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Abstract

Recent literature suggests that risk shocks – idiosyncratic uncertainty on asset returns – plays an important role in explaining business cycle fluctuations. In this paper, we study the effect of risk shocks in a small open economy with tradable and non-tradable sectors of production. Following Christiano, Motto and Rostagno (2014), we assume that firms are subject to uncertainty when converting raw capital into effective capital. Due to the financial frictions, when risk is high firms pay higher borrowing costs. This leads to a decline in investment and output. We conduct Bayesian estimation and draw implications on the sources of the Canadian business cycle. Our findings suggest that a significant fraction of the fluctuations in output, investment, risk premium and firms' net worth can be accounted for by risk shocks.

JEL: classification: E31;E32
Keywords: Risk; Financial frictions; Business Cycles.

*Views expressed in this paper are those of the authors and should not be attributed to the European Central Bank.

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1 Introduction

Since the seminal paper of Bloom (2009) a growing strand of the macroeconomic literature started investigating the role of fluctuations in uncertainty for business cycle dynamics. In the context of a DSGE model, Christiano, Motto and Rostagno (2014) document that idiosyncratic uncertainty experienced by entrepreneurs (risk shocks) is the most important source of business cycle fluctuations in the U.S. economy. Indeed, they document that risk shocks account for 60 percent of the fluctuations in the growth rate of aggregate US output since the mid-1980. Arellano, Bai and Kehoe (2012) argue that increased idiosyncratic volatility at the firm level accounted for about 70 per cent of the decline in output during the Great Recession of 2007-2009. Gilchrist, Sim and Zakrajšek (2014) use micro- and macro-level evidence to support the idea that financial frictions are an important part of the mechanism through which uncertainty shocks affect the economy.

This paper explores the role of risk shocks in a small open economy model with tradable and non-tradable good producers. The tradable sector produces goods that are exported or used domestically, whereas the non-tradables sector produces goods that are destined only for the local market. Following Christiano, Motto and Rostagno (2014) (CMR hereafter), we model risk shocks as disturbances to the variance of the cross-sectional idiosyncratic volatility to the sector-specific returns of capital. In the model, entrepreneurs in both tradable and non-tradable sectors need to borrow from external sources to finance their capital acquisition. Given the information asymmetry between the entrepreneurs and the external financiers, the borrowing costs are negatively related to volatility in the capital returns. Differently from CMR, our risk shocks are sector-specific. We assume that risk shocks faced by the entrepreneurs in the tradable sector are different from those in the non-tradable sector. This not only allows us to examine the role of risk shocks at the sectoral level, but also to study the spill-over from one sector to the other.

Our model also features a rich stochastic structure that takes into account several other sources of business cycle fluctuations, including sectoral level equity shocks, technology shocks and a variety of other aggregate shocks, as typically considered in the DSGE literature. We use Canada as a benchmark small open economy and estimate the model using Canadian aggregate and sectorial data for the domestic economy and US data for the rest of the world. The use of sector level data on credit and net worth helps us to pin down the sector-level of risk shocks.[1]

Our findings suggest that changes in the volatility of the capital returns in both tradable and non-tradable sectors of production are quantitatively important in generating aggregate business cycle dynamics. Higher uncertainty in one sector increases the default probability of entrepreneurs operating in the sector. As a result, the risk premium rises implying higher borrowing costs in the sector. Thus, debt, net worth, investment and output fall. In contrast, the other sector experiences easier financial conditions since the risk is relatively lower. At the aggregate level, however, a sector-

[1] See Dib (2008) for the importance of multi-tiered production sector in a small open-economy model for Canada. See also Bouakez, Cardia, and Ruge-Murcia (2009) who use input-output tables to describe in even finer detail the various levels of production.

specific risk shock still lead to a decline in aggregate investment and GDP. Our results suggest that risk shocks account for about 30% of the fluctuations in GDP, 20% of the fluctuations in investment, 40% of the fluctuations in the risk premium and a sizable portion of fluctuations in the firms' net worth.

Although this paper represents the first attempt to quantify the role of risk shocks for the business cycle in Canada, our work is related to the previous estimated models of the Canadian economy. Closed-economy DSGE models of the Canadian economy have been estimated by, among others, Dib (2003, 2006), Dib, Gammoudi and Moran(2008), Atta-Mensah and Dib (2008) and Covas and Zhang (2010). For estimated small open economy models of the Canadian economy, see Ambler, Dib and Rebei (2004), Justiniano and Preston (2010a, 2010b) and Lubik and Schorfheide(2005) for standard one sector models; Ortega and Rebei (2006) for a two-sector small open economy model model; Dib (2008) for a multi-sector model; and Dib, Mendicino and Zhang (2013) for a multi-sector model with credit frictions. In particular, our paper is closely related to Dib, Mendicino and Zhang (2013).

The rest of the paper proceeds as follows. Section 2 describes the model. Section 3 presents the estimation methodology and data. Section 4 presents the results, discusses the model property and assesses the role of the risk shocks. Section 5 presents the conclusions of the study.

2 The Model

We follow CMR to assume that entrepreneurs (the wholesale producers in the economy) are subject to risk shocks. When entrepreneurs convert raw capital into effective capital, they are subject to idiosyncratic uncertainty on their returns. We refer to the degree of dispersion in the uncertain return as "risk". In particular, we consider the production of tradable and non-tradable goods and allow risk shocks to be sector-specific.

The basic setup of the model is as follows. Households work, consume and save by buying either domestic bonds or foreign bonds. In each sector, in addition to entrepreneurs, who produce wholesale goods, there are capital producers, who provide capital, and retailers, who package together wholesale goods to produce final output at the sector level. The retailers are monopolistically competitive and set nominal prices on a staggered fashion. Finally, there are final goods producers, who produce final consumption and investment goods using sector-specific final goods. We also consider a government who balance the budget and a monetary authority who conduct monetary policy following a standard Taylor rule.

We start this section by describing the problem that the entrepreneurs face and introducing the risk shock. We then describe the remaining features of the model, which allow the model to match the main properties of the Canadian business cycle.

2.1 Risk Shocks and Entrepreneurs

There are two sectors of production in the economy: the tradable (T) and the non-tradable (NT). In each sector $i = \{N, T\}$, entrepreneur j produces intermediate goods using labor services and sector-specific capital

$$Y_{i,t}(j) = A_{i,t}(K_{i,t}(j))^{\alpha}(L_{i,t}(j))^{1-\alpha},$$

where $A_{i,t}$ is the technology shock which follows an AR(1) process

$$\log A_{i,t} = \rho_{A,i} \log A_{i,t-1} + \epsilon_t^{A_i}, \epsilon_{i,t}^{A_i} \sim i.i.d.N(0, \sigma_{\epsilon^{A_i}}^2).$$

Entrepreneur j transforms raw physical capital $K_t(j)$ into efficiency unit $\omega_t(j)K_t(j)$, where $\omega_t(j)$ is an idiosyncratic shock to returns to capital. Sometimes the realization of ω_t is high, i.e. the entrepreneur j enjoys a high return of converting capital $K_t(j)$; sometimes the realization of ω_t is low, i.e. entrepreneur j suffers from a low return of converting capital. We assume that ω_t has a log normal distribution that is independently drawn across time and across entrepreneurs, with $E(\omega_t) = 1$, and the standard deviation of $log(\omega_t)$ is denoted by σ_t. We use $F(\omega_t)$ to denote the cumulative distribution function of ω_t. We refer to σ_t as to a risk shock. This captures the extent of cross sectional dispersion in ω_t, which varies stochastically over time. Following CMR, we assume that the risk shock has an unanticipated and an anticipated component (news)

$$\log \sigma_{i,t} = \rho_{\sigma,i} \log \sigma_{i,t-1} + \epsilon_{0,t}^{\sigma_i} + \epsilon_{1,t-1}^{\sigma_i} + ... + \epsilon_{p,t-p}^{\sigma_i},$$

where $\epsilon_{0,t}^{\sigma_i}$ is the unanticipated component with

$$\epsilon_{0,t}^{\sigma_i} \sim i.i.d.N(0, \sigma_{ua,\epsilon^{\sigma_i}}^2),$$

and $\epsilon_{1,t-1}^{\sigma_i}$, $\epsilon_{1,t-1}^{\sigma_i}$, ...$\epsilon_{p,t-p}^{\sigma_i}$ are the news components with

$$\epsilon_{p,t-p}^{\sigma_i} \sim i.i.d.N(0, \sigma_{a,\epsilon^{\sigma_i}}^2).$$

In the period $t + 1$ after the shock is realized, the entrepreneurs rent out the effective capital in competitive markets at a rent equal to $\omega_t K_{t+1} r_{t+1}^k$. At the end of production in period $t + 1$, the entrepreneur is left with $(1 - \delta)\omega_t K_{t+1}$ physical capital after depreciation. This capital is sold in competitive markets to households at the prices $q_{i,t-1}$.The return on capital is

$$E_t R_{i,t+1}^k = \frac{E_t[p_{i,t+1}^w \alpha \frac{y_{i,t+1}}{k_{i,t+1}} + q_{i,t+1}(1 - \delta)]}{q_{i,t}},$$

where $p_{i,t+1}^w$ is the relative price for the wholesale products in the tradable and non-tradable sectors.

