (2005). Acknowledging the importance of the non-tradable sector, Santacreu (2005) extended the Gali and Monacelli (2005) by adding a non-tradable good (as well as habit persistence and price indexation). Likewise, the Monacelli (2005) model

[1] For example, the Bank of Canada has developed a new DSGE model to replace its old Quarterly Projection Model (QPM) (Murchison and Rennison 2006). DSGEs are also currently being developed at the central banks of Chile, New Zealand, Norway and Sweden, to name a few.

has been augmented with habit persistence and price indexation by Justiniano and Preston (2004) and Liu (2006). But the question remains: Which additional features are key to improving the overall empirical fit of the canonical small open economy DSGE?[2]

We outline a general model that allows for deviations from the law of one price, habit persistence, price indexation and a non-tradable good. This general model nests a variety of different specifications of the small open economy DSGE, such as Monacelli's one-good model and versions of the one- and two-good model that exclude habit persistence and/or price indexation. Altogether, we have eight different specifications of the model. The empirical fit of the model is then tested in a Bayesian framework using data for three inflation targeting small open economies – Australia, Canada, and New Zealand.

The results show that the two-good model fits the data better than the one-good model across all specifications considered. In contrast to the Rabanal and Rubio-Ramarez (2005) results for the closed economy, we also find that the addition of price indexation to either the one- or two-good model deteriorates overall empirical fit. Indeed, our results suggest that, if one were to augment the one- or two-good model with endogenous persistence mechanisms, better fit can be achieved by using habit formation rather than price indexation.

The paper proceeds as follows. We first outline the general model specification in section 2. Next, we discuss the Bayesian estimation methodology and the data. The results of the model comparison are discussed in section 6, and we conclude in section 7.

2 The general model

This section sketches our general model specification. For a more detailed description of the tradable side of the model, the reader is referred to Gali and Monacelli (2005) and Monacelli (2005). More details on the inclusion of the non-tradable sector, habit formation, and price indexation can be found in Santacreu (2005).

[2] The fit of the closed economy New Keynesian DSGE with price (and wage) indexation was tested in a Bayesian framework by Rabanal and Rubio-Ramarez (2005). However, to date, the fit of its open economy counterpart has not been fully assessed.

2.1 Consumers

There is a representative household which maximizes the intertemporal utility function:

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

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

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

where h is the parameter of habit persistence, and C_t is a consumption index consisting of differentiated goods. Labour is supplied to both traded and non-traded sectors in the following way:

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

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

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

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

where P_t is the price index, E_t is the expectations operator, D_{t+1} is the nominal payoff in period $t+1$ of the portfolio held at the end of period t, F_{t+1} is the stochastic discount factor, and W_t is the nominal wage.

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

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

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

Households allocate aggregate expenditure based on the following demand functions:

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

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

$$C_{T,t} = \left((1-\alpha)^{1/\eta} C_{H,t}^{\frac{\eta-1}{\eta}} + \alpha^{1/\eta} C_{F,t}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \tag{7}$$

where α is the share of the foreign consumption component in the tradable consumption index and η is the intra-temporal elasticity of substitution between home and foreign goods ($\eta > 0$).

Given the CES aggregator, the demand for domestic goods and imports is:

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

where the price indexes are:

$$P_{T,t} = \left((1-\alpha) P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta} \right)^{\frac{1}{1-\eta}} \text{ and } P_t = \left((1-\lambda) P_{T,t}^{1-\nu} + \lambda P_{N,t}^{1-\nu} \right)^{\frac{1}{1-\nu}} \tag{9}$$

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

$$\tilde{C}_t^{\sigma} N_t^{\psi} = \frac{W_t}{P_t} \tag{10}$$

$$\beta \left(\frac{\tilde{C}_{t+1}}{\tilde{C}_t}\right)^{-\sigma} \left(\frac{P_t}{P_{t+1}}\right) = F_{t+1} \tag{11}$$

$$\beta R_t E_t \left(\left(\frac{\tilde{C}_{t+1}}{\tilde{C}_t}\right)^{-\sigma} \left(\frac{P_t}{P_{t+1}}\right) \right) = 1 \tag{12}$$

where $R_t^{-1} = E_t\{F_{t+1}\}$ is the price of a risk-less one-period bond. R_t is then the gross interest rate of that bond. Log-linearising equations (10)-(12) (with lower-case denoting the log deviation from the steady state) produces:

$$\sigma \tilde{c}_t + \psi n_t = \omega_t - p_t \tag{13}$$

$$\tilde{c}_t = E_t \tilde{c}_{t+1} - \frac{1}{\sigma}(r_t - E_t \pi_{t+1}) \tag{14}$$

$$\tilde{c}_t = \frac{c_t - hc_{t-1}}{1-h} \tag{15}$$

where $\pi_t = p_t - p_{t-1}$. Combining equations (14) and (15) results in the familiar Euler equation for consumption:

$$c_t = \frac{h}{1+h}c_{t-1} + \frac{1}{1+h}E_t c_{t+1} - \frac{1-h}{\sigma(1+h)}(r_t - E_t\pi_{t+1}) \tag{16}$$

2.2 Producers

There exists a continuum of identically monopolistic competitive firms in each of the tradable and non-tradable sectors of the domestic economy, each firm operates with a linear technology production function:

$$Y_{i,t} = Z_{i,t}A_{i,t}N_{i,t} \tag{17}$$

where $i = H, N$; $Z_{i,t}$ is the overall level of technology; and $A_{i,t}$ is the deviation of technology from steady state growth.

The level of technology $Z_{i,t}$ is assumed to be a unit root process with a growth rate of γ. In logs:

$$z_{i,t} = \gamma + z_{i,t-1} + a_{i,t} \tag{18}$$

where $a_{i,t}$ denotes the (stationary) deviation of productivity from the steady and is assumed to follow an AR(1) process:

$$a_{i,t} = \rho_i a_{i,t-1} + \kappa_i \varepsilon_t \tag{19}$$

where $\varepsilon_{i,t}$ is distributed normally with mean 0 and variance σ_{ε_i}, $|\rho_i| < 0$, $\kappa_T = 1$, and $\kappa_N > 0$. Note that, while the time series processes for productivity can differ across the two sectors, the primitive productivity shock ε_t is the same.[3]

The non-stationary technology process $Z_{i,t}$ induces a stochastic trend in output. We remove this stochastic trend by re-defining output as the ratio of output to the level of technology, similarly for consumption (in logs, $y_t \equiv \log(Y_t/Z_t)$).

Producers in each sector then solve the cost minimization problem:

$$\min \frac{W_t}{P_{i,t}} N_{i,t} \tag{20}$$

subject to the production function (17). The log-linear first order condition is:

$$\omega_t - p_{i,t} = mc_{i,t} + a_{i,t} \tag{21}$$

[3] Ideally, the model would allow different shocks for the two sectors. However, to assess model fit in a Bayesian framework, we require the same shocks in each model.

Price-setting

Following Gali and Gertler (1999), a fraction $1-\omega_i$ of the firms in each sector i behave as in Calvo's model and can set prices optimally in a forward-looking manner, $P^0_{i,t}$. The remaining ω_i firms set prices in a rule-of-thumb fashion, according to the recent history of aggregate price behaviour.

The price level for each good evolves according to:

$$p_{i,t} = \theta_i p_{i,t-1} + (1-\theta_i)\bar{p}_{i,t} \tag{22}$$

where $\bar{p}_{i,t}$ is an index for prices set in period t:

$$\bar{p}_{i,t} = (1-\omega_i)p^f_{i,t} + \omega_i p^b_{i,t} \tag{23}$$

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

Forward-looking firms behave as in the Calvo model:

$$p^f_{i,t} = (1-\beta\theta_i)\sum_{k=0}^{\infty}(\beta\theta_i)^k E_t\{MC_{i,t+k}\} \tag{24}$$

where MC denotes nominal marginal cost (see Gali and Monacelli (2005) for details of the derivation). The 'backward-looking firms' set prices according to the rule:

$$p^b_{i,t} = \bar{p}_{i,t-1} + \pi_{i,t-1} \tag{25}$$

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

The following hybrid Phillips curve is obtained for each sector by combining equations (22) to (25):

$$\pi_{i,t} = \gamma_{f,i}E_t\{\pi_{i,t+1}\} + \gamma_{b,i}\pi_{i,t-1} + \lambda_i mc_{i,t} \tag{26}$$

where $mc_{i,t}$ is (log) real marginal cost, and:

$$\lambda_i = \frac{(1-\omega_i)(1-\theta_i)(1-\beta\theta_i)}{\phi_i}, \quad \gamma_{f,i} = \frac{\beta\theta_i}{\phi_i}, \quad \gamma_{b,i} = \frac{\omega_i}{\phi_i}$$

with $\phi_i = \theta_i + \omega_i(1-\theta_i(1-\beta))$.

Notice that setting $\omega_i = 0$ produces the standard forward-looking New Keynesian Phillips Curve. Note also that the allowance of some backward-looking firms $\omega_i > 0$ yields a lagged inflation term in the Phillips cure. Domestic inflation is thus driven by expected inflation, lagged inflation, and marginal cost.

2.3 Inflation, the real exchange rate and the terms of trade

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

The log-linearized expressions for CPI inflation and tradable inflation are:

$$\pi_t = (1-\lambda)\pi_{T,t} + \lambda\pi_{N,t} \text{ and } \pi_{T,t} = (1-\alpha)\pi_{H,t} + \alpha\pi_{F,t} \tag{27}$$

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

The terms of trade is defined to be the relative price of exports (log terms of trade is $s_t \equiv p_{H,t} - p_{F,t}$). Tradable inflation can thus be re-written as:

$$\pi_{T,t} = \pi_{H,t} - \alpha\Delta s_t \tag{28}$$

Incomplete pass-through and the real exchange rate

With complete pass-through the real exchange rate is defined as the ratio of foreign prices expressed in domestic currency to the domestic prices. However, we follow Monacelli (2005) and assume that the law of one price (LOP) *does not* hold. Specifically, defining $\mathcal{E}_t$ to be the nominal exchange rate, the real exchange rate Q_t can be written in logs as:

$$\begin{aligned} q_t &= e_t + p^*_t - p_t \\ &= \psi_{F,t} - (1-\alpha(1-\lambda))s_t - \lambda p_{N,t} \end{aligned} \tag{29}$$

where $e_t = \ln(\mathcal{E}_t)$ and the LOP gap $\psi_{F,t}$ (the difference between the world price and the domestic price of imports) evolves according to:

$$\Delta\psi_{F,t} = (\Delta e_t + \pi^*_t) - \pi_{F,t} \tag{30}$$

There are thus two sources of deviation from PPP in the model. The first results from heterogeneity in the consumption baskets of the domestic and foreign economy, captured by the last two terms in (29). Deviations from PPP in our model also arise from the existence of the non-tradable good; the remainder of the deviation from PPP is captured by the LOP gap, $\psi_{F,t}$.

