Do World Shocks Drive Domestic Business Cycles? Some Evidence from Structural Estimation*

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Abstract

Existing results on the contribution of terms of trade and world interest rate shocks to output fluctuations in small open economies range from less than 10% to almost 90%. We argue that an dentification problems lies at the heart of these vastly different results. In this paper, we overcome this by estimating a DSGE model using a structural Bayesian estimation approach. We apply our methodology to five developed and developing economies.. Our approach allows us to efficiently exploit cross-equation restrictions implied by the structural model. We find that world interest rate shocks are the main driving forces of business cycles in small open economies while terms of trade shocks are not.

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1 Introduction

It is widely believed that world shocks, such as terms of trade and world interest rate shocks, are the main driving forces of business cycles in small open economies. However, the actual empirical evidence is mixed. Estimates of the contribution of these shocks range from almost nothing to close to 90%, using various empirical methodologies. Identifying the separate contributions of each shock is one of the difficulties encountered in this literature. In this paper, we estimate a canonical small open economy model to quantify the importance of world shocks in explaining business cycles in small open economies. Our approach is explicitly structural and utilizes Bayesian estimation methods, which provide a theoretically consistent and efficient means for identification.

The existing literature in this area typically makes use of one of two methodologies. The first one is the vector autoregression (VAR) approach, which combines recursive ordering of innovations and/or long run restrictions to achieve identification. Recursive ordering of shocks makes use of the assumption that domestic shocks in small open economies have no effects on world shocks. Long-run restrictions, on the other hand, are derived from theoretical predictions that 'demand shocks' have no long run effects on macroeconomic variables, unlike supply shocks[1]. Using this methodology, Hoffmaister and Roldós (1997) find that terms of trade shocks explain up to 7% of the forecast variance of output in Asia and Latin America. Hoffmaister, Roldós and Wickham (1998) find slightly higher contributions of terms of trade shocks in sub-Saharan Africa of up to 15%. Similarly, Ahmed and Murthy (1994) find that terms of trade movements can account for only up to 6% of the forecast variance of output in Canada.

VAR studies typically do not find quantitatively significant effects of world interest rate shocks on domestic output dynamics either. For example, Hoffmaister and Roldós (1997) report that world interest rate shocks account for up to 6% of the forecast variance of output in Asia and up to 20% of the forecast variance of output in Latin America. Hoffmaister, Roldós and Wickham (1998) and Ahmed and Murthy (1994) find that world interest rate shocks can explain only up to 8% of the forecast variance of output in sub-Saharan Africa and Canada, respectively. In these studies, domestic supply shocks turn out to be the most important driving forces of domestic business cycles.

An exception in this literature is Cushman and Zha (1997). They estimate a VAR on U.S. and Canadian data and impose the identification assumption that macroeconomic variables in Canada do not feed back on those in the United States. In addition to this block exogeneity, they impose contemporaneous restrictions on the relation between money demand and money supply. They find that external shocks (which include shocks to U.S. output, price levels and interest rates as well as shocks to world export prices) account for up to 74% of the forecast variance of output in Canada.

[1] This identification scheme has been introduced by Blanchard and Quah (1989).

Since they do not report the contributions of each kind of external shocks separately, it is difficult to assess the importance of individual shocks.

The other methodology that has been commonly used to assess the contribution of world shocks to the business cycles of small open economies is calibrated dynamic stochastic general equilibrium (DSGE) modeling. It starts out with the construction of a fully specified structural model, where the equations in the model are derived from the intertemporal optimization problems of economic agents. The structural parameters of the model are then chosen to match first, and sometimes second, moments of business cycle statistics of interest. The model is then simulated and its time-series predictions are compared to actual, observed data. The calibrated model is then considered to be an approximation to the true data-generating process, and hence is used to identify various shock processes and their transmission mechanisms.

Mendoza (1991) is the first paper that uses a calibrated DSGE model to assess the importance of various shocks in the business cycles of a small open economy. In a model calibrated to Canadian data, he shows that world interest rate shocks have only minimal effects on output fluctuations. Kose and Riezman (2001) and Kose (2002) similarly find that world interest rate shocks explain less than 2% of output fluctuations in more elaborate calibrated DSGE models. On the other hand, using a slightly different methodology[2], Blankenau, Kose and Yi (2001) find that world interest rate shocks can account for up to a third of the output fluctuations in Canada.

In contrast, studies that use calibrated DSGE models typically find that terms of trade shocks account for a substantial fraction of output fluctuations. For instance, Mendoza (1995) finds that terms of trade shocks explain nearly half of output movements in his model. Kose and Riezman (2001) similarly find that fluctuations in international relative prices explain 44% of the output fluctuations in Africa, while Kose (2002) even reports that these shocks can account for nearly 90% of the output fluctuations in developing countries.

In this paper, we depart from the existing literature and assess the contributions of world shocks to the business cycles of small open economies by using an *estimated* DSGE model. We begin by constructing a fully specified DSGE model. However, instead of calibrating the structural parameters, we estimate the model on data from five countries (Australia, Canada, New Zealand, Chile and Mexico) using Bayesian methods[3]. Compared to calibrated DSGE models, the method used in this paper has the advantage that it explicitly takes into consideration the uncertainty surrounding the values of the structural parameters. In addition, structural estimation allows us to take full advan-

[2] In particular, they calibrate the structural parameters in their model except for those related to shock processes and use the model equilibrium conditions to back out the implied shock processes.

[3] A partial list of recent papers that make use of this method include: Lubik and Schorfheide (2003, 2005), Smets and Wouters (2003), Adolfsen, Laseen, Linde and Villani (2004), Justiniano and Preston (2004), Lubik (2005a,b), and Elekdag, Justiniano and Tchakarov (2005).

tage of the cross-equation restrictions implied by our model to achieve identification. In contrast, studies that employ VARs typically only make use of some but not all of the restrictions implied by economic theories.

We find in this paper that terms of trade shocks account for a very small fraction of business cycle fluctuations in the five economies while world interest rate shocks have substantial explanatory power. In the benchmark model, terms of trade shocks explain less than 3% of output movements and less than 10% of labor hour fluctuations. In contrast, the mean levels of contribution of world interest rate shocks to output fluctuations range from 40% to 75%. More strikingly, the mean levels of contribution of world interest rate shocks to the labor hour fluctuations are larger than 90% for all five economies. As a robustness check, we also consider two alternative specifications of the model. The qualitative results regarding the importance of various shocks remain roughly the same. Moreover, econometric tests indicate that the data favor the benchmark model over the alternative models.

The rest of the paper is organized as follows: Section 2 sets up the benchmark structural model. Section 3 discusses the econometric methodology. The results are presented in Section 4. Section 5 presents the results from the sensitivity analysis. Section 6 concludes and discusses future research directions.

