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Abstract

This paper examines the transmission of U.S. real and financial shocks to Canada and, in particular, the role of financial frictions in affecting the transmission of these shocks. These questions are addressed within the Bank of Canada's Global Economy Model (de Resende et al. forthcoming), a dynamic stochastic general-equilibrium model with an active banking sector and a detailed role for financial frictions. We find that U.S. financial shocks, as well as real shocks, have important effects on the Canadian economy. Moreover, financial frictions on both the demand and supply sides of credit amplify the first round impact of all types of U.S. shocks on the U.S. economy, as well as the second round impact on Canada. Real-financial linkages also increase the persistence of the Canadian response to U.S. shocks. We find that the interaction between the endogenous response of commodity prices and U.S. financial frictions plays an important role in the propagation of U.S. shocks to the Canadian economy. Finally, real-financial linkages also help to generate the positive cross correlation between domestic demand in the United States and Canada observed in the data, which is difficult to explain with a model where the transmission of shocks between countries is only based only on trade.

JEL classification: E21, E27, E32, F36, F40
Bank classification: Business fluctuations and cycles; Economic models; International topics

Résumé

Les auteurs étudient comment les chocs qui touchent l'économie réelle et le secteur financier aux États-Unis se propagent au Canada et, en particulier, l'incidence que peuvent avoir les frictions financières dans leur diffusion. Ils exploitent à cette fin le modèle de l'économie mondiale utilisé par la Banque du Canada (de Resende et autres, à paraître), un modèle d'équilibre général dynamique et stochastique qui comporte un secteur bancaire actif et délimite précisément le rôle des frictions financières. Ils constatent que les chocs provenant des États-Unis, relatifs tant au secteur financier qu'à l'économie réelle, ont d'importantes répercussions sur l'économie canadienne. De plus, les frictions financières qui s'exercent aussi bien sur la demande que sur l'offre de crédit amplifient les effets de première vague de tous les types de chocs touchant l'économie américaine, ainsi que les effets de seconde vague au Canada. Les liens entre l'économie réelle et la sphère financière augmentent aussi la persistance des réactions canadiennes aux chocs survenant aux États-Unis. Les auteurs établissent que l'interaction entre la réaction endogène des prix des produits de base et les frictions financières joue un grand rôle dans la propagation au Canada des chocs nés aux États-Unis. Enfin, ces liens contribuent également à rendre compte de la corrélation positive croisée entre les demandes intérieures américaine et canadienne qui ressort des données, corrélation difficile à expliquer à l'aide d'un modèle dans lequel la transmission des chocs d'un pays à l'autre se fonde uniquement sur les échanges commerciaux existants.

Classification JEL : E21, E27, E32, F36, F40
Classification de la Banque : Cycles et fluctuations économiques; Modèles économiques; Questions internationales

1 Introduction

The recent global financial crisis highlighted the financial interdependencies that exist among the world's major economies. What began as a crisis in the U.S. subprime mortgage market spread quickly, and had pronounced adverse effects on global financial markets. As the crisis played out, it quickly became apparent that trade linkages, which form the basis of traditional models of the international business cycle, are not the only form of interdependence in the global economy. In particular, the crisis highlighted the importance of cross-country financial linkages through markets and institutions. Moreover, it demonstrated that the financial system can cause, propagate, and magnify business cycles within and across countries. Recognizing the international dimension of the financial system, the linkages between developments in the financial system and the real economy must be taken into account by policymakers when conducting domestic policy. Indeed, many of the actions taken by central banks during the financial crisis were motivated by the observed linkages between developments in the global financial system and in the real economy (Bank of Canada 2008). However, much uncertainty remains with respect to the relative importance of financial factors in business cycles and the channels through which financial conditions influence the propagation of shocks within and across countries. Clearly, a better understanding of these relationships could enhance the ability of policymakers to deal effectively with the international shocks facing their economies.

In this paper, we aim to improve the understanding of the importance of financial conditions for business cycles, in particular the Canadian business cycle. We first assess how shocks to global financial conditions are transmitted to Canada, focusing specifically on how U.S. financial shocks are transmitted to Canada. These two economies are highly integrated through strong trade and financial linkages: the United States account for over three quarters of Canadian exports, and is an important source of financing for Canadian firms, with the stock of U.S. claims on Canadian assets equal to over 50 per cent of Canada's GDP. [1] Consequently, the state of the U.S. business cycle has important implications for Canadian economic activity. Given these linkages, it is not surprising that recent empirical research has shown that movements in U.S. financial conditions can have significant implications for financial conditions and real activity in Canada (Klyuev (2008) and Beaton and Desroches (forthcoming)). We build on these studies and consider the transmission of shocks to U.S. financial conditions to Canada within the framework of a multi-country, multi-sector dynamic stochastic general equilibrium (DSGE) model, the Bank of Canada's Global Economy Model (de Resende et al. forthcoming). Moreover, the model includes financial frictions on the demand side of credit through a financial accelerator (à la Bernanke, Gertler, Gilchrist 1999, henceforth BGG 1999) and frictions on the supply side of credit through a banking sector (based on the framework in Dib forthcoming). This framework allows us to consider the different channels by which U.S. financial shocks are transmitted to Canada.

Given that the model used in our analysis includes both frictions on the demand and supply sides of credit, we can also use the model to assess how financial frictions affect the transmission of U.S. shocks to Canada. We assess the importance of financial frictions in the propagation of U.S. shocks to Canada in two key ways. First, when studying the transmission of U.S. financial shocks to Canada, we assess how

[1] The sum of U.S. direct, U.S. portfolio and U.S. other investment in Canada represented 57 per cent of Canadian GDP in 2009. Source: Statistics Canada.

different types of financial frictions affect the Canadian response to these shocks by comparing the response in different versions of the model that include (or exclude) frictions on the demand and/or supply of credit. Second, we use the model to consider the role of financial frictions as a propagation mechanism of shocks to the U.S. real economy as they may also affect the Canadian response to U.S. real shocks. Indeed, Gilchrist, Hairault and Kempf (2002) show that the presence of a financial accelerator increases the degree of cross-country transmission of shocks and the degree of co-movement across countries. Likewise, Devereux and Yetman (2009) show that when highly levered investors hold interconnected portfolios across countries, that binding leverage constraints introduce a powerful financial transmission channel that results in a high correlation between macroeconomic aggregates during business cycle downturns that is independent of the size of international trade linkages. We build on their work by assessing the role of both demand and supply-side credit frictions in the transmission of U.S. real shocks to Canada.

Our results suggest that U.S. financial shocks have important effects on financial conditions and real activity in Canada. U.S. financial shocks are transmitted to Canada mainly via real channels, such as trade, exchange rates, and commodity prices; but, financial channels, such as international loan flows, are also important, accounting for about 20 per cent of the Canadian response. Moreover, financial frictions in the Canadian economy amplify the Canadian response to U.S. financial shocks and increase the persistence of the Canadian response. In addition, financial frictions help to explain the positive correlation between investment and consumption in a single country and the positive correlation between domestic demand in Canada and the United States. Finally, our results show that the required monetary policy response to real and financial shocks is larger when there are financial frictions.

The remainder of the paper is organized as follows. Section 2 provides stylized facts on the linkages between the Canadian and U.S. business cycles. Section 3 describes the model and discusses its calibration. Finally Section 4 presents results and Section 5 concludes.

2 Stylized Facts

In considering the transmission of U.S. shocks to Canada, it is first useful to understand the relationship between the two countries. Therefore, this section investigates the cross country correlations of national account and financial variables between Canada and the United States.

Table 1 shows correlations between Canadian and U.S. national accounts variables for both Hodrick-Prescott filter detrended and growth rate series. The correlation between detrended real GDP in the two economies over 1979Q3-2009Q3 was 0.81 (0.64 for growth rates).[2] The strong co-movement between the two business cycles may reflect the fact that Canada and the United States are affected by common shocks. Alternatively, the strong co-movement may reflect the fact that the Canadian business cycle tends to be heavily affected by shocks to the U.S. economy due to Canada's sizeable bilateral trade linkages with and reliance on financing from the United States. At a more disaggregate level, the correlations between detrended Canadian and U.S. consumption and investment are 0.62 and 0.51 (0.42 and 0.41 for growth rates), respectively. Note that these correlations are smaller than the correlation

[2] Backus et al. (1992) and Stockman and Tesar (1995) among others also found strong correlation.

between Canadian and U.S. output due to the large share of Canadian exports destined to the United States. Moreover, there are also positive cross correlations between consumption and investment in the two countries. The correlation between detrended U.S. investment and Canadian consumption is 0.59 and the correlation between detrended U.S consumption and Canadian investment is 0.29 (Table 1).

Canadian and U.S. financial variables are also highly correlated (Table 2). Consider the co-movement of interest rates spreads, a key indicator of financial stress. The first difference of the spread between Libor and the monetary policy interest rate (the interbank spread), the spread between the prime lending rate and Libor (the prime spread), and the spread between the corporate rate and the prime lending rate (the corporate spread) are highly correlated between Canada and the United States with correlations of 0.45, 0.67 and 0.80, respectively. These strong correlations suggest that U.S. financial conditions, as well as U.S. real activity, have important implications for the Canadian economy.

3 The Model

3.1 The Structure of the model

We examine how U.S. real and financial shocks are transmitted to Canada and the role that financial frictions play in their transmission using the Bank of Canada's Global Economy Model (henceforth the BoC-GEM-FIN). The model has been documented elsewhere (de Resende et al forthcoming); therefore, we focus on the features of the model pertinent to our analysis; namely, the model's financial sector.

The model is multi-region, encompassing the world economy in five regional blocks: Canada; the United States; emerging Asia; the commodity exporting countries; and a residual economy, comprised mainly of Japan and the European Union. Each region is modelled symmetrically and consists of households, firms, a government, a central bank, and a banking sector.

Households provide differentiated labour services to firms to produce goods and consume the final goods they help to produce. There are both forward-looking households, who own all of the firms and the capital stock used by firms for production, and liquidity-constrained households, who have no access to capital markets and depend solely on their labour income to finance their consumption. Forward-looking households optimize inter-temporally by saving part of their income in government bonds, foreign assets, bank deposits, and bank capital, which they rent to banks. Liquidity-constrained households optimize only intra-temporally between consumption and leisure. All households derive utility from consumption and leisure. Forward-looking households also derive utility from liquidity services originated in their holdings of deposits in banks, which they optimally choose with their current levels of consumption and labour effort. To better capture the sluggishness observed in consumption and the labour supply, there is habit persistence in both variables.

Firms operate in multi-tiered productive sectors. Firms produce raw materials, intermediate, and final goods.[3] Two types of raw materials are produced by monopolistically competitive retail firms by combining capital, labour, and natural resources: *(i)* energy and *(ii)* non-energy commodities. Three

[3] Production technology in all sectors is represented by a constant-elasticity-of-substitution production function.

types of intermediate goods are produced by monopolistically competitive firms: *(i)* tradable goods, *(ii)* non-tradable goods, and *(iii)* refined energy products for the domestic market, and in the case of tradable goods, for export. Although labour is mobile across production sectors, capital is sector-specific. Both labour and capital are immobile internationally. Commodities are mobile across sectors and internationally. Firms purchase capital in perfectly competitive capital markets and labour in monopolistically competitive labour markets. Firms can adjust their use of capital and labour, but face real adjustment costs when doing so. Finally, perfectly competitive wholesale firms use intermediate goods as inputs in the production of homogenous final goods: *(i)* consumption and *(ii)* investment goods.

Investment decisions at the firm level are managed by risk-neutral **entrepreneurs** who are skilled at managing capital. At the beginning of each period, entrepreneurs rent capital that they purchased at the end of the previous period to retail firms. Entrepreneurs finance their capital purchases using their net worth and bank loans. When financing their capital purchases with debt, entrepreneurs pay an external finance premium, rp_t, to compensate banks for the risk they take on. The risk premium depends inversely on entrepreneurs' net worth, N_t:

$$rp_t = \left(\frac{Q_t^K K_{t+1}}{N_t}\right)^{\psi_t}, \quad (1)$$

where K_{t+1} is entrepreneurs' capital stock in period $t+1$, Q_t^K is the price of capital in period t, and ψ_t is the time-varying elasticity of the external finance premium with respect to the entrepreneurs' leverage ratio.[4] In our multi-sector model, the external finance premium optimally differs across all sectors and regions.

The inverse relationship between the external finance premium and entrepreneurs' net worth arises because, when borrowers have little wealth to contribute to project financing, the potential divergence of borrower and lender interests is greater, implying increased agency costs. To compensate for increased agency costs when borrower net worth is low, lenders demand a higher risk premium. Borrower net worth tends to be procyclical due to, for example, the procyclicality of profits and asset prices. Therefore, the external finance premium tends to be countercyclical and to enhance movements in borrowing, spending and production. This is called the financial accelerator effect (BGG 1999).