2.4 Import pricing

As with the domestic firms, a fraction $1-\omega_F$ of the importing firms behave as in Calvo's model and can set prices optimally in a forward-looking manner, $P^f_{F,t}$, and the remaining ω_F firms set prices in a rule-of-thumb fashion.

Using similar notation to section 2.2, the price level for imports evolves according to:

$$p_{F,t} = \theta_i p_{F,t-1} + (1-\theta_F)\bar{p}_{F,t} \tag{31}$$

where:

$$\bar{p}_{F,t} = (1-\omega_i)p^f_{F,t} + \omega_F p^b_{F,t} \tag{32}$$

Forward-looking importers behave as in the Calvo model, producing the log-linear first order condition (Monacelli 2005):

$$p^f_{F,t} = (1-\beta\theta_F)\sum_{k=0}^{\infty}(\beta\theta_F)^k E_t\{\psi_{F,t+k} + p_{F,t+k}\} \tag{33}$$

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

$$p^b_{F,t} = \bar{p}_{F,t-1} + \pi_{F,t-1} \tag{34}$$

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

The hybrid Phillips curve for the importing firms is obtained by combining equations (31) to (34):

$$\pi_{F,t} = \gamma_{f,F}E_t\{\pi_{F,t+1}\} + \gamma_{b,F}\pi_{F,t-1} + \lambda_F\psi_{F,t} \tag{35}$$

where:

$$\lambda_F = \frac{(1-\omega_F)(1-\theta_F)(1-\beta\theta_F)}{\phi_F}, \quad \gamma_{f,F} = \frac{\beta\theta_F}{\phi_F}, \quad \gamma_{b,F} = \frac{\omega_F}{\phi_F}$$

and $\phi_F = \theta_F + \omega_F(1-\theta_F(1-\beta))$.

Import inflation is thus driven by expected inflation, lagged inflation, and deviations from LOP. Import inflation rises if the world price of imports exceeds the domestic currency price of the same good. This acts to increase the real marginal cost of imported goods, boosting foreign goods inflation. The parameter θ_F determines the degree of pass-through; $\theta_F = 0$ implies that the LOP holds and $\theta_F > 0$ implies that pass-though is incomplete. Notice that setting $\omega_F = 0$ produces the Phillips curve for foreign inflation described in Monacelli (2005).

2.5 Risk sharing and uncovered interest parity (UIP)

Under complete financial markets, the expected nominal return from the risk-free bond in domestic currency terms must be the same as the domestic currency return on foreign bonds: $E_t\{F_{t+1}\} = E_t\{\mathcal{E}_t/\mathcal{E}_{t+1}F^*_{t+1}\}$. Equating the intertemporal optimality conditions for the domestic and foreign households yields:

$$\beta E_t\left\{\frac{P_t}{P_{t+1}}\left(\frac{\tilde{C}_{t+1}}{\tilde{C}_t}\right)^{-\sigma}\right\} = \beta E_t\left\{\frac{P^*_t}{P^*_{t+1}}\frac{\mathcal{E}}{\mathcal{E}_{t+1}}\left(\frac{\tilde{C}^*_{t+1}}{\tilde{C}^*_t}\right)^{-\sigma}\right\} \tag{36}$$

Assuming the habit formation parameter is the same in each country, the following holds in equilibrium Gali and Monacelli (2005):

$$C_t - hC_{t-1} = \vartheta(C^*_t - hC^*_{t-1})Q_t^{1/\sigma} \tag{37}$$

where ϑ is a constant that depends on the initial conditions regarding relative net asset positions. Log-linerising this expression around the steady state yields:

$$c_t - hc_{t-1} = y^*_t - hy^*_{t-1} + \frac{1-h}{\sigma}q_t \tag{38}$$

where we assume $y^*_t = c^*_t$, and $ln(Q_t) = q_t$ as before.

Under the assumption of complete international financial markets, UIP holds:

$$E_t\{F_{t+1}(R_t - R^*_t(\mathcal{E}_{t+1}/\mathcal{E}_t))\} = 0 \tag{39}$$

Log-linearisation around the steady state produces:

$$r_t - r^*_t = E_t\Delta e_{t+1} + \varepsilon_{uip,t} \tag{40}$$

where $\varepsilon_{uip,t}$ a normally distributed UIP shock with variance σ_{uip}. This shock is introduced to capture deviations from UIP resulting from risk premium shocks.

2.6 Goods market clearing and marginal cost

The market clearing condition in the domestic tradable sector is given by the log-linearized version of:

$$Y_{H,t} = C_{H,t} + C^*_{H,t} \tag{41}$$

where $C_{H,t}$ is obtained by combining (6) and (8). Its foreign counterpart is given by:

$$C^*_{H,t} = \left(\frac{P_{H,t}}{Q_tP_t}\right)^{-\eta} C^*_t \tag{42}$$

Log-linearising yields:

$$c_{H,t} = \alpha(\nu\lambda - \eta)s_t + \nu\lambda p_{N,t} + c_t \quad (43)$$

and

$$c^*_{H,t} = \eta\lambda p_{N,t} - \eta(1-\lambda)\alpha s_t + c^*_t + \eta q_t \quad (44)$$

The domestic tradable sector clearing condition is:

$$\begin{aligned} y_{H,t} &= \alpha((1-\alpha)(\nu\lambda - \eta) - \eta(1-\lambda)\alpha)s_t \\ &\quad +((1-\alpha)\nu\lambda + \alpha\eta\lambda)p_{N,t} + (1-\alpha)c_t + \alpha c^*_t + \eta\alpha q_t \end{aligned} \quad (45)$$

and the market clearing condition for the non-tradable sector is:

$$y_{N,t} = -\nu(1-\lambda)\alpha s_t - \nu(1-\lambda)p_{N,t} + c_t \quad (46)$$

The market clearing condition in the home economy is then a weighted average of domestic tradable and domestic non-tradable output, $y_t = (1-\lambda)y_{H,t} + \lambda y_{N,t}$.

The log-linearised real marginal cost in the traded sector is obtained by combining equations (13), (21), and the aggregate production function $y_t = a_t + n_t$.

$$mc_{H,t} = \frac{\sigma}{(1-h)}(c_t - hc_{t-1}) + \psi(y_t - a_t) - a_{H,t} - (p_{H,t} - p_t) \quad (47)$$

Similarly, log-linearised marginal cost in the non-traded sector is:

$$mc_{N,t} = \frac{\sigma}{(1-h)}(c_t - hc_{t-1}) + \psi(y_t - a_t) - a_{N,t} - (p_{N,t} - p_t) \quad (48)$$

In each sector, marginal cost is thus driven by consumer demand, aggregate labour productivity, the overall level productivity in the sector, and by the relative price of output.

2.7 The foreign sector and monetary policy

Because the foreign economy is exogenous to the domestic economy, there is some flexibility in specifying the behaviour of foreign variables, y^*_t, r^*_t and π^*_t. For simplicity, we assume they are AR(1) processes:

$$y^*_t = \rho_{y^*} y^*_{t-1} + \varepsilon_{y^*,t} \quad (49)$$

$$\pi_t^* = \rho_{\pi^*} \pi_{t-1}^* + \varepsilon_{\pi^*,t} \tag{50}$$

$$r_t^* = \rho_{r^*} r_{t-1}^* + \varepsilon_{r^*,t} \tag{51}$$

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

The model is closed by specifying the monetary policy reaction function:

$$r_t = \rho_r r_{t-1} + (1-\rho_r)(\psi_1 y_t + \psi_2 \pi_t + \psi_3 e_t) + \varepsilon_{r,t} \tag{52}$$

where $\varepsilon_{r,t}$ is a normally distributed policy shock with zero mean and variance σ_r. The central bank thus responds to output, inflation, and exchange rate deviations from steady states.[4]

3 Model summary

We label the full model described above *BHI* (B for 'both' tradable and non-tradable goods, H for habit persistence, and I for price indexation). It has the following six shocks: productivity $\varepsilon_{a,t}$, UIP $\varepsilon_{uip,t}$; monetary policy $\varepsilon_{r,t}$; foreign output $\varepsilon_{y^*,t}$; foreign inflation $\varepsilon_{\pi^*,t}$; and foreign monetary policy $\varepsilon_{r^*,t}$. Given these shocks, the linearised model can be solved using standard techniques.

Notice that, by setting $h = 0$ and/or $\omega_T = \omega_N = \omega_H = 0$, we have three variants of the model, one with habit formation and no price indexation, denoted *BH*, one with price indexation and no habit formation, denoted *BI*, and one without habit persistence and price indexation, denoted *B*.

Importantly, the full model nests the one-good model proposed by Monacelli (2005), allowing us to compare the empirical fit of the two models in a Bayesian framework. Specifically, setting $\lambda = \nu = 0$ and removing all non-tradable variables from *B* produces the single-good Monacelli (2005) model, denoted *M* for 'Monacelli'. This model can also be augmented with habit persistence (*MH*), price indexation (*MI*), and both habit persistence and price indexation (*MHI*). Thus, we have four variants for the one- and two-good models; eight different specifications in total.

[4] Lubik and Schorfheide (2006b) find that the overall fit of a simplified version of the Gali and Monacelli (2005) can be improved by excluding exchange rate terms from the monetary policy reaction function. However, for completeness, we choose to leave the exchange rate in our reaction function.

4 Estimation methodology

Our objective is to estimate variants of the model outlined above using Bayesian methods. The Bayesian approach provides a natural framework for making model comparisons and yields posterior odds for each of the models being considered. Our estimation methodology is outlined below.

The DSGE model m_i and its associated parameters ϑ_i can be estimated using the methods outlined in An and Schorfheide (2006). Specifically, given a prior $p(\vartheta_i)$ and a sample of data Y, the posterior density of the model parameters ϑ_i is proportional to the likelihood of the data multiplied by the prior $p(\vartheta_i)$:

$$p(\vartheta_i|Y) \propto L(\vartheta_i|Y)p(\vartheta_i) \tag{53}$$

The likelihood function is estimated using the Kalman filter by combining the state-space representation of the model solution with a measurement equation, linking the state vector to the observed data. Specifically, the model solution can be written as:

$$s_t = \Phi_1(\vartheta_i)s_{t-1} + \Phi_\varepsilon(\vartheta_i)\varepsilon \tag{54}$$

A measurement equation then relates the model variables s_t to a vector of observables x_t:

$$x_t = A(\vartheta_i) + Bs_t \tag{55}$$

Here, B selects elements of s_t and is not related to the model parameters ϑ_i. The matrix $A(\vartheta_i)$ is related to the model parameters and captures the means of the variables contained in s_t.