2 A Model of a Small Open Economy

Our modeling framework is based on Mendoza (1991). A small open economy is populated by a representative household which maximizes its expected discounted lifetime utility:

$$E_t \sum_{t}^{\infty} \beta^t \left[\ln C_t - \frac{(L_t)^{1+\vartheta}}{1+\vartheta} \right], \tag{1}$$

by choosing aggregate consumption (C_t), labor hours (L_t), aggregate investment (I_t), the capital stock (K_t), and internationally traded bonds denominated in terms of foreign goods (b_t), subject to the budget constraint and the capital accumulation equation:

$$P_t C_t + P_t I_t + P_{F,t} b_t + \frac{\zeta}{2} \left(\frac{P_{F,t} b_t}{P_{H,t} Y_t} \right)^2 P_{H,t} Y_t = P_{H,t} Y_t + R_{t-1} P_{F,t} b_{t-1}, \tag{2}$$

$$K_t = (1-\delta) K_{t-1} + \varphi\left(\frac{I_t}{K_{t-1}}\right) K_{t-1}, \tag{3}$$

where $\beta \in (0,1)$ is the subjective discount factor; $\vartheta \geq 0$ is the inverse of the elasticity of labor supply; Y_t is the output that the representative household produces; P_t is the aggregate price index; $q_t \equiv \frac{P_{H,t}}{P_{F,t}}$ is the terms of trade, defined as the price of domestic goods $P_{H,t}$ over the price of foreign goods $P_{F,t}$; R_t is the gross interest rate on the bond; $\frac{\zeta}{2} \left(\frac{P_{F,t} b_t}{P_{H,t} Y_t} \right)^2 P_{H,t} Y_t$, with $\zeta > 0$, is a convex cost of bond adjustment, introduced to ensure stationarity of bonds and consumption (see Schmitt-Grohé and Uribe, 2003 or Lubik, 2003); I_t, is the investment of physical capital; $\delta \in (0,1)$ is the rate of depreciation of capital. Adjustment of the capital stock is subject to convex costs $\varphi(\frac{I_t}{K_{t-1}})K_{t-1}$, with $\varphi > 0, \varphi' > 0, \varphi'' < 0$.

Aggregate consumption is specified as a Cobb-Douglas function of consumption of domestic goods $C_{H,t}$ and consumption of foreign goods $C_{F,t}$:

$$C_t = \frac{(C_{H,t})^{(1-\gamma)}(C_{F,t})^{\gamma}}{(1-\gamma)^{1-\gamma}\gamma^{\gamma}}. \tag{4}$$

Investment is also modeled as a Cobb-Douglas composite of domestic and foreign investment goods, $I_{H,t}$ and $I_{F,t}$. For simplicity, the composite investment goods are assumed to have the same functional form as the composite consumption goods:

$$I_t = \frac{(I_{H,t})^{(1-\gamma)}(I_{F,t})^{\gamma}}{(1-\gamma)^{1-\gamma}\gamma^{\gamma}}. \tag{5}$$

The associated consumption-based price index $P_t \equiv P_{H,t}^{1-\gamma}P_{F,t}^{\gamma}$. Consequently, we can rewrite the budget constraint as:

$$C_t + I_t + q_t^{\gamma-1}b_t + \frac{\zeta}{2}\left(\frac{b_t}{q_tY_t}\right)^2 q_t^{\gamma}Y_t = q_t^{\gamma}Y_t + R_{t-1}q_t^{\gamma-1}b_{t-1}. \tag{6}$$

The production technology is a Cobb-Douglas function of the labor hours and the capital stock:

$$Y_t = A_t(K_{t-1})^{\alpha}(L_t)^{1-\alpha}, \tag{7}$$

where A_t is a productivity shifter.

The first-order conditions for the household's maximization problem are:

$$(L_t)^{\vartheta} = (1-\alpha)\frac{1}{C_t}q_t^{\gamma}\frac{Y_t}{L_t}, \tag{8}$$

$$\frac{1}{C_t}\left[q_t^{\gamma-1} + \zeta\frac{b_t}{q_tY_t}q_t^{\gamma-1}\right] = \beta E_t\frac{1}{C_{t+1}}R_tq_{t+1}^{\gamma-1}, \tag{9}$$

$$\begin{aligned} & E_t\frac{\alpha\beta}{C_{t+1}}q_{t+1}^{\gamma}\frac{Y_{t+1}}{K_t} + E_t\frac{\beta}{C_{t+1}}/\varphi'(\frac{I_{t+1}}{K_t})\left[(1-\delta) + \varphi(\frac{I_{t+1}}{K_t}) - \varphi^{'}(\frac{I_{t+1}}{K_t})\frac{I_{t+1}}{K_t}\right] \\ = \; & \frac{1}{C_t}/\varphi'(\frac{I_t}{K_{t-1}}). \end{aligned} \tag{10}$$

Equation (8) equates the marginal utility and disutility of labor hours. Equations (9) and (10) are the bond Euler equation and the capital Euler equation, respectively. The productivity shifter, the terms of trade and the gross interest rate on bonds are assumed to evolve according to first-order autoregressive processes:

$$\ln A_t = \rho_A \ln A_{t-1} + \varepsilon_{A,t}, \tag{11}$$

$$\ln q_t = \rho_q \ln q_{t-1} + \varepsilon_{q,t}, \tag{12}$$

$$\ln R_t = \rho_R \ln R_{t-1} + (1-\rho_R)\ln \bar{R} + \varepsilon_{R,t}, \tag{13}$$

where $\rho_A, \rho_q, \rho_R \in (0,1)$ are parameters, $\varepsilon_{A,t}, \varepsilon_{q,t}, \varepsilon_{R,t}$ are i.i.d. normal innovations with zero mean and standard deviations $\sigma_A, \sigma_q, \sigma_R$, respectively; variables with a bar denotes the steady state of that variable. We proceed by log-linearizing the equation system around a deterministic steady state.

3 Estimation Strategy

3.1 Econometric Methodology

The log-linearized system of equations can be written in the canonical form:

$$\Gamma_0(\theta) w_t = \Gamma_1(\theta) w_{t-1} + \Gamma_\varepsilon(\theta)\varepsilon_t + \Gamma_\eta(\theta)\eta_t, \tag{14}$$

where w_t denotes the vector of model variables; ε_t is composed of the white noise shocks in the exogenous processes; η_t denotes the vector of rational expectations forecast errors; θ collects the structural parameters of the model; the Γ matrices, which are functions of the structural parameters, collect the coefficients in the log-linearized system of equations. The system of equation, (14), can then be solved using the methods described in Sims (2002) to get:

$$W_t = \Phi_1(\theta) W_{t-1} + \Phi_\varepsilon(\theta)\varepsilon_t, \tag{15}$$

where Φ_1 and Φ_ε are functions of structural parameters. Let x_t denote a vector of observable variables and $X^T = \{x_1, ..., x_T\}$. x_t is related to the vector of model variables, w_t, through the measurement equation:

$$x_t = B(\theta) w_t, \tag{16}$$

where B is a matrix that selects the elements of w_t.

