Financial Frictions and Macroeconomy During Financial Crises: A Bayesian DSGE Assessment

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ABSTRACT
The recent global financial crisis and the Eurozone sovereign default have rekindled the debate on the interactions between the real sector and the financial sphere. The present paper provides an assessment of the role of financial frictions on business cycles in Canada, the Euro Area, the U.K., and the U.S. during these recent financial crises using an extension of the DSGE methodology described by Merola (2015). The main goal is to examine whether and the extent to which those crises enhanced the contribution of financial frictions in driving macroeconomic fluctuations. The models' properties are examined with posteriors distributions, variance decomposition, and historical decomposition. Posteriors distributions show that the role of real shocks in driving macroeconomic fluctuations decrease with the incorporation of financial frictions in the core DSGE model. Variance decomposition shows that financial frictions and financial shocks affect the business cycle through investment. The empirical estimates also suggest that the contribution of financial frictions and financial shocks in driving investment increases during the global financial crisis.

KEYWORDS
Financial Frictions, DSGE Model, Bayesian Estimation

INTRODUCTION

The recent financial crisis has drawn attention to the impact that financial frictions have on business cycle fluctuations. Furthermore, the amount of literature on dynamic stochastic general equilibrium (DSGE) and the financial system has been increasing in recent years. Some researchers focus on the source of financial frictions (see Carlstrom and Fuerst, 1997; Kiyotaki and Moore, 1997, and Gerali et al., 2010), while others discuss the role of liquidity (Brunnermeir and Pedersen, 2009). Much of the literature proposes a different micro-foundation for financial frictions. Bernanke et al. (1999) remains the benchmark DSGE model for financial frictions, the authors introduce an agency problem between borrowers and lenders that make a wedge between the cost of external finance and the opportunity cost of internal resources. Their findings suggest that the external finance premium (EFP) decreases with the borrowers' percentage stake in the outcome of an investment project.

Bernanke, Gertler, and Gilchrist (BGG, 1999) influential financial accelerator is used frequently to analyze credit market imperfections in DSGE modeling. The BGG model features constrained firms that

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are the sources of frictions in the form of a costly state verification problem through asymmetric information between lenders or banks and borrowers or nonfinancial firms. Then, Gertler and Karadi (2011) presented a DSGE framework where financial frictions arise because of a moral hazard problem between lenders and financial intermediaries.

The main objective of this study is to examine whether and the extent to which financial frictions play a role in driving business fluctuations during the recent financial crises using a Bayesian DSGE assessment.

One of the main contributions of this article is a comparative analysis of the effects of financial frictions on economic fluctuations in Canada, the Eurozone, the U.K., and the U.S. The U.K. and the U.S. are chosen because these countries have the largest financial systems in the world. Financial frictions can therefore be expected to play a crucial role in economic cycles during financial crises in these two countries. The Eurozone is included to examine the role of credit frictions in economic activity fluctuations during the European debt crisis. Finally, Canada is included in our study in an attempt to understand why its economy was relatively resilient during the 2008 financial crisis.

Our approach relies on a comparative analysis of the results from the DSGE methodology incorporating financial frictions described in Merola (2015), and those obtained from the core Smets and Wouters' (2003, 2007) DSGE models. The estimates are conducted in different periods: (i) a pre-crisis period covering 2000:Q1-2007:Q4 before the occurrence of the recent financial crises, (ii) a crisis period from 2000:Q1 to 2014:Q4, including the recent financial crises. The paper also focuses on the periods 2008:Q1-2009:Q3 and 2009:Q1-2013:Q4 corresponding to the peak of the global financial crisis and the Eurozone debt crisis, respectively. This allows us to see the size of financial frictions in driving business fluctuations at the epicenter of financial crises. To our knowledge, this the pioneer research putting into perspective the contribution of financial constraints to explain the economic outlook during the peak of recent crises within a DSGE model. The study digs deeper to understand whether the financial restraints that occurred (credit crunch and government debt crunch) have not simply eclipsed the worst fundamentals of economies.