In our empirical exercise, Y is composed of (log) quarterly changes in output growth (YGR), annualised (log) quarterly changes in the consumers price index (INF), annualised (log) quarterly changes in import prices ($INFF$), nominal interest rates (R), (log) quarterly changes in the terms of trade (TOT), and (log) quarterly changes in the nominal exchange rate (E). All observables are measured in percentages.

All of the model variables are expressed in percentage deviations from steady state levels. The steady state rate of annual inflation $\bar{\pi}$ is the inflation target. We also allow for non-zero steady states for TOT and E, $\Delta\bar{s}$ and $\Delta\bar{e}$. The measurement equations, relating the model variables to the observables, are then:

$$\begin{aligned} YGR_t &= \gamma + y_t - y_{t-1} + a_t \\ INF_t &= \bar{\pi} + 4\pi_t \\ INFF_t &= \bar{\pi} + 4\pi_{F,t} \\ R_t &= \bar{\pi} + \bar{r} + 4\sigma\gamma + 4r_t \\ TOT_t &= \Delta\bar{s} + s_t - s_{t-1} \\ E_t &= \Delta\bar{e} + e_t - e_{t-1} \end{aligned} \tag{56}$$

Note that the model variables are scaled to be measured in the same units as the observables: γ is the steady state quarterly growth rate of technology, $\bar{r} + 4\sigma\gamma$ is the steady state real interest rate, and $\beta = 1/(1 + \bar{r}/400)$. The structural parameters, including the estimated steady states, are collected into the vector ϑ. To check the robustness of our long-run assumptions, we also estimate the models with demeaned data ($A(\vartheta_i) = 0$), relaxing the long-run restrictions imposed by the measurement equations described above.

Posterior draws are obtained using Markov Chain Monte Carlo methods. We make 200,000 draws from the posterior distribution using the random walk Metropolis Hastings algorithm, discarding the first half of the draws to ensure convergence.[5]

Following Rabanal and Rubio-Ramarez (2005), after estimating the posterior distribution from N models, we compare how well each model fits the observable variables using Bayes factors. Specifically, the Bayes factor of model i over model j is:

$$\hat{L} = \frac{p(Y|i)}{p(Y|j)} \tag{57}$$

where $p(Y|i)$ is the marginal likelihood of model i:

$$p(Y|i) = \int L(\vartheta_i|Y)p(\vartheta_i)d\vartheta_i \tag{58}$$

In our empirical exercise, we estimate the marginal likelihood of each model using the modified harmonic mean estimator proposed by Geweke (1999).

4.1 Comparison to reference models

Potential model misspecification of the DSGE models can be assessed in the Bayesian framework by comparing our models to a more general reference model.

[5] The start-values for our Metropolis Hastings algorithm are found using Chris Sims's optimisation routine 'csminwel', available from his website.

An and Schorfheide (2006) suggest that a natural choice of reference model is a VAR, since linearised DSGE models can be approximately interpreted as restrictions on a VAR representation.

Del Negro and Schorfheide (2004) develop an estimation methodology that allows researchers to use DSGE models as priors for VARs – the so-called DSGE-VAR. Their approach can be thought of as generating artificial data using the DSGE model to extend the sample of actual data. The VAR is then applied to this augmented data sample. The number of data observations generated by the DSGE model determines the influence that the DSGE model will have on the VAR. If more data is simulated from the DSGE model, then it will have greater influence on the parameter estimates obtained from the VAR. The ratio of dummy observations over actual observations – which we call ι – measures the weight of the prior relative to the sample. As $\iota \rightarrow \infty$ more weight is put on the restrictions implied by the DSGE model; $\iota = 0$ puts no weight on the DSGE restrictions (so that the model is an unrestricted VAR).[6] Thus, lower values of ι imply less weight on the DSGE restrictions, suggesting a potential misspecification in the DSGE model.

We report estimates of the marginal data density for our models without habit persistence and price indexation (B and M) to assess their fit relative to an unrestricted VAR. We do this for a variety of different values of the hyperparameter ι. We also report log marginal likelihoods from a Bayesian VARs (BVAR) with a Minnesota prior.[7] As in the case of the DSGE-VAR, we report a variety of different values of a hyper-parameter that controls the overall tightness of the prior, τ.

5 Data and priors

We use quarterly data for Australia, Canada and New Zealand. All data range from 1990Q1 to 2006Q1. Output is measured as seasonally adjusted real gross domestic product (GDP), the domestic price level is the consumers price index (CPI), the import price level is the implicit GDP deflator for imports (nominal imports divided by real imports – both are seasonally adjusted), the nominal interest rate is the 90 day bank bill yield, and the terms of trade is the merchandise terms of trade measured 'at the dock' using overseas trade statistics. We use trade weighted indexes (TWI) as our exchange rates for Australia and New Zealand, while the Canadian exchange rate is measured as the CAD/USD cross rate.

[6] Refer to Del Negro and Schorfheide (2004) for a full description of the methodology.

[7] See the appendix of Lubik and Schorfheide (2006a) for a more detailed description of the BVAR.

The same priors are used for all countries (see table 7). The prior means are largely derived from previous studies, but we remain agnostic on the variance of the parameters by imposing reasonably loose prior variances. In estimation, all priors are truncated at the boundary of the indeterminacy region.

6 Empirical results

6.1 Parameter estimates and impulse responses

The estimated parameters for each model are displayed in appendix B. Table 1 shows that some of the largest differences in the parameter estimates across the one- and two-good models occur for the share of foreign goods in the domestic CPI α (the degree of openness) and the Calvo parameters. Focussing our attention on these parameters, we find the estimates of the degree of openness are lower in the one-good model than in the two-good model. Across all specifications of the one-good model, α is estimated to be between 0.09 and 0.21. The estimates of α from the two-good models are between 0.24 and 0.43 for Australia and Canada and about 0.6 in New Zealand. Moreover, we find that all of the estimates of the share of the non-tradable good in the domestic CPI λ in the two good models are above 0.58.

Both the Australian Bureau of Statistics and Statistics New Zealand produce a split of the CPI into tradables and non-tradables. Interestingly, our Bayesian estimates of the shares of non-tradable goods in the domestic CPIs for Australia and New Zealand are reasonably close to those used in official statistics: the shares of non-tradables in the Australian and New Zealand CPIs are 0.53 and 0.56, respectively.

These results imply that the one- and two-good models have very different implications for the share of home-produced tradable goods in the domestic economy. In the one-good model this share is estimated to be between 0.79 and 0.91 $(= 1-\alpha)$. While, in the two-good model, taking $\alpha = 0.35$ and $\lambda = 0.6$, the share is much lower at around 0.26 $(= (1-\alpha)(1-\lambda))$. The estimated size of the home-produced tradable sector is thus much smaller in the two-good than in the one-good model, a direct result of the inclusion of the non-tradable good into the two-good model.

We find that the Calvo parameter estimates for import inflation θ_F are similar across the one- and two-good models. However, the inclusion of the non-tradable good more than halves the Calvo parameter in the home tradable sector θ_H for all model specifications. The inclusion of the non-tradable sector in the domestic

Table 1
Selected parameter estimates

	One-good				Two-good			
	MHI	*M*	*MH*	*MI*	*BHI*	*B*	*BH*	*BI*
Australia								
α	0.10	0.21	0.12	0.19	0.43	0.24	0.43	0.38
λ	–	–	–	–	0.84	0.70	0.82	0.82
θ_H	0.64	0.72	0.75	0.63	0.14	0.14	0.22	0.12
θ_F	0.22	0.33	0.27	0.26	0.33	0.25	0.24	0.37
θ_N	–	–	–	–	0.51	0.43	0.53	0.36
Canada								
α	0.12	0.21	0.14	0.18	0.36	0.43	0.38	0.42
λ	–	–	–	–	0.74	0.63	0.71	0.60
θ_H	0.55	0.62	0.64	0.55	0.20	0.27	0.30	0.18
θ_F	0.15	0.22	0.18	0.18	0.15	0.21	0.18	0.18
θ_N	–	–	–	–	0.45	0.55	0.54	0.52
New Zealand								
α	0.09	0.14	0.11	0.11	0.58	0.60	0.62	0.61
λ	–	–	–	–	0.84	0.75	0.81	0.80
θ_H	0.80	0.81	0.84	0.77	0.20	0.23	0.30	0.16
θ_F	0.18	0.24	0.21	0.21	0.19	0.22	0.20	0.25
θ_N	–	–	–	–	0.75	0.69	0.75	0.69

MHI (one-good, habits, price indexation); M (one-good, no habits, no price indexation); MH (one-good, habits, no price indexation); MI (two-good, no habits, price indexation); BHI (two-good, habits, price indexation); B (two-good, no habits, no price indexation); BH (two-good, habits, no price indexation); BI (two-good, no habits, price indexation) economy thus re-attributes some of the stickiness in home tradable prices to non-tradable prices.

The estimated impulse response functions for the one- and two-good models without habit persistence and price indexation (*M* and *B*) are displayed in appendix C. By and large, the impulse responses are quite similar across the two models in each country. But, while the overall inflation π and the import inflation π_F responses to the six shocks are generally of the same sign and magnitude, there are some large differences across the responses of inflation for the domestically-produced tradable good π_H. The responses of π_H for the two-good model are generally larger in magnitude than in the one-good model. However, since the share of the home tradable sector in the domestic economy is much smaller in the two-good model, the overall difference in the inflationary impact of shocks to π_H is attenuated somewhat. Nevertheless, as with the results for the Calvo parameters described above, what is clear is that a key difference between the one- and two-good models is in the estimated behaviour of the domestically-produced home tradable good.

6.2 Assessing model fit

Marginal data densities and Bayes factors comparing the log marginal likelihood of each model to that of the fully-specified one-good model, *MHI*, are displayed n table 2. For all three countries, the fully specified one-good model (*M*) does not fit the data as well as the other model specifications – all Bayes factors are positive. The results are particularly striking for the comparison between the one- and two-good specifications. Inclusion of the non-tradable good produces a higher log marginal likelihood in all cases considered, regardless of the model specification.

The smallest difference in likelihoods between the one- and two good models is for the models with only price indexation in New Zealand – 3.88. This suggests that in order to choose *MI* over *BI* based on Bayes factors we would need a prior probability for *MI* that is nearly 50 times (=exp(3.88)) greater than our prior probability over *BI*. The most decisive evidence in favour of the two-good model occurs for the fully-specified model in Australia; to choose *MHI* over *BHI* we would need a prior probability over *MHI* 2×10^{10} times (=exp(23.72)) greater than our prior probability over *BHI*.