Equations (15) and (16) form a state-space representation for x_t. A conditional likelihood function for the structural parameters, $L(\theta|X^T)$, can then be computed under the assumption of normally distributed white noise exogenous shocks using the Kalman filter. Given a prior density on the structural parameters $p(\theta)$ data of the observable variables X^T are used to update the priors through the likelihood function. The joint posterior density of the parameters, $p(\theta|X^T)$, is computed using the Bayes Theorem:

$$p(\theta|X^T) = \frac{L(\theta|X^T)p(\theta)}{\int L(\theta|X^T)p(\theta)d\theta}. \tag{17}$$

Estimation of the structural parameters proceeds in two steps (see Lubik and Schorfheide, 2005, for a more thorough discussion). First, an approximation to the mode of the posterior is obtained by maximizing the posterior density using a numerical algorithm. In the next step, the posterior mode is used as the starting value of a Random Walk Metropolis-Hastings algorithm. This Markov Chain Monte Carlo (MCMC) method generates draws from the posterior density. Point estimates as well as confidence intervals of the structural parameters can then be obtained from the generated draws. Posterior draws of variance decomposition and impulse response functions are obtained by transforming the parameter draws.

3.2 Data Description

We estimate the model using quarterly data on output, labor hours and the terms of trade. Data from three industrialized small open economies, Australia, Canada and New Zealand, as well as two developing small open economies, Mexico and Chile, are considered.[4] All data are seasonally adjusted. The sample periods are 1978:1 to 2004:2 for Australia, 1981:1 to 2004:2 for Canada, 1987:2 to 2004:1 for New Zealand and 1996:1 to 2003:4 for both Mexico and Chile. The output series correspond to real GDP per civilian labor force for the three industrialized countries and real GDP per capita for the two developing countries. The series on labor hours correspond to total civilian employment hours over civilian labor force for the three industrialized countries, total manufacturing hours per capita for Mexico and total employment per capita for Chile. The series on terms of trade correspond to the ratio of export price over import price, both obtained from the price deflators in national income account. Except for data on civilian labor force and civilian employment, which are obtained from the Source-OECD database, all other series are obtained from the DRI International database. All data are logged, HP-filtered and demeaned prior to estimation.

3.3 The Choice of Priors

Table 1 summarizes the prior distributions for the structural parameters. These priors are assumed to be independent across parameters. They are also assumed to be identical for all model economies except for the parameters related to the exogenous shock processes, to allow for possibly different shock histories. Their choices are guided by several considerations. First, they reflect beliefs about the values that the parameters should take. These beliefs can be influenced by results from existing research, like micro-level studies or existing work on estimation of dynamic stochastic general equilibrium models. They can also be influenced by economic theories. Second, the degrees of certainty about the values of the parameters are captured by the tightness of the priors. For instance, a loose prior would be used when there is little prior information about what the value of a parameter should be. Finally, the choices of priors also reflect restrictions on the parameters. For instance, Beta distributions are used for parameters that are restricted to be on the unit interval. Gamma distributions

[4] The selection of countries is primarily based on data availability.

and Inverse Gamma distributions are chosen for parameters in R^+ and standard deviations of shock processes respectively.

We set the prior mean of the capital share α, the discount factor β, and the depreciation rate δ at values commonly used in the literature with low standard deviation. The preference parameter γ is set at a mean of 20%, which reflects the average import share in the economies in question. However, we allow for a reasonably wide prior. The labor disutility parameter is assigned a prior mean of 2.5 with a large standard deviation. This implies a fairly inelastic labor supply, but is consistent with estimates in several recent empirical studies. The adjustment cost parameter ϕ is set at a value that implies fairly smooth investment dynamics as has been suggested by Baxter and Crucini (1993). The choice of prior for the exogenous stochastic processes follows common practice by assigning fairly large values to the autoregressive parameter. Finally, we do not estimate the portfolio adjustment cost parameter ζ. Instead, as in Bergin (2004), we assign it very small value, 0.0001, which preserves the stationarity of the model.[5]

4 Results

4.1 Parameter Estimates

Table 2 reports the posterior means and 90% posterior probability intervals for the parameters estimates in the benchmark model. The estimates are reasonable and broadly similar for the five countries. This is in line with the view that business cycles are all alike, both in developing and developed economies, since they are generated by the same underlying driving forces. A closer look reveals some interesting differences, however. Consistent with the conventional view that capital plays a more important role in the production of advanced economies than in developing economies, the posterior means for the estimates of capital share α are slightly higher in the three advanced economies compared to the two developing economies. They range from 0.367 to 0.379 for the advanced economies Australia, Canada, and New Zealand, and 0.347 to 0.350 for Mexico and Chile. On the other hand, capital depreciation rates are higher in the latter than in the former group.

The posterior means for the estimates of the inverse of elasticity of adjustment cost ϕ range from 0.310 to 0.568, which imply elasticities of 2 to 3. These values are substantially smaller than the benchmark value of 15 that Baxter and Crucini (1993) and many other papers in the calibration literature use in their one-good, two-country real business cycle model. This illustrates a potential pitfall of calibration. Adjustment cost parameters are typically chosen so that the model-implied investment volatility matches that found in the data. This is often done in disregard of the effects

[5] In preliminary work, we attempted to estimate this parameter. This resulted in implausibly large estimates that conflicted with restriction implied by the steady state. This point is further discussed in Lubik (2003).

on the behavior of other variables. This can lead to conclusions being drawn that a model does not perform well in explaining the stylized facts in specific directions.

Our estimation approach, on the other hand, 'adapts' the model to the observed data conditional on the cross-equation restrictions implied by theory. Since the model might be at odds with the data along some dimensions, the estimation procedure involves weighting overall model fit against the requirements of matching the behavior of individual variables. This tension can be seen by the difference between prior and posterior. The data clearly pull away the adjustment cost elasticity ϕ^{-1} from its high value used in calibration to our low estimates. We regard this as support against high adjustment costs.[6]

The estimates of the inverse of labor elasticity θ are also of interest. Their posterior means are above 3 in all five economies. These estimates are larger than those found by Justiniano and Preston (2004) in a monetary small open economy model without capital accumulation for Australia, Canada, New Zealand and United Kingdom, which have median values of 1 to 2. However, they are close to the values estimated by Elekdag, Justiniano and Tchakarov (2005) for Korea, with a median value of 4. 90% probability intervals are very wide, however, which reflects a lack of identification of this labor supply parameter and possibly misspecification of the employment and hours choice in the underlying model.[7] Finally, the discount factor β is tightly estimated at 0.99, while the preference parameter γ, the import share, varies from 0.178 to 0.211 with fairly wide probability intervals.

Another interesting result from Table 2 is that the estimated world interest rate processes are rather different for the five model economies. The posterior means for the autoregressive coefficients range from a low of 0.689 for Mexico to a high of 0.909 for Australia. Estimates of the technology shock parameters, on the other hand, are largely similar. Since we use data on the terms of trade, the estimates reflect the actual time series properties of this variable. Our results show that the terms of trade are most persistent for Canada and Mexico, while Australia's and Mexico's innovations to relative prices are most volatile. Since the five countries exhibit widely divergent export and import structures, this result is not surprising per se. To what extent this determines what drives business cycles in these economies we will address in what follows.

4.2 Impulse Response Functions

Before moving on to the results of the variance decomposition, it is instructive to study the dynamic behavior of the model economy. Impulse response functions to one standard deviation terms of trade,

[6] Although we do not use observations on investment - it is instead treated as an unobservable component -, the model implies dynamic behavior from which the adjustment cost elasticity parameter can be identified. Lubik and Schorfheide (2005) point out that this can have undesirable consequences from an identification point of view. We plan to address this issue in further research and use a larger data set.