As in Bernarke et al (BGG hereafter) and CMR, we assume that entrepreneurs borrow to finance part of their investment in capital used in the production processes. In order to capture the different dynamics of the financial variables (debt/credit and equity) in the tradable and non-tradable sectors, we assume that the financial intermediaries are specialized in lending to a particular sector.[2] At the end of period t, entrepreneur j in sector i uses its own net worth $N_{t+1}(j)$ and borrows $B_{t+1}(j)$, to purchase capital at price $q_{i,t}$,

$$B_{i,t+1}(j) = q_{i,t}K_{i,t+1}(j) - N_{i,t+1}(j).$$

The financial intermediaries receive deposits from households, provide loans to entrepreneurs and operate in a perfectly competitive markets. Following BGG, the financial intermediaries cannot observe the idiosyncratic shocks ω_t unless they pay a monitoring cost. In this environment, the loan contracts between the financial intermediaries and the entrepreneurs are standard debt contracts, which are characterized by a gross non-default loan rate, Z_{t+1}, and a threshold value for of the idiosyncratic shock, $\bar{\omega}$. Since the financial intermediaries operate in a perfectly competitive market, they earn zero profit. In equilibrium, the following equation holds for the intermediaries lending to the sector i

$$(1 - F_t(\bar{\omega}_{i,t+1}))Z_{i,t+1}B_{i,t+1} + (1-\mu)\int_0^{\bar{\omega}_i} \omega_t R^k_{i,t+1} q_{i,t} K_{i,t+1} dF_t(\omega_t) \geq B_{i,t+1}R_{t+1}. \tag{1}$$

Equation (1) means that the average return of the loans made to the entrepreneurs has to be equal to the repayment to the households, whose deposits earn a safe return R_{t+1}. The average return consists of two terms: The first term indicates the revenues received from the entrepreneurs with $\omega_t \geq \bar{\omega}$ and the second term indicates the revenues received from the entrepreneurs with $\omega_t < \bar{\omega}$, i.e. the entrepreneurs that are not able to repay the loan. In this situation the intermediaries pay the auditing costs $\mu \int_0^{\bar{\omega}_i} \omega_t R^k_{i,t+1} q_{i,t} K_{i,t+1} dF_t(\omega_t)$ and get the remaining part, where μ is the proportion of the assets used as the monitoring costs.

Given the assumption of constant-returns-to-scale in production, the relationship between the demand for capital goods and net worth of the entrepreneurs is linear. The evolution of aggregate net worth for sector i is

$$N_{i,t+1} = \gamma_{i,t}\zeta_i[R^k_{i,t}q_{i-1,t}K_{i,t} - (R_t + \frac{\mu\int_0^{\bar{\omega}_i} \omega_t R^k_{i,t} q_{i,t-1} K_{i,t} dF_t(\omega_t)}{q_{i,t-1}K_{i-1,t} - N_{i,t-1}})(q_{i,t-1}K_{i,t} - N_{i,t})] + w^e_i, \tag{2}$$

where $\gamma_{i,t}$ is the equity shock, a shock to the net worth of entrepreneurs, which follows

$$\log \gamma_t = \rho_\gamma \log \gamma_{t-1} + \epsilon^\gamma_t, \quad \epsilon^\gamma_t \sim i.i.d.\, N(0, \sigma^2_{\epsilon^\gamma}).$$

[2] We assume that each financial intermediary provide funds to either the entrepreneur operating in the tradable or non-tradable sector. In Canada business borrowing in the tradable sector is more volatile than in the non-tradable sector. In particular, debt in the tradable sector is about two times volatile as in the non-tradable sector. See Table 5 in Section 4 for the comparison of the volatilities in debt between the tradable and non-tradable sectors.

The risk premium is defined as

$$s_t = \frac{\mu \int_0^{\bar{\omega}_i} \omega R^k_{i,t} q_{i,t-1} K_{i,t} dF_t(\omega)}{q_{i,t-1}K_{i-1,t} - N_{i,t-1}}. \tag{3}$$

This is premium that the financial intermediaries charge to the entrepreneurs in order to cover the monitoring costs incurred by the bankrupt entrepreneurs. The last term w^e_i in equation (2) is the entrepreneurs labour income.[3] Entrepreneurs are risk neutral and have a finite expected horizon with the probability of surviving until the next period denoted by ζ_i.

Entrepreneurs that are going out of business consume their residue equity:

$$ce_{i,t+1} = (1-\zeta_i)[R^k_{i,t} q_{i-1,t} K_{i,t} - (R_t + \frac{\mu \int_0^{\bar{\omega}_i} \omega R^k_{i,t} q_{i,t-1} K_{i,t} dF_t(\omega)}{q_{i,t-1}K_{i-1,t} - N_{i,t-1}})(q_{i,t-1}K_{i,t} - N_{i,t})].$$

2.2 The Rest of the Model

2.2.1 Households

Household h maximizes a life-time utility function defined over consumption, C_{ht}, and hours supplied, H_{ht}

$$E_0 \sum_{t=0}^{\infty} \beta^t \iota_t \left(\frac{C_{ht}^{1-\gamma}}{1-\gamma} + \frac{(1-H_{ht})^{1-\tau}}{1-\tau} \right),$$

where E_0 denotes the expectations operator conditional on information available at the period 0, and $\beta \in (0,1)$ is the subjective discount factor. ι_t is the preference shock, which follows

$$\log\, \iota_t = \rho_\iota \log\, \iota_{t-1} + \epsilon^\iota_t, \quad \epsilon^\iota_t \sim i.i.d.\, N(0, \sigma^2_{\epsilon^\iota}).$$

We assume that the household supplies labour to both tradable $H_{T,ht}$ and non-tradable $H_{N,ht}$ sectors of production. The total wage income is $W_{T,ht}H_{T,ht} + W_{N,ht}H_{N,ht}$. The aggregate labour supply H_{ht} is a composite of the sectoral-specific labour supply in the form of $H_{ht} = [\eta_t H_{T,ht}^{\frac{1+\varsigma}{\varsigma}} + \eta_n H_{N,ht}^{\frac{1+\varsigma}{\varsigma}}]^{\frac{\varsigma}{1+\varsigma}}$. The household pays a lump-sum tax, Υ_{ht}, to the government, receives dividend payments from retailers and importers, Ω_{ht}, deposits funds at the domestic financial intermediary, D_{ht}, and trades foreign bonds denominated in foreign currency, B^*_{ht}.

$$\begin{aligned} P_t C_{ht} + D_{ht} + \frac{e_t B^*_{ht}}{\kappa_t R^*_t} &\leq W_{T,ht}H_{T,ht} + W_{N,ht}H_{N,ht} \\ &+ R_{t-1}D_{ht-1} + e_t B^*_{ht-1} + \Omega_{ht} - \Upsilon_{ht}. \end{aligned} \tag{4}$$

where e_t is the nominal exchange rate. The foreign bond return rate, $\kappa_t R^*_t$, depends on the foreign interest rate R^*_t and a country-specific risk premium κ_t, which is assumed to be increasing in the

[3]As in BGG, we assume that the total labour input is the composite of household labour and entrepreneurial labour. The reason for this is to give entrepreneurs some initial wealth to begin operations.

foreign-debt-to-GDP ratio:

$$\kappa_t = \exp\left(-\upsilon \frac{e_t \tilde{B}_t^*}{P_t Y_t}\right),$$

where $\upsilon > 0$ is a parameter determining the foreign-debt-to-GDP ratio. Y_t is total real GDP and $\tilde{B}_t^*$ is the total level of indebtedness of the economy. We define the CPI inflation rate and the real exchange rate, respectively as $\pi_t = P_t/P_{t-1}$ and $S_t = e_t P_t^*/P_t$ where P_t^* is a foreign price index.

Note in equilibrium total household deposits at intermediaries equal total loan supplied to entrepreneurs:

$$D_t = B_{T,t} + B_{N,t}.$$

As in Erceg, Henderson and Levin (2000), we assume that households are monopolistic suppliers of differentiated labour services. Households set nominal wages in staggered contracts, where $(1-\varphi_i)$ is the probability of changing the nominal wage for the labor services used in tradable and non-tradable sector, $i = \{T, N\}$, as in Calvo (1983). Full indexation as in Yun (1996) is assumed. Thus, if household h is not allowed to change its nominal wage, it charges last period's wage multiplied by the average inflation rate, $W_{i,ht+1} = \pi W_{i,ht}$, where $\pi > 1$. The nominal wage index in the sector i evolves over time according to the following recursive equation:

$$(W_{i,t})^{1-\vartheta} = \varphi_i (\pi W_{i,t-1})^{1-\vartheta} + (1-\varphi_i)(\widetilde{W}_{i,t})^{1-\vartheta}, \tag{5}$$

where $\widetilde{W}_{i,t}$ is the wage of those workers who are allowed to revise their wage at period t in the sector i. Household h's real optimized wage in the sector i, $\widetilde{w}_{i,ht} = \widetilde{W}_{i,ht}/P_t$ is

$$\widetilde{w}_{i,ht} = \frac{\vartheta}{\vartheta - 1} \frac{E_t \sum_{l=0}^{\infty} (\beta\varphi_i)^l \lambda_{t+l} \zeta_{i,t+l} w_{i,t+l}^{\vartheta} L_{i,t+l} \prod_{k=1}^{l} \pi^{-\vartheta l} \pi_{t+k}^{\vartheta}}{E_t \sum_{l=0}^{\infty} (\beta\varphi_i)^l \lambda_{t+l} w_{i,t+l}^{\vartheta} L_{i,t+l} \prod_{k=1}^{l} \pi^{l(1-\vartheta)} \pi_{t+k}^{\vartheta-1}}, \tag{6}$$

where $\zeta_{i,t} = -\frac{\partial U/\partial H_{i,ht}}{\partial U/\partial C_{ht}}$ is the marginal rate of substitution between consumption and labour type i. λ_{t+l} denotes the marginal utility of consumption in period $t+l$, and $w_{i,t} = W_{i,t}/P_t$ is the real wage index in the sector i.