With the exception of the two-good model with habit persistence in Australia (*BH*), the best fitting model in each country is the two-good model without habit formation and without price indexation (*B*). These results are in stark contrast to Rabanal and Rubio-Ramarez (2005), who show that adding price indexation to

Table 2
Log marginal likelihoods and Bayes factors

	One-good		Two-good	
	$\log(p(Y))$	$\log(\hat{L})$	$\log(p(Y))$	$\log(\hat{L})$
Australia				
Full specification	-930.75	0.00	-907.03	23.72
No habits or indexation	-876.62	54.13	-871.06	59.69
Habits	-890.36	40.39	-870.30	60.45
Indexation	-915.58	15.17	-910.83	19.92
Canada				
Full specification	-863.78	0.00	-845.00	18.78
No habits or indexation	-803.27	60.51	-790.97	72.82
Habits	-820.65	43.14	-803.56	60.22
Indexation	-846.11	17.67	-834.30	29.48
New Zealand				
Full specification	-933.30	0.00	-918.33	14.97
No habits or indexation	-882.75	50.56	-876.37	56.93
Habits	-896.66	36.64	-885.07	48.23
Indexation	-919.86	13.45	-915.97	17.33

The log marginal data densities are based on 100,000 draws from the posterior density after burning the first 100,000 draws. The Bayes factors compare each model to the fully-specified one-good model in each country, i.e. $\log(\hat{L}) = \log(\hat{(}p(Y|i)/p(Y|MHI))$ for $i = M, MI, MH, MHI, B, BI, BH, BHI$.

the baseline closed economy New Keynesian sticky price model improves its fit to US data. Indeed, our results suggest that, if one were to augment the one- or two-good model with endogenous persistence mechanisms, better fit can be achieved by using habit formation rather than price indexation. However, aside from the New Zealand case, the inclusion of price indexation yields better empirical fit than models that include both habit formation and price indexation for both the one- and two-good models.

Looking at density estimates and Bayes factors for the models estimated with demeaned data (relaxing the long-run restrictions implied by the model), we find that similar conclusions can be drawn (appendix D). In fact, the evidence suggesting that the two-good model fits the data better than the one-good model is even stronger when using demeaned data.

6.3 Comparisons to VARs

Because the one- and two-good models without habit formation and price indexation provide the best fit to the data on average, across all countries (M and B), we assess the fit of these models using DSGE-VARs. The log marginal likelihoods of DSGE-VARs for M and B are displayed in table 6.3.[8] The fit of the DSGE model is assessed by considering a number of values of the hyper-parameter governing the weight on the DSGE model ι. The values of ι that maximise the posterior density for each specification $\hat{\iota}$ are displayed in bold.

The restrictions implied by the DSGE models improve the fit of an unrestricted VAR across all specifications, as indicated by $\hat{\iota}$ being between 1.6 and 2.5. Looking across the three countries, the DSGE restrictions improve the fit of the VAR by a greater margin for Canada and New Zealand, with $\hat{\iota}$ averaging around 2 for these countries; $\hat{\iota}$ is slightly lower in Australia. The posterior distributions of ι have an inverted U shape, similar to those found by Del Negro *et al* (2005). This reflects the fact that the DSGE models are misspecified to some extent. Indeed, the fit of any of the DSGE models is a lot worse when compared with its associated DSGE-VAR($\hat{\iota}$), suggesting that dogmatically imposing the (misspecified) DSGE restrictions is detrimental to the overall empirical fit of the VAR.

When working with DSGE-VARs, it is important to check that the VAR can adequately approximate the state space representation of the DSGE model. From looking at the differences in the log marginal likelihoods of the DSGE and DSGE-VAR(∞), we find that the VAR approximation is not particularly accurate for some of our specifications – a 'perfect' approximation would lead to identical values of

[8] All VARs in this section are estimated with 4 lags.

Table 3
Log marginal likelihoods

		Australia		Canada		New Zealand	
		M	*B*	*M*	*B*	*M*	*B*
DSGE-VAR(ι)	0.80	-871.40	-849.83	-806.76	-791.54	-888.44	-875.16
	1.00	-865.27	-843.51	-800.11	-784.06	-882.12	-868.43
	1.20	-862.26	-840.70	-796.80	-780.10	-879.12	-865.26
	1.40	-860.83	-839.46	-794.98	-777.79	-877.40	-863.58
	1.60	-860.04	**-839.11**	-794.09	-776.64	-876.58	-862.78
	1.80	**-859.66**	-839.24	-793.58	-775.91	-876.19	-862.20
	2.00	-859.72	-839.44	-793.36	-775.57	-875.99	**-862.08**
	2.50	-859.96	-840.80	**-793.27**	**-775.44**	**-875.82**	-862.27
	3.00	-860.61	-842.28	-793.53	-775.63	-876.09	-862.85
	5.00	-862.70	-846.41	-794.79	-777.27	-877.10	-864.34
	∞	-868.40	-854.66	-798.54	-781.96	-880.55	-868.77
DSGE		-876.62	-871.06	-803.27	-790.97	-882.75	-876.37
BVAR(τ)	1	-781.38		-814.57		-890.44	
	3	-740.27		-729.36		-801.68	
	5	-748.05		-710.39		-782.87	
	20	-822.88		-725.16		-794.99	

The log marginal data densities are based on 100,000 draws from the posterior density after burning the first 100,000 draws.

the log likelihoods. Thus, the results of the DSGE-VAR analysis should be viewed with a certain degree of caution. The quality of the VAR approximations to our models can be further assessed by way of comparing the impulse responses of the DSGE and the DSGE-VAR(∞) as in An and Schorfheide (2006) or, more formally, using the method outlined in Fernandez-Villaverde *et al* (2005).

The log marginal data densities of the BVARs are quite sensitive to THE choice of the hyperparameter τ. With the exception of when $\tau = 1$ in Canada and New Zealand, the BVARs fit the data considerably better than the DSGEs and the DSGE-VARs. This further suggests that the restrictions implied by the DSGE model are misspecified. A more detailed taxonomy of the misspecification could be achieved by using the loss-function based framework proposed by Schorfheide (2000).

7 Summary and conclusion

We outlined an extension of the Monacelli (2005) model that includes a non-tradable sector, habit persistence, and price indexation. The empirical fit of eight different specifications of this model were then tested in a Bayesian framework using data from Australia, Canada, and New Zealand, three inflation-targeting small open economies.

We found that a key difference between the one- and two-good models is in the estimated behaviour of the domestically-produced tradable good. Specifically, the estimated one-good model suggested a much larger home-produced tradable sector than the two-good model, and the impulse responses and the Calvo parameter estimates for inflation in the home-produced tradable sector differed notably across the one- and two-good models.

In comparing the marginal likelihoods of the models, we found that the two-good model fits the data better than the one-good model across all specifications considered. Also, in contrast to the findings of Rabanal and Rubio-Ramarez (2005), we found that the addition of price indexation to either the one- or two-good model deteriorates overall empirical fit.

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Appendices

A Priors for all countries

Table 4
Priors for all countries

Parameter		Domain	Dist	Mean	Std.dev
α	Share of Foreign goods	$[0,1)$	Beta	0.50	0.10
λ	Share of Non-tradable goods	$[0,1)$	Beta	0.50	0.10
ν	Elasticity: Tradable/Non-tradable	$[0,\infty)$	Gamma	1.00	0.20
η	Elasticity: Home/Foreign	$[0,\infty)$	Gamma	1.00	0.20
ψ	Inv elasticity: Labour	$[0,\infty)$	Gamma	1.00	0.20
σ	Inv elasticity: Cons/Labour	$[0,\infty)$	Gamma	2.00	0.50
θ_H	Calvo: Home	$[0,1)$	Beta	0.50	0.10
θ_F	Calvo: Foreign	$[0,1)$	Beta	0.50	0.10
θ_N	Calvo: Non-tradable	$[0,1)$	Beta	0.50	0.10
ω_H	Backward-looking: Home	$[0,1)$	Beta	0.50	0.10
ω_F	Backward-looking: Foreign	$[0,1)$	Beta	0.50	0.10
ω_N	Backward-looking: Non-tradable	$[0,1)$	Beta	0.50	0.10
h	Habit persistence	$[0,1)$	Beta	0.50	0.10
ρ_r	Taylor: Interest smoothing	$[0,1)$	Beta	0.80	0.10
ψ_1	Taylor: Output	$[0,\infty)$	Gamma	0.50	0.10
ψ_2	Taylor: Inflation	$[0,\infty)$	Gamma	1.50	0.20
ψ_3	Taylor: Exchange rate	$[0,\infty)$	Gamma	0.10	0.05
ρ_{a_H}	AR: Home productivity	$[0,1)$	Beta	0.80	0.10
ρ_{a_N}	AR: Non-tradable productivity	$[0,1)$	Beta	0.80	0.10
κ	Rel variance NT productivity shock	$[0,\infty)$	Gamma	0.50	0.20
ρ_{y^*}	AR: Foreign output	$[0,1)$	Beta	0.80	0.10
ρ_{π^*}	AR: Foreign inflation	$[0,1)$	Beta	0.80	0.10
ρ_{r^*}	AR: Foreign interest rate	$[0,1)$	Beta	0.80	0.10
$\bar{r}$	Steady state: Discount rate	$[0,\infty)$	Gamma	0.50	0.10
γ	Steady state: Technology growth	$(-\infty,\infty)$	Normal	0.50	0.10
$\bar{\pi}$	Steady state: Inflation	$(-\infty,\infty)$	Normal	2.00	0.20
$\Delta\bar{e}$	Steady state: Exchange rate change	$(-\infty,\infty)$	Normal	0.00	0.50
$\Delta\bar{s}$	Steady state: ToT change	$(-\infty,\infty)$	Normal	0.00	0.50
σ_{a_H}	Std dev: Productivity shock	$[0,\infty)$	InvGamma	2.00	4.00
σ_{uip}	Std dev: UIP shock	$[0,\infty)$	InvGamma	2.00	4.00
σ_r	Std dev: Monetary policy shock	$[0,\infty)$	InvGamma	2.00	4.00
σ_{y^*}	Std dev: Foreign output shock	$[0,\infty)$	InvGamma	2.00	4.00
σ_{r^*}	Std dev: Foreign interest shock	$[0,\infty)$	InvGamma	2.00	4.00
σ_{π^*}	Std dev: Foreign inflation shock	$[0,\infty)$	InvGamma	2.00	4.00

The Inverse Gamma priors are of the form $p(\sigma|\nu,s) \propto \sigma^{-\nu-1}e^{-s/2\sigma^2}$. We report the parameters s and ν.