[7] This issue is discussed extensively in Lubik and Schorfheide (2005), and also in a closed economy context by Lubik (2005b).

technology and world interest rate shocks are reported in Figure 1. Since the impulse responses are very similar for all five countries, only those of Australia are shown.

In response to a positive terms of trade shock, labor hours increase, as does output since the capital stock cannot adjust initially. The hours response fairly quickly dissipates on account of the low persistence of the terms of trade in Australia.[8] Before returning to its long-run level, the output response turns negative after several quarters. This is caused by a fall in investment and, thus, capital. An improvement in the terms of trade, i.e. the price of domestic goods relative to imports, increases domestic consumers' purchasing power, and thus the Harberger-Laursen-Metzler effect obtains (see Mendoza, 1995). This temporary windfall leads to an increase in net foreign assets (they increase on impact by 2% relative to their long-run level and continue to rise for a few periods) and the current account improves. At the same time as there is substitution away from capital as an asset towards foreign bonds, the labor supply rises to take advantage of the temporary windfall. Net foreign asset accumulation is highly persistent due to the incomplete markets assumption. In the longer run, consumption remains above steady state, while output and labor supply remain below, as consumers live off the interest payments from foreign asset holdings.

The response of hours worked and output to world interest rate shocks is largely similar. Both labor hours and output increase initially. As the interest rate increases, the representative agent reduces current consumption, which increases marginal utility. A marginal unit of hours worked will therefore be less costly in utility terms so that the representative agent will work more. As the increase in world interest rate slowly dissipates, consumption increases over time and overshoots the steady state before returning to the steady state value. Mirroring the time path of consumption, labor hours and output decline overtime and overshoot their steady state values before returning to them. Similarly, a positive productivity shock also leads to an increase in labor hours and output. Investment, capital, consumption, and net foreign assets all rise due to the persistent productivity increases.

4.3 Variance Decompositions

We now assess the contribution of world shocks to domestic business cycles by computing variance decompositions. The results are reported in Table 3. The most striking result is that the contribution of terms of trade shocks to output fluctuations is close to zero. The upper bound of the 90% coverage region reaches at best 4% in the case of Mexico. These estimates are even smaller than those found in the VAR literature. For instance, Hoffmaister and Roldós (1997) and Hoffmaister, Roldós, and Wickham (1998) find that terms of trade shocks can explain 7% of the output fluctuations in Asia

[8] The main difference in dynamic responses between the five countries is the speed of adjustment to shocks, consistent with the stochastic properties discussed in Section 4.1.

and Latin America and up to 15% of the output fluctuations in Africa. Similarly, using a structural VAR with long run restriction, Ahmed and Murthy (1994) find that terms of trade shocks explain up to 6% of the output fluctuations in Canada. Nevertheless, the results in Table 3 are in line with the results in Lubik and Schorfheide (2003), who find in their structural estimation of a monetary small open economy model that terms of trade shocks explain only up to 2% of the output fluctuations in four industrialized countries (Australia, Canada, New Zealand and United Kingdom). While the estimates of the contribution of terms of trade shocks to output fluctuations are essentially zero, their effects on labor hour fluctuations are slightly larger. For instance, up to 9% of the labor hour variability in Mexico can be attributed to terms of trade shocks.

The small contribution of terms of trade shocks makes for an interesting comparison with the results found in international real business cycle models. In a more elaborate model with three sectors of production– exportable, importable and non-traded sectors– Mendoza (1995) finds that terms of trade shocks account for nearly half of the output fluctuations in his model. Similarly, using a model that disaggregates terms of trade into relative price of capital goods and relative price of intermediate inputs, and calibrated to African data, Kose and Riezman (2001) find that fluctuations in relative prices explain roughly half of the variability of output in their model. Kose (2002) even reports that fluctuations in relative prices can account for almost 90% of output fluctuations. These results suggest that it might be necessary to allow for a richer production structure to accurately capture the contribution of terms of trade shocks to business cycle fluctuations.

In contrast, we find world interest rate shocks to be the most important driving force of business cycles in the five economies. Their contribution to output fluctuations ranges from a low of 40% in New Zealand to a high of 75% in Australia. An even more striking result is the contribution of world interest rate shocks to labor hour fluctuations: the lower bounds of the contribution of world interest rate shocks to labor hour fluctuations are larger than 80% in all five countries. These findings stand in marked contrast to most of the calibration literature. Using a model very similar to our benchmark model, Mendoza (1991) finds that world interest rate shocks have only small effects on output fluctuations in Canada. In particular, he finds that adding a world interest rate shock to a model with only technology shocks increases the predicted standard deviation of output by only 0.03%. This difference in results seems to arise from the fact that the shock processes in his paper are calibrated instead of estimated (see the discussion in the previous sections). For instance, the first-order autoregressive coefficients of technology and world interest rate processes are estimated to be larger than 0.8 for Canada in this paper. In contrast, Mendoza uses a value of only 0.36 for the first-order autoregressive coefficients of productivity and world interest rate in his calibrated model.

Similar results as ours are reported by Blankenau, Kose and Yi (2001). Their simulation approach is to calibrate only preference and technology parameters. They then make use of the equilibrium conditions of their model to back out the implied shock processes in Canadian data. This type of a simulated methods of moments approach goes beyond simple calibration in that it utilizes information from the implied cross-equation restrictions. It can be regarded as a step towards full-blown estimation without the burden of estimating all structural parameters. They find that world interest rate shocks can account for up to a third of output fluctuations[9]. However, their method is not fully efficient because they do not exploit all the cross-equation restrictions implied by the model. Finally, while the estimates of the contribution of world interest rate shocks are much higher than the results found in most of the studies in the VAR literature, it is consistent with Cushman and Zha (1997) who show that external shocks can explain up to 74% of the forecast variance of output in Canada.

What explains the dominant role of the world interest rate in our estimation results? At the heart of the model lies a strong wealth effect operating via the accumulation of net foreign assets. Positive shocks to the world interest rate prompt agents to strongly increase their foreign bond holdings, which is simply a substitution away from current consumption towards savings. At the same time, domestic households substitute away from investment as its relative return has declined. Terms of trade shocks, on the other hand, have only weak intratemporal substitution effects due to the simple structure of the model. The results are likely to be changed when more elaborate multi-sectoral production structure are taken into account. Since the data exhibit strong persistence, the estimation algorithm attempts to attribute this to the model's propagation mechanisms, one of which is net foreign asset accumulation. Due to the incomplete market structure, the model exhibits almost unit-root like behavior to the effect that its direct source, gross purchases of foreign bonds, essentially swamps the contribution of other shocks.

5 Sensitivity Analysis

In this section, we consider several deviations from the benchmark model to assess the robustness of the results. We begin by studying a model with a richer specification for the exogenous shock processes. Subsequently, we consider a version of the model that allows for contemporaneous adjustment in capital services. Finally, we compare the marginal data densities of the different models to determine which model provides the best fit.

[9] They include shocks to productivity, the depreciation rate and preferences in their model. However, since there is only a single perfectly substitutable good in their model, there are no meaningful terms of trade dynamics.