In the model, all debt contracts are in nominal terms. Therefore, unexpected changes in the price level over the period of the loan contract result in a reallocation of wealth between entrepreneurs and lenders. For example, an unexpected increase in the price level reduces the real value of debt and increases borrower net worth, leading to a decline in the external finance premium that enhances movements in borrowing, spending, and production. This is the "Fisher deflation effect" after Irving Fisher (1933). In the case of shocks that move prices and output in the same direction, such as demand shocks, the Fisher deflation effect and the financial accelerator effect reinforce each other; however, in

[4] Following Christiano, Motto, and Rostagno (2009) ψ_t is a risk shock that follows an AR(1) process. A positive risk shock may result from an exogenous *(i)* increase in the standard deviation of entrepreneurs' idiosyncratic shocks, which makes it more difficult for banks to assess the creditworthiness of entrepreneurs, *(ii)* reduction in the entrepreneurs' default threshold, and/or *(iii)* increase in monitoring and agency costs.

the case of shocks that move the price level and output in opposite directions, such as supply shocks, they tend to cancel each other out.

By the end of the current period, entrepreneurs' net worth is determined after they settle their debt to banks and sell the undepreciated capital back to capital producers. At this time, entrepreneurs exit the economy with a positive probability. When entrepreneurs exit the economy they are replaced by an equal number of new entrepreneurs who receive a transfer of net worth from those exiting the economy. This transfer is sufficiently small such that this assumption – that entrepreneurs survive to continue to another period with a probability lower than 1 – ensures that the net worth of entrepreneurs is not enough to self-finance new capital acquisitions, so that they must issue debt contracts to finance any desired investment expenditures in excess of their net worth.

For each sector-specific type of physical capital, there is a single, representative, competitive **capital producer** who combines newly produced equipment (investment goods purchased from wholesalers) with used, undepreciated capital (purchased from entrepreneurs) to produce new capital, which is then re-sold to entrepreneurs to be used in the next period's production cycle.

The **government** in each region purchases consumption goods, investment goods, and services, which it finances through taxation or by borrowing from the domestic private sector. Moreover, the government's net tax rate adjusts so that government debt eventually converges to a long-run debt-to-GDP ratio. All domestic debt is held exclusively by domestic forward-looking agents with the exception of U.S. debt, which is traded internationally. The short-term nominal interest rate paid on each type of government bond is equal to the policy rate in the country that issued the bond.

Each region also includes a **central bank** that provides a nominal anchor for the domestic economy using the short-term nominal interest rate as its instrument. The central bank can also engage in quantitative easing, by providing liquidity injections to lending banks, and in qualitative easing, by allowing lending banks to swap a fraction of their loans (risky assets) for government bonds (risk-free assets). With the exception of emerging Asia, all countries target core inflation as their monetary policy objective.[5]

The **banking sector** is modelled following Dib (forthcoming).[6] The banking sector consists of "savings" and "lending" banks, which supply different banking services and interact in an interbank market.

There are a continuum of monopolistically competitive, profit maximizing **savings banks** indexed by $j \in (0,1)$. Savings banks are net creditors in the interbank market. These banks collect fully insured deposits $\left(D_{j,t}\right)$ from forward-looking households and in return pay them the deposit interest rate $(R_{j,t}^{D})$ which is set optimally by savings banks as a mark-down over the marginal return on their assets. As in Gerali et al. (2009), the j^{th} savings bank faces an individual deposit supply function that is increasing in *(i)* the deposit interest rate relative to the market average, R_t^D, and *(ii)* the total supply of deposits, D_t:

[5] Emerging Asia is assumed to follow a nominal exchange rate peg relative to the U.S. dollar.
[6] Christiano et al 2007, Christiano et al 2009, Gerali, Neri, Sessa and Signoretti 2009, Markovic 2006, and Meh and Moran 2008 also introduce banking sectors into DSGE models.

$$D_{j,t} = \left(\frac{R^D_{j,t}}{R^D_t}\right)^{\vartheta_D} D_{t,} \tag{2}$$

where $\vartheta_D > 1$ is the elasticity of substitution between different types of deposits. When adjusting the deposit interest rate, savings banks face quadratic adjustment costs à la Rotemburg (1982):

$$Adj^{R^D}_{j,t} = \frac{\phi_{R^D}}{2}\left(\frac{R^D_{j,t}}{R^D_{j,t-1}} - 1\right)^2 D_t, \tag{3}$$

where ϕ_{R^D} is the adjustment cost parameter. These adjustment costs generate an interest rate spread that varies over the business cycle.

Savings banks optimally allocate a fraction of total deposits, $s_{j,t}$, to lending in the interbank market and invest the remaining deposits,$(1 - s_{j,t})$, in risk-free government bonds, $B_{j,t}$. The optimal allocation of deposits depends on the return earned on risky interbank lending, R^{IB}_t, and on riskless government bonds, R_t. These interest rates are determined by the equilibrium in the interbank market and the policy interest rate, respectively. When lending in the interbank market, savings banks must monitor banks borrowing in the interbank market as those banks default on their borrowing with a positive probability, δ^D_t. When monitoring, savings banks pay a quadratic monitoring cost that depends on the amount lent in the interbank market. Therefore, the interbank interest rate depends on the cost of monitoring as well as the probability of default on interbank borrowing.

Formally, the problem of the j^{th} savings bank is:

$$\max_{\{(s_{j,t}R^D_{j,t})\}} E_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \left\{\left[s_{j,t}(1-\delta^D_t)R^{IB}_t + \left(1 - s_{j,t}\right)R_t - R^D_{j,t}\right]D_{j,t} - \frac{\chi_s}{2}(s_{j,t}D_{j,t})^2 - Adj^{R^D}_{j,t}\right\}, \tag{4}$$

subject to (2) and (3), taking R_t and δ^D_t as given. Since households are the owners of banks, the stream of profits is discounted by $\beta^t \lambda_t$, where λ_t denotes the marginal utility of consumption, $\frac{\chi_s}{2}(s_{j,t}D_{j,t})^2$ represents the quadratic monitoring cost of lending in the interbank market, and $\chi_s > 0$ is a parameter determining the steady-state level of these costs.

In a symmetric equilibrium, where $s_t = s_{j,t}$ and $R^D_t = R^D_{j,t}$, the first-order conditions of this optimization problem with respect to $s_{j,t}$ and $R^D_{j,t}$ are:

$$s_t = \frac{(1-\delta^D_t)R^{IB}_t - R_t}{\chi_s D_t}, \text{ and} \tag{5}$$

$$R^D_t = \frac{\vartheta_D}{1+\vartheta_D}\left[s_t(1-\delta^D_t)R^{IB}_t + \left(1 - s_{j,t}\right)R_t - \chi_s s^2_t D_t - \Omega_t + \frac{\beta\lambda_{t+1}}{\lambda_t}\Omega_{t+1}\left(\frac{D_{t+1}}{D_t}\right)\right], \tag{6}$$

where

$$\Omega_t \equiv \frac{\phi_{R^D}}{\vartheta_D}\left(\frac{R^D_t}{R^D_{t-1}} - 1\right)\frac{R^D_t}{R^D_{t-1}} \tag{7}$$

is the marginal cost of adjusting the deposit interest rate.

As described in condition (5), *ceteris paribus* savings banks reduce the share of deposits allocated to interbank lending when the probability of default on interbank lending rises and when the total supply of deposits rises. Moreover, an increase in the interest rate on government bonds reduces the relative attractiveness of interbank lending and leads to a fall in the share of deposits allocated to interbank lending. Finally, an increase in the interbank interest rate leads to an increase in the share of deposits allocated to interbank lending. An increase in s_t indirectly leads to an expansion in credit supply in the interbank market. Condition (6) defines the deposit interest rate as a mark-down of the interbank rate.

Lending banks are net debtors in the interbank market. Lending banks combine funds received on the interbank market, $\widetilde{D}_t = (1 - s_t)D_t$, with the value of bank capital raised from households, $Q_t^z Z_{j,t}$, to supply loans to entrepreneurs. The stock of bank capital, $Z_{j,t}$, valued at price Q_t^z is held by banks as government bonds. To produce loans, the j^{th} bank uses Leontief technology:

$$L_{j,t} = \min\{\widetilde{D}_{j,t}; k_{j,t}\,(Q_t^z Z_{j,t} + x_{j,t})\}\,\Gamma_t, \tag{8}$$

where Γ_t, is an AR(1) shock to the intermediation process (loan production) that may represent exogenous factors that affect the bank's balance sheet such as perceived changes in creditworthiness, technological changes in the intermediation process, and sophisticated methods of risk sharing.

Lending banks earn the prime loan rate, $R_{j,t}^L$, which is set optimally as a mark-up over the marginal cost of loan production, plus the risk premium, rp_t, on loans made to entrepreneurs. When lending to entrepreneurs lending banks face a Dixit-Stiglitz type demand function for loans:

$$L_{j,t} = \left(\frac{R_{j,t}^L}{R_t^L}\right)^{-\vartheta_L} L_t, \tag{9}$$

where $\vartheta_L > 1$is the elasticity of substitution between loans provided by different lending banks.

Lending banks face adjustment costs when setting the prime lending rate. As with the adjustment costs on the deposit interest rate, these adjustment costs are modelled à la Rotemburg (1982):

$$Adj_{j,t}^{R^L} = \frac{\phi_{R^L}}{2}\left(\frac{R_{j,t}^L}{R_{j,t-1}^L} - 1\right)^2 L_t, \tag{10}$$

where $\phi_{R^L} > 0$ is the adjustment cost parameter.

Lending banks optimally default on a share of their interbank borrowing and on part of the return on bank capital owed to households, R_t^z. This follows Goodhart et al. (2006). The optimally chosen default rates on interbank borrowing and bank capital are $\delta_{j,t}^D$ and $\delta_{j,t}^Z$, respectively. Defaulting banks must pay convex penalties, $\Omega_t^D$and Ω_t^Z, in the next period that generate a spread over the interbank interest rate:

$$\Omega_t^D = \frac{\chi_{\delta^D}}{2}\left(\frac{\delta_{j,t-1}^D \widetilde{D}_{j,t-1}}{\pi_t}\right)^2 R_{t-1}^{IB}, \text{and} \tag{11}$$

$$\Omega_t^Z = \frac{\chi_{\delta^Z}}{2}\left(\frac{\delta_{j,t-1}^Z Q_{t-1}^Z Z_{j,t-1}}{\pi_t}\right)^2 R_{t-1}^Z, \quad (12)$$

where χ_{δ^D} and χ_{δ^Z} are positive parameters.

Lending banks optimally choose their leverage ratio (loans-to-capital ratio), $k_{j,t}$ defined as:

$$k_{j,t} = L_{j,t}/Q_t^Z Z_{j,t}. \quad (13)$$

However, in order to lend to entrepreneurs, lending banks must maintain sufficient capital to satisfy a minimum capital requirement required by regulators, $1/\bar{k}$, where $k_{j,t} \geq \bar{k}$. Lending banks that hold capital in excess of the required level receive convex gains, Ω_t^k, so that variations in banks' capital directly affect the marginal cost of capital. The quadratic gains are given by:

$$\Omega_t^k = \frac{\chi_k}{2}\left(\frac{\bar{k} - k_{j,t}}{\bar{k}} Q_t^Z Z_{j,t}\right)^2, \quad (14)$$

where χ_k is a parameter determining the steady-state value of k_t.

Formally, the problem of the j^{th} bank that borrows in the interbank market to lend to entrepreneurs is:

$$\max_{\{R_{j,t}^L, k_{j,t}, \delta_{j,t}^D, \delta_{j,t}^Z\}} E_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \left\{R_{j,t}^L L_{j,t} - \left(1-\delta_{j,t}^D\right) R_t^{IB} \bar{D}_{j,t} - \left[\left(1-\delta_{j,t}^Z\right) R_{t+1}^Z - R_t\right] Q_t^Z Z_{j,t} - \Omega_t^D - \Omega tZ + \Omega tk - Adjj,tRL\right. \quad (15)$$

subject to Equations 8-14.

In a symmetric equilibrium, the first-order conditions of this optimization problem are:

$$k_t = \bar{k}\left[1 - \frac{\Gamma_t \bar{k}(R_t^L - 1)}{\chi_k Q_t^Z Z_t}\right]; \quad (16)$$

$$\delta_t^D = E_t\left[\frac{\pi_{t+1} R_t}{\chi_{\delta^D} \bar{D}_t}\right]; \quad (17)$$

$$\delta_t^Z = E_t\left[\frac{\pi_{t+1} R_t}{\chi_{\delta^Z} Q_t^Z Z_t}\right]; \text{ and} \quad (18)$$

$$R_t^L = 1 + \frac{\vartheta_L}{\vartheta_L - 1}(\zeta_t - 1) - \frac{\phi_{R^L}}{\vartheta_L - 1}\left(\frac{R_t^L}{R_{t-1}^L} - 1\right)\frac{R_t^L}{R_{t-1}^L} + \frac{\beta \lambda_{t+1}}{\lambda_t}\frac{\phi_{R^L}}{\vartheta_L - 1} E_t\left[\left(\frac{R_{t+1}^L}{R_t^L} - 1\right)\frac{R_{t+1}^L}{R_t^L}\right], \quad (19)$$

where $k_t = k_{j,t}$, $\delta_t^D = \delta_{j,t}^D$, $\delta_t^Z = \delta_{j,t}^Z$, $R_t^L = R_{j,t}^L$, and

$$\zeta_t = \Gamma_t^{-1}\left\{R_t^{IB} + \left[R_{t+1}^Z - R_t^{IB} - (R_t^L - 1)\frac{\bar{k} - k_t}{\bar{k}}\right]\frac{Q_t^Z}{k_t}\right\} \quad (20)$$

is the marginal cost of producing loans.