B Posteriors

Table 5
Posterior – one good (Australia)

	MHI (Full)		M (No habits or index)		MH (Habits)		MI (Indexation)	
Parameter	Mean	99% CI	Mean	99% CI	Mean	99% CI	Mean	99% CI
α	0.10	[0.04, 0.18]	0.21	[0.13, 0.31]	0.12	[0.06, 0.19]	0.19	[0.11, 0.29]
η	0.90	[0.56, 1.26]	0.96	[0.63, 1.31]	0.84	[0.53, 1.21]	0.98	[0.67, 1.37]
ψ	0.95	[0.50, 1.49]	0.91	[0.46, 1.45]	0.91	[0.49, 1.42]	0.96	[0.52, 1.50]
σ	1.46	[0.96, 2.12]	1.61	[1.01, 2.34]	1.50	[0.98, 2.18]	1.75	[1.09, 2.53]
θ_H	0.64	[0.48, 0.77]	0.72	[0.62, 0.81]	0.75	[0.66, 0.84]	0.63	[0.49, 0.75]
θ_F	0.22	[0.12, 0.32]	0.33	[0.23, 0.43]	0.27	[0.18, 0.37]	0.26	[0.16, 0.37]
ω_H	0.22	[0.09, 0.38]	0.00	[0.00, 0.00]	0.00	[0.00, 0.00]	0.20	[0.09, 0.36]
ω_F	0.06	[0.03, 0.11]	0.00	[0.00, 0.00]	0.00	[0.00, 0.00]	0.07	[0.03, 0.12]
h	0.17	[0.07, 0.30]	0.00	[0.00, 0.00]	0.19	[0.08, 0.33]	0.00	[0.00, 0.00]
ρ_r	0.75	[0.63, 0.86]	0.72	[0.59, 0.83]	0.76	[0.62, 0.86]	0.72	[0.60, 0.83]
ψ_1	0.65	[0.37, 0.97]	0.65	[0.39, 0.95]	0.65	[0.37, 0.96]	0.62	[0.36, 0.92]
ψ_2	1.30	[1.04, 1.68]	1.49	[1.15, 1.91]	1.42	[1.06, 1.82]	1.37	[1.09, 1.73]
ψ_3	0.02	[0.00, 0.04]	0.02	[0.00, 0.05]	0.03	[0.00, 0.06]	0.02	[0.00, 0.04]
ρ_{a_H}	0.55	[0.30, 0.80]	0.56	[0.33, 0.79]	0.52	[0.29, 0.77]	0.59	[0.34, 0.83]
ρ_{y^*}	0.96	[0.92, 1.00]	0.93	[0.89, 0.96]	0.97	[0.93, 1.00]	0.91	[0.87, 0.95]
ρ_{π^*}	0.28	[0.13, 0.50]	0.35	[0.16, 0.60]	0.31	[0.14, 0.54]	0.32	[0.14, 0.55]
ρ_{r^*}	0.97	[0.93, 1.00]	0.96	[0.92, 1.00]	0.97	[0.93, 1.00]	0.97	[0.92, 1.00]
$\bar{r}$	0.49	[0.27, 0.76]	0.49	[0.26, 0.76]	0.49	[0.27, 0.76]	0.48	[0.26, 0.75]
γ	0.52	[0.31, 0.73]	0.49	[0.27, 0.71]	0.52	[0.31, 0.72]	0.48	[0.26, 0.68]
$\bar{\pi}$	1.98	[1.48, 2.48]	1.97	[1.44, 2.47]	1.97	[1.47, 2.47]	1.96	[1.45, 2.50]
$\Delta\bar{e}$	-0.05	[-0.56, 0.43]	-0.16	[-0.65, 0.34]	0.03	[-0.45, 0.51]	-0.18	[-0.66, 0.27]
$\Delta\bar{s}$	0.19	[-0.43, 0.78]	0.01	[-0.50, 0.52]	0.17	[-0.43, 0.80]	0.06	[-0.42, 0.49]
σ_{a_H}	0.83	[0.64, 1.06]	0.84	[0.66, 1.07]	0.86	[0.66, 1.10]	0.85	[0.65, 1.10]
σ_{uip}	2.65	[1.97, 3.49]	2.50	[1.88, 3.23]	2.48	[1.88, 3.24]	2.62	[1.97, 3.47]
σ_r	0.56	[0.43, 0.71]	0.59	[0.46, 0.76]	0.56	[0.43, 0.72]	0.59	[0.46, 0.76]
σ_{y^*}	2.54	[1.54, 3.92]	3.26	[2.00, 4.78]	2.32	[1.38, 3.52]	3.21	[2.04, 4.77]
σ_{r^*}	2.29	[1.77, 2.93]	2.21	[1.72, 2.84]	2.17	[1.71, 2.76]	2.34	[1.78, 3.09]
σ_{π^*}	1.20	[0.78, 1.73]	1.16	[0.78, 1.66]	1.16	[0.77, 1.67]	1.21	[0.83, 1.72]

Table 6
Posterior – two good (Australia)

	BHI (Full)		B (No habits or index)		BH (Habits)		BI (Indexation)	
Parameter	Mean	99% CI	Mean	99% CI	Mean	99% CI	Mean	99% CI
α	0.43	[0.20, 0.66]	0.24	[0.08, 0.51]	0.43	[0.22, 0.66]	0.38	[0.16, 0.65]
λ	0.84	[0.72, 0.92]	0.70	[0.47, 0.95]	0.82	[0.68, 0.93]	0.82	[0.66, 0.94]
ν	1.14	[0.63, 1.68]	1.20	[0.64, 1.90]	1.30	[0.71, 2.00]	1.25	[0.70, 1.97]
η	0.82	[0.45, 1.27]	0.80	[0.43, 1.27]	0.77	[0.40, 1.20]	0.79	[0.44, 1.24]
ψ	0.86	[0.46, 1.38]	0.86	[0.46, 1.37]	0.84	[0.45, 1.33]	0.89	[0.45, 1.38]
σ	1.69	[1.05, 2.49]	1.93	[1.31, 2.75]	1.64	[1.05, 2.35]	2.16	[1.37, 3.10]
θ_H	0.14	[0.07, 0.24]	0.14	[0.08, 0.22]	0.22	[0.14, 0.30]	0.12	[0.05, 0.23]
θ_F	0.33	[0.19, 0.52]	0.25	[0.14, 0.36]	0.24	[0.16, 0.34]	0.37	[0.17, 0.70]
θ_N	0.51	[0.31, 0.70]	0.43	[0.31, 0.58]	0.53	[0.38, 0.68]	0.36	[0.16, 0.57]
ω_H	0.19	[0.10, 0.29]	0.00	[0.00, 0.00]	0.00	[0.00, 0.00]	0.15	[0.07, 0.24]
ω_F	0.06	[0.03, 0.10]	0.00	[0.00, 0.00]	0.00	[0.00, 0.00]	0.07	[0.03, 0.13]
ω_N	0.20	[0.08, 0.33]	0.00	[0.00, 0.00]	0.00	[0.00, 0.00]	0.28	[0.15, 0.41]
h	0.32	[0.19, 0.45]	0.00	[0.00, 0.00]	0.28	[0.16, 0.42]	0.00	[0.00, 0.00]
ρ_r	0.74	[0.61, 0.84]	0.61	[0.41, 0.81]	0.72	[0.58, 0.83]	0.70	[0.56, 0.82]
ψ_1	0.45	[0.26, 0.69]	0.31	[0.15, 0.55]	0.40	[0.20, 0.65]	0.38	[0.20, 0.61]
ψ_2	1.69	[1.31, 2.12]	1.94	[1.40, 2.52]	1.75	[1.35, 2.24]	1.66	[1.29, 2.06]
ψ_3	0.04	[0.02, 0.08]	0.04	[0.02, 0.07]	0.05	[0.02, 0.09]	0.04	[0.01, 0.07]
ρ_{a_H}	0.79	[0.53, 0.97]	0.92	[0.75, 1.00]	0.77	[0.50, 0.98]	0.84	[0.60, 0.99]
ρ_{a_N}	0.65	[0.34, 0.96]	0.85	[0.46, 1.00]	0.72	[0.37, 0.98]	0.76	[0.43, 0.99]
κ	0.30	[0.07, 0.60]	0.31	[0.07, 0.60]	0.29	[0.08, 0.56]	0.32	[0.09, 0.58]
ρ_{y^*}	0.96	[0.91, 0.99]	0.93	[0.85, 0.99]	0.96	[0.92, 0.99]	0.89	[0.81, 0.98]
ρ_{π^*}	0.60	[0.21, 0.97]	0.44	[0.20, 0.74]	0.49	[0.20, 0.83]	0.62	[0.25, 0.97]
ρ_{r^*}	0.96	[0.91, 1.00]	0.96	[0.89, 1.00]	0.97	[0.92, 1.00]	0.97	[0.91, 1.00]
$\bar{r}$	0.49	[0.26, 0.76]	0.49	[0.26, 0.74]	0.50	[0.27, 0.76]	0.48	[0.26, 0.76]
γ	0.50	[0.28, 0.72]	0.45	[0.27, 0.64]	0.50	[0.30, 0.71]	0.43	[0.24, 0.61]
$\bar{\pi}$	1.99	[1.48, 2.52]	1.98	[1.48, 2.50]	1.98	[1.46, 2.49]	1.98	[1.48, 2.51]
$\Delta\bar{e}$	-0.16	[-0.48, 0.17]	-0.42	[-0.72, -0.13]	-0.15	[-0.44, 0.20]	-0.36	[-0.75, 0.02]
$\Delta\bar{s}$	0.29	[-0.22, 0.78]	0.23	[-0.21, 0.67]	0.27	[-0.24, 0.72]	0.22	[-0.20, 0.58]
σ_{a_H}	1.36	[0.83, 2.04]	1.07	[0.74, 1.57]	1.23	[0.81, 1.71]	1.16	[0.78, 1.68]
σ_{uip}	2.50	[1.67, 3.59]	1.29	[0.85, 1.95]	1.40	[0.90, 2.11]	2.46	[1.51, 3.72]
σ_r	0.57	[0.44, 0.71]	0.66	[0.47, 0.93]	0.58	[0.45, 0.74]	0.58	[0.46, 0.75]
σ_{y^*}	1.79	[1.11, 2.78]	1.59	[1.03, 2.33]	1.63	[1.05, 2.40]	1.98	[1.21, 3.11]
σ_{r^*}	2.59	[1.89, 3.48]	2.09	[1.62, 2.69]	2.08	[1.61, 2.68]	2.66	[1.83, 3.95]
σ_{π^*}	1.64	[1.07, 2.45]	1.45	[0.98, 1.99]	1.31	[0.87, 1.83]	1.66	[1.07, 2.40]