5.1 Alternative Shock Processes

In the benchmark model, we assume that the terms of trade and the world interest rate are univariate first-order autoregressive processes, and that their innovations are uncorrelated with each other. However, both variables are likely to share common underlying sources of their dynamics, such as business cycle fluctuations in the U.S., that affect international supply and demand for commodities (thus, the terms of trade) and capital (thus, the world interest rate). Instead of modeling the relationship between the rest of the world variables more formally (as in Justiniano and Preston, 2004, for instance), we attempt to capture it by means of a bi-variate autoregression with correlated disturbances.

We assume that the terms of trade and the world interest rate follow the joint process:

$$\begin{bmatrix} \hat{q}_t \\ \hat{R}_t \end{bmatrix} = \begin{bmatrix} \rho_q & \rho_{qR} \\ \rho_{Rq} & \rho_R \end{bmatrix} \begin{bmatrix} \hat{q}_{t-1} \\ \hat{R}_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}, \tag{18}$$

where ρ_{qR} captures the lag dependence of the terms of trade on the world interest rate; ρ_{Rq} captures the lag dependence of the world interest rate on the terms of trade; ε_{1t} and ε_{2t} are white noise shocks with standard deviations, σ_1 and σ_2, respectively; the correlation between ε_{1t} and ε_{2t} are denoted by ρ_{12}. We specify the prior distributions for ρ_{Rq}, ρ_{qR} and ρ_{12} to be Normal with zero means and standard deviations equal to 0.1. The prior distributions for $\sigma_1$and σ_2 are the same as their benchmark counterparts, σ_q and σ_R.

Table 4 reports the posterior means and 90% posterior probability intervals for the estimates of the structural parameters. Compared to the benchmark model, the posterior means for the estimates of the inverse elasticity of labor supply, θ, and the first-order autoregressive coefficient of terms of trade, ρ_q, are slightly smaller. The posterior means for the estimates of the lag dependence coefficients, ρ_{Rq} and ρ_{qR}, as well as the correlation of shocks, ρ_{12}, are all close to zero. Moreover, the absolute values for the lower and upper bounds of the estimates of these three parameters only exceed 0.2 in one case – the upper bound of the estimates of ρ_{qR} for Mexico, with a value of 0.259.

The impulse response functions of the model in this subsection are broadly similar to those of the benchmark model, so we proceed directly to the discussion of the results from the variance decomposition, reported in Table 5. The outcome is very similar to the benchmark case. While terms of trade shocks contribute now 2 to 5 times as much to output fluctuations, they are still relatively small. Mexico has the largest mean, but even in this case, it is smaller than 8%. The upper bound for the contribution of the terms of trade shocks to the output fluctuations in Mexico is a modest 17%. Consistent with the benchmark results, the estimates for the contribution of the terms of trade shocks to labor hour fluctuations are larger than the estimates of their contribution to the output fluctuations. Mexico again has the highest upper bound of the contribution of terms of trade shocks to the labor hour fluctuations at 24%. The fact that the variance decomposition results in this subsection are broadly in line with the benchmark case is not surprising considering that the estimates of the 3 new parameters, ρ_{Rq}, ρ_{qR} and ρ_{12}, are close to zero and the estimates of other structural parameters do not differ much from the benchmark case.

5.2 Variable Capacity Utilization

In the benchmark model, the capital stock is a predetermined variable as newly installed capital becomes productive only one period hence. In response to shocks, output can only move contemporaneously through adjustment of labor hours worked. This implies that output movements are tightly linked to labor supply elasticities and, thus, marginal utility, which can result in counterfactual labor movements. Some studies have suggested that while the capital stock might not be able to change contemporaneously, the intensity with which it is used can be altered (Greenwood, Hurcowitz and Huffman, 1988; Burnside and Eichenbaum, 1996). This idea is known as variable capacity utilization in the literature. In this section, we introduce variable capacity utilization into the model to assess the robustness of the results.

Let u_t be the capital utilization rate. The production function and the capital accumulation equation in the model with variable capacity utilization are specified as:

$$Y_t = A_t(u_t K_{t-1})^{\alpha}(L_t)^{1-\alpha}, \quad (19)$$

$$K_t = (1 - u_t^{\nu}\delta)K_{t-1} + \varphi(\frac{I_t}{K_{t-1}})K_{t-1}, \quad (20)$$

where $\nu > 0$ is a parameter that controls the rate at which differential utilization of capital affects the rate of depreciation of the capital stock[10]. Normalizing the steady state capital utilization rate to 1, the parameter δ can be interpreted as the steady state depreciation rate. This functional form for the depreciation rate also implies that a restriction between the parameters ν and δ.[11] The first-order condition for capital utilization rate is given by:

$$\nu\delta u_t^{\nu} = \alpha q_t^{\gamma}\frac{Y_t}{K_{t-1}}\varphi'(\frac{I_t}{K_{t-1}}), \quad (21)$$

[10] The functional form for the time varying depreciation rate of capital stock used in this model follows Burnside and Eichenbaum (1996).

[11] In the steady state, the capital Euler equation and the first-order condition for capital utilization rate are:

$$\beta\bar{q}^{\gamma}\alpha\frac{\bar{Y}}{\bar{K}} = 1 - \beta(1-\delta),$$

$$\nu\delta = \alpha q^{\gamma}\frac{\bar{Y}}{\bar{K}}.$$

Combining the two equations, we obtain an inverse relation between δ and ν:

$$\nu = \frac{1-\beta(1-\delta)}{\beta\delta}.$$

In our estimation, we use this relation to substitute out ν, and parameterize the empirical model in terms of δ to maintain comparability with the benchmark model.

We can use this relationship to substitute out u_t, which results in a system of equations with the same set of variables as the benchmark model. Consequently, we proceed to estimate this alternative model with the same priors and data. The estimation results are reported in Table 6.

Compared to the benchmark results, the most conspicuous difference is that the posterior means for the estimates of the steady state depreciation rate δ are less than half the values estimated from the benchmark model for the three advanced countries. The posterior means for the two developing countries decline slightly, too. In addition to the estimates for δ, the posterior means for the estimates of the inverse elasticity of labor θ and the inverse elasticity of adjustment cost ϕ are also lower in the variable capacity utilization model.[12] There are also some noteworthy differences in the estimated shock processes. First, the estimates of the standard deviation of productivity shocks are larger in the variable capacity utilization model. This result is contrary to the argument of Burnside and Eichenbaum (1996) that part of the estimated variability of productivity shocks in models without variable capacity utilization reflects changes in capital utilization rate. It is also of interest to note that the standard deviations of world interest rate shocks are smaller in the variable capacity utilization model for three of the model economies, New Zealand, Mexico and Chile.