2.2.2 Capital producers

Capital producers use investment goods to produce new capital purchased from entrepreneurs. At the end of the period *t*, they buy investment goods I_t, at real price $p_{I,t} = P_{I,t}/P_t$ to produce sector-specific capital that can be used by entrepreneurs at time $t+1$. Following Christiano, Eichenbaum and Evans (2005), we assume that capital producers in sector $i = \{T, N\}$ face investment adjustment costs $S(I_{i,t}, I_{i,t-1})$, such that in steady state $S = S' = 0$ and $S'' > 0$, and $\chi_i > 0$ is an investment adjustment cost parameter. The production of each capital stock yields the following time-t profit function

$$\Pi_t^i = q_{i,t} I_{i,t} \left[\mu_t - S(I_{i,t}, I_{i,t-1})\right] - p_{I,t} I_{i,t}. \tag{7}$$

The aggregate stock of capital evolves as follows:

$$K_{i,t+1} = I_{i,t}\left[\mu_t - S(I_{i,t}, I_{i,t-1})\right] + (1-\delta)K_{i,t}, \tag{8}$$

where μ_t is the investment specific shock, which follows

$$\log\, \mu_t = \rho_\mu \log\, \mu_{t-1} + \epsilon_t^\mu, \quad \epsilon_t^\mu \sim i.i.d.\, N(0, \sigma_{\epsilon^\mu}^2).$$

2.2.3 Retailers

Retailers in each sector buy intermediate inputs from entrepreneurs, and differentiate them slightly into $Y_t(z^\varkappa)$, $z^\varkappa \in [0,1]$, with $\varkappa = \{N, T\}$. Retailers aggregate $Y_t(z^\varkappa)$ into a final good for each sector by using a technology: $Y_{\varkappa,t} = \left[\int_o^1 (Y_t(z^\varkappa))^{\frac{\theta_\varkappa - 1}{\theta_\varkappa}} dz^\varkappa\right]^{\frac{\theta_\varkappa}{\theta_\varkappa - 1}}$, and sell $Y_{\varkappa,t}$ at price $P_{i,t}$ in a competitive manner. This implies that $P_{\varkappa,t} = \left[\int_o^1 (P_t(z^\varkappa))^{1-\theta_\varkappa} dz^d\right]^{\frac{1}{1-\theta_\varkappa}}$. In order to introduce nominal rigidity, we assume that the retailers in each sector set prices in a manner as in Calvo (1983). At time t each retailer $z^\varkappa$ is allowed to revise its price at time with probability $(1-\phi_\varkappa)$. When producer $z^\varkappa$ is allowed to change its price, it chooses $\tilde{P}_t(z^\varkappa)$ so that

$$\tilde{p}_t(z^\varkappa) = \frac{\theta_j}{\theta_j - 1} \frac{E_t \sum_{l=0}^\infty (\beta\phi_\varkappa)^l \lambda_{t+l} p_{t+l}^\varkappa p_{\varkappa,t+l}^{\theta_\varkappa} Y_{\varkappa,t+l} \prod_{k=1}^l \pi^{-\theta_\varkappa l} \pi_{t+k}^{\theta_\varkappa}}{E_t \sum_{l=0}^\infty (\beta\phi_\varkappa)^l \lambda_{t+l} p_{\varkappa,t+l}^{\theta_\varkappa} Y_{\varkappa,t+l} \prod_{k=1}^l \pi^{l(1-\theta_\varkappa)} \pi_{t+k}^{\theta_\varkappa - 1}}; \tag{9}$$

where $p_t^\varkappa = P_t^\varkappa / P_t$ is the unit cost in real terms of the input used to produce the brand-good $\varkappa$, $\beta\lambda_{t+l}$ is the producer's discount factor where λ_{t+l} denotes the marginal utility of consumption in period $t+l$, $\tilde{p}_t(z^\varkappa) = \tilde{P}_t(z^\varkappa)/P_t$ is the real optimized price for the brand-good $z^\varkappa$, and $p_{\varkappa,t} = P_{\varkappa,t}/P_t$ is the relative price of the final good in sector $\varkappa$. We assume full indexation as in Yun (1996). If the firm cannot re-set the price, it charges last period's price multiplied by the average inflation rate, $P_t(z^\varkappa) = \pi P_{t-1}(z^\varkappa)$. It is possible to show that the price index in sector $\varkappa$ evolves as follows:

$$P_{\varkappa,t} = \left(\phi_\varkappa \left(\pi P_{\varkappa,t-1}\right)^{1-\theta_\varkappa} + (1-\phi_\varkappa)\left(\widetilde{P}_{\varkappa,t}\right)^{1-\theta_\varkappa}\right)^{\frac{\theta_\varkappa}{1-\theta_\varkappa}}.$$

We also assume that there are similar retailers in the sector that the imported goods are produced. The unit cost for imported intermediate goods is $e_t P_t^*$ for a given nominal exchange rate, e_t, and foreign price level, P_t^*.

Retailers in the tradable sector produce goods for domestic use, $Y_{T,t}^d$, and exports, $Y_{T,t}^e$, so that $Y_{T,t} = Y_{T,t}^d + Y_{T,t}^e$. The aggregate foreign demand function for exports of manufactured goods under the assumption of producer currency pricing is

$$Y_{T,t}^e = \varpi \left(\frac{e_t P_{T,t}}{P_t^*}\right)^{-\nu} Y_t^*, \tag{10}$$

where Y_t^* is foreign output. The elasticity of demand for domestic manufactured goods among foreigners is $-\nu$, and $\varpi > 0$ is a parameter determining the fraction of domestic manufactured-goods exports in foreign spending. Since the economy is small, exports represent an insignificant fraction of foreign expenditures and have a negligible weight in the foreign price index.

2.2.4 Final goods producers

There is a representative firm that acts in a perfectly competitive market and uses sectoral output to produce final consumption and investment goods, Z_t^j, with $j = \{C, I\}$, according to the following CES technology:

$$Z_t^j = \left[(\omega_T^j)^{\frac{1}{\nu_j}} \left(Y_{T,t}^{d,j} \right)^{\frac{\nu_j - 1}{\nu_j}} + \left(\omega_N^j \right)^{\frac{1}{\nu_j}} \left(Y_{N,t}^j \right)^{\frac{\nu_j - 1}{\nu_j}} + \left(\omega_F^j \right)^{\frac{1}{\nu_j}} \left(Y_{F,t}^j \right)^{\frac{\nu_j - 1}{\nu_j}} \right]^{\frac{\nu_j}{\nu_j - 1}}, \tag{11}$$

where ω_T^j, ω_N^j, and ω_F^j denote the shares of domestically-used tradable, non-tradable, and imported composite sectoral goods, $Y_{N,t}^{d,j}$, $Y_{N,t}^j$, $Y_{F,t}^j$, respectively, in the final good, where $\omega_T^j + \omega_T^j + \omega_F^j = 1$, and $\nu_j > 0$ is the elasticity of substitution between sectoral goods.

2.2.5 Government and Monetary Policy

We assume that the government consumes a fraction G of the final consumption good and runs a balanced-budget financed with lump-sum taxes: $P_t G_t = \Upsilon_t$, where G_t follows an AR(1) process.

The central bank is assumed to operate according to a standard Taylor-type Rule. The central bank adjusts the nominal interest rate, R_t, in response to deviations of inflation, π_t, from its inflation target value, π_t^{tar}, and output, Y_t, from its steady-state level, Y.

$$\frac{R_t}{R} = (\frac{R_{t-1}}{R})^{\rho_r} ((\frac{\pi_t}{\pi_t^{tar}})^{\rho_\pi} (\frac{Y_t}{Y})^{\rho_y})^{1-\rho_r} e^{\epsilon_{Rt}},$$

where R, and Y are the steady-state values of R_t, and Y_t, and ϵ_{Rt} is a monetary policy shock which follows

$$\epsilon_{Rt} \sim i.i.d.\, N(0, \sigma_{\epsilon_{Rt}}).$$

π_t^{tar} is the central bank's inflation target, which follows

$$\log \pi_t^{tar} = (1 - \rho_{\pi^{tar}}) \log \pi_{ss} + \rho_{\pi^{tar}} \log \pi + \epsilon_t^{\pi^{tar}}, \quad \epsilon_t^{\pi^{tar}} \sim i.i.d.\, N(0, \sigma^2_{\epsilon_t^{\pi^{tar}}}).$$

2.2.6 Aggregation and equilibrium

At the equilibrium, the final consumption goods x_t^C are divided among households' consumption C_t, government spending G_t, entrepreneurs' consumption $ce_{T,t} + ce_{N,t}$, and the monitoring costs

$$x_t^C = C_t + G_t + ce_{T,t} + ce_{N,t} + \mu \int_0^{\bar{\omega}_i} \omega_t R_{T,t+1}^k q_{T,t} K_{T,t+1} dF_t(\omega_t) + \mu \int_0^{\bar{\omega}_i} \omega_t R_{N,t+1}^k q_{N,t} K_{N,t+1} dF_t(\omega_t),$$

where G_t follows an AR(1) process,

$$\log G_t = (1 - \rho^g) \log G_{ss} + \rho^g \log G_{t-1} + \zeta_t^G, \zeta_t^G \sim i.i.d.N(0, \sigma_{\zeta^G}^2),$$

where $G_{ss} = g_y Y_{ss}$ and g_y is the fraction of GDP spent on government spending.