Table 7
Posterior – one good (Canada)

	MHI (Full)		M (No habits or index)		MH (Habits)		MI (Indexation)	
Parameter	Mean	99% CI	Mean	99% CI	Mean	99% CI	Mean	99% CI
α	0.12	[0.06, 0.19]	0.21	[0.12, 0.31]	0.14	[0.07, 0.22]	0.18	[0.09, 0.27]
η	0.67	[0.38, 1.04]	0.79	[0.47, 1.15]	0.67	[0.39, 1.02]	0.79	[0.48, 1.17]
ψ	0.99	[0.56, 1.54]	0.93	[0.49, 1.46]	0.93	[0.49, 1.47]	1.01	[0.55, 1.56]
σ	1.29	[0.80, 1.98]	1.65	[1.09, 2.39]	1.38	[0.79, 2.12]	1.64	[1.04, 2.42]
θ_H	0.55	[0.39, 0.68]	0.62	[0.51, 0.73]	0.64	[0.52, 0.74]	0.55	[0.39, 0.67]
θ_F	0.15	[0.08, 0.21]	0.22	[0.15, 0.30]	0.18	[0.12, 0.25]	0.18	[0.10, 0.26]
ω_H	0.21	[0.08, 0.36]	0.00	[0.00, 0.00]	0.00	[0.00, 0.00]	0.18	[0.07, 0.32]
ω_F	0.05	[0.02, 0.08]	0.00	[0.00, 0.00]	0.00	[0.00, 0.00]	0.05	[0.02, 0.09]
h	0.16	[0.07, 0.30]	0.00	[0.00, 0.00]	0.16	[0.06, 0.28]	0.00	[0.00, 0.00]
ρ_r	0.67	[0.53, 0.79]	0.67	[0.51, 0.80]	0.69	[0.55, 0.82]	0.65	[0.50, 0.79]
ψ_1	0.65	[0.37, 0.98]	0.67	[0.41, 1.00]	0.65	[0.37, 0.96]	0.65	[0.37, 0.98]
ψ_2	1.16	[0.97, 1.38]	1.32	[1.06, 1.66]	1.26	[1.02, 1.56]	1.20	[1.01, 1.47]
ψ_3	0.01	[0.00, 0.03]	0.02	[0.00, 0.05]	0.02	[0.00, 0.04]	0.02	[0.00, 0.04]
ρ_{a_H}	0.71	[0.50, 0.89]	0.70	[0.49, 0.90]	0.71	[0.48, 0.91]	0.68	[0.46, 0.89]
ρ_{y^*}	0.84	[0.73, 0.95]	0.82	[0.72, 0.91]	0.85	[0.74, 0.95]	0.81	[0.70, 0.90]
ρ_{π^*}	0.66	[0.39, 0.91]	0.67	[0.42, 0.91]	0.70	[0.44, 0.92]	0.64	[0.38, 0.90]
ρ_{r^*}	0.97	[0.93, 1.00]	0.97	[0.93, 1.00]	0.97	[0.93, 1.00]	0.97	[0.93, 1.00]
$\bar{r}$	0.48	[0.27, 0.74]	0.48	[0.27, 0.74]	0.48	[0.25, 0.74]	0.48	[0.27, 0.74]
γ	0.47	[0.25, 0.69]	0.41	[0.20, 0.61]	0.46	[0.24, 0.67]	0.41	[0.20, 0.62]
$\bar{\pi}$	1.97	[1.44, 2.48]	2.00	[1.50, 2.53]	1.98	[1.49, 2.49]	1.98	[1.47, 2.47]
$\Delta\bar{e}$	-0.01	[-0.67, 0.56]	0.16	[-0.38, 0.67]	0.02	[-0.57, 0.56]	0.10	[-0.44, 0.63]
$\Delta\bar{s}$	0.16	[-0.08, 0.36]	0.07	[-0.20, 0.30]	0.16	[-0.08, 0.36]	0.09	[-0.16, 0.30]
σ_{a_H}	0.75	[0.57, 1.04]	0.72	[0.55, 0.92]	0.72	[0.55, 0.92]	0.75	[0.56, 0.98]
σ_{uip}	2.18	[1.63, 2.95]	1.97	[1.44, 2.62]	2.07	[1.54, 2.80]	2.08	[1.54, 2.78]
σ_r	0.61	[0.49, 0.78]	0.63	[0.49, 0.81]	0.62	[0.48, 0.79]	0.63	[0.48, 0.80]
σ_{y^*}	2.22	[1.34, 3.38]	2.37	[1.49, 3.48]	2.08	[1.27, 3.11]	2.35	[1.45, 3.61]
σ_{r^*}	1.04	[0.81, 1.31]	0.97	[0.74, 1.21]	0.96	[0.76, 1.21]	1.05	[0.80, 1.33]
σ_{π^*}	0.94	[0.64, 1.32]	0.97	[0.68, 1.35]	0.97	[0.67, 1.40]	0.94	[0.66, 1.35]

Table 8
Posterior – two good (Canada)

	BHI (Full)		B (No habits or index)		BH (Habits)		BI (Indexation)	
Parameter	Mean	99% CI	Mean	99% CI	Mean	99% CI	Mean	99% CI
α	0.36	[0.15, 0.62]	0.43	[0.24, 0.62]	0.38	[0.19, 0.60]	0.42	[0.22, 0.65]
λ	0.74	[0.51, 0.90]	0.63	[0.45, 0.81]	0.71	[0.53, 0.87]	0.60	[0.37, 0.81]
ν	1.07	[0.64, 1.58]	1.30	[0.83, 1.83]	1.15	[0.68, 1.70]	1.25	[0.81, 1.83]
η	0.71	[0.38, 1.12]	0.66	[0.39, 1.00]	0.69	[0.38, 1.07]	0.61	[0.37, 0.92]
ψ	0.90	[0.44, 1.45]	0.88	[0.47, 1.37]	0.86	[0.45, 1.43]	0.88	[0.46, 1.39]
σ	1.91	[1.14, 2.75]	2.41	[1.58, 3.39]	2.09	[1.36, 2.94]	2.22	[1.38, 3.21]
θ_H	0.20	[0.09, 0.32]	0.27	[0.17, 0.36]	0.30	[0.20, 0.40]	0.18	[0.08, 0.29]
θ_F	0.15	[0.09, 0.24]	0.21	[0.15, 0.28]	0.18	[0.12, 0.24]	0.18	[0.10, 0.26]
θ_N	0.45	[0.25, 0.62]	0.55	[0.44, 0.67]	0.54	[0.42, 0.66]	0.52	[0.33, 0.67]
ω_H	0.21	[0.11, 0.33]	0.00	[0.00, 0.00]	0.00	[0.00, 0.00]	0.22	[0.12, 0.34]
ω_F	0.06	[0.03, 0.10]	0.00	[0.00, 0.00]	0.00	[0.00, 0.00]	0.08	[0.04, 0.12]
ω_N	0.17	[0.07, 0.31]	0.00	[0.00, 0.00]	0.00	[0.00, 0.00]	0.13	[0.05, 0.25]
h	0.27	[0.11, 0.45]	0.00	[0.00, 0.00]	0.19	[0.08, 0.34]	0.00	[0.00, 0.00]
ρ_r	0.70	[0.56, 0.83]	0.63	[0.47, 0.78]	0.68	[0.53, 0.80]	0.64	[0.48, 0.78]
ψ_1	0.45	[0.22, 0.74]	0.45	[0.24, 0.72]	0.43	[0.22, 0.70]	0.52	[0.26, 0.80]
ψ_2	1.49	[1.13, 2.01]	1.63	[1.29, 2.06]	1.57	[1.23, 2.01]	1.58	[1.22, 1.99]
ψ_3	0.03	[0.01, 0.07]	0.04	[0.01, 0.08]	0.04	[0.01, 0.07]	0.03	[0.01, 0.06]
ρ_{a_H}	0.87	[0.67, 0.99]	0.87	[0.71, 0.99]	0.88	[0.70, 0.99]	0.84	[0.64, 0.99]
ρ_{a_N}	0.73	[0.47, 0.95]	0.77	[0.51, 0.97]	0.75	[0.51, 0.96]	0.78	[0.49, 0.97]
κ	0.26	[0.08, 0.50]	0.23	[0.05, 0.46]	0.26	[0.08, 0.51]	0.23	[0.05, 0.50]
ρ_{y^*}	0.77	[0.64, 0.89]	0.70	[0.62, 0.78]	0.76	[0.67, 0.85]	0.66	[0.53, 0.78]
ρ_{π^*}	0.66	[0.39, 0.91]	0.62	[0.40, 0.83]	0.66	[0.43, 0.88]	0.61	[0.38, 0.86]
ρ_{r^*}	0.97	[0.92, 1.00]	0.97	[0.92, 1.00]	0.97	[0.93, 1.00]	0.96	[0.88, 1.00]
$\bar{r}$	0.48	[0.27, 0.77]	0.47	[0.26, 0.74]	0.47	[0.26, 0.73]	0.47	[0.26, 0.71]
γ	0.39	[0.19, 0.60]	0.31	[0.15, 0.49]	0.35	[0.18, 0.55]	0.33	[0.16, 0.52]
$\bar{\pi}$	1.99	[1.49, 2.50]	1.97	[1.45, 2.47]	1.98	[1.46, 2.50]	1.97	[1.46, 2.48]
$\Delta\bar{e}$	-0.04	[-0.56, 0.43]	0.03	[-0.40, 0.43]	-0.01	[-0.43, 0.39]	0.03	[-0.44, 0.46]
$\Delta\bar{s}$	0.14	[-0.03, 0.30]	0.12	[0.00, 0.23]	0.14	[0.00, 0.27]	0.12	[-0.01, 0.25]
σ_{a_H}	0.95	[0.66, 1.34]	0.84	[0.61, 1.18]	0.90	[0.63, 1.25]	0.85	[0.61, 1.18]
σ_{uip}	2.66	[1.77, 3.81]	1.65	[1.03, 2.38]	1.77	[1.10, 2.61]	2.51	[1.66, 3.55]
σ_r	0.61	[0.47, 0.80]	0.67	[0.50, 0.88]	0.63	[0.49, 0.79]	0.65	[0.50, 0.84]
σ_{y^*}	1.57	[0.98, 2.42]	1.46	[0.93, 2.14]	1.44	[0.94, 2.13]	1.85	[1.11, 2.84]
σ_{r^*}	1.07	[0.82, 1.42]	0.99	[0.78, 1.28]	0.96	[0.76, 1.22]	1.12	[0.85, 1.46]
σ_{π^*}	1.35	[0.87, 1.92]	1.14	[0.79, 1.60]	1.14	[0.79, 1.57]	1.34	[0.87, 2.02]