Similar to the model in the last subsection, the impulse response functions of the variable capacity utilization model turn out to be broadly similar to those of the benchmark case. Therefore, we proceed directly to the discussion of the results from the variance decomposition analysis. As can be seen from Table 7, the results are very similar to the benchmark case. Terms of trade shocks are now two to three times as important for driving output compared to the benchmark model, although the upper bound of the of the 90% coverage probability is still less than 8%. Similar results emerge for their contribution to labor fluctuations, with an upper bound of 16% for Mexico. The estimates of the contribution of world interest rate shocks are smaller compared to the benchmark model, however. The posterior means of the contribution of world interest rate shocks to output fluctuations range from 27% in New Zealand to 62% in Australia, compared to 40% and 75% in the benchmark model. The posterior means of the contribution of world interest rate shocks to labor hour fluctuations also decline from over 90% in all five economies in the benchmark model to ranging from 72% to 93% in the variable capacity utilization model. This is likely due to the lower standard deviations of world interest rate shocks and the higher standard deviations of productivity shocks in the variable capacity utilization model. Overall, however, the conclusions we arrived at in the benchmark model remain unaffected.

[12] Similar findings are reported and discussed in Lubik (2005a).

5.3 Model Comparison

Finally, we evaluate which of the model specifications provides the best fit. Table 8 shows the marginal data densities for the three models considered in this paper. The marginal data densities are approximated using Geweke's (1999) harmonic mean estimator. The marginal data densities can be interpreted as likelihood values of the model given the data with the structural parameters integrated out. The marginal data densities penalize over-parameterization. A simple model comparison involves comparing the densities, with the preferred model having the highest value.

As can be seen from the table, the benchmark model has the highest marginal data densities for all five model economies. This means that the data favor the benchmark model over the alternatives. The better performance of the benchmark model over the model with a vector autoregressive exogenous process lends some support to the common practice in the literature, which usually treats exogenous shock processes as uni-variate processes. The poorer performance of the variable capacity utilization model might be due to the restrictive relation between the steady state depreciation rate, δ, and the capital utilization parameter, ν, implied by the model. Using a functional form that decouples the capital utilization parameter from the steady state depreciation rate might improve the fit of the variable capacity utilization model, but we leave that for future research.

6 Conclusion

We estimate a dynamic stochastic general equilibrium model of a small open economy using Bayesian methods. Our focus is on the contribution of world shocks to the business cycles of small open economies. Contrary to previous studies we fully exploit the cross-equation restrictions implied by the model to distinguish between the contributions of individual shocks instead of conditioning on one shock at a time. Our approach also allows us to formally take into consideration of uncertainty surrounding the structural parameters. Our main finding is that terms of trade shocks have only very small contribution to the fluctuations of output and labor hours while world real interest rate shocks are important driving forces of business cycles in Australia, Canada, New Zealand, Mexico and Chile.

Naturally, our findings are likely to be model dependent. Therefore, more work needs to be done to investigate the robustness of the results in this paper. We believe several extensions would be particularly useful. First, as mentioned briefly above, it would be instructive to investigate the robustness of the results in this paper in models with richer production structure. A non-traded sector can be introduced into the model and the terms of trade can be disaggregated into relative prices of different kinds of goods as in Kose and Riezman (2001) and Kose (2002). A richer production structure might introduce more endogenous transmission mechanism and allow for terms of trade shocks to have bigger effects on business cycles.

Second, additional data can be used in the estimation and more shocks can be introduced into the model. While the use of additional data and the inclusion of additional shocks are not totally independent of each other as a technical matter[13], both are of independent interest. Additional data can provide more information about the actual economic environment while additional shocks can provide a more complete characterization of the reality. For the model in this paper, additional data can come from data on net exports, consumption and investment. Shocks that can be readily introduced into the model include shocks on consumption preferences, labor hour preferences and the depreciation rate of capital.

Finally, the analysis can be extended to models with nominal rigidity where monetary policy plays a role. The effects of world shocks on the business cycles of small open economies can then be compared alongside their exchange rate or monetary policies. Terms of trade shocks, for instance, might have smaller effects on the business cycles of countries with flexible exchange rate regimes. Domestic monetary policy might also be an independent driving force of business cycles.

[13] Specifically, the estimation procedure requires the number shocks in the model to be no less than the number of data series.

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Parameter		Range	Density	Para (1)	Para (2)	90% Interval	
α	Share of capital	[0,1)	B	0.34	0.02	0.3074	0.3732
β	Discount factor	[0,1)	B	0.99	0.002	0.9865	0.9930
γ	Import share	[0,1)	B	0.2	0.05	0.1235	0.2874
δ	Depreciation rate	[0,1)	B	0.025	0.005	0.0174	0.0337
θ	Inverse of labor elasticity	R^+	G	2.5	1.5	0.8782	4.7942
ϕ	Inverse of adjustment cost elasticity	R^+	G	0.2	0.1	0.0002	0.8310
ρ^q	AR coeff. of terms of trade	[0,1)	B	0.8	0.1	0.6146	0.9389
ρ^A	AR coeff. of technology	[0,1)	B	0.9	0.02	0.8652	0.9308
ρ^R	AR coeff. of interest rate	[0,1)	B	0.8	0.1	0.6146	0.9389
σ^q	SD of terms of trade shock	R^+	IVG	0.015	1	0.0128	0.0180
σ^A	SD of technology shock	R^+	IVG	0.015	1	0.0128	0.0180
σ^R	SD of interest rate shock	R^+	IVG	0.015	1	0.0128	0.0180

Table 1: Prior Distribution

Notes: B, G, IVG refer to Beta, Gamma and Inverse Gamma distributions respectively. Para (1) and Para (2) correspond to means and standard deviations for Beta and Gamma distributions; s and v for the Inverse Gamma distribution, where p(σ|v,s) $\propto \sigma^{-v-1} e^{-vs^2/2\sigma^2}$. "SD" denotes standard deviation, "AR" denotes autoregressive and "coeff." denotes coefficient.

	Australia	Canada	New Zealand	Mexico	Chile
α	0.379	0.377	0.367	0.347	0.350
	[0.339, 0.409]	[0.349, 0.411]	[0.339, 0.393]	[0.311, 0.380]	[0.323, 0.385]
β	0.990	0.990	0.990	0.990	0.990
	[0.988, 0.993]	[0.988, 0.993]	[0.987, 0.993]	[0.987, 0.993]	[0.987, 0.994]
γ	0.178	0.191	0.203	0.211	0.196
	[0.099, 0.242]	[0.132, 0.261]	[0.135, 0.280]	[0.116, 0.289]	[0.125, 0.276]
δ	0.019	0.020	0.021	0.022	0.023
	[0.012, 0.025]	[0.014, 0.027]	[0.014, 0.029]	[0.014, 0.030]	[0.016, 0.030]
θ	5.422	5.368	4.678	5.828	3.667
	[3.717, 7.366]	[3.713, 7.518]	[2.706, 6.345]	[3.440, 8.578]	[2.399, 5.247]
ϕ	0.568	0.501	0.429	0.331	0.310
	[0.370, 0.786]	[0.305, 0.709]	[0.244, 0.578]	[0.145, 0.451]	[0.146, 0.465]
ρ_q	0.665	0.832	0.600	0.808	0.623
	[0.533, 0.788]	[0.748, 0.912]	[0.495, 0.705]	[0.707, 0.912]	[0.502, 0.733]
ρ_R	0.909	0.796	0.703	0.689	0.77
	[0.873, 0.956]	[0.719, 0.882]	[0.584, 0.817]	[0.525, 0.848]	[0.680, 0.897]
ρ_A	0.904	0.904	0.891	0.884	0.895
	[0.885, 0.937]	[0.876, 0.934]	[0.856, 0.928]	[0.849, 0.920]	[0.865, 0.934]
σ_q	0.019	0.008	0.013	0.018	0.009
	[0.017, 0.020]	[0.007, 0.009]	[0.011, 0.015]	[0.015, 0.021]	[0.007, 0.011]
σ_R	0.011	0.017	0.032	0.033	0.035
	[0.006, 0.015]	[0.010, 0.027]	[0.019, 0.051]	[0.011, 0.047]	[0.016, 0.051]
σ_A	0.015	0.010	0.017	0.013	0.027
	[0.013, 0.017]	[0.008, 0.011]	[0.015, 0.019]	[0.011, 0.016]	[0.022, 0.032]

Table 2: Parameter Estimates for the Benchmark Model

Notes: Results reported are posterior means and 90% probability intervals (in brackets).