Condition (16) describes lending banks' optimal leverage ratio which is decreasing in the regulated minimum capital requirement and the prime loan interest rate and increasing in the value of bank

capital. Conditions (17) and (18) describe the optimal default rates on interbank borrowing and on the return on bank capital owed to households, respectively. Both default rates increase with the policy interest rate. Moreover, the probability of default on interbank borrowing is decreasing in the total amount borrowed and the probability of default on the return on bank capital owned to households is decreasing in the value of bank capital. Condition (19) relates the prime lending rate to the marginal cost of producing loans (Equation 20) and to current costs/future gains of adjusting the prime lending rate. The marginal cost of producing loans is the sum of the marginal cost of interbank borrowing, R_t^{IB}, and that of raising bank capital (including the shadow price of using capital to satisfy the capital requirement) adjusted by the leverage ratio, given by $\left[R_{t+1}^{Z} - R_t^{IB} - (R_t^{L} - 1)\,\bar{k} - k_t/\bar{k}\right] Q_t^{Z}/k_t$. This relationship arises due to the fact that loans are produced using Leontief technology, implying perfect complementarily between interbank borrowing and bank capital. As a result, the optimal choice of leverage ratio directly affects the cost of lending through its impact on the cost of raising bank capital and the marginal cost of producing loans.

The use of Leontief technology to produce loans implies the following demand functions for interbank borrowing and bank capital:

$$L_t = \Gamma_t \widetilde{D}_t, and \tag{21}$$

$$L_t = \Gamma_t k_t Q_t^{Z} Z_t. \tag{22}$$

Overall, there are several channels through which the banking sector affects credit market conditions. First, defaults on interbank borrowing and bank capital affect the marginal cost of interbank borrowing and raising bank capital. Second, variations in bank capital and bank capital price expectations alter the resources available to lending banks and thus the availability of credit. Third, savings and lending banks have monopoly power in setting nominal deposit and lending interest rates, respectively, with nominal rigidities that imply moving interest rate spreads over the business cycle. Fourth, savings banks optimally allocate their portfolio between interbank lending and risk-free assets. Fifth, lending banks optimally choose their leverage ratio subject to the bank capital requirement condition. These choices made by savings and lending banks affect credit supply conditions.

Finally, there are several **bilateral linkages** between the regions of the world economy. Regions trade in oil, non-energy commodities, and tradable consumption and investment goods. Moreover, firms in all sectors obtain a share of their financing from domestic banks and another share from foreign banks. Therefore, there are important bilateral loan flows. The regions also trade positions in the international bond (U.S. debt) and their positions in this bond determine their net foreign asset (NFA) position.

3.2 Calibration

The calibration of the model's parameters is based on data, microeconomic studies, and by drawing on other DSGE models (see de Resende et al. forthcoming for a detailed account of the calibration of the model). Of particular interest for this study is the calibration of international trade and loan flows.

Trade linkages are calibrated based on current trading trends in the COMTRADE database of the United Nations. Figure 1 illustrates the calibration of all bilateral trade flows in tradable goods between the regions.[7] These calibrated trade flows are used to derive the regional composition of imports as well as the weights of imported consumption and investment goods in each region's production functions. Pertinent to the results of this study is also the fact that trade accounts for a large share of Canadian GDP (73 per cent) and the majority of this trade occurs with the United States (82 per cent).[8] Thus, U.S. shocks transmitted through trade linkages may have particularly large implications for Canada.

International loan flows are calibrated based on recent movements in loans observed in the International Banking Statistics data maintained by the Bank for International Settlements. This data suggests that roughly 56 per cent of Canadian loans originate from domestic lenders, while the remaining 44 per cent are obtained from foreign financial institutions. Figure 2 shows that Canada receives the majority of its foreign financing from the remaining countries (which mainly consist of European Union and Japan), while the United States also accounts for a large share (40 per cent). Thus, a domestic shock that affects loan flows will affect access to credit in both the domestic economy as well as other countries that rely on foreign banks for financing.

4 Results

In this section, we assess the transmission of U.S. financial shocks to Canada and the role that financial frictions play in the transmission of other types of U.S. demand and supply shocks to Canada.

4.1 U.S. Financial Shocks

In the recent financial crisis, the difficulties in U.S. financial markets also affected other countries. We focus our analysis on two of the financial shocks that occurred in the United States over the financial crisis and examine how these types of shocks can affect other countries. First, the U.S. financial crisis was characterized by a pullback in lending by U.S. banks as many U.S. financial institutions faced funding problems. This shock was both directly and indirectly transmitted to other countries. For instance, Canadian firms obtain approximately 18 per cent of their total loans from U.S. financial institutions; therefore, this pullback in lending was likely an important contributor to the Canadian downturn. At the same time, there was likely an indirect effect on Canada as the shock affected the U.S. real economy and spread to Canada through other channels. Second, there was an increase in the probability of default on U.S. interbank borrowing that likely also affected other countries both directly and indirectly. We thus focus our analysis on the transmission of a shock to U.S. loan supply and a shock to the probability of default on U.S. interbank borrowing to Canada.

A Fall in U.S. Loan Supply

We first consider a negative shock to U.S. loan supply, achieved through a negative shock to the productivity of loan production, Γ_t, in Equation (8). The shock increases the marginal cost of producing loans (see Equation 20) and leads to a fall in credit supply without directly varying the inputs used in the

[7] Trade flows are calculated as the sum of imports and exports.
[8] These shares reflect the calibration in the BoC-GEM-FIN.

loan production function (Figure 3). This fall in credit supply has important effects on both financial conditions and real economic activity. The increase in the marginal cost of loan production causes an increase in the loan prime interest rate (see Equation 19) and entrepreneurs face a higher cost of external finance, reflected in increases in the financial risk premiums across all sectors. With a higher cost of external finance, entrepreneurs invest less and households, who own firm's capital, consume less and economic activity and inflation decline. The fall in inflation further reduces the entrepreneurs' net worth. Given the inverse relationship between net worth and the cost of external finance (see Equation 1), the decline in net worth reinforces the increases in the financial risk premiums and the decline in economic activity and inflation. Moreover, given the large relative size of the U.S. economy, the fall in U.S. demand induces an important drop in world commodity prices. Monetary policy reacts to the fall in inflation and reduces the nominal policy interest rate. These developments are in line with what was observed throughout the financial crisis.

The negative shock to U.S. loan supply is transmitted to Canada through three main real channels:

- First, the fall in U.S. demand for tradable goods decreases the demand for Canadian exports.
- Second, Canada, as a net exporter of commodities, suffers from negative terms-of-trade and wealth effects as world commodity prices decline. These negative effects reduce Canadian consumption. Moreover, the decline in world commodity prices contributes to a fall in Canadian entrepreneurs' net worth and, as such, to increases in the financial risk premiums in these sectors (see Equation 1), which exert additional negative pressure on Canadian investment.
- Third, because of the fall in U.S. interest rates relative to Canadian interest rates the Canadian dollar appreciates on impact before depreciating. The subsequent depreciation, which is caused by the fall in commodity prices, reduces the price of Canadian goods and increases the demand for Canadian exports (the price effect). Nevertheless, this positive effect on Canadian exports is outweighed by the negative income and wealth effects.

and two financial channels:

- First, the negative shock to U.S. loan supply also reduces the total amount of lending by U.S. banks to Canadian firms and their access to financing; however, this channel interacts with the response of the Canadian exchange rate. The depreciation of the Canadian exchange rate increases the value of existing loans received by Canadian firms from U.S. banks causing a deterioration in the balance sheet conditions of Canadian entrepreneurs, contributing to increases in the financial risk premiums (see Equation 1), and leading to a reduction in Canadian investment, spending, and output. This loss in Canadian output occurs in the model because firms do not hedge their exposure to foreign currency loans. In practice however, this negative effect on Canadian economic activity would be mitigated by the fact that many Canadian firms hedge their foreign currency liabilities either through natural or financial hedges.
- Second, all of the aforementioned real and financial transmission channels reduce Canadian demand for all types of goods. As a result, inflation, asset prices, and goods prices fall, inducing a fall in entrepreneurs' net worth and a further increase in the financial premiums in all sectors, which leads to an additional fall in Canadian economic activity.

Overall, the contraction in U.S. loan supply leads to a decrease in Canadian real output of one per cent compared to 1.7 per cent in the United States (Figure 4), highlighting the importance of developments in foreign financial conditions for real activity in Canada. As a result, inflation falls and the central bank decreases the policy interest rate, suggesting that domestic policy must take into consideration developments in foreign financial conditions.

As discussed above, the transmission of the decline in U.S. loan supply to Canada occurs through both real and financial channels. We can assess the importance of the main financial channel, international loan flows, in the transmission of the shock to U.S. loan supply by comparing the Canadian response to the shock in the BoC-GEM-FIN to a version of the model that excludes the international loan flow channel.[9] As seen in Figure 4, our results suggest that international loan flows explain about 20 per cent of the decline in Canadian output following the decline in U.S. loan supply, highlighting the importance of a clear understanding of cross-country financial linkages.

Previous research (e.g. Gilchrist et al. 2002) has also shown that financial frictions may increase the degree of cross-country transmission of shocks. We thus also assess the relative importance of different types of financial frictions in the Canadian economy in propagating the Canadian response to the decline in U.S. loan supply. To do so, we compare impulse response in three versions of the model: the BoC-GEM-FIN, the BoC-GEM-FIN excluding the financial accelerator in Canada, and the BoC-GEM-FIN excluding the banking sector in Canada (see Figure 5). While the U.S. loan supply shock has an important effect on the Canadian economy, financial frictions in Canada amplify only slightly the Canadian response to the shock. 10 per cent of the total decline in Canadian output following the decline in U.S. loan supply can be attributed to amplifying effect of the Canadian financial accelerator. This relatively small effect can be explained by the fact that Canada is a net importer of investment goods. Given that the financial accelerator affects mostly investment, for Canada, its contribution to real GDP is dampened by a strong fall in imports of investment goods. Therefore, although the overall impact of the Canadian financial accelerator on output may be relatively small, there is an important change in the distribution of economic activity associated with the financial accelerator. The Canadian banking sector plays a small role in amplifying the effect of the U.S. loan supply shock on Canada and, as with the financial accelerator; its effect is offset by the fact that the additional weakness in investment is mostly imported.

An Increase in the Probability of Default on Interbank Borrowing

In the recent financial crisis, the probability of default on U.S. interbank borrowing increased and was partly responsible for a decline in lending activity by major U.S. financial institutions. We thus examine how a temporary positive shock to probability of default on U.S. interbank borrowing can be transmitted to Canada. The shock that we examine doubles the probability of default on interbank borrowing, increasing it temporarily from its steady-state value of 1.4 to 2.8 per cent.

[9] This latter model is created by calibrating the model such that the share of foreign banks in total loans is set to zero in all regions. This does not alter the steady-state loan to output ratio in each region, but merely redistributes it such that all financing in all regions is obtained from only domestic sources.

In the United States, the increase in the probability of default on interbank lending causes the spread between the interbank interest rate and the policy rate to widen substantially (Figure 6). The shock is transmitted to the lending rate, which rises. The higher financing cost for entrepreneurs induces a drop of investment, consumption, and output. Inflation falls and the central bank reacts by reducing the policy interest rate. The deposit interest rate falls alongside the policy interest rate. Moreover, there is an important credit crunch in the U.S. economy as savings banks respond to the shock by reducing the share of deposits allocated to interbank lending (see Equation 5). With less interbank borrowing from which to produce loans, lending banks restrict lending to entrepreneurs and the reduction in credit supply leads to a further fall in U.S. economic activity. The fall in U.S. economic activity is mirrored in the rest of the world. As global economic activity declines, the demand for, and prices of, commodities decline as well. Similar responses were observed in financial conditions and real economic activity following the increase in the probability of default on U.S. interbank borrowing observed in the recent financial crisis, suggesting that our model does a reasonably good job of capturing the linkages between financial conditions themselves and between financial conditions and the real economy.

Canada is affected by the increase in the probability of default on U.S. interbank borrowing through the same channels by which it is affected following a shock to U.S. loan supply. Mainly, the decrease in U.S. demand depresses Canadian exports and the declines in commodity prices incite negative terms-of-trade and wealth effects on Canada. As a result, consumption falls and the Canadian dollar depreciates. Although U.S. banks restrict their lending to Canadian firms, initially the total value of the existing loans received by Canadian firms from U.S. banks rises as the Canadian dollar depreciates. As the liabilities of Canadian firms rise and as the cost of foreign financing rises, the financial risk premiums in all sectors rise (see Equation 1) and contribute to the decline in Canadian economic activity. Over the medium-term, loans to Canadian firms from U.S. banks decline, reducing access to credit for Canadian firms. These developments in Canadian financial conditions show the importance of developments in foreign financial conditions for financial conditions in Canada. On net, Canadian real output is lower following the increase in the probability of default on U.S. interbank borrowing (Figure 7). As the shock is transmitted to the Canadian economy, real output falls by 0.2 per cent compared to 0.3 per cent in the United States. To offset these negative effects on the Canadian output and inflation, there is an expansion in monetary policy that is passed-through into all other interest rates in the economy.