Table 9
Posterior – one good (New Zealand)

	MHI (Full)		M (No habits or index)		MH (Habits)		MI (Indexation)	
Parameter	Mean	99% CI	Mean	99% CI	Mean	99% CI	Mean	99% CI
α	0.09	[0.05, 0.13]	0.14	[0.09, 0.21]	0.11	[0.07, 0.15]	0.11	[0.07, 0.16]
η	0.83	[0.48, 1.21]	0.92	[0.58, 1.31]	0.80	[0.48, 1.15]	0.95	[0.58, 1.37]
ψ	0.95	[0.48, 1.49]	0.89	[0.48, 1.40]	0.92	[0.47, 1.44]	0.95	[0.53, 1.48]
σ	1.69	[1.11, 2.38]	1.84	[1.27, 2.60]	1.71	[1.12, 2.46]	1.85	[1.22, 2.56]
θ_H	0.80	[0.67, 0.92]	0.81	[0.73, 0.89]	0.84	[0.76, 0.92]	0.77	[0.65, 0.88]
θ_F	0.18	[0.08, 0.26]	0.24	[0.14, 0.35]	0.21	[0.12, 0.31]	0.21	[0.11, 0.31]
ω_H	0.24	[0.10, 0.40]	0.00	[0.00, 0.00]	0.00	[0.00, 0.00]	0.23	[0.09, 0.40]
ω_F	0.07	[0.03, 0.13]	0.00	[0.00, 0.00]	0.00	[0.00, 0.00]	0.07	[0.03, 0.13]
h	0.18	[0.08, 0.32]	0.00	[0.00, 0.00]	0.18	[0.07, 0.29]	0.00	[0.00, 0.00]
ρ_r	0.74	[0.59, 0.85]	0.68	[0.52, 0.81]	0.71	[0.56, 0.84]	0.71	[0.56, 0.84]
ψ_1	0.65	[0.38, 0.99]	0.67	[0.39, 1.01]	0.64	[0.37, 0.98]	0.67	[0.40, 1.01]
ψ_2	1.47	[1.08, 2.02]	1.64	[1.20, 2.15]	1.65	[1.20, 2.19]	1.46	[1.11, 1.96]
ψ_3	0.02	[0.00, 0.06]	0.02	[0.01, 0.04]	0.02	[0.01, 0.05]	0.02	[0.00, 0.05]
ρ_{a_H}	0.61	[0.36, 0.84]	0.55	[0.34, 0.79]	0.57	[0.34, 0.80]	0.59	[0.34, 0.82]
ρ_{y^*}	0.85	[0.73, 0.95]	0.85	[0.73, 0.94]	0.87	[0.75, 0.96]	0.81	[0.69, 0.91]
ρ_{π^*}	0.28	[0.12, 0.47]	0.33	[0.14, 0.59]	0.30	[0.12, 0.50]	0.31	[0.14, 0.52]
ρ_{r^*}	0.97	[0.93, 1.00]	0.96	[0.91, 1.00]	0.96	[0.92, 1.00]	0.97	[0.93, 1.00]
$\bar{r}$	0.50	[0.28, 0.77]	0.49	[0.27, 0.77]	0.50	[0.28, 0.79]	0.50	[0.27, 0.77]
γ	0.56	[0.35, 0.77]	0.53	[0.34, 0.73]	0.56	[0.37, 0.76]	0.53	[0.33, 0.72]
$\bar{\pi}$	1.99	[1.47, 2.53]	1.99	[1.50, 2.48]	1.98	[1.44, 2.51]	1.99	[1.47, 2.52]
$\Delta\bar{e}$	0.04	[-0.56, 0.68]	-0.04	[-0.62, 0.54]	0.04	[-0.61, 0.64]	0.00	[-0.59, 0.58]
$\Delta\bar{s}$	0.00	[-0.30, 0.24]	-0.08	[-0.44, 0.20]	-0.01	[-0.38, 0.23]	-0.03	[-0.33, 0.21]
σ_{a_H}	0.99	[0.77, 1.25]	1.02	[0.79, 1.31]	1.00	[0.80, 1.25]	1.02	[0.80, 1.31]
σ_{uip}	2.99	[2.25, 3.90]	2.79	[2.12, 3.59]	2.87	[2.16, 3.75]	2.88	[2.23, 3.72]
σ_r	0.57	[0.45, 0.71]	0.59	[0.46, 0.76]	0.57	[0.46, 0.72]	0.58	[0.46, 0.73]
σ_{y^*}	1.93	[1.17, 2.84]	2.19	[1.43, 3.17]	1.82	[1.17, 2.72]	2.31	[1.46, 3.57]
σ_{r^*}	2.73	[2.05, 3.60]	2.54	[1.94, 3.26]	2.52	[1.90, 3.23]	2.79	[2.08, 3.74]
σ_{π^*}	1.35	[0.83, 2.04]	1.32	[0.83, 1.97]	1.29	[0.83, 2.02]	1.35	[0.86, 2.06]

Table 10
Posterior – two good (New Zealand)

	BHI (Full)		B (No habits or index)		BH (Habits)		BI (Indexation)	
Parameter	Mean	99% CI	Mean	99% CI	Mean	99% CI	Mean	99% CI
α	0.58	[0.37, 0.77]	0.60	[0.39, 0.80]	0.62	[0.40, 0.81]	0.61	[0.41, 0.81]
λ	0.84	[0.75, 0.91]	0.75	[0.58, 0.88]	0.81	[0.66, 0.89]	0.80	[0.67, 0.89]
ν	1.14	[0.67, 1.66]	1.34	[0.75, 1.97]	1.23	[0.68, 1.81]	1.36	[0.82, 1.91]
η	0.99	[0.59, 1.45]	0.92	[0.54, 1.36]	0.97	[0.58, 1.43]	0.95	[0.57, 1.39]
ψ	0.85	[0.44, 1.37]	0.77	[0.43, 1.23]	0.78	[0.41, 1.26]	0.83	[0.45, 1.38]
σ	2.04	[1.37, 2.91]	2.34	[1.65, 3.18]	2.04	[1.42, 2.74]	2.46	[1.63, 3.48]
θ_H	0.20	[0.09, 0.32]	0.23	[0.14, 0.34]	0.30	[0.18, 0.43]	0.16	[0.07, 0.26]
θ_F	0.19	[0.10, 0.30]	0.22	[0.10, 0.35]	0.20	[0.10, 0.29]	0.25	[0.11, 0.49]
θ_N	0.75	[0.62, 0.87]	0.69	[0.53, 0.83]	0.75	[0.57, 0.87]	0.69	[0.54, 0.81]
ω_H	0.22	[0.13, 0.31]	0.00	[0.00, 0.00]	0.00	[0.00, 0.00]	0.18	[0.10, 0.27]
ω_F	0.08	[0.04, 0.13]	0.00	[0.00, 0.00]	0.00	[0.00, 0.00]	0.09	[0.04, 0.14]
ω_N	0.18	[0.07, 0.30]	0.00	[0.00, 0.00]	0.00	[0.00, 0.00]	0.19	[0.07, 0.33]
h	0.34	[0.18, 0.53]	0.00	[0.00, 0.00]	0.26	[0.12, 0.43]	0.00	[0.00, 0.00]
ρ_r	0.69	[0.54, 0.82]	0.57	[0.36, 0.77]	0.63	[0.41, 0.78]	0.68	[0.52, 0.82]
ψ_1	0.51	[0.27, 0.81]	0.38	[0.19, 0.65]	0.45	[0.23, 0.73]	0.48	[0.25, 0.77]
ψ_2	1.92	[1.40, 2.52]	2.21	[1.59, 2.84]	2.07	[1.56, 2.69]	1.95	[1.41, 2.56]
ψ_3	0.04	[0.01, 0.07]	0.04	[0.01, 0.06]	0.03	[0.01, 0.07]	0.04	[0.01, 0.07]
ρ_{a_H}	0.81	[0.56, 0.99]	0.92	[0.70, 1.00]	0.86	[0.65, 1.00]	0.86	[0.64, 0.99]
ρ_{a_N}	0.66	[0.37, 0.95]	0.77	[0.42, 0.99]	0.70	[0.42, 0.97]	0.71	[0.40, 0.97]
κ	0.40	[0.13, 0.73]	0.36	[0.08, 0.77]	0.41	[0.11, 0.78]	0.36	[0.08, 0.70]
ρ_{y^*}	0.79	[0.64, 0.91]	0.69	[0.53, 0.83]	0.76	[0.61, 0.88]	0.63	[0.46, 0.77]
ρ_{π^*}	0.32	[0.12, 0.65]	0.34	[0.13, 0.68]	0.29	[0.10, 0.61]	0.45	[0.17, 0.90]
ρ_{r^*}	0.95	[0.88, 0.99]	0.96	[0.89, 1.00]	0.96	[0.90, 1.00]	0.94	[0.87, 1.00]
$\bar{r}$	0.50	[0.26, 0.76]	0.50	[0.28, 0.79]	0.50	[0.27, 0.77]	0.49	[0.27, 0.75]
γ	0.52	[0.33, 0.71]	0.47	[0.30, 0.64]	0.51	[0.34, 0.70]	0.46	[0.29, 0.63]
$\bar{\pi}$	1.99	[1.49, 2.52]	1.96	[1.49, 2.48]	1.97	[1.47, 2.50]	1.98	[1.47, 2.48]
$\Delta\bar{e}$	-0.12	[-0.63, 0.35]	-0.24	[-0.67, 0.22]	-0.18	[-0.63, 0.30]	-0.19	[-0.64, 0.30]
$\Delta\bar{s}$	0.06	[-0.11, 0.21]	0.05	[-0.10, 0.17]	0.07	[-0.06, 0.18]	0.06	[-0.08, 0.18]
σ_{a_H}	1.43	[0.90, 2.13]	1.29	[0.85, 1.95]	1.31	[0.86, 1.95]	1.37	[0.88, 2.05]
σ_{uip}	3.11	[2.04, 4.40]	1.84	[1.10, 2.82]	2.15	[1.32, 3.11]	2.82	[1.85, 4.00]
σ_r	0.58	[0.46, 0.76]	0.64	[0.49, 0.84]	0.61	[0.47, 0.80]	0.59	[0.46, 0.75]
σ_{y^*}	1.41	[0.88, 2.25]	1.22	[0.77, 1.80]	1.24	[0.77, 1.95]	1.64	[1.02, 2.51]
σ_{r^*}	2.90	[2.15, 3.82]	2.52	[1.92, 3.28]	2.51	[1.90, 3.27]	3.16	[2.24, 4.49]
σ_{π^*}	1.90	[1.07, 2.99]	1.70	[1.02, 2.41]	1.61	[0.96, 2.40]	1.77	[1.05, 2.69]