	Variance Decomposition of Output				
Shocks	Australia	Canada	New Zealand	Mexico	Chile
Terms of Trade	0.003	0.006	0.003	0.022	0.001
	[0.001, 0.005]	[0.001, 0.010]	[0.001, 0.007]	[0.005, 0.037]	[0.000, 0.002]
Technology	0.245	0.419	0.598	0.470	0.483
	[0.075, 0.399]	[0.211, 0.659]	[0.405, 0.773]	[0.212, 0.665]	[0.294, 0.713]
Interest Rate	0.752	0.575	0.398	0.508	0.516
	[0.592, 0.921]	[0.325, 0.777]	[0.224, 0.594]	[0.303, 0.776]	[0.287, 0.705]
	Variance Decomposition of Labor Hours				
Shocks	Australia	Canada	New Zealand	Mexico	Chile
Terms of Trade	0.009	0.013	0.013	0.048	0.003
	[0.002, 0.015]	[0.004, 0.023]	[0.002, 0.025]	[0.013, 0.087]	[0.001, 0.004]
Technology	0.016	0.029	0.062	0.039	0.066
	[0.003, 0.030]	[0.007, 0.053]	[0.013, 0.115]	[0.008, 0.073]	[0.019, 0.115]
Interest Rate	0.975	0.958	0.925	0.912	0.931
	[0.955, 0.995]	[0.924, 0.989]	[0.853, 0.973]	[0.850, 0.977]	[0.880, 0.980]

Table 3: Variance Decomposition for the Benchmark Model

Notes: Results reported are posterior means and 90% probability intervals (in brackets).

	Australia	Canada	New Zealand	Mexico	Chile
α	0.381	0.379	0.356	0.347	0.353
	[0.352, 0.414]	[0.351, 0.409]	[0.327, 0.390]	[0.310, 0.377]	[0.326, 0.381]
β	0.990	0.990	0.990	0.991	0.990
	[0.988, 0.993]	[0.987, 0.993]	[0.988, 0.994]	[0.987, 0.994]	[0.988, 0.993]
γ	0.181	0.206	0.190	0.193	0.197
	[0.102, 0.245]	[0.139, 0.288]	[0.117, 0.259]	[0.106, 0.256]	[0.120, 0.291]
δ	0.019	0.020	0.019	0.022	0.024
	[0.013, 0.024]	[0.013, 0.028]	[0.014, 0.025]	[0.016, 0.029]	[0.015, 0.031]
θ	4.778	4.608	4.314	3.886	3.635
	[3.429, 6.203]	[2.777, 6.107]	[2.977, 5.627]	[2.087, 5.769]	[1.816, 5.234]
ϕ	0.488	0.502	0.386	0.284	0.336
	[0.287, 0.650]	[0.284, 0.658]	[0.241, 0.543]	[0.150, 0.411]	[0.141, 0.522]
ρ_q	0.634	0.823	0.584	0.781	0.608
	[0.563, 0.734]	[0.735, 0.915]	[0.445, 0.698]	[0.682, 0.877]	[0.512, 0.712]
ρ_R	0.894	0.794	0.732	0.747	0.755
	[0.844, 0.955]	[0.706, 0.867]	[0.643, 0.811]	[0.652, 0.852]	[0.656, 0.842]
ρ_A	0.909	0.899	0.893	0.894	0.903
	[0.883, 0.942]	[0.870, 0.935]	[0.861, 0.937]	[0.849, 0.940]	[0.868, 0.938]
ρ_{qR}	0.020	-0.013	0.022	0.084	-0.047
	[-0.063, 0.097]	[-0.051, 0.027]	[-0.059, 0.107]	[-0.048, 0.259]	[-0.094, -0.010]
ρ_{Rq}	-0.002	0.018	0.016	-0.058	-0.021
	[-0.070, 0.042]	[-0.050, 0.112]	[-0.137, 0.146]	[-0.110, -0.009]	[-0.138, 0.103]
σ_1	0.019	0.008	0.013	0.019	0.009
	[0.017, 0.021]	[0.008, 0.009]	[0.011, 0.014]	[0.016, 0.023]	[0.007, 0.010]
σ_2	0.013	0.016	0.028	0.016	0.037
	[0.005, 0.020]	[0.010, 0.022]	[0.017, 0.040]	[0.008, 0.025]	[0.021, 0.053]
σ_A	0.015	0.010	0.017	0.013	0.027
	[0.013, 0.016]	[0.009, 0.011]	[0.016, 0.020]	[0.010, 0.015]	[0.022, 0.031]
ρ_{12}	-0.038	-0.031	0.032	-0.043	-0.045
	[-0.183, 0.112]	[-0.150, 0.112]	[-0.111, 0.179]	[-0.184, 0.065]	[-0.147, 0.120]

Table 4: Parameter Estimates for the Model with VAR Shock Processes

Notes: Results reported are posterior means and 90% probability intervals (in brackets).

Shocks	Variance Decomposition of Output				
	Australia	Canada	New Zealand	Mexico	Chile
Terms of Trade	0.014	0.030	0.015	0.076	0.006
	[0.001, 0.041]	[0.000, 0.080]	[0.000, 0.037]	[0.000, 0.170]	[0.000, 0.012]
Technology	0.270	0.417	0.571	0.580	0.556
	[0.099, 0.406]	[0.255, 0.635]	[0.350, 0.735]	[0.402, 0.804]	[0.331, 0.800]
Interest Rate	0.716	0.553	0.414	0.343	0.438
	[0.539, 0.864]	[0.362, 0.738]	[0.211, 0.620]	[0.161, 0.566]	[0.219, 0.679]
	Variance Decomposition of Labor Hours				
Shocks	Australia	Canada	New Zealand	Mexico	Chile
Terms of Trade	0.021	0.043	0.038	0.113	0.010
	[0.002, 0.047]	[0.000, 0.102]	[0.001, 0.094]	[0.004, 0.243]	[0.000, 0.026]
Technology	0.019	0.033	0.059	0.096	0.091
	[0.007, 0.030]	[0.009, 0.056]	[0.021, 0.100]	[0.020, 0.174]	[0.016, 0.160]
Interest Rate	0.960	0.924	0.902	0.791	0.899
	[0.934, 0.989]	[0.875, 0.988]	[0.832, 0.978]	[0.641, 0.946]	[0.831, 0.979]

Table 5: Variance Decomposition for the Model with VAR Shock Processes

Notes: Results reported are posterior means and 90% probability intervals (in brackets).