In Figure 7, it can be seen that, as with the U.S. loan supply shock, international loan flows are an important transmission channel of the shock to the probability of default on U.S. interbank borrowing to Canada. Exactly as in the case of a shock to U.S. loan supply, our results suggest that international loans flows account for about 20 per cent of the decline in Canadian output following the shock to the probability of default on U.S. interbank borrowing, mainly due to their effect on Canadian investment.

Financial frictions in the Canadian economy play a relatively small role in propagating the Canadian response to the increase in the probability of default on U.S. interbank borrowing (Figure 8). The Canadian banking sector in particular has almost no effect on the Canadian response. However, the financial accelerator in Canada does amplify the Canadian response, particularly the fall in Canadian

investment. Our results suggest that the financial accelerator in Canada explains about one third of the peak decline in Canadian investment in the BoC-GEM-FIN. However, it explains only about 15 per cent of the total fall in Canadian output given that Canada is a net importer of investment goods.

Finally, note that in our simulations the central bank is able to offset part of the effect of shocks to U.S. financial conditions on the domestic and Canadian economies by lowering the policy interest rate. To illustrate the role of monetary policy in dampening the impact of financial shocks on the real economy, we re-run the same shock to the probability of default on U.S. interbank borrowing, but restrict the reaction of monetary policy in both countries such that the nominal policy interest rate cannot respond to the shock. The results in Figure 9 show that, with such a constraint imposed for four quarters and absent any other monetary stimulus, the propagation of U.S. financial shocks to both the U.S. and Canadian economies would be substantially larger.[10] In particular, with the nominal policy rate unable to respond, the fall in inflation following the increase in the probability of default on U.S. interbank borrowing would cause a large spike in the real interest rate in both the United States and in Canada. As a result, output in both countries would fall by about triple the decline when the nominal policy interest rate reacts to the increase in the probability of default on interbank borrowing. This simulation represents an upper bound of the impact of the shock on the real economy and it is not a scenario that is likely to happen. As the recent financial crisis shows, in the event of the nominal interest rate reaching the lower bound, central banks have alternative monetary policy tools that can be used to intervene and stimulate the economy. For instance, the Bank of Canada provided monetary stimulus using a conditional statement regarding the future path of the policy interest rate, while the Federal Reserve engaged in large scale asset purchases and credit easing. This exercise highlights the important potential role of the "unconventional" monetary policies that central banks have at their disposal.

4.2 Other Shocks to the U.S. Economy

We now consider financial frictions as a mechanism for the propagation of U.S. real demand and supply shocks and their transmission to Canada. The interplay between financial conditions and real economic activity is not unidirectional. That is, financial conditions do not just affect real economic activity, but real economic activity may also affect financial conditions. In order to completely understand the importance of real-financial linkages in the economy, we must understand all sides of this multi-directional relationship. We examine how financial frictions propagate real demand and supply shocks by drawing comparisons between the impulse responses of key macroeconomic and financial variables to shocks in the BoC-GEM-FIN and two alternative calibrations of the model that shut down the various types of financial frictions. First, we consider a version of the BoC-GEM-FIN, the BoC-GEM-BGG, that shuts down the banking sector in the model but includes the financial accelerator. Second, we consider the BoC-GEM, which shuts down both the banking sector and the financial accelerator. To understand the role of financial frictions in the transmission of U.S. real shocks to Canada, we consider both a temporary increase in U.S. consumption and a permanent U.S. productivity shock.

[10] This is accomplished by reducing the coefficient on inflation in the interest rate rule to 0.01 for four quarters. We restrict the monetary policy reaction in the United States, Canada, and the remaining countries as these regions all attained the nominal lower bound on policy interest rates in the financial crisis.

A Temporary Increase in U.S. Consumption

The first demand shock that we consider is a temporary increase in the marginal utility of U.S. consumption that triggers a temporary rise in consumption. The size of the shock is calibrated such that the peak response of U.S. consumption in the BoC-GEM is 1 per cent. Figures 10 and 11 describe the impact of the shock on the United States and Canada, respectively. In the United States, the rise in consumption increases the demand for oil, tradable, and non-tradable goods. The increase in demand puts upward pressure on wages, oil, and non-energy commodity prices and, therefore, marginal cost, leading to an increase in inflation. In response, the central bank raises the policy interest rate, which generates an appreciation of the real effective exchange rate and a decrease in investment.

In the BoC-GEM-BGG, financial frictions amplify the domestic effect of the U.S. consumption shock through two channels. First, there is a positive debt deflation effect as the increase in inflation reduces the real value of entrepreneurs' debt, increases their net worth, and thus pushes down the financial risk premiums that entrepreneurs pay on borrowed funds (see Equation 1). This effect dominates in the short-run. Second, as the economy is better off following the increase in consumption, sales and profits rise, contributing to a further increase in the net worth of borrowers and to a further fall in the financial risk premiums. This effect dominates in the medium-term. The declines in the financial risk premiums caused by both effects stimulate investment, household spending, and output. In BoC-GEM-BGG, stronger investment abroad also contributes to a stronger response of exports in the United States as the foreign financial accelerator amplifies the responses of foreign domestic demand.

The two channels through which financial frictions affect the economy in the BoC-GEM-BGG operate in the same direction following the U.S. consumption shock therefore; we observe a persistent increase in U.S. investment in contrast to the fall observed in the BoC-GEM. Thus, the model with the financial accelerator is able to generate the positive correlation between consumption and investment observed empirically that is not easily captured by a model with limited financial frictions (e.g. Lalonde and Muir 2007). The increase in investment, as well as the magnified consumption response, leads to an increase in output that is almost twice as large as in the BoC-GEM.[11] Therefore, inflation rises by more and the forward-looking central bank increases the policy interest rate by about 50 per cent more. Absent this additional contraction in monetary policy, we would observe an even larger increase in U.S. economic activity after the increase in consumption in the model with the financial accelerator.

In both the BoC-GEM-BGG and in the BoC-GEM-FIN, partly because of large adjustment costs on investment, net worth increases by more than investment, reducing the demand for loans. In the BoC-GEM-FIN, in addition to the fall in demand for loans there is a slight fall in the supply of loans that also affects the transmission of the U.S. consumption shock throughout the economy. With the banking sector present, the increase in the policy interest rate is passed-through to the other borrowing rates.

[11] Note that the positive response of investment is observed only in response to a temporary shock to U.S. consumption. A more persistent shock to U.S. consumption would have a larger effect on inflation expectations causing a more aggressive and persistent monetary policy reaction that would induce a fall in investment.

The increases in interest rates, as well as the increase in inflation, lead to an increase in the probability of default on interbank borrowing (see Equation 17), which causes savings banks to decrease the share of deposits devoted to interbank lending (see Equation 5). Moreover, the increase in the return on the risk-free asset as the policy interest rate rises also reduces interbank lending supply as it makes investment in the risk-free asset relatively more attractive than lending on the interbank market (see Equation 5). As households consume more, they allocate a smaller share of their resources to purchasing bank capital and the value of bank capital falls. Therefore, lending banks, which produce loans using interbank borrowing and bank capital, reduce their lending to firms. As credit supply falls in the BoC-GEM-FIN, total loans to firms fall by more than in the model with a passive banking sector (BoC-GEM-BGG). In reaction to the U.S. consumption shock, investment is already on a rising path. Large investment adjustments costs limit the ability of firms to reduce their investment in response to the reduction in the Canadian loan supply. Therefore, the fall in loans, with a relatively constant capital stock, implies higher net worth. As a result, the financial risk premiums fall by slightly more over the medium-term and investment and output are slightly stronger than in BoC-GEM-BGG. These slightly larger responses are partially offset by monetary policy.

The shock to U.S. consumption is transmitted to Canada through five main channels:

- First, the increase in U.S. demand for tradable goods increases demand for Canadian exports. This channel is active in all versions of the model. However, in the BoC-GEM-BGG and the BoC-GEM-FIN the financial accelerator magnifies the increase in U.S. domestic demand. As a result, the increase in Canadian exports is about twice as large as in the BoC-GEM.
- Second, the rise in U.S. economic activity induces an increase in world demand for commodities, causing an increase in world commodity prices. As a result, Canada benefits from positive terms-of-trade and wealth effects that stimulate Canadian consumption in all models. The positive effect on Canada is relatively larger in the BoC-GEM-BGG and the BoC-GEM-FIN as U.S. output, and therefore, the commodity prices rise by more. The increase in commodity prices also contributes to an increase in the net worth of Canadian entrepreneurs and, as such, to declines in the financial risk premiums (see Equation 1), which stimulates Canadian investment.
- Third, the Canadian dollar depreciates, reducing the price of Canadian goods and increasing the demand for Canadian exports. In the models with more developed financial frictions, the depreciation is short-lived and the Canadian dollar appreciates over the medium-term. This appreciation episode is explained by the stronger reaction of commodity prices in the models with financial frictions. The medium-term appreciation reduces the demand for Canadian exports by a similar magnitude in the models with more developed financial frictions.
- Fourth, the financial accelerator in Canada amplifies the responses of Canadian consumption and investment to the U.S. consumption shock. The increase in wealth generated from the boost in trade and the increase in commodity prices increases domestic demand for Canadian goods. In response, sales and profits increase and the net worth of Canadian entrepreneurs rises. As a result, the financial risk premiums decline further and stimulate investment and consumption in Canada. This positive effect is compounded by a positive debt deflation effect as the increase in inflation reduces the real value of debt and increases entrepreneurs' net worth. Therefore, in both the BoC-GEM-BGG and the BoC-GEM-FIN we observe a positive correlation between the

responses of consumption and investment in both countries and between both countries. In contrast, in the model without financial frictions (i.e. the BoC-GEM), Canadian investment falls. Thus, with the financial accelerator present, the model can replicate the positive correlation between investment across countries and the positive correlation between consumption and investment in the domestic economy discussed in Section 2.[12]

- Fifth, in the BoC-GEM-BGG and the BoC-GEM-FIN, the total amount of lending by U.S. banks declines. Part of this decline in lending is a decline in loans from U.S. banks to Canadian firms. Given that in the BoC-GEM-FIN, U.S. loans fall by more than in the BoC-GEM-BGG, the effect of the decline in U.S. loans to Canadian firms is slightly larger.

Overall, Canadian economic activity and inflation rise in all models following the U.S. consumption shock and the central bank increases the policy interest rate. This monetary policy response dampens the effect of the U.S. shock on Canada. Interestingly, the monetary policy response is larger when financial frictions are taken into account, suggesting that the Canadian central bank must respond by more to foreign demand shocks when there are important financial frictions in order to maintain inflation at its target. Notably, in the model that excludes financial frictions, investment falls in both countries following the increase in U.S. consumption as its response is dominated by the contraction in monetary policy. In the models with more complex financial frictions, financial frictions in the U.S. economy magnify the Canadian response to the U.S. consumption shock through their effects on Canadian trade, commodity prices, and loans. Combined with the Canadian financial accelerator these magnified responses change the sign of the response of Canadian investment to the U.S. consumption shock.

The Canadian banking sector plays a minor role in the propagation of U.S. consumption shock to the Canadian economy. The dynamics are similar to those in the United States. The Canadian banking sector leads to a slightly stronger, more persistent medium-term increase in investment relative to the model with the financial accelerator. This slight amplification is mainly associated with a pullback in lending by Canadian banks. Savings banks, in reaction to the increase in inflation and the monetary policy rate, which increase the probability of default on interbank lending (see Equation 17) restrict lending on the interbank market (see Equation 5). Lending banks, with less access to interbank borrowing and a decline in bank capital, also restrict credit supply. As a result, total loans to firms fall by more than in the model with the financial accelerator. In the context of large adjustment costs on investment, the fall in loans implies that entrepreneurs react optimally by accumulating net worth. In our model, about 15 per cent of the decline in lending is associated with a tightening in lending by U.S. banks, while the remaining 85 per cent is due to the pullback in lending by Canadian banks. The larger increase in net worth leads to a larger falls in the financial risk premiums (see Equation 1) and, after a delay explained by large adjustment costs, correspondingly larger increases in investment, spending, and output.

[12] The positive correlation between U.S. and Canadian consumption and investment is not observed in the case of a more persistent shock to U.S. consumption as, like in the United States, the more persistent shock would have a larger positive effect on inflation expectations generating a more aggressive monetary policy response.

A Permanent Increase in U.S. Productivity

Next we consider a permanent one per cent increase in U.S. productivity in the tradable and non-tradable sectors (Figures 12 and 13). The increase in productivity occurs equally in the two largest sectors of the economy therefore; it increases supply and reduces the prices of domestic goods including investment goods. Moreover, the increase in productivity induces depreciation in the real effective exchange rate in order to sell abroad the additional supply of goods from the increase in domestic production.[13] In the United States, the increase in productivity reduces marginal cost and inflation, leading to a decline in the policy interest rate. To capitalize on their productivity gains, U.S. firms increase their demand for all inputs of production including oil and non-energy commodities. As a result, the prices of oil and non-energy commodities increase substantially and permanently.