The production of investment goods equals the use of investment in the production of capital goods:

$$x_t^I = I_{N,t} + I_{T,t}.$$

A current account equation is yielded by combining the household's budget constraint, government budget, single-period profit functions of firms that produce tradable and non-tradable goods, and foreign goods importers. Under the producer currency pricing assumption, the current account equation in real terms is given by

$$\frac{b_t^*}{\kappa_t R_t^*} = \frac{b_{t-1}^*}{\pi_t^*} + \frac{p_{T,t}}{s_t} Y_{T,t}^e - Y_{F,t},$$

where $b_t^* = B_t^*/P_t^*$ is the stock of real foreign debt in the domestic economy, $Y_{T,t}^e$ is the aggregate foreign demand function for exports of manufactured goods and $Y_{F,t}$ is the final good for the imported goods sector.

2.2.7 Rest of the World

We consider Canada to be a small open economy. Thus, domestic developments do not affect the rest of the world economy. However, the foreign economy's dynamics have an impact on the Canadian economy. For simplicity we assume that the foreign interest rate, foreign output and the world inflation rate are exogenous and follow AR(1) processes. Since the U.S. is the main trade and financial partner for the Canadian economy, we use U.S. data to estimate the block characterizing the rest of the world.

3 Estimation

3.1 Data, calibration and priors

Data. We estimate the model using eleven quarterly Canadian data series and three quarterly U.S. series. Among the eleven series of Canadian data, five of them are aggregate data: GDP, consumption, investment, the nominal interest rate and the inflation rate; the remaining six variables are sectoral series: production, credit and net worth of the tradable and non-tradable sectors. The desire to consider a period of stable conduct of monetary policy restricts us to estimate the model over the 1991Q1 to 2012Q3 sample period.[4]

Consumption is measured by personal spending on services and non-durable and semi-durable goods. Investment is measured by private investment and durable consumption. The nominal interest rate is measured by the rate on Canadian three-month treasury bills. Domestic inflation is measured using CPI. The series of tradable and non-tradable output, consumption and investment are expressed in real per capita terms using the Canadian population aged 15 and over. Tradable good production is measured by output in manufacturing sectors. Non-tradable output is basically measured by total services.[5] Our measures of credit and net worth are the total liabilities and total equity in both tradable and non-tradable sectors deflated by the GDP deflator.[6]

We use US data on output, inflation and the interest rate as our time series to estimate the rest of the world block. Foreign inflation is measured by quarter-to-quarter changes in the U.S. GDP implicit price deflator. Foreign output is measured by U.S. real GDP per capita. Foreign interest rate is measured by U.S. Federal Funds rates.

Following Smets and Wouters (2007), for most of the above time series, we take log difference of the corresponding series as our observables. This includes GDP, consumption, investment, tradable and non-tradable production, credit and net worth for the tradable and non-tradable sectors and the foreign GDP. The series for the domestic and foreign nominal interest rates, and inflation rate are demeaned.

Calibration. We calibrate some of the model's parameters to capture the salient features of the Canadian economy. In particular, we calibrate the parameters for which the data used in the estimation contain only limited information. Table 1 reports the calibration values. The discount factor, β, is set to 0.99, which implies an annual steady-state real interest rate of 4 percent which matches the average observed in the estimation sample. The curvature parameter in the utility function, γ, is set to 2, implying an elasticity of intertemporal substitution of 0.5. Following Bouakez et al. (2009), we set the labour elasticity of substitution across sectors and the inverse of the elasticity of intertemporal substitution of labour, ς and τ, to unity. We assume that households allocate one third of their time to market activities. The country risk premium parameter υ is calibrated to match a foreign-debt-to-GDP of about 10 percent as in the data.

The parameter measuring the degree of monopoly power in the intermediate-goods markets, θ, is set to be equal to 6, which implies a 20 percent markup in the steady-state. The parameter ϑ, which measures the degree of monopoly power in the labour market, is set equal to 8, implying a

[4]In 1991 the Bank of Canada and the Minister of Finance agreed on an inflation-control target framework to guide Canadian monetary policy.

[5]See Appendix for detailed information for the sectors included in the non-tradable sector.

[6]There is no data available for risk premium at sectorial level. CMR (2014) have also included a time series for the term-structure. Since this time series turns out to be unimportant for the results, we have not included it in the estimation.

Table 1: Calibrated Parameters

Param.	Definition	Values
β	discount factor	0.99
γ	inverse of intertemporal substitution of consumption	2
ς	labor elasticity of substitution across sectors	1
τ	inverse of Frisch elasticity of labor supply	1
υ	parameter of country-specific risk premium	0.03
ν^C	elasticity of substitution between sectors in consumption	0.8
ν^I	elasticity of substitution between sectors in investment	0.6
θ	intermediate good elasticity of substitution	6
ϑ	labor elasticity of substitution	8
	Parameters related to shares	
α_T	capital share in tradable goods production	0.35
α_N	capital share in non-tradable goods production	0.30
δ_T	capital depreciation rate in tradable sector	0.025
δ_N	capital depreciation rate in non-tradable sector	0.025
ω_T^C	share of tradable good in consumption	0.20
ω_N^C	share of non-tradable good in consumption	0.58
ω_F^C	share of imported good in consumption	0.22
ω_T^I	share of tradable good in investment	0.20
ω_N^I	share of non-tradable good in investment	0.40
ω_F^I	share of imported good in investment	0.40
	Parameters related to financial frictions	
ζ	survival probability for entrepreneurs	0.973
μ	monitoring costs	0.12
$F(\omega)$	default rate	0.03
σ_{ss}	steady-state value of the s.d. of the risk shock	0.28

steady-state wage markup of 14 percent. Based on Dib (2003), both the elasticity of substitution between tradable, non-tradable and imported goods in the production of final consumption goods, ν^C, and the elasticity of demand for domestic manufactured-goods among foreigners, ν, are set equal to 0.8. The elasticity of substitution between tradable, non-tradable and imported goods in the production of final investment goods, ν^I, is set equal to 0.6, implying that imported goods are less substitutable in producing investment than against the consumption good production .

The capital shares in the production of tradable and non-tradable goods, α_T and α_N, are set to 0.35 and 0.3, which are close to the values suggested by Macklem et al. (2000). The capital depreciation rate, δ, is assumed to be common to both tradable and non-tradable sectors and set to 0.025, a value commonly used in the literature. The shares of tradable, non-tradable, and imported goods in the production of consumption good, ω_T^C, ω_N^C, and ω_F^C, equal 0.2, 0.58 and 0.22, respectively, to match the average ratios observed in the data for the estimation period. Since the share of imported good in the production of the investment good is higher than that in consumption good production. we set ω_T^I, ω_N^I, and ω_F^I equal to 0.2, 0.4 and 0.4, respectively.

The parameter μ measures the monitoring costs and is calibrated to 0.12. The steady-state value of the risk shock is set to 0.28, which is not far from the 0.26 estimates of CMR. Following BGG, the quarterly default rate is set to 0.03, and the survival probability for entrepreneurs is set to 0.9728.

Prior Distribution. Bayesian estimation allows us to formally use informative priors on the probability distributions of the model's parameters. The priors are based on earlier macro and micro evidence. Tables 2-4 report the prior distributions assumed for the estimated parameters. We use Beta distributions for all parameters bounded in the [0,1] range. This applies to the shocks' autoregressive coefficient, whose mean we set to 0.6. The parameters of nominal stickiness are also assumed to follow a beta distribution with mean 0.85, which corresponds to changing prices and wages every five quarters on average. Gamma and Inverted Gamma (IG) distributions are assumed for parameters that are supposed to be positive. Our priors on the investment adjustment cost are in line with previous literature.[7] For the standard deviation of the shocks we assume an Inverted Gamma distribution with mean 0.5 percent and standard deviation 2. We follow previous literature in setting the priors on the monetary policy parameters. The prior assumptions on the monetary policy parameters allow for a range of interest-rate inertia between 0 and 1, and a positive response to inflation. We use a normal distribution for the reaction to output in order to allow for a negative response.

3.2 Estimates

Since the dynamics of the key variables for the rest of the world are exogenous to the Canadian economy, we assume that foreign output, inflation and the nominal interest rate follow an AR(1) process. We estimate the parameters governing these processes as a separate block. Table 2 reports

[7] See, among others, Christensen and Dib (2008), Elekdagn, Justiniano and Tchakarov (2006), Justiniano et al (2010), Queijo von Heideken (2007), Smets and Wouters (2007).

the priors and the modes for the posterior distribution. Taking the estimated foreign shocks as given and using quarterly Canadian data, we estimate the model for the domestic economy. The results are presented in Tables 3 and 4.