	Australia	Canada	New Zealand	Mexico	Chile
α	0.353	0.360	0.339	0.325	0.327
	[0.318, 0.383]	[0.333, 0.397]	[0.308, 0.364]	[0.299, 0.351]	[0.292, 0.355]
β	0.981	0.982	0.983	0.986	0.987
	[0.977, 0.985]	[0.979, 0.986]	[0.980, 0.987]	[0.983, 0.990]	[0.984, 0.990]
γ	0.204	0.201	0.190	0.195	0.211
	[0.117, 0.290]	[0.126, 0.277]	[0.121, 0.255]	[0.111, 0.278]	[0.130, 0.298]
δ	0.003	0.004	0.007	0.018	0.016
	[0.002, 0.005]	[0.002, 0.007]	[0.004, 0.010]	[0.011, 0.025]	[0.009, 0.023]
θ	3.228	2.929	2.479	3.196	2.239
	[2.356, 4.105]	[2.130, 3.985]	[1.697, 3.171]	[1.809, 4.002]	[1.228, 3.190]
ϕ	0.230	0.207	0.226	0.178	0.208
	[0.131, 0.407]	[0.072, 0.300]	[0.096, 0.409]	[0.041, 0.258]	[0.085, 0.375]
ρ_q	0.624	0.816	0.581	0.810	0.622
	[0.465, 0.775]	[0.749, 0.926]	[0.485, 0.690]	[0.707, 0.944]	[0.487, 0.747]
ρ_R	0.885	0.796	0.666	0.801	0.765
	[0.826, 0.944]	[0.745, 0.879]	[0.584, 0.779]	[0.710, 0.927]	[0.646, 0.898]
ρ_A	0.909	0.903	0.899	0.905	0.893
	[0.875, 0.936]	[0.877, 0.929]	[0.864, 0.933]	[0.875, 0.936]	[0.863, 0.927]
σ_q	0.018	0.008	0.013	0.020	0.009
	[0.017, 0.020]	[0.007, 0.009]	[0.011, 0.014]	[0.016, 0.024]	[0.008, 0.011]
σ_R	0.010	0.011	0.021	0.012	0.022
	[0.006, 0.014]	[0.007, 0.014]	[0.015, 0.028]	[0.008, 0.020]	[0.013, 0.032]
σ_A	0.018	0.012	0.022	0.020	0.043
	[0.015, 0.020]	[0.010, 0.013]	[0.018, 0.025]	[0.015, 0.023]	[0.034, 0.053]

Table 6: Parameter Estimates for the Variable Capacity Utilization Model

Notes: Results reported are posterior means and 90% probability intervals (in brackets).

	Variance Decomposition of Output				
Shocks	Australia	Canada	New Zealand	Mexico	Chile
Terms of Trade	0.007	0.013	0.009	0.043	0.002
	[0.001, 0.013]	[0.004, 0.023]	[0.002, 0.014]	[0.014, 0.075]	[0.001, 0.003]
Technology	0.377	0.522	0.726	0.519	0.650
	[0.213, 0.625]	[0.366, 0.683]	[0.623, 0.843]	[0.328, 0.749]	[0.438, 0.862]
Interest Rate	0.616	0.464	0.265	0.438	0.348
	[0.366, 0.784]	[0.312, 0.627]	[0.150, 0.369]	[0.235, 0.672]	[0.131, 0.557]
	Variance Decomposition of Labor Hours				
Shocks	Australia	Canada	New Zealand	Mexico	Chile
Terms of Trade	0.016	0.027	0.026	0.092	0.005
	[0.005, 0.030]	[0.008, 0.045]	[0.011, 0.042]	[0.014, 0.160]	[0.001, 0.008]
Technology	0.053	0.091	0.252	0.154	0.277
	[0.009, 0.098]	[0.035, 0.149]	[0.128, 0.386]	[0.030, 0.260]	[0.085, 0.511]
Interest Rate	0.931	0.881	0.722	0.754	0.718
	[0.873, 0.984]	[0.810, 0.955]	[0.590, 0.855]	[0.611, 0.956]	[0.482, 0.914]

Table 7: Variance Decomposition for the Variable Capacity Utilization Model

Notes: Results reported are posterior means and 90% probability intervals (in brackets).

	Marginal Data Densities		
	Benchmark	VAR Shock Processes	Variable Capacity Utilization
Australia	815.733	812.930	757.369
Canada	873.821	870.618	816.533
New Zealand	532.101	526.347	487.095
Mexico	250.774	250.685	229.668
Chile	223.981	223.117	198.753

Table 8: Model Comparison

Notes: Results reported are marginal data densities as approximated by Geweke's (1999) harmonic mean estimator.

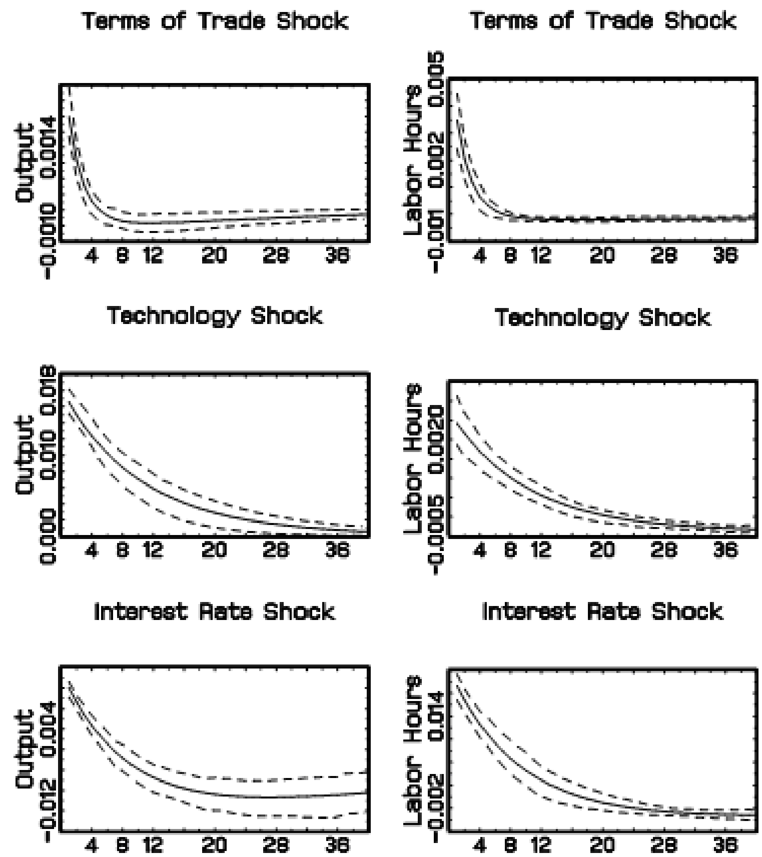

Figure 1: Impulse Responses for Australia for the Benchmark Model