In the BoC-GEM-BGG the response of real output to the increase in productivity is very similar to in the BoC-GEM. However, there are differences in the dynamics of the U.S. economy. Mainly, profits and asset prices rise, leading to an increase in net worth and to declines in the financial risk premiums in all sectors (see Equation 1). The lower financial risk premiums stimulate the economy however; this positive effect is offset by less expansionary monetary policy as the forward-looking central bank recognizes the stimulative effect of the decline in the financial risk premiums on the economy and reduces the nominal policy interest rate by less than in the BoC-GEM. This relatively tighter monetary policy stance counteracts the positive effect of the fall in the risk premiums on the economy. On net, the overall level of economic activity in the BoC-GEM-BGG is comparable to that in the BoC-GEM.

The increase in U.S. real GDP is larger when we take into account the existence of an active banking sector. The stronger increase in real GDP is mainly associated with a boost in exports as developments in the foreign banking sector amplify the increase in foreign investment. The United States, as a large net exporter of investment goods, benefits from this additional increase in foreign investment.

In the short run, Canada is affected by the increase in the U.S. productivity through:

- a positive income effect as U.S. demand for Canadian goods rises. This effect is stronger in the BoC-GEM-BGG, and to a larger extent, the BoC-GEM-FIN than in the BoC-GEM.

- positive terms-of-trade and wealth effects, generated by the increases in the prices of oil and non-energy commodities that stimulate Canadian consumption.

- a negative price substitution effect as the Canadian dollar appreciates, putting downward pressure on Canadian exports. This effect is stronger in the BoC-GEM model than in the models with more developed financial frictions.

- a decline in the value of U.S. loans to Canadian firms. Although loans made by U.S. banks to both domestic and foreign borrowers rise in U.S. dollars, the value of U.S. loans to Canadian firms declines due to the appreciation of the Canadian dollar. This decline boosts the net worth of

[13] Although not examined here, a productivity shock specific to the tradable sector would generate an appreciation, rather than a depreciation of the real effective exchange rate. Hence, the BoC-GEM is able to capture the Balassa-Samuelson effect.

Canadian entrepreneurs, decreases the financial risk premiums charged to Canadian firms when financing through debt, and helps to stimulate investment in Canada.

Over the long run, Canadian output is permanently higher because of the following channels:

- The United States is more efficient at producing investment goods, which permanently decreases the price of these goods worldwide. For all the regions, the permanent fall in the price of investment goods permanently increases potential output.

- The positive terms-of-trade and wealth effects generated by the permanent rise in commodity prices are permanent and thus permanently increase Canadian consumption.

On net, Canadian economic activity increases as U.S. productivity rises and the increase is larger when there are financial frictions in the U.S. economy. In the BoC-GEM-BGG, the increase in U.S. productivity reduces the real price of imported investment goods in Canada, stimulating investment and increasing the capital stock. As a result, the net worth of Canadian entrepreneurs rises and entrepreneurs demand less external financing. The increase in net worth reduces the financial risk premiums that entrepreneurs pay on their debt, boosting investment, spending, and output relative to the BoC-GEM. The rise in net worth and subsequent boost to economic activity is also partially associated with a positive debt deflation effect as inflation rises. Finally, the amplification of Canada's benefit from the rise in U.S. productivity in the presence of financial frictions through the financial accelerator occurs despite the fact that the forward-looking monetary authority contracts its monetary policy stance slightly relative to the BoC-GEM. For Canada, this implies that when there are important financial frictions present in the economy, the central bank must respond by more to foreign supply shocks.

The expanded role of financial frictions in the model with the banking sector further amplifies Canada's benefit from the increase in U.S. productivity. The increase in the policy interest rate increases the return on the risk-free asset and the probability of default on interbank borrowing. As a result, Canadian savings banks reduce the share of their deposits devoted to interbank lending and lending banks, with fewer resources available from interbank borrowing, reduce credit supply to entrepreneurs. Given the Leontief technology used to produce loans, the fall in interbank lending generates a fall in the supply of loans despite an increase in bank capital. Also, given the important rigidities in investment, firms react by accumulating more net worth. In fact, net worth rises by about 90 per cent more than in the BoC-GEM-BGG at its peak. Consequently, the financial risk premiums decline and investment, spending, and output increase by more than in the model with the financial accelerator. This occurs despite the fact that monetary policy contracts by more than in the model with the financial accelerator. Again, this response of monetary policy highlights the fact that monetary policy in Canada must respond by more to foreign supply shocks when there are important financial frictions.

5 Conclusions

Shocks to U.S. financial conditions are transmitted quickly to Canada with important implications for financial conditions and real economic activity. Notably, in spite of the endogenous response of monetary policy, the response of Canadian output to U.S. financial shocks is typically two thirds of the response of U.S. output. This response is larger than the share of Canadian exports to the United States in Canadian output. The transmission of U.S. financial shocks to Canada occurs mainly through real channels like trade, exchange rates, and commodity prices; however, financial channels, such as international loan flows, are also important. Our results suggest that international loan flows account for about 20 per cent of the total Canadian response to shocks to U.S. financial conditions. Moreover, financial frictions in the Canadian economy tend to amplify the effect of shocks to U.S. financial conditions and to increase the persistence of the Canadian response to U.S. financial conditions. This effect is, however, mitigated by the fact that Canada is a large net importer of investment goods as any amplifying effect on Canadian investment from financial frictions tends to be offset by movements in Canadian imports of investment goods. Overall, financial frictions in the Canadian economy tend to amplify the effect of shocks to U.S. financial conditions by 10-15 per cent. The transmission of U.S. real shocks to Canada is also affected by financial frictions. Both demand and supply side financial frictions amplify the responses of the U.S. and Canadian economies to all types of U.S. shocks. Finally, financial frictions help to explain the positive co-movement between consumption and investment observed within each country and between the two economies.

Overall, these results provide insight into how the recent U.S. financial crisis spread quickly across the world, with far reaching implications for financial conditions and real economic activity globally. Not only can financial shocks be transmitted quickly across countries through both real and financial channels, but financial frictions tend to amplify both the domestic and foreign response to domestic shocks. Moreover, our results show the required policy response to shocks, in both the domestic economy and in affected foreign economies, is larger when there are important financial frictions. Therefore, policymakers must take into account the linkages between developments in financial conditions and in the real economy when conducting domestic policy. In part, this should be pursued by continuing to enhance the real-financial linkages in the main macroeconomic models used by policymakers to form their economic outlooks.

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Table 1: Correlation of U.S. and Canadian National Accounts
(1979Q3-2009Q3)

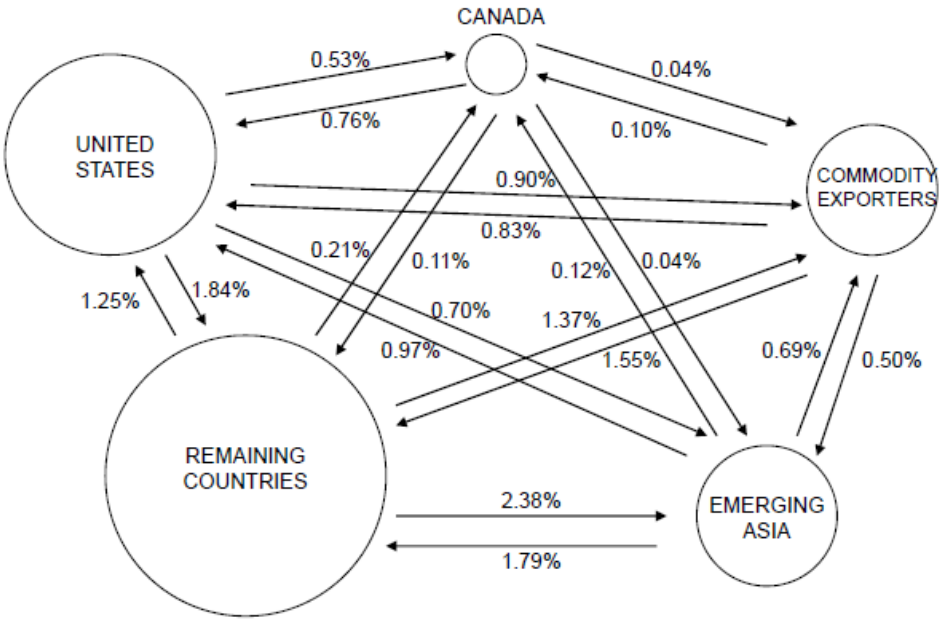
Hodrick-Prescott filter detrended			
	U.S. Consumption	U.S. Investment	U.S. Output
Canadian Consumption	0.62	0.59	0.76
Canadian Investment	0.29	0.51	0.54
Canadian Output	0.66	0.72	0.81
Growth Rate			
	U.S. Consumption	U.S. Investment	U.S. Output
Canadian Consumption	0.42	0.30	0.48
Canadian Investment	0.19	0.41	0.34
Canadian Output	0.41	0.60	0.64

Table 2: Correlation of U.S. and Canadian Interest Rate Spreads
(1996Q4-2009Q4, in levels)

Level			
	U.S. Prime	U.S. Interbank	U.S. Corporate
Canadian Prime	0.77	-0.76	-0.23
Canadian Interbank	-0.66	0.67	0.52
Canadian Corporate	-0.34	0.34	0.91
First difference			
	U.S. Prime	U.S. Interbank	U.S. Corporate
Canadian Prime	0.67	-0.67	-0.31
Canadian Interbank	-0.43	0.45	0.16
Canadian Corporate	-0.29	0.29	0.80

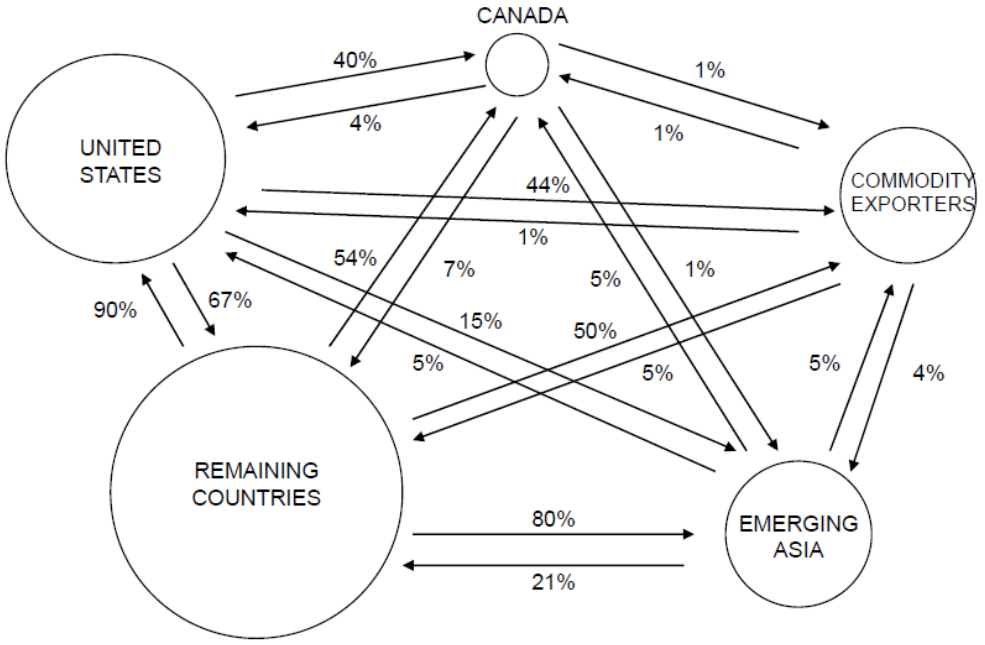
Note: The prime spread is the spread between the prime lending rate and the Libor, the interbank spread is the spread between the Libor and the monetary policy interest rate, and the corporate spread is the spread between the corporate interest rate and the prime lending rate.

Figure 1: Global Trade Linkages in the BoC-GEM (All Goods – Per cent of World GDP)



Note: Circle sizes represent the share of global GDP that is held by each region.

Figure 2: Global Loan Flows in the BoC-GEM-BGG and the BoC-GEM-FIN



Note: Circle sizes represent the share of global GDP that is held by each region. Loan flows are expressed as the per cent of total foreign loans in the domestic economy from each foreign source.