New to Merola (2015), our model introduces the entrepreneurs' net worth variable, proxied by the value of the stock market index for each country/area as suggested by Alpanda and Aysun (2014). Next, our model also explicitly takes into consideration the net worth shock. Although Merola (2015) and Suh and Walker (2016) examine the role of financial frictions during 2008/2009 in the U.S., our study is the first that uses a Bayesian approach from a DSGE model with the same prior distributions for all the countries/areas. This assumption allows for a valid international comparison of the effects of financial frictions and financial shocks on the macroeconomics.

The paper is organized as follows. Section 2 briefly reviews the literature on DSGE models with financial frictions. Section 3 presents the linearized DSGE models with and without financial frictions. Data, priors, and posteriors estimates are discussed in Section 4. Using variance decompositions, Section 5 illustrates the main forces driving macro-economy during the pre-crisis period, the crisis period, at the peak of the crisis period, and during the Eurozone sovereign crisis. Section 6 presents historical decompositions in order to understand the individual contributions of each structural shock to the movements in output, consumption, and investment during the 2008 global financial crisis and the European debt crisis. Section 7 discusses the main findings across the world while Section 8 provides some concluding remarks.

RELATED LITERATURE

DSGE MODELS WITH FINANCIAL MARKET FRICTIONS

This section reviews research regarding the general framework used for the specification of financial market frictions in DSGE models. In this paper, financial frictions are prime candidates for the endogenous amplification of small transitory nonfinancial shocks. Recent economic events, including the subprime mortgage crisis in the summer of 2007 and the debt crisis in 2008, led to the emergence of widespread interest in macroeconomic models that focus on financial frictions and disturbances. Alpanda and Aysun (2014) and Suh and Walker (2016) focus on the role that the financial sector plays in propagating shocks that originate in other sectors of the economy. These studies highlight the importance of the financial activity in business cycle fluctuations. However, there is no international comparative analysis of the role played by financial shocks in driving business activity across countries.

Pre-crisis macroeconomic models rely only on the specifications of the real economy and neglect the financial sector, which is considered to be almost irrelevant in the context of low inflation rates. Moreover, the prevailing view among policymakers is that price stability alone could ensure macroeconomic stability. Therefore, policymakers generally embrace the idea that the deterioration of financial markets is just a reflection of a declining economy, even though, in reality, it might have been a factor that significantly affects business cycle dynamics.

Pre-crisis operational macroeconomic models did not present a detailed specification of the financial sector; instead, these models focused mostly on the perturbations of the demand for credits. However, some attempts were made in the literature to tackle this problem. Bernanke and Gertler (1989) are pioneers in incorporating financial aspects into a DSGE model. This model is further developed by Carlstrom and Fuerst (1997) and later merges with the New Keynesian framework by BGG (1999). These studies demonstrate how the financial sector interacts with the business cycle through the financial accelerator mechanism. Frictions occur in these models through an external finance premium (EFP) between the lending rate and the risk-free rate.[1]

In the aftermath of the global financial crisis, researchers have begun to look for new ways to improve the current macroeconomic models. For example, Gerali et al. (2010) study the role of credit-supply factors in business cycle dynamics by including a competitive banking sector in a DSGE model. In their model, the only savings instrument is a bank deposit, and the only way to borrow is via a bank loan. Funds in the banking sector travel along the following path: The customer makes a deposit at a retail bank, and these funds are then transferred to the wholesale bank. The wholesale bank uses these funds along with the bank's capital to supply loans to specialized retail banks that, in turn, provide loans to economic agents. Because retailers operate in a monopolistic environment, they put a markup over the policy interest rate for loans and under the policy rate for deposits. The retail banks obtain profits that are transferred to the wholesale bank, where only a fraction of profits remains in the banking sector while the rest is transferred to customers in the form of dividends.

The modelling of financial frictions through the credit side differs. Using the financial accelerator mechanism, Akinci (2017) assumes that firms borrow in the international debt markets from risk neutral foreign lenders to purchase intermediate inputs. As foreign lenders are not able to observe the productivity of these firms, they charge a risk premium to the firms on their debt. Chatterjee (2019) documents the relevance of financial frictions in driving business cycles in emerging countries, especially when they interact with uncertainty shocks. In Chatterjee's model, financial frictions reflect differences in borrowing costs across advanced and emerging countries. Therefore, the risk premium faced by entrepreneurs is a function of a global component and a country-specific component.

[1] Other methods for introducing credit frictions are developed later (see e.g., Kiyotaki and Moore (1997)).