Table 2: Estimation, Foreign Block

		Prior			Posterior Mode
Coef.	Description	Density	Mean	Std	
ρ_{R^*}	Foreign interest rate	Beta	0.80	0.10	0.98
ρ_{π^*}	Foreign inflation	Beta	0.80	0.10	0.79
ρ_{y^*}	Foreign output	Beta	0.80	0.10	0.92
σ_{R^*}	Foreign interest rate	IG	0.50	1.00	0.19
σ_{π^*}	Foreign inflation	IG	0.50	1.00	0.27
σ_{Y^*}	Foreign output	IG	0.50	1.00	0.96
	Log likelihood at mean		-1371.15		

The estimated monetary policy rule features a positive reaction to the lagged interest rate, $\varrho_R = 0.87$, a moderate response to inflation, $\varrho_\pi = 0.49$, and a positive but small response to output $\varrho_y = 0.006$. These findings are in line with previous estimates for the Canadian economy.[8] The investment adjustment cost parameters, χ_T and χ_N, are estimated at 5.69 and 6.85. Thus, it is slightly more costly to adjust investment in the non-tradable sector. The estimated values of the nominal price and wage stickiness parameters, ϕ_T, ϕ_N, ϕ_F, φ_T, and φ_N, indicate sectoral heterogeneity, and that prices are less rigid than wages. The average duration for price adjustment in the tradable sector is about five months, and the average durations for non-tradable and imported sectors are about eight and six months. The average duration for wage adjustment is much longer: 14 months for the tradable sector and 18 months for the non-tradable sector.

For the shock parameters, the risk shocks are found to be the most volatile with an average standard deviation of 10 per cent, including both the unanticipated and anticipated (news) components.[9] The investment-specific shock is also quite volatile with a standard deviation of 9.9 per cent. The government spending, preference and technology shock in the tradable sector also exhibit a large volatility with a standard deviation of about two to three per cent. The estimated standard deviations for the remaining parameters are ranging from 0.14 to 1.14 per cent. The technology shock in the tradable sector is the most persistent shock with $\rho_{AT} = 0.99$. The preference shocks and technology shocks in the non-tradable sector are also quite persistent with $\rho_\iota = 0.97$ and $\rho_{AN} = 0.95$. On the

[8] See, among others, Ortega and Rebei (2006) and Dib (2008).

[9] We have experienced different specifications for the anticipated innovations in the risk shocks. The results reported in this section are based on the specification that gives us the highest likelihood. In this specification, the risk shocks are governed by

$$\log \sigma_{i,t} = \rho_{\sigma,i} \log \sigma_{i,t-1} + \epsilon^{\sigma_i}_{0,t} + \epsilon^{\sigma_i}_{4,t-4}.$$

other hand, equity shocks and investment specific shocks are the least persistent.

Table 3: Estimation, Structural Parameters

Coef.	Description	Prior Density	Prior Mean	Prior Std.	Posterior Mode
χ_T	Investment adj. cost parameter, T	Gamma	4.00	1.50	5.69
χ_N	Investment adj. cost parameter, N	Gamma	4.00	1.50	6.85
ϕ_T	Calvo price parameter,T	Beta	0.85	0.10	0.37
ϕ_N	Calvo price parameter,N	Beta	0.85	0.10	0.64
ϕ_F	Calvo price parameter, F	Beta	0.85	0.10	0.55
φ_T	Calvo wage parameter,T	Beta	0.85	0.10	0.78
φ_N	Calvo wage parameter, N	Beta	0.85	0.10	0.83
ϱ_R	Taylor rule smoothing	Beta	0.50	0.25	0.87
ϱ_π	Taylor rule inflation	Gamma	0.50	0.50	0.49
ϱ_y	Taylor rule output	Normal	0.125	0.15	0.006

4 Results

4.1 Performance of the model

In this section we examine how well the model economy is able to account for the overall volatility in the data. Table 5 reports the standard deviations of key aggregate and sectoral variables. Overall, the model appears to capture well the basic features of the data. The model comes quite close in terms of matching the volatility in GDP, investment, and of the nominal interest rate. The model overestimates the volatilities in consumption and inflation. As for the sectoral variables, the model replicates well the fact that output and debt in the tradable sector are both more volatile than those in the non-tradable sector. In the data, the output in the tradable sector is about four times as volatile as that in the non-tradable sector, while in the model it is about two times. The relative volatility of debt in the tradable and non-tradable sector is better matched by the model. Regarding net worth, despite overestimating the volatility of both variables, the model capture the fact that the volatility in the two sectors is approximately the same.

4.2 Sources of the Canadian business cycle fluctuations

Table 6 reports the forecast error variance decomposition at the eight quarter horizon based on the mode of the model's posterior distribution. For the GDP, the fluctuations are mainly explained by the technology, risk, and foreign shocks. In particular, 56 per cent of fluctuations in GDP are accounted for by the technology shocks (32 per cent from the tradable sector, and 24 per cent from the non-tradable sector), 26 per cent by the risk shocks (with a similar contribution of the anticipated and unanticipated components of the risk shocks), and 10 per cent by the foreign shocks. Fluctuations

Table 4: Estimation, Shock Processes

		Prior			Posterior
Coef.	Description	Density	Mean	Std	Mode
ρ_{AT}	Technology, T	Beta	0.60	0.20	0.99
ρ_{AN}	Technology, N	Beta	0.60	0.20	0.95
ρ_{G}	Government spending	Beta	0.60	0.20	0.93
ρ_{μ}	Investment-specific	Beta	0.60	0.20	0.36
ρ_{Γ_T}	Equity, T	Beta	0.60	0.20	0.19
ρ_{Γ_N}	Equity, N	Beta	0.60	0.20	0.49
ρ_{σ_T}	Risk, T	Beta	0.60	0.20	0.79
ρ_{σ_N}	Risk, N	Beta	0.60	0.20	0.80
$\rho_{\tilde{\pi}}$	Inflation target	Beta	0.60	0.20	0.44
ρ_{ι}	Preference	Beta	0.60	0.20	0.97
σ_{AT}	Technology, T	IG	0.50	2.00	2.14
σ_{AN}	Technology, N	IG	0.50	2.00	0.71
σ_{G}	Government spending	IG	0.50	2.00	2.49
σ_{R}	Monetary policy	IG	0.50	2.00	0.14
σ_{μ}	Investment-specific	IG	0.50	2.00	9.99
σ_{Γ_T}	Equity, T	IG	0.50	2.00	1.14
σ_{Γ_N}	Equity, N	IG	0.50	2.00	0.80
σ_{σ_T}	Risk, unanticipated, T	IG	0.50	2.00	9.82
σ_{σ_N}	Risk, unanticipated, N	IG	0.50	2.00	10.2
σ_{t-4,Γ_T}	Risk, anticipated, T	IG	0.50	2.00	11.5
σ_{t-4,Γ_N}	Risk, anticipated, N	IG	0.50	2.00	10.6
σ_{ι}	Preference	IG	0.50	2.00	3.13
$\sigma_{\pi^{tar}}$	Inflation target	IG	0.50	2.00	0.16
	log likelihood at mean			2754.2	

Table 5: Standard Deviations of the Key Variables: Data Vs. Model

		Data	Model
Aggregate variables			
GDP		0.0062	0.0069
Consumption		0.0047	0.0117
Investment		0.0201	0.0213
Nominal interest rate		0.0052	0.0069
Inflation		0.0020	0.0106
Sectoral variables			
Output	Tradable	0.0204	0.0254
	Non-tradable	0.0053	0.0117
Debt	Tradable	0.0254	0.0275
	Non-tradable	0.0148	0.0231
Net worth	Tradable	0.0236	0.0443
	Non-tradable	0.0244	0.0420

in consumption are mainly explained by the technology shocks (45 per cent total contribution of the two sectors) and government spending shocks (23 per cent). Fluctuations in aggregate investment, are mainly driven by the investment-specific shocks (65 per cent) and risk shocks (19 per cent). For nominal variables, fluctuations in the nominal interest rate and inflation are mainly related to the technology shocks in the tradable sector and preference shocks. Overall, fluctuations in risk premium are mainly explained by the risk shocks and investment-specific shocks.[10] Lastly, variations in the real exchange rate are mainly accounted for by the technology shock in the tradable sector and the foreign output shock.

For the sectoral variables, we focus on output, credit and net worth. Fluctuations in the tradable sector output is mainly driven by technology shocks in the tradable sector. Interestingly, in the non-tradable sector, the risk shocks contribute to a larger portion of the output fluctuations than the technology shocks. The dynamics of credit and net worth at the sectoral level are mainly explained by the risk, equity and investment-specific shocks, with the majority of the fluctuations in credit in the two sectors accounted for by the equity shock, and the majority of the fluctuations in net worth accounted for by the risk shocks.

In sum, risk shocks explain a significant portion of the volatilities in aggregate output, investment and risk premium. At the sectorial level, risk shocks, together with equity shocks, are the main drivers of fluctuations in credit and net worth.

[10]The risk premium listed in the table is computed as the weighted aggregate of risk premium in the tradable sector and non-tradable sector.