Figure 3: A Shock to U.S. Loan Supply - U.S. Effects
(Deviation From Control)

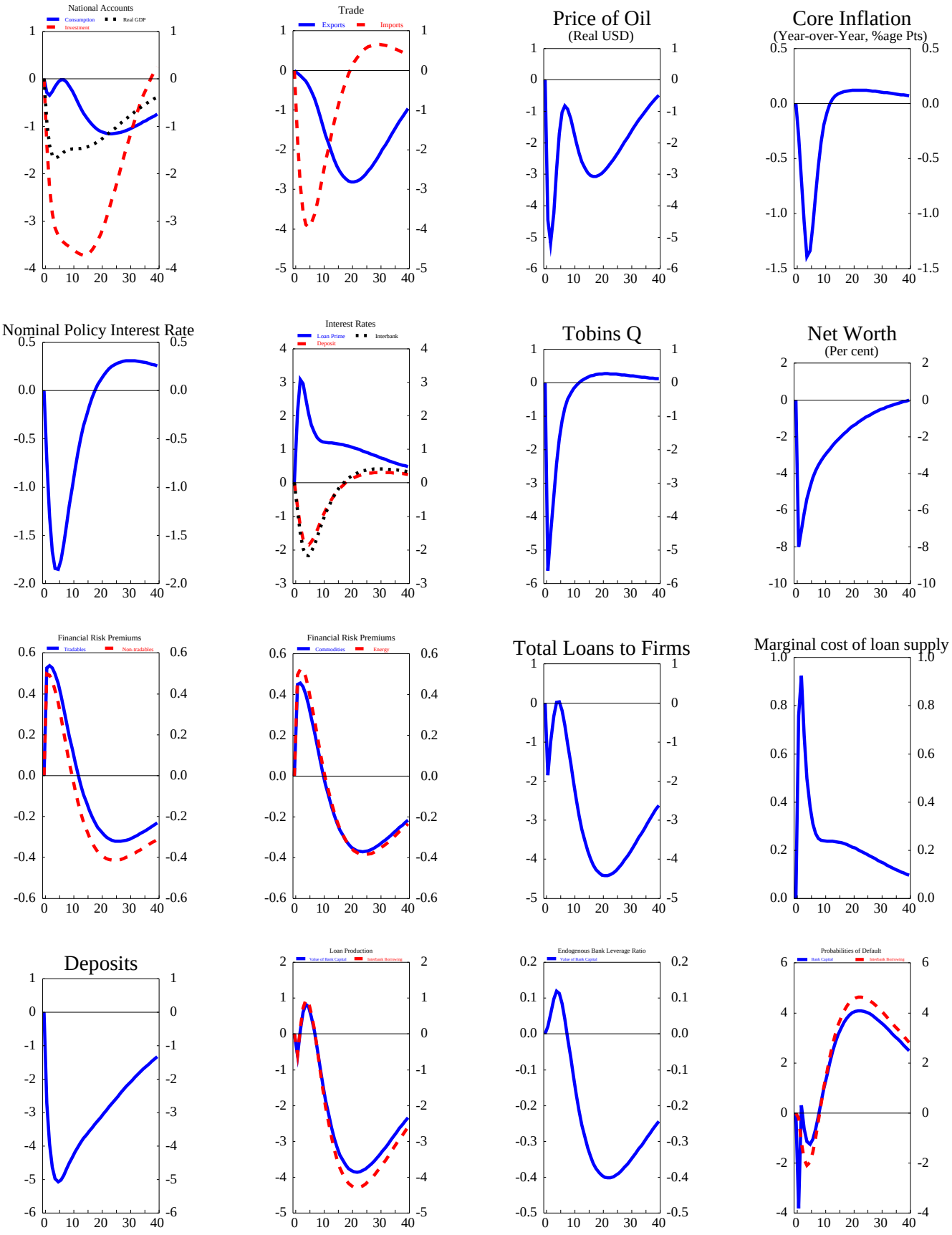


Figure 4: A Shock to U.S. Loan Supply - Effects on Canada

(Deviation From Control)

Solid = BOC-GEM-FIN; Dashed = BOC-GEM-FIN ex. International Loan Flows

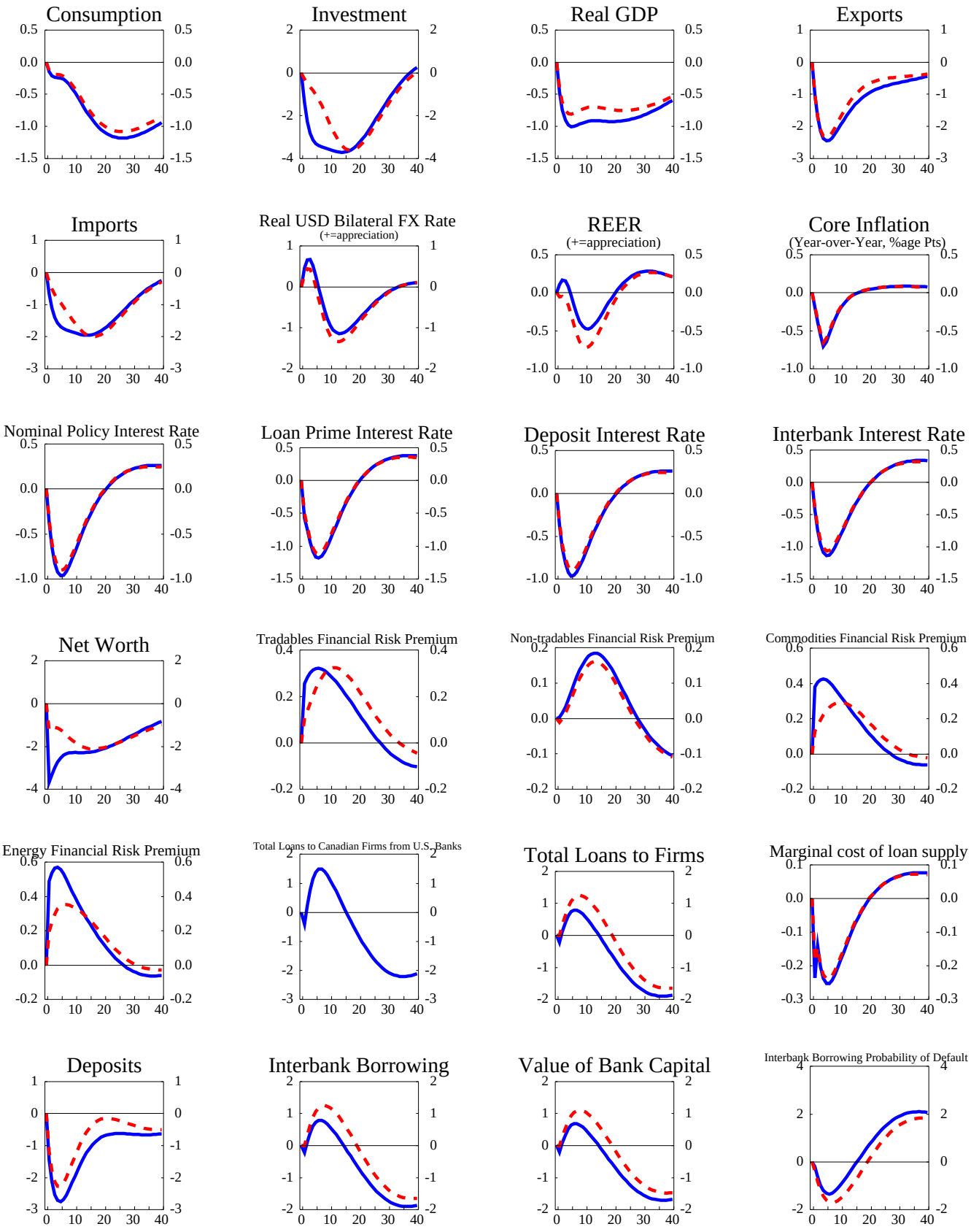


Figure 5: A Shock to U.S. Loan Supply - Effects on Canada

(Deviation From Control)

Solid = BOC-GEM-FIN; Dashed = BOC-GEM-FIN ex. Cdn. BGG; Dotted = BOC-GEM-FIN ex. Cdn. Banking Sector

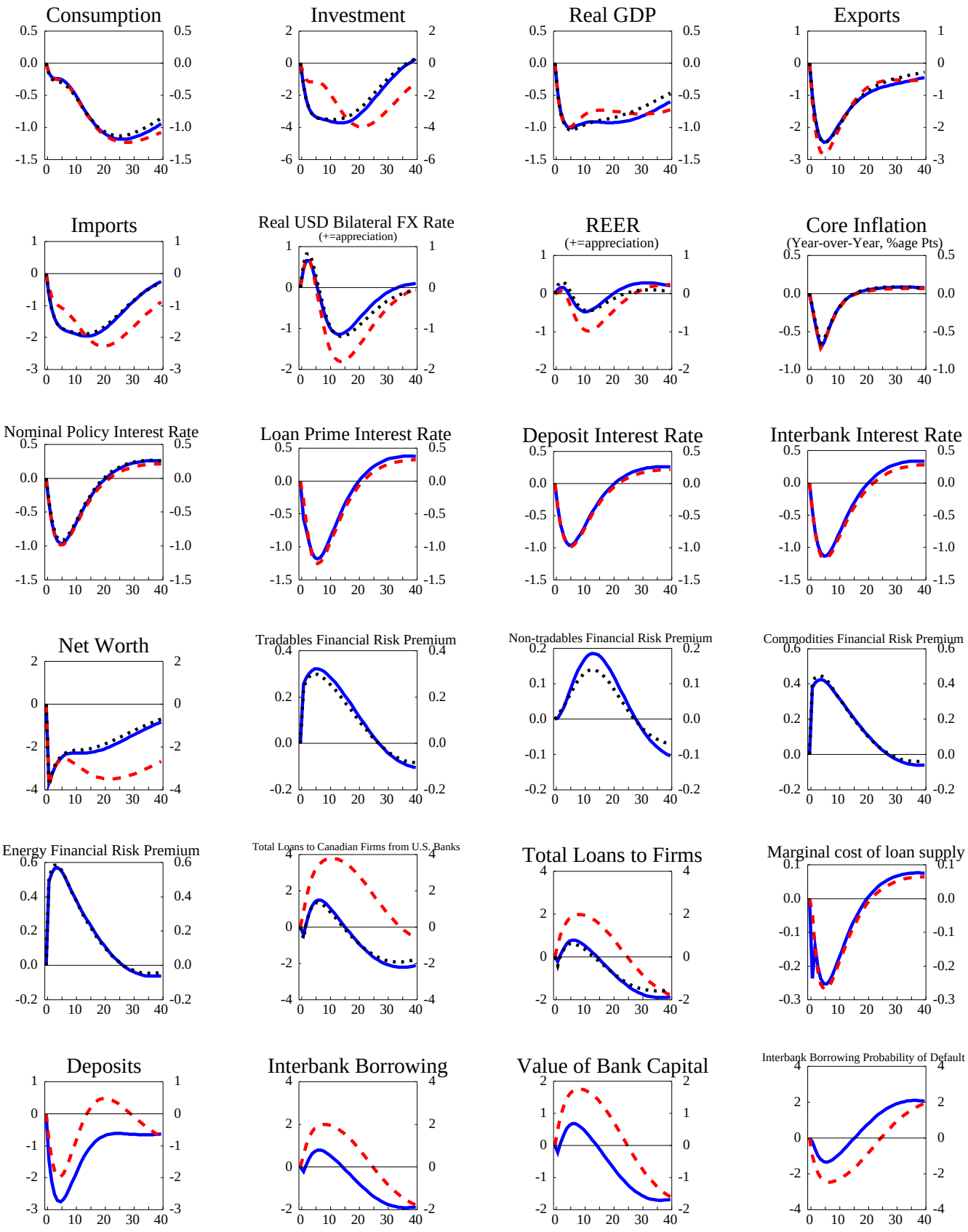


Figure 6: A Shock to the Probability of Default on U.S. Interbank Borrowing - U.S. Effects
(Deviation From Control)