Gertler and Karadi (2011) develop a quantitative DSGE with financial intermediaries that face balance sheet constraints. They aim to capture the depreciation of banks' balance sheets and its effects on the economy. To accomplish this objective, the authors introduce a simple agency problem involving financial intermediaries and depositors. In this setting a bank can be affected by a disruption to the quality of its capital; this shock produces a decline in the net worth of the financial intermediary, thereby negatively affecting its activities. An immediate impact of the shock is a decrease in the value of the intermediary's assets. As a result of its weakened balance sheet, the financial intermediary's demand for assets lessens, leading to a decline in its market valuation. This reduction in asset prices shrinks the bank's balance sheet further, thus affecting its ability to supply new loans even more. With this mechanism embedded into the framework, such a shock will affect the gross domestic product drastically.

CREDIT MARKETS AND BUSINESS CYCLE FLUCTUATIONS

The present paper tries to establish linkages between the financial and the real sectors showing how financial frictions impact business cycle fluctuations. The focus consists to frictions on the credit markets. Cycles allow borrowers to access credit. Credit cycles appear during periods when funds are easy to borrow; these periods are characterized by low interest rates, less stringent lending requirements, and more available credit.

In advanced economies, a massive infusion of government funds and credit-easing policies aiming to fight a recession and improve bank balance sheets has not prevented the decrease in lending to the private sector during the global crisis (see, e.g., Puri et al. (2011) and Merilainen (2015)). Several factors explain why better financial conditions do not result in renewed growth in lending to the private sector in these economies. First, as economic conditions collapsed, the demand for credit decreased as GDP declined. Additionally, banks tightened lending rules because of greater uncertainty and weaker capital positions. The banks' balance sheets still remain under strain, and funding conditions became tighter. In a different range, Hogan (2018) defends that the FED's interest on excess reserves policy differs from the standard interest rate floor framework, which influences banks' incentives to provide loans and reserves. They document that banks' loan and reserve assets are related to output growth but not to demand for credit or economic uncertainty.

Philippon (2008) provides a theoretical framework in which the predictive content of corporate bond spreads for economic activity, without financial frictions, reflects a deterioration in economic fundamentals. The rise of credit spreads can also reflect disturbances in the credit supply coming from the deterioration of corporate balance sheets. In this vein, a contraction in credit supply brings asset values to collapse, increase risk defaults, and leads corporates spreads to widen before economic slowdown, as lenders claim compensation for the expected rise in defaults. By contrast, Gertler and Lown (1999) and Mody and Taylor (2004) document that yield spreads based on indexes of high-yield corporate bonds are well suited at forecasting output growth during the previous decade. More recently, Boivin et al. (2020) show that credit spread shocks significantly caused the deterioration in economic conditions during the December 2007 to June 2009 great recession.

Market monetarism also argues that an important interaction exists between credit and economic fluctuations by assuming that monetary policy leads to monetary equilibrium and, therefore, to macroeconomic stability.[2] The money supply, especially the credit supply is the main driver of business cycles fluctuations. The nominal GDP (NGDP) targeting (Sumner, 2012) or the productivity norm (Selgin, 1997) are the denomination of this monetary position. In contrast to an inflation targeting regime where the central bank mainly reacts to demand shocks, an NGDP-targeting regime holds that

[2] The main policy recommendation of market monetarism is that the Central Banks should set a level target of Nominal GDP to lessen economic shocks and guarantee the right tradeoff between inflation and real GDP growth.

the monetary authority adjusts the money supply after both aggregate supply and aggregate demand shocks (Sumner, 2012).

LINEARIZED DSGE MODEL

The methodology used here is a DSGE model with real, nominal, and financial frictions.[3] The anatomy is not complex. The economy is populated by a continuum of households and producers. Government and central bank implement the fiscal and the monetary policy, respectively. Households consume, accumulate capital and offer their work. Producers provide final goods and capital goods in the economy. The fiscal policy consists in government expenditures and the monetary policy is conducted according to the Taylor rule. In the following, we briefly describe the equations that characterize the equilibrium of the DSGE model. All the series are log-linearized around their steady-state.