Table 6: Variance Decomposition at Business Cycle Frequency (in percent)

	Risk (unantip.)		Risk (antip.)		Equity		Tech		Inv	Mon	Gov	Inf. Tar.	Pref	F. output	F. int.	F. inf
	T	*NT*	*T*	*NT*	*T*	*NT*	*T*	*NT*								
GDP	4.27	8.17	5.43	7.8	0.87	0.87	31.51	24.24	3.28	0.44	1.25	0.23	1.03	10.35	0.06	0.18
Consumption	0.31	0.52	1.22	1.55	0.7	1.07	28.02	16.67	2.49	0.34	33.31	0.16	9.74	3.76	0.03	0.11
Investment	1.93	3.23	5.99	7.7	1.76	2.84	0.75	2.18	65.44	0.03	2.08	0.02	3.55	2.49	0	0.01
Int.rate	0.95	2.05	3.82	6.21	1.13	3.17	14.95	5.84	14.73	0.37	13.39	0.15	27.12	5.95	0.05	0.11
Inflation	0.46	0.88	1.59	2.3	0.19	0.38	30.73	6.46	11.41	4.62	12.39	3.72	12.11	12.51	0.11	0.14
Risk Premium	7.32	17.12	3.01	5.72	1.8	3.28	10.88	6.18	27.07	0.53	7.71	0.31	8.48	0.47	0.03	0.08
Exchange rate	1.58	3.03	3.89	5.35	0.15	0.37	34.84	10.75	0.63	0.78	6.31	0.44	5.76	25.12	0.36	0.64
Sectoral Level																
Output, *T*	5	0.01	5.93	0.26	0.98	0.19	77.47	3.93	0.84	0.46	2.13	0.25	1.84	0.69	0	0.01
Output, *NT*	0.02	24.15	0.08	20.34	0.12	6.47	0.1	13.84	12.69	0.35	10.56	0.18	10.23	0.86	0.01	0
Credit, *T*	1.6	0.16	8.54	0.5	72.59	0.22	1.14	0.41	12.28	0.39	0.4	0.18	0.81	0.78	0	0.01
Credit, *NT*	0.14	3.06	0.49	11.62	0.11	61.48	3.3	0.2	16.15	0.53	0.34	0.25	0.74	1.58	0.01	0.01
Net worth, *T*	29.78	0.15	12.98	1.11	25.48	0.14	1.37	3.89	16.5	0.12	3.83	0.08	4.36	0.19	0.01	0.03
Net worth, *NT*	0.08	40.43	0.81	13.31	0.07	19.15	3.29	1.58	15.68	0.13	2.33	0.09	2.68	0.3	0.01	0.05

4.3 Risk shocks

4.3.1 Impulse response functions

To shed light on the importance of the risk shocks in explaining output, net worth and investment dynamics, we report the risk shocks' impulse responses of key variables in the model. Figure 1 displays the impulse responses to a standard deviation increase in the risk shock in the tradable sector. An increase in risk in the tradable sector translate into a higher default probability that pushes up the risk premium in the tradable sector. Since entrepreneurs in the tradable sector face a higher borrowing cost, they reduce their demand for loans. Investment and the price of capital in the tradable sector falls, leading the decline in the net worth for the entrepreneurs in the tradable sector. As a result, output in the tradable sector falls.

In addition, there are spillovers to the non-tradable sector. Indeed, heightened uncertainty in the tradable sector encourages lending and investment in the non-tradable sector. The non-tradable sector in fact enjoys an increase in total loans. Both net worth and price of capital in the non-tradable sector rise slightly. As a result, output in the non-tradable sector rises slightly as well.

At the aggregate level, however, total investment still falls (Figure 2) since the investment decline in the tradable sector dominates the rise in the non-tradable sector. Aggregate consumption rises due to a substitution effect. Both GDP and inflation decrease on impact. Risk shocks in the non-tradable sector have a similar effect. See Figures 3 and 4.

4.3.2 Comparing risk shocks with other shocks

CMR has shown that it is crucial to include financial time series into the estimation. They find that once financial time series are included, the data prefer risk shocks to equity and investment specific shocks. They argue that this is because the other two shocks generate counterfactual implications on the cyclicality for net worth and credit. The investment efficiency shock has the implication that the value of equity is countercyclical, and the equity shock has the implication that the credit (debt) is countercyclical. Our model generates similar predictions. Figure 5 displays the dynamic responses of these variables to a risk shock, a equity shock and an investment efficiency shock.[11]

As we described in the previous section, after a risk shock, the rise in uncertainty leads to an increase in the risk premium and, thus, a decline in the debt level and net worth. This in turn leads to a decline in investment. After a negative equity shock, the risk premium rises, and net worth and investment decline. However, debt increases. This is because a decline in the net worth leads to a drop in the demand for capital, leading a decline in the price of the capital on impact. Expectation of a future higher price of capital leads to a rise in the expected return to capital, pushing towards an increase in the demand for loans.[12] Risk and equity shock are both demand shocks, whereas

[11] In Figure 5, we use the tradable sector as an example to illustrate the impulse responses of the model to the three shocks. That is, the variables plotted are at the sectoral level.

[12] Although this expectation effect also exists after a positive risk shock, it is offset by the the rise in uncertainty.

the investment efficiency shock is a supply shock. Thus, a positive shock of this kind leads to an increase in investment and a decline in the price of capital, which causes a drop in the net worth of firms.

Although the impulse responses are similar to CMR, our results suggest that equity shocks are still quite important even when the risk shocks are present. In order to understand the difference, in Table 7 we report the correlations between the growth in credit, output and net worth that we find in the data. Interestingly, except the positive correlation between net worth and output growth in the non-tradable sector, the other three correlations are negative. Given that the equity shock implies that credit is countercyclical, it is, then, not surprising that equity shock plays a bigger role in explaining business cycle fluctuations in credit in our model. Figures 6-9 present the contributions of risk shocks and equity shocks to net worth and credit at the sector level over the sample periods. In each graph, the solid blue lines indicate historical data. The dotted red lines indicate the results of simulated results responding to corresponding shocks. It is clear that risk shocks account well for the fluctuations in net worth growth, and equity shocks account well for the fluctuations in credit growth.

Table 7: Correlations of the Financial Variables with Output: Data

	Tradable	Non-tradable
Credit growth, output growth	-0.42	-0.24
Net worth growth, output growth	-0.22	0.0625

5 Concluding Remarks

In this paper we study the role of risk shocks in explaining the Canadian business cycle. To this purpose, we imbed a financial accelerator mechanism into an otherwise standard small open economy model with tradable and non-tradable sectors of production. We use sector level data on credit and net worth to pin down sector-specific risk shocks and study their impact on the sectoral and aggregate economy. We find that risk shocks explain a significant portion of the fluctuations in GDP, investment, credit, net worth and risk premium.

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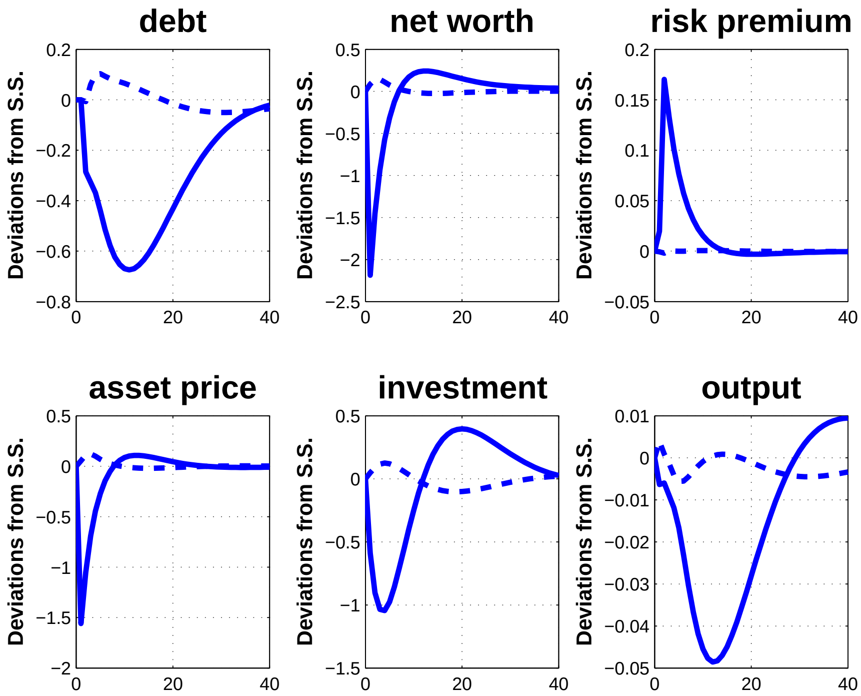
Figure 1: Dynamic Responses to a Risk Shock in the Tradable Sector: Sectoral Level



Solid line represents the variables in the tradable sector and the dotted line represents those in the non-tradable sector.