C Impulse response functions

Figure 1
Australia – one good (dotted) and two good (solid)

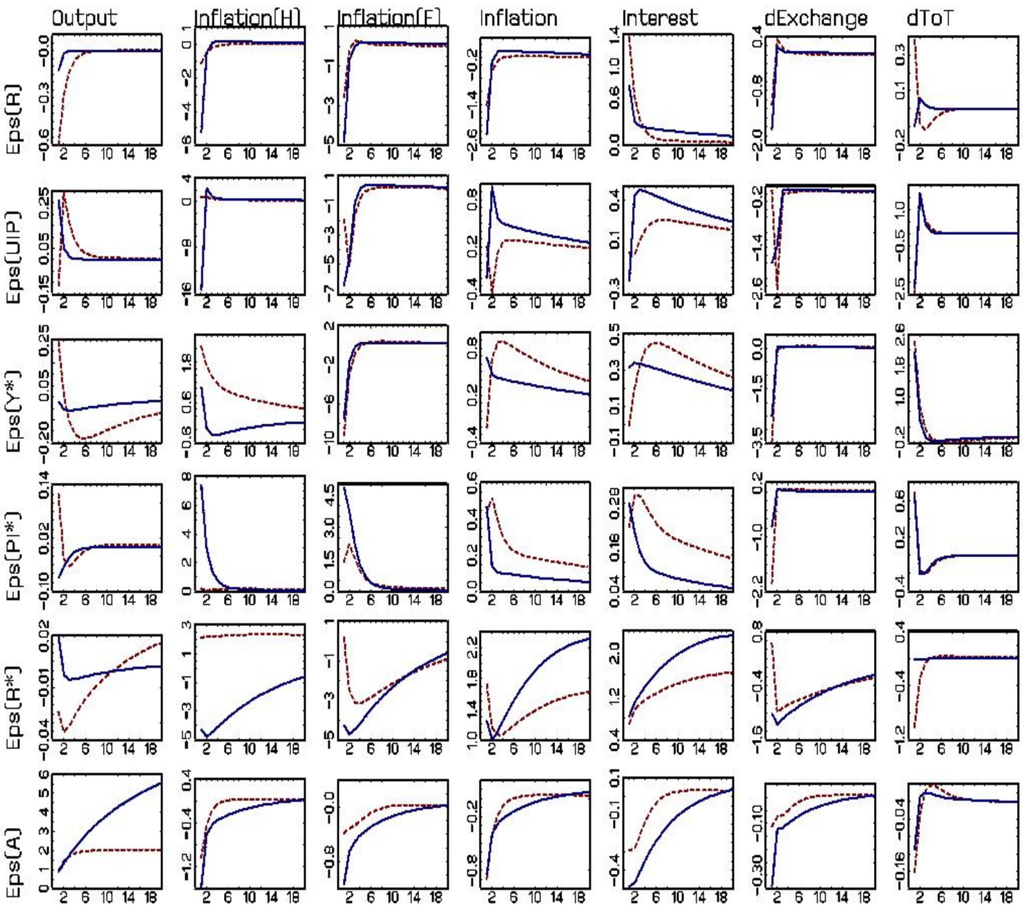


Figure 2
Canada – one good (dotted) and two good (solid)

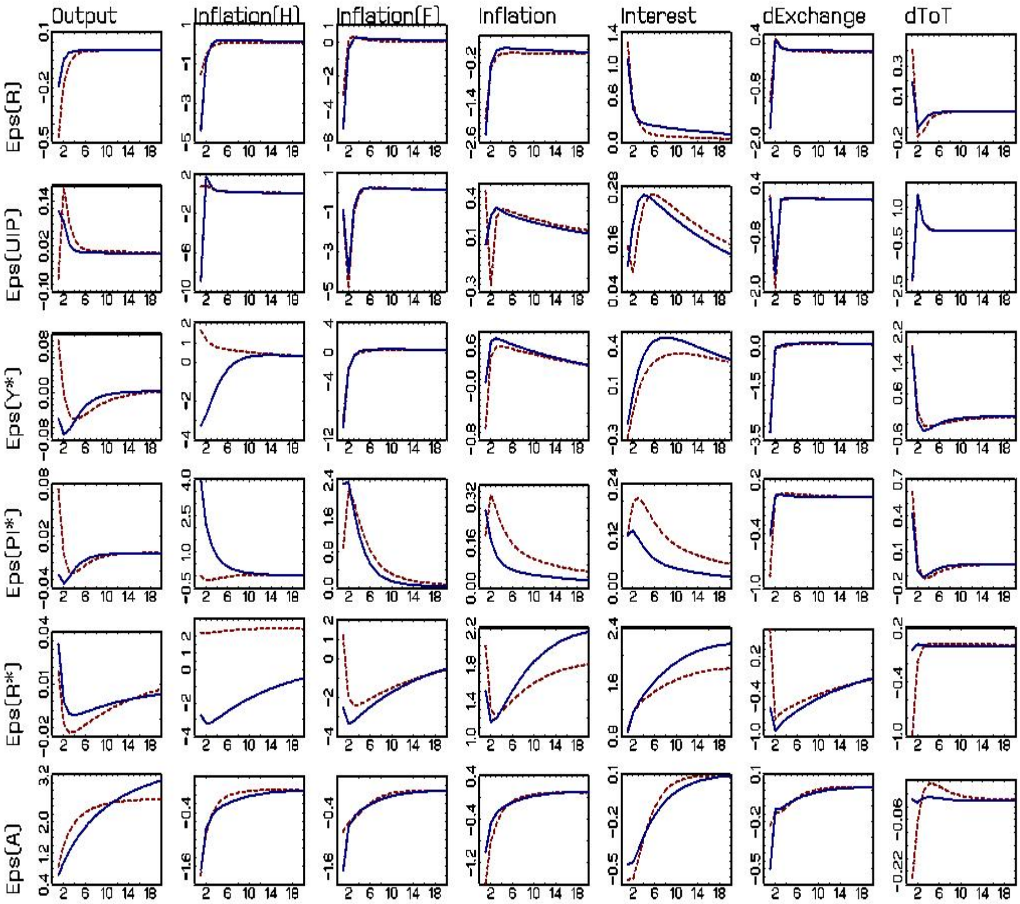
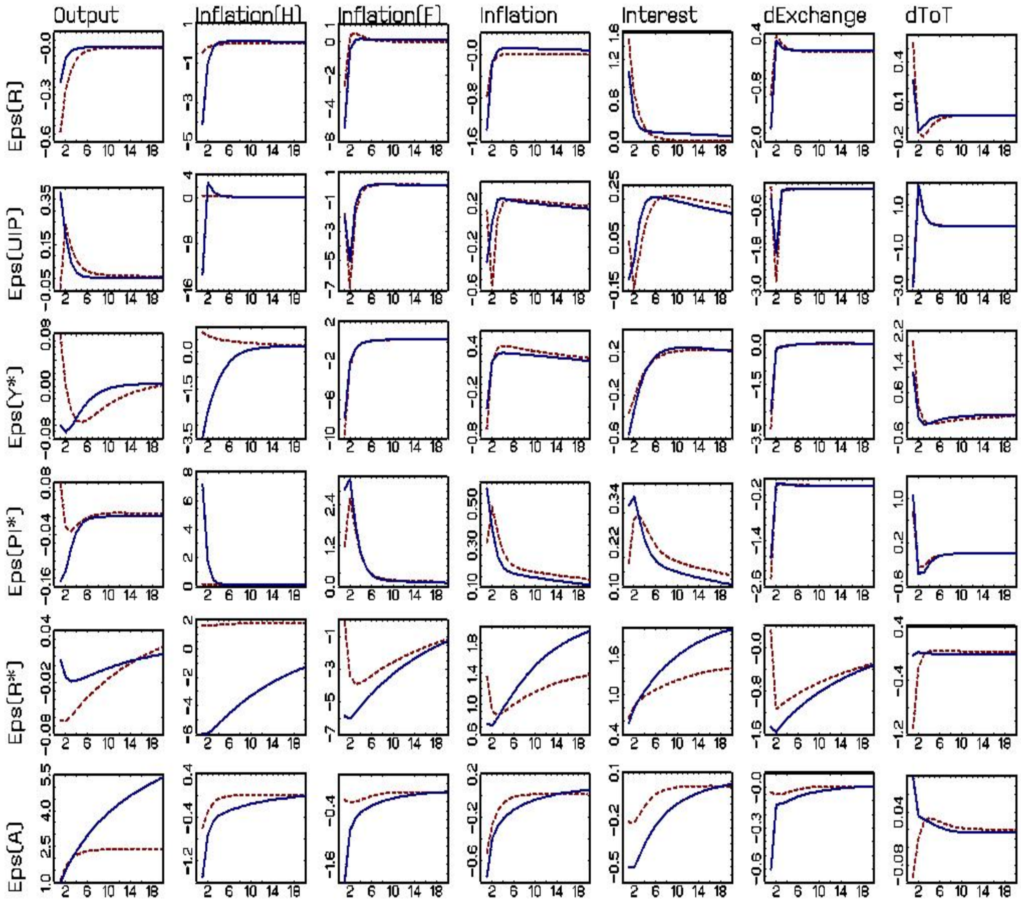


Figure 3
New Zealand – one good (dotted) and two good (solid)



D Log marginal likelihoods and Bayes factors (demeaned data)

Table 11
Log marginal likelihoods and Bayes factors (demeaned data)

	One-good		Two-good	
	$\log(p(Y))$	$\log(\hat{L})$	$\log(p(Y))$	$\log(\hat{L})$
Australia				
Full specification	-956.36	0.00	-922.03	34.32
No habits or indexation	-924.85	31.50	-884.65	71.71
Habits	-929.98	26.38	-888.62	67.74
Indexation	-950.11	6.25	-918.95	37.41
Canada				
Full specification	-907.32	0.00	-871.90	35.42
No habits or indexation	-875.27	32.04	-819.73	87.58
Habits	-876.86	30.45	-832.81	74.51
Indexation	-890.24	17.07	-863.56	43.76
New Zealand				
Full specification	-960.75	0.00	-935.70	25.06
No habits or indexation	-937.60	23.15	-895.44	65.32
Habits	-947.36	13.40	-905.83	54.93
Indexation	-958.29	2.47	-931.58	29.18

The log marginal data densities are based on 100,000 draws from the posterior density after burning the first 100,000 draws. The Bayes factors compare each model to the fully-specified one-good model in each country.