MARKET CLEARING

The aggregate resource constraint is given by the following equation:

$$y_t = \frac{c}{y}c_t + \frac{i}{y}i_t + \xi_t^g + r^k\left(\frac{k}{y}\right)z_t^k + \left(\frac{k}{y}\right)f\left(1-\frac{r}{f}\right)\left(1-\frac{1}{lev}\right)\left(f_t + p_{t-1}^k + k_t\right) \tag{1}$$

where t indexes time. Output (y_t) is absorbed by consumption (c_t), investment (i_t), costs that are a function of the capital-utilization rate (z_t^k), and exogenous government expenditures (ξ_t^g). $\frac{c}{y}$ and $\frac{i}{y}$ represent the steady-state of consumption-to-output ratio and investment-to-output ratio, respectively, and they are defined as : $\frac{c}{y} = 1 - \frac{g}{y} - \frac{i}{y}$; $\frac{i}{y} = [\gamma - (1-\delta)]\frac{k}{y}$, where g is the steady-state of government spending, $\frac{g}{y}$ is the steady-state of government spending-to-output ratio, γ is the steady-state growth rate, and δ is the depreciation rate of capital. The term $r^k\left(\frac{k}{y}\right)u_t$ measures the cost associated with the capital utilization, where r^k is the steady-state of rental of capital, k is the steady-state of capital, and y is the steady-state of output. Therefore, $\frac{k}{y}$ is the capital coefficient. The term $\left(\frac{k}{y}\right)f\left(1-\frac{r}{f}\right)\left(1-\frac{1}{lev}\right)\left(f_t + p_{t-1}^k + k_t\right)$ measures bankruptcy costs, where k_t stands for capital services, r is the steady-state of the risk-free interest rate, p_{t-1}^k is the lagged value of capital stock, f is the steady-state of the external funding cost, and *lev* is the steady-state value of the leverage ratio (i.e., the ratio of capital to net worth in the corporate sector). The term suggests that the external funding cost increases the bankruptcy costs of debt while the rental of capital and the price of capital decrease the costs of financing with debt. More specifically, high costs of borrowing increase the probability of bankruptcy while a high rate of capital return reduces the risk of bankruptcy.

Public spending follows a first-order autoregressive (AR (1)) process with an identically and independently distributed (i.i.d)-normal error term and is also affected by a productivity shock as $\xi_t^g = \rho_g \xi_{t-1}^g + \eta_t^g + \rho_{ga}\eta_t^a$, with $\eta_t^g \sim \mathbb{N}(0,1)$ and $\eta_t^a \sim \mathbb{N}(0,1)$.

[3] The DSGE model is a combination of Smets and Wouters (SW) (2003, 2007) and Merola (2015), but we add a net worth shock. For an exhaustive description of the technical framework, we refer the reader to the original papers.

CONSUMPTION

The dynamics of consumption c_t deducted from the Euler equation is given as follows:

$$c_t = \left[\frac{h/\gamma}{1+h/\gamma}\right] c_{t-1} + \left[\frac{1}{1+h/\gamma}\right] E_t c_{t+1} + \left[\frac{\sigma-1}{\sigma(1+h/\gamma)}\right] \frac{w^h l}{c} (l_t - E_t l_{t+1}) - \left[\frac{1-h/\gamma}{\sigma(1+h/\gamma)}\right] \left(r_t - E_t \pi_{t+1} + \xi_t^{\beta}\right) \quad (2)$$

where the current consumption is given by (c_t), the parameter h captures the intensity of habit formation and introduces non-separability of preferences over time[4], and γ is the steady-state growth rate. The operator E_t represents the expected value, σ represents the inverse of elasticity of intertemporal substitution, π_t represents inflation, and $\frac{w^h l}{c}$ is the steady-state of the ratio of labor income-to-consumption where w^h is the steady-state of wage, *l* the steady-state of labor services, and *c* the steady-state of consumption. Equation (2) also states that current consumption (c_t) depends on a weighted average of past and expected future consumption and on expected growth in labor services $(l_t - E_t l_{t+1})$, the ex-ante real interest rate $(r_t - E_t \pi_{t+1})$, and a preference disturbance ξ_t^{β} that is specified as in Smets and Wouters (SW) (2003, 2007) by $\xi_t^{\beta} = \rho_{\beta} \xi_{t-1}^{\beta} + \eta_t^{\beta}$, with $\eta_t^{\beta} \sim \mathbb{N}$ (0.1).