Figure 2: Dynamic Responses to a Risk Shock in Tradable Sector: Aggregate Level

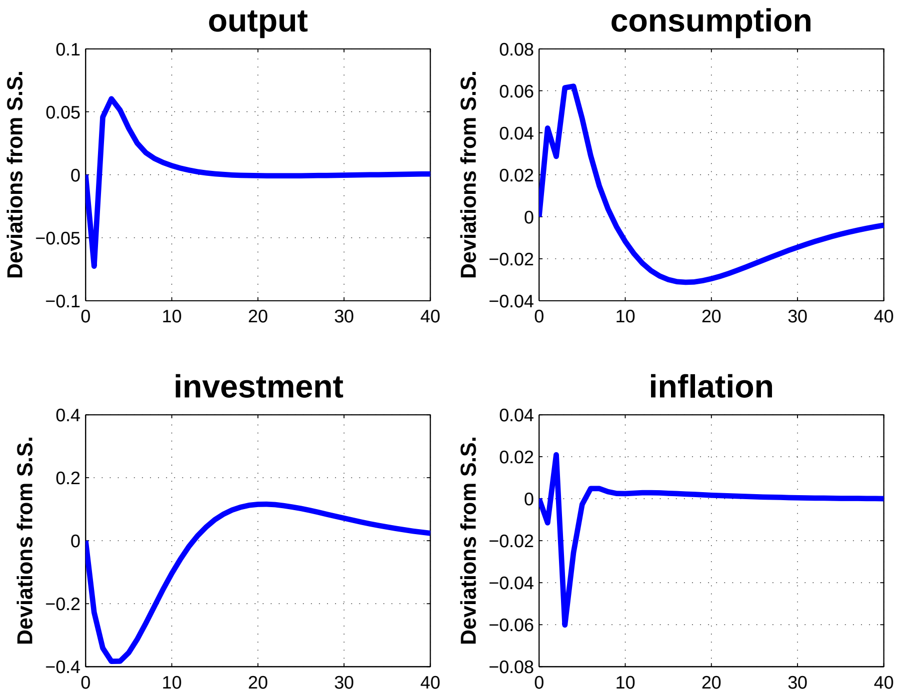
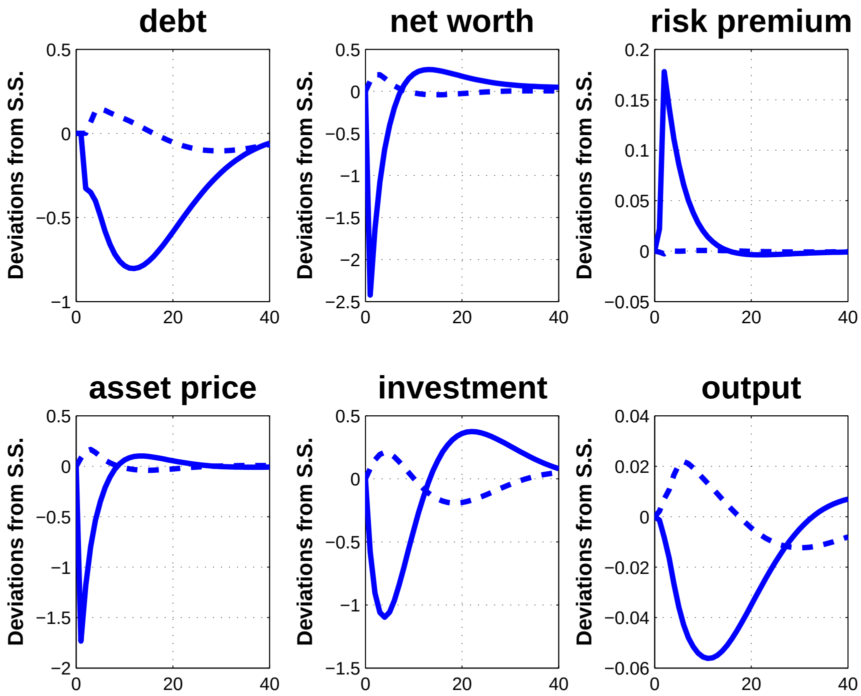


Figure 3: Dynamic Responses to a Risk Shock in Non-Tradable Sector: Sectoral Level



Solid line represents the variables in the non-tradable sector and the dotted line represents those in the tradable sector.

Figure 4: Dynamic Responses to a Risk Shock in Non-Tradable Sector: Aggregate Level