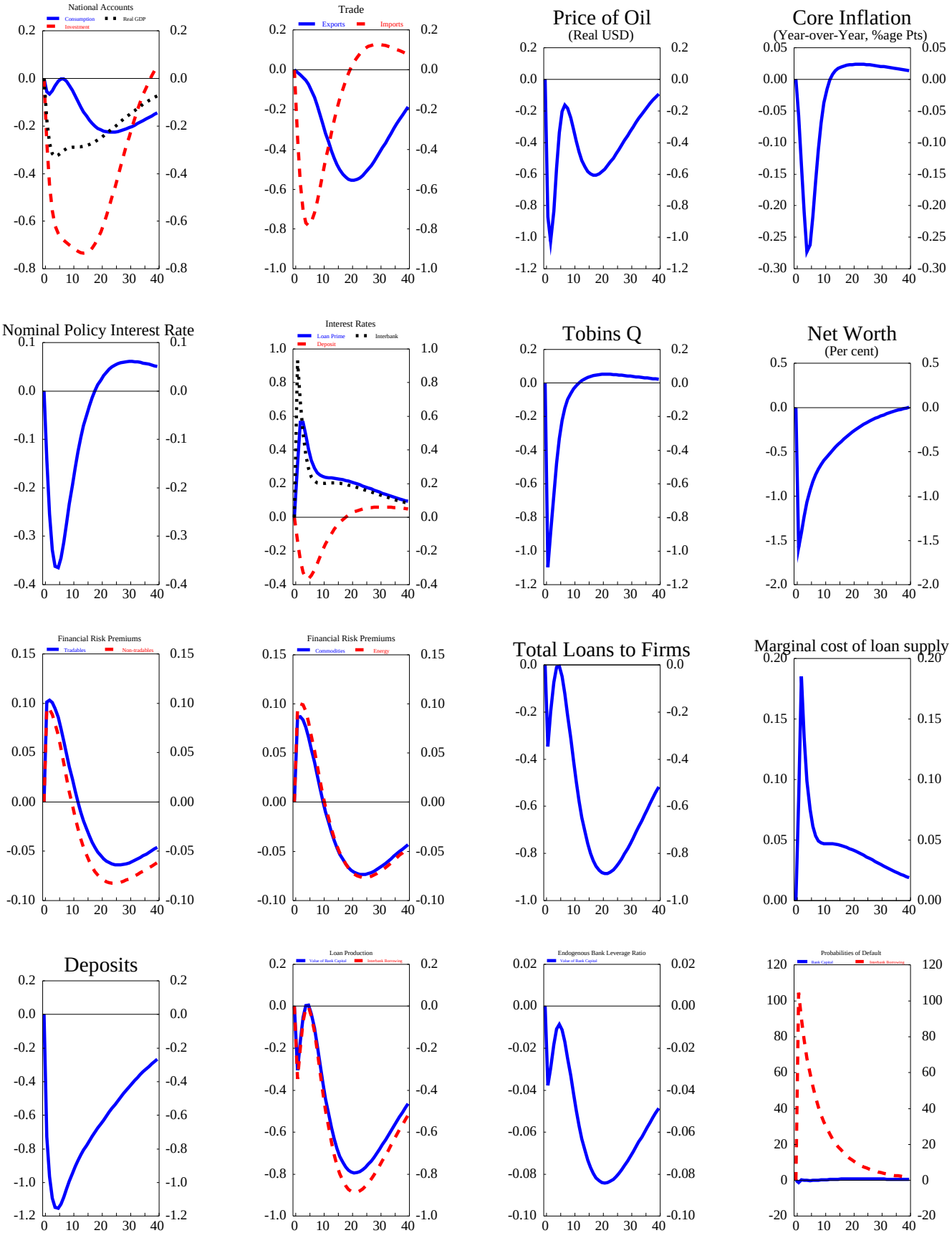


Figure 7: A Shock to the Probability of Default on U.S. Interbank Borrowing - Effects on Canada

(Deviation From Control)

Solid = BOC-GEM-FIN; Dashed = BOC-GEM-FIN ex. International Loan Flows

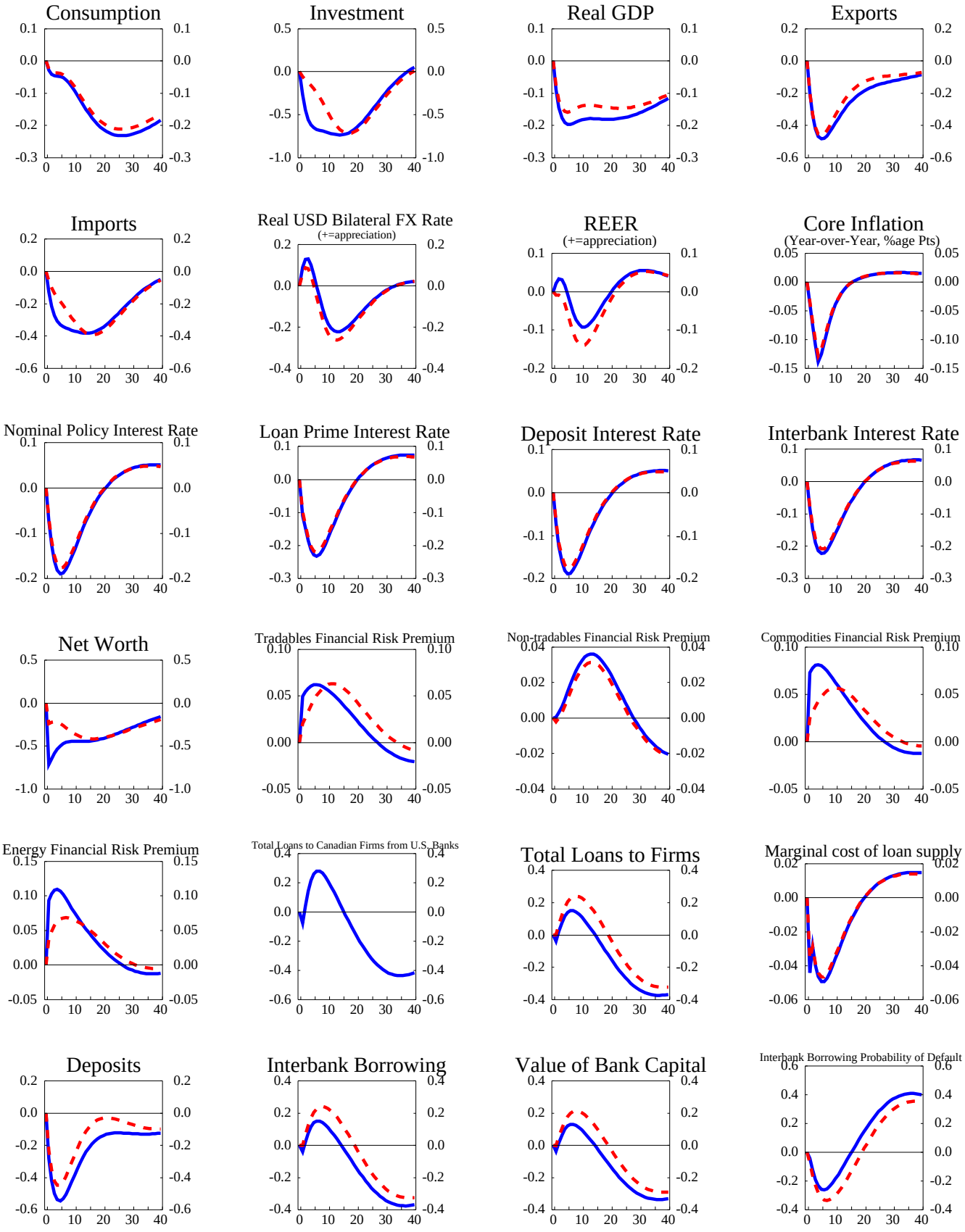


Figure 8: A Shock to the Probability of Default on U.S. Interbank Borrowing - Effects on Canada

(Deviation From Control)

Solid = BOC-GEM-FIN; Dashed = BOC-GEM-FIN ex. Cdn. BGG; Dotted = BOC-GEM-FIN ex. Cdn. Banking Sector

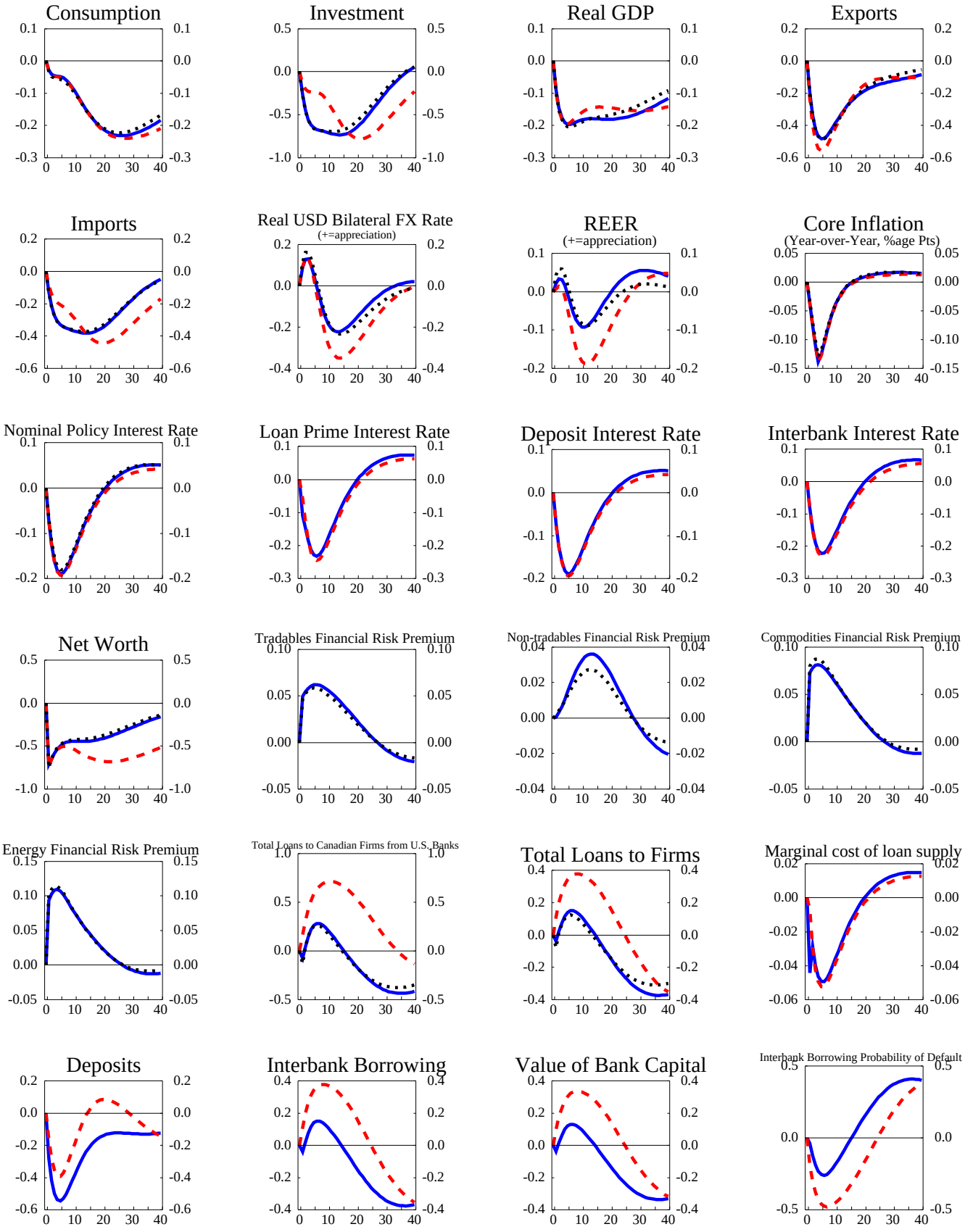


Figure 9: A Shock to the Probability of Default on U.S. Interbank Borrowing

(Deviation From Control)

Solid = Unconstrained Monetary Policy; Dashed = Constrained Monetary Policy

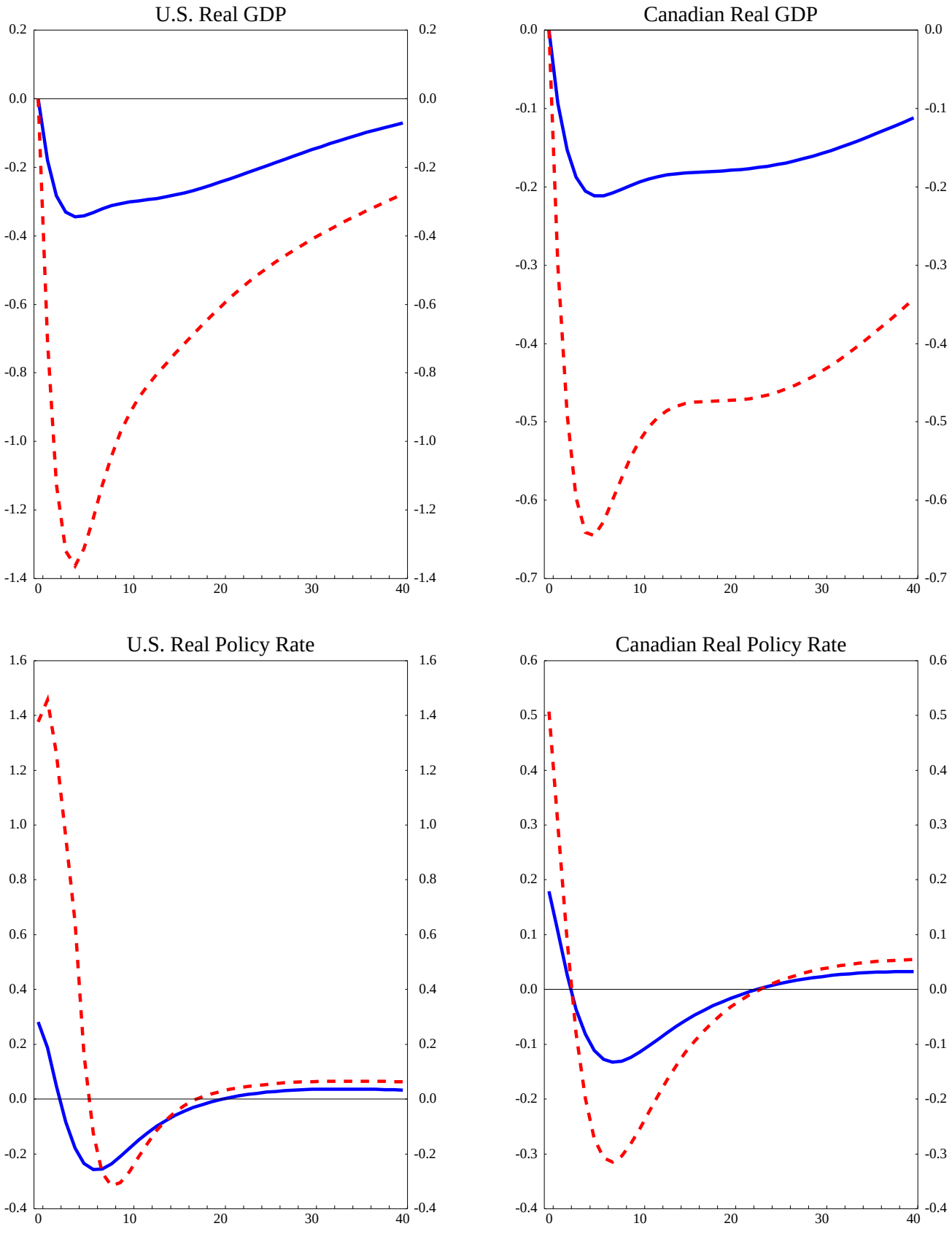


Figure 10: Temporary Consumption Shock in the United States - U.S. Effects

(Deviation From Control)