INVESTMENT

The dynamics of investment (i_t) comes from the investment Euler:

$$i_t = \frac{1}{1+\beta_\gamma} \left[i_{t-1} + \beta_\gamma E_t i_{t+1} + \frac{1}{\gamma^2 \varphi} p_t^k\right] + \xi_t^i \quad (3)$$

where φ is the steady-state elasticity of the capital adjustment cost function, and β is the discount factor rate applied by households. The shock to the investment-specific technology process is assumed to follow an *AR(1)* as follows $\xi_t^i = \rho_i \xi_{t-1}^i + \eta_t^i$, with $\eta_t^i \sim \mathbb{N}(0,1)$.

The following equation corresponds to the intertemporal arbitrage for the value of capital:

$$p_t^k = -\left(f_t + \xi_t^b\right) + \frac{r^k}{r^k + (1-\delta)} r_{t+1}^k + \frac{(1-\delta)}{r^k + (1-\delta)} p_{t+1}^k \quad (4)$$

where f_t is the external cost of funding and r_t^k is the rental cost of capital. Equation (4) shows that the current value of capital stock is positively linked to its expected future value and the expected real rental rate on capital, and negatively on the ex-ante cost of external funding. The term $\xi_t^b = \rho_i \xi_{t-1}^b + \eta_t^b$ with $\eta_t^b \sim \mathbb{N}(0,1)$, represents the risk premium shock defined as an exogenous disruption to the external cost of financing. This shock assesses the wedge between the policy rate and the cost of external finance faced by entrepreneurs; therefore, it has similar effects as the net worth shock integrated in Bernanke et al. (1999) and Christiano et al. (2010).

[4] Under the assumption of no external consumption habit, *h=0.*

FINANCIAL FRICTION IN THE BUSINESS SECTOR

We extend the original SW (2007) DSGE model and introduce the presence of an agency problem that makes external funding more expensive than internal funding as in Merola (2015). We introduce financial frictions as in Bernanke et al. (1999), the demand for capital should fulfill the following condition, which shows that the real expected return on capital is equal to the real cost on external funds:

$$E_t f_{t+1} = (r_t - E_t \pi_{t+1}) + \omega\left(p_t^k + k_{t+1} - n_{t+1}\right) \quad (5)$$

where n_t represents the entrepreneur's net worth and the parameter ω captures the elasticity of the external finance premium with respect to the leverage ratio.

The EFP, $prem_t$, depends on the borrower's leverage ratio and ω as follows:

$$prem_t = E_t f_{t+1} - (r_t - E_t \pi_{t+1}) = \omega\left(p_t^k + k_{t+1} - n_{t+1}\right) \quad (6)$$

The size of the EFP is related positively to leverage the conditions of entrepreneurial balance sheets. The presence of an EFP magnifies the effect of adverse shocks because it raises the cost of borrowing and worsens balance sheet conditions.

To ensure that entrepreneurs' net worth will never be enough to fully finance new capital acquisition, the model assumes that entrepreneurs have a limited lifespan and that the probability of entrepreneurs surviving until next period is n. The entrepreneur's net worth is given as the following:

$$\frac{1}{vf} n_{t+1} = (lev) f_t - \omega(lev - 1)\left(p_{t-1}^k + k_t\right) - (lev - 1)(r_{t-1} - \pi_t) + [\omega(lev - 1) + 1] n_t + \xi_t^{n_w} \quad (7)$$

where $\xi_t^{n_w}$ is a shock to the entrepreneurial net worth. The incorporation of this shock is an extension of the DSGE with financial frictions proposed by Merola (2015). This shock, defined as the unexpected gain or loss that affects the entrepreneur's balance sheet is given as: $\xi_t^{n_w} = \rho_{nw} \xi_{t-1}^{n_w} + \eta_t^w$, with $\eta_t^{n_w} \sim \mathbb{N}(0,1)$. In the EFP model Brzoza-Brzezina et al. (2013) define the net worth shock as a decrease in the number of entrepreneurs that exit the model. Then, the net worth disturbance allows entrepreneurs borrowing at a lower premium than the risk-free rate.