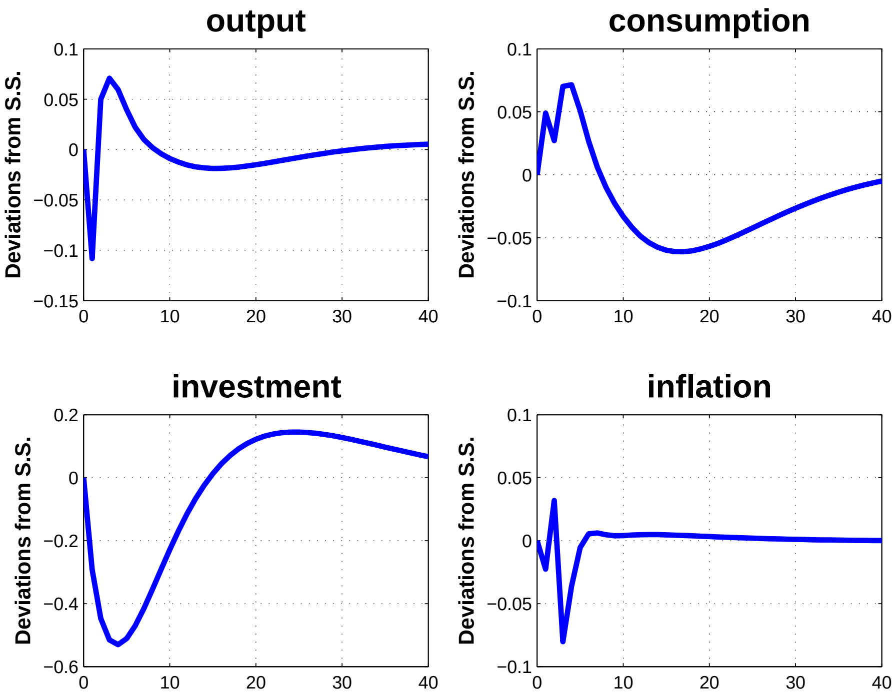


Figure 5: Dynamic Responses to Three Shocks

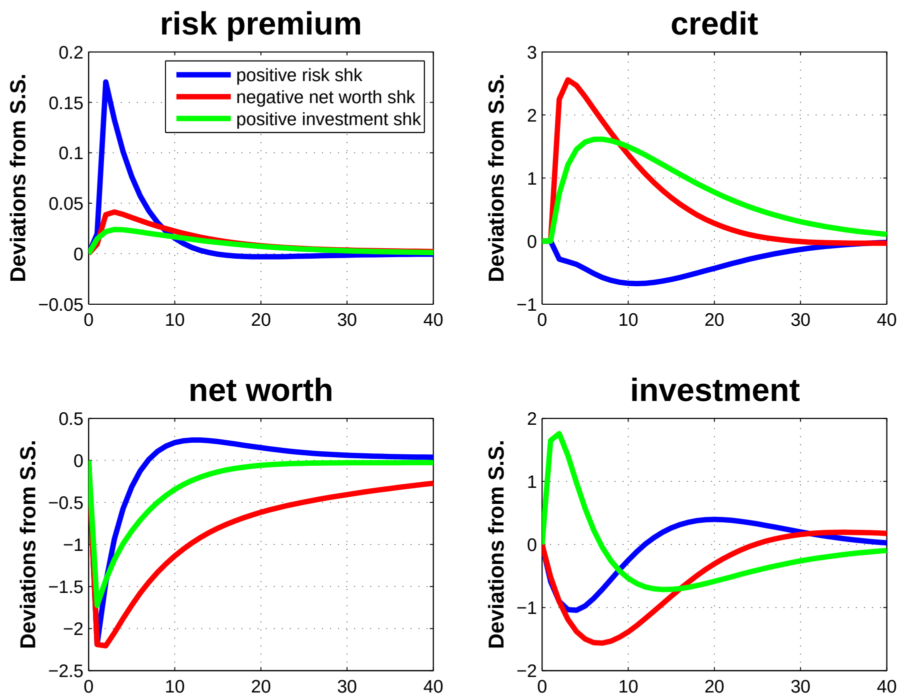


Figure 6: Contribution of the Risk Shock in Tradable Sector

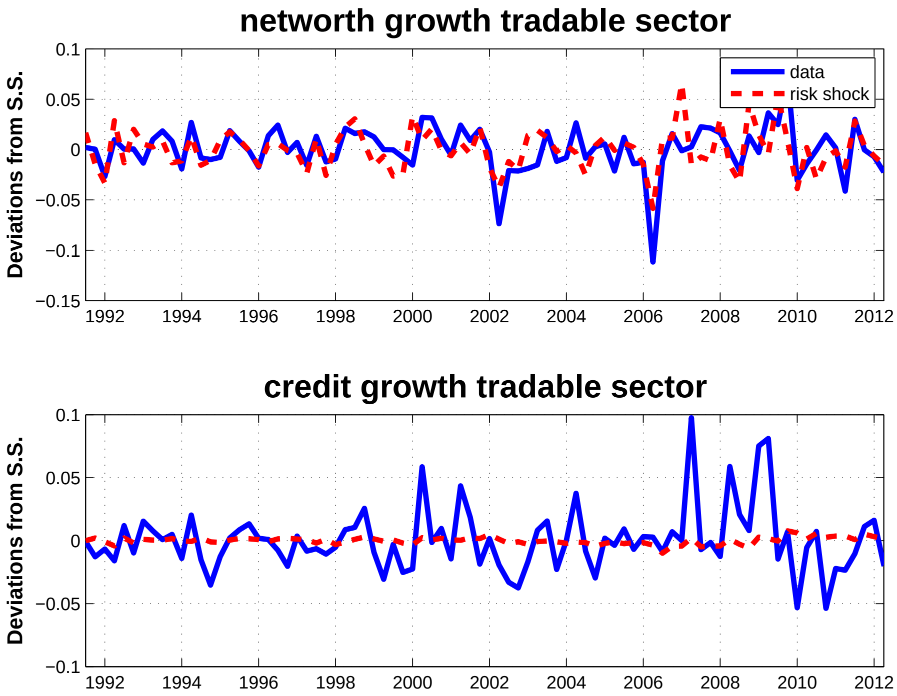


Figure 7: Contribution of the Risk Shock in Non-tradable Sector

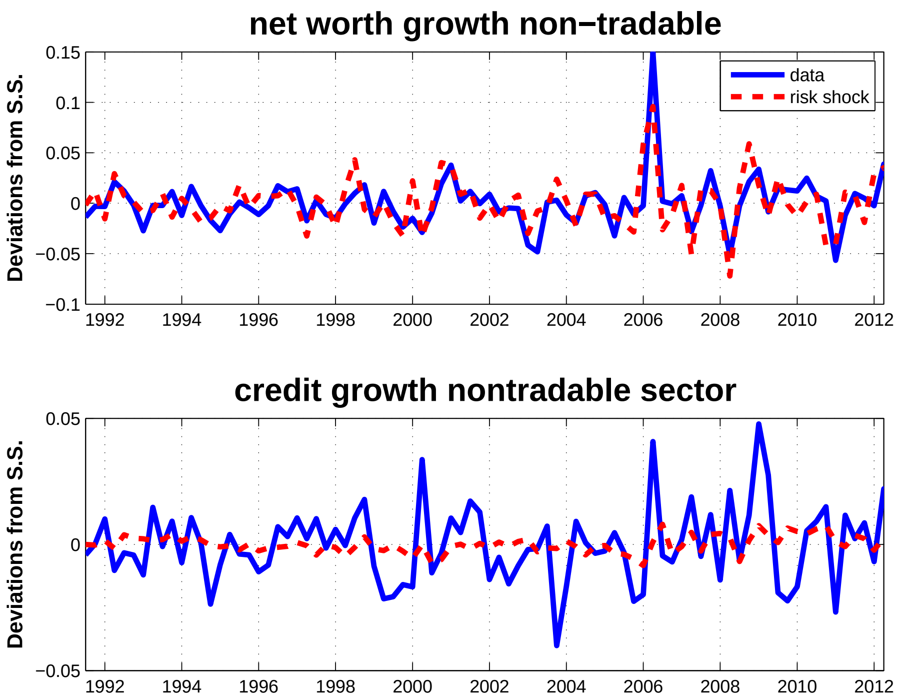


Figure 8: Contribution of the Equity Shock in Tradable Sector

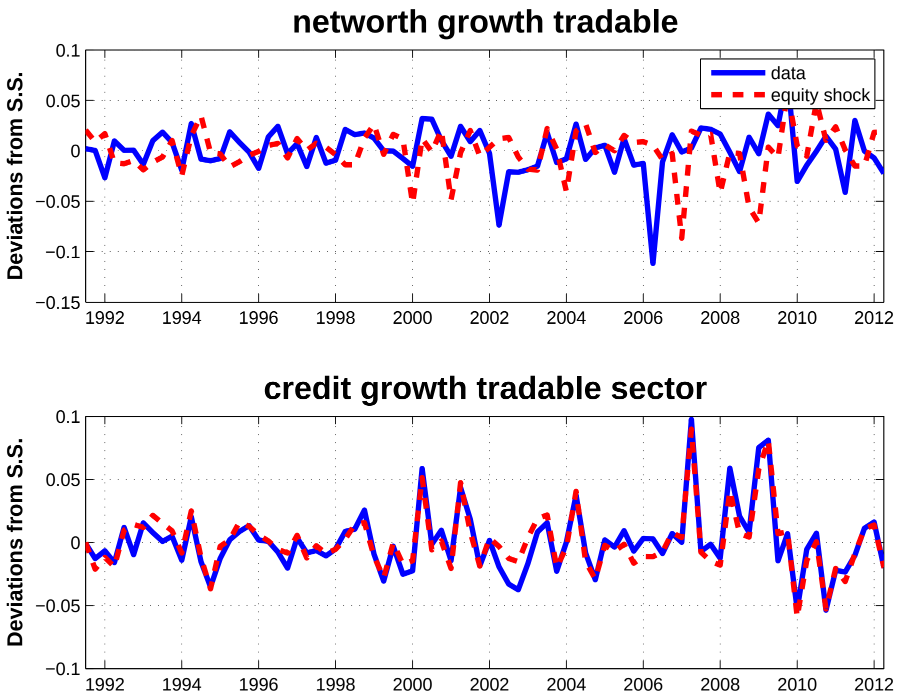
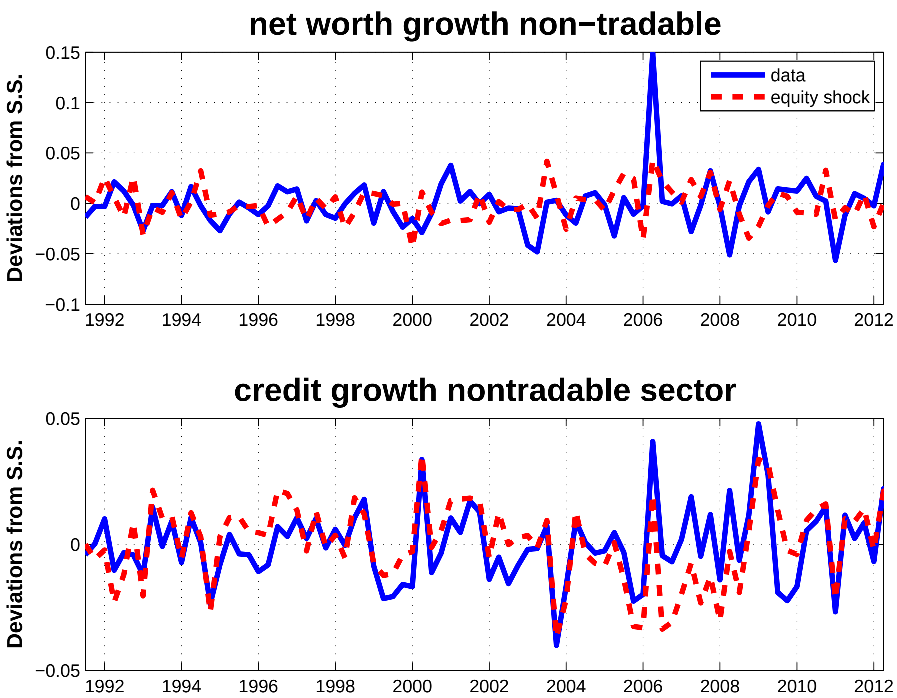


Figure 9: Contribution of the Equity Shock in Non-tradable Sector



Appendix: Data Construction

The data sample is from 1991Q1 to 2012Q3. Throughout the paper, the tradable sector is defined as the manufacturing industries: North American Industry Classification [31-36]. The non-tradable sector is defined as the service-producing sector (excluding financial sector [52-53] and public administration sector [91]). To be precise, the non-tradable sector includes: wholesale trade [41], retail trade[44-45], transportation and warehousing [48-49], information and cultural industries[51], real estate and rental and leasing[53], professional, scientific and technical services[54], management of companies and enterprisers[55], administrative and support, waste management[56], educational services[61], health care and social assistance[62], arts, entertainment and recreation[71], accommodation and food services[72], and other services (except public administration) [81].

All the real variables are normalized by civilian population, logged and detrended by first difference. All nominal variables are demeaned.

1. Output: aggregate output: gross domestic product at market prices (Sources: CANSIM, Table 380-0064); output in the tradable and non-tradable sectors: output in the sectors defined above. (Sources: CANSIM, Table 379-0027)

2. Consumption: non-durable, semi-durable and services (Sources: CANSIM, Table 380-0064)

3. Investment: business fixed capital formation and durable goods (Sources: CANSIM, Table 380-0064)

4. Government spending: General governments final consumption expenditure. (Sources: CANSIM, Table 380-0064)

7. Inflation: It is computed using core CPI (Bank of Canada definition) (Sources: CANSIM, Table 326-0022)

8. Nominal interest rate: Rates on 3 month treasury bills (Sources: CANSIM, Table 176-0043)

9. Exchange rate: Nominal exchange rate (Source: CANSIM, Table 176-0064)

10. Credit: Total liabilities for both tradable and non-tradable sectors, deflated using GDP implicit price deflator and normalized by civilian population. (Sources: Table 187-0001)

11. Net worth: Total equities for both tradable and non-tradable sectors, deflated using GDP implicit price deflator, normalized by civilian population. (Sources: Table 187-0001)

12. US output: US GDP. (Source: Federal Reserve Bank of St. Louis)

13. US inflation: Computed from GDP deflator (Source: Federal Reserve Bank of St. Louis)

14. US nominal interest rate: Federal funds rate (Source: Federal Reserve Bank of St. Louis)