Solid = BOC-GEM-FIN; Dashed = BOC-GEM-BGG; Dotted = BOC-GEM

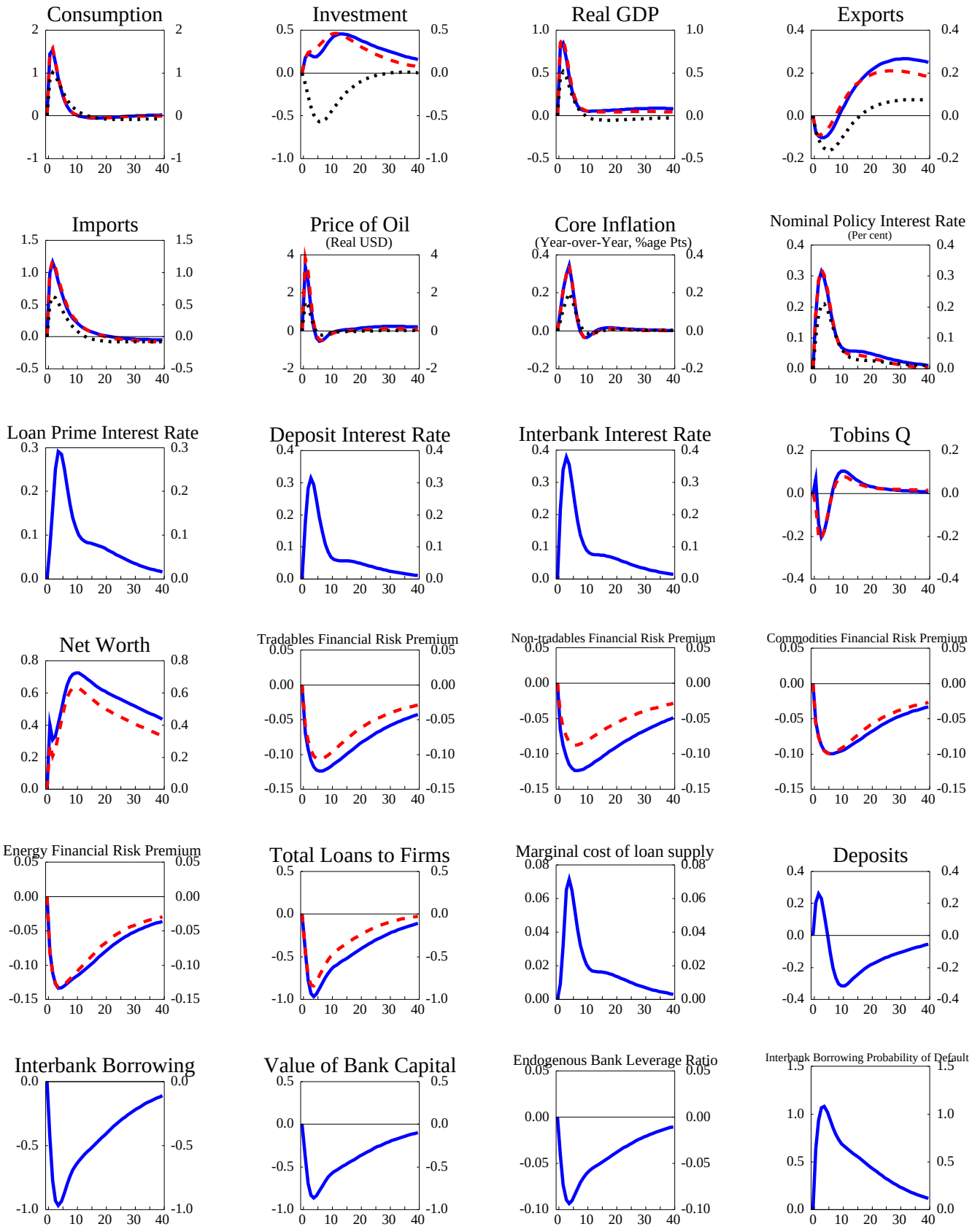


Figure 11: Temporary Consumption Shock in the United States - Effects on Canada

(Deviation From Control)

Solid = BOC-GEM-FIN; Dashed = BOC-GEM-BGG; Dotted = BOC-GEM

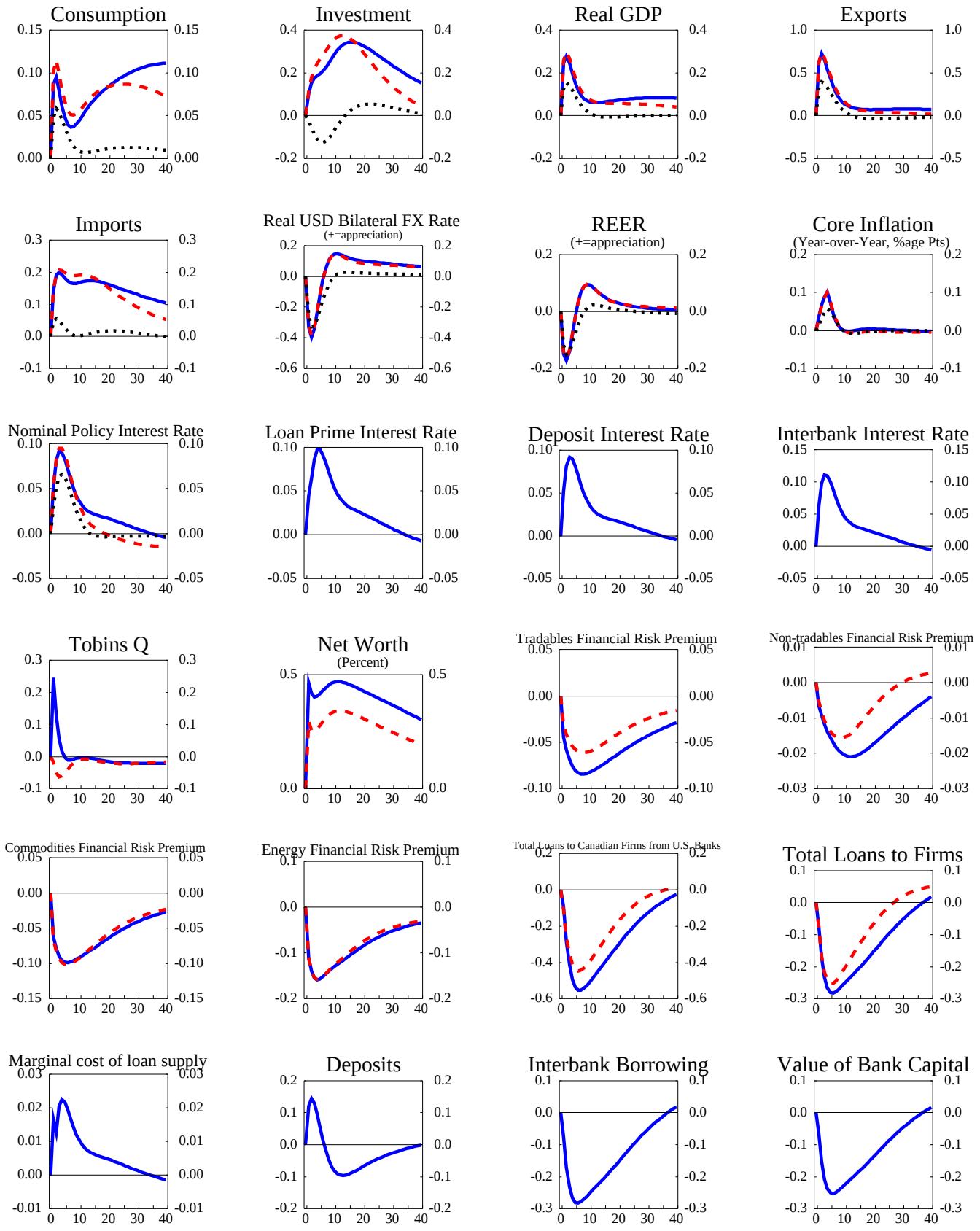


Figure 12: A Permanent Shock to U.S. Aggregate Productivity - U.S. Effects

(Deviation From Control)

Solid = BOC-GEM-FIN; Dashed = BOC-GEM-BGG; Dotted = BOC-GEM

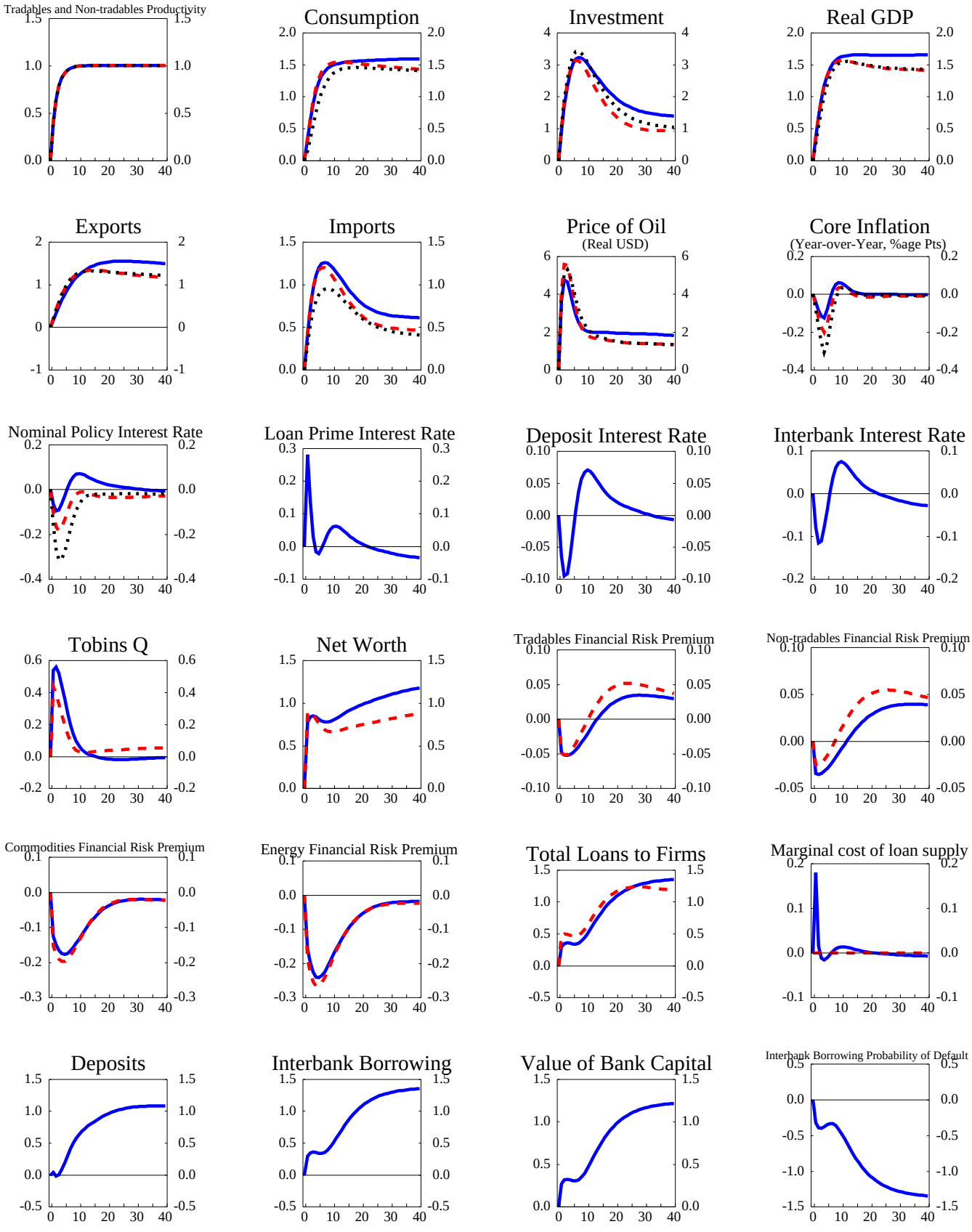


Figure 13: A Permanent Shock to U.S. Aggregate Productivity - Effects on Canada

(Deviation From Control)

Solid = BOC-GEM-FIN; Dashed = BOC-GEM-BGG; Dotted = BOC-GEM