PRODUCTION

Turning to the production side, the output (y_t) is produced using capital (k_t) and labor services (l_t) according to the following specification:

$$y_t = \Sigma_p[\alpha k_t + (1 - \alpha) l_t + \xi_t^a] \quad (8)$$

where α represents the share of capital in production and Σ_p captures fixed production costs. Shocks in productivity are captured by the term ξ_t^a, defined as $\xi_t^a = \rho_i \xi_{t-1}^a + \eta_t^a$.

CAPITAL ACCUMULATION

Current capital services (k_t) depend on capital installed during the previous period $\left(k_{t-1}^p\right)$ and the degree of capital utilization (z_t):

$$k_t = k_{t-1}^p + z_t \tag{9}$$

The accumulation of installed capital $\left(k_t^p\right)$ depends on the investment expenditures and the relative efficiency of investment flows, as given by the investment-specific technology shock:

$$k_t^p = \frac{(1-\delta)}{\gamma} k_{t-1}^p + \frac{\delta}{\gamma} i_t + \delta\gamma^2\phi\xi_t^i \tag{10}$$

And the rate of capital utilization is positively linked to the capital rental rate $\left(r_t^k\right)$:

$$z_t = \frac{1-z^k}{z^k} r_t^k \tag{11}$$

where z^k determines the elasticity of utilization costs with respect to capital input. The capital rental rate, is derived by cost minimization:

$$r_t^k = w_t + l_t - k_t \tag{12}$$

where (w_t) is real wage and the other variables are defined as earlier.

PRICE AND WAGE SETTING

The setting of price and wages follows a Calvo price-adjustment mechanism with partial indexation. Due to sticky prices and partial indexation, prices and wages adjust slowly to their desired markup. Under monopolistic competition, price markup $\left(\mu_t^p\right)$ is defined as the difference between the marginal product of labor (mpl_t) and the real wage (w_t):

$$\mu_t^p = mpl_t - w_t = \alpha r_t^k + (1-\alpha) w_t + \xi_t^a \tag{13}$$

Similarly, wage markup is given as the gap between the real wage, w_t and the marginal rate of substitution between work and consumption, mrs_t:

$$\mu_t^w = w_t - mrs_t = w_t - \left[w_t \sigma_l l_t + \frac{1}{1-\frac{h}{\gamma}} c_t + \frac{\frac{h}{\gamma}}{1-\frac{h}{\gamma}} c_{t-1} \right] \tag{14}$$

where σ_l is the elasticity of the labor supply with respect to the real wage. Profit maximization by price-setting firms gives rise to the following New-Keynesian Phillips curve:

$$\pi_t = \frac{1}{1+\beta\gamma\iota_p} \left[\beta\gamma E_t \pi_{t+1} + \iota_p \pi_{t-1} - \pi_{mk} \mu_t^p \right] + \xi_t^p \tag{15}$$

Equation (15) states that inflation (π_t) depends positively on past and expected inflation, negatively on the current price markup $\left(\mu_t^p\right)$, and positively on an inflation disturbance $\left(\xi_t^p\right)$. The parameter (ι_p) captures the degree of indexation to past inflation. The inflation shock is specified as $\xi_t^p = \rho_p \xi_{t-1}^p + \eta_t^p - \mu_p \eta_{t-1}^p$, with $\eta_t^p \sim \mathbb{N}(0,1)$. The MA term describes the high-frequency movements of inflation. $\pi_{mk} = \frac{(1-\xi_p)(1-\beta\xi_p)}{\xi_p[(\Phi_p - 1)\kappa_p + 1]}$ measures the speed of adjustment to the desired markup; it depends on the level of price stickiness (ξ_p), the degree of indexation to past inflation (ι_p), the curvature of the Kimball (1995) goods market aggregator(κ_p), and the steady-state markup, which, in equilibrium, is related to the share of fixed production costs (Φ_p) in a zero-profit condition.

Calvo-style wage setting implies the following:

$$w_t = \frac{1}{1+\beta\gamma}[w_{t-1} + \iota_w \pi_{t-1} - (1 + \beta\gamma\iota_w)\pi_t + \beta\gamma E_t \pi_{t+1} - w_{mk}\mu_t^w] + \xi_t^w \quad (16)$$

Equation (16) states that real wage is a function of expected and past real wages; expected, current, and past inflation; the wage markup; and a wage disturbance (ξ_t^w). The wage disturbance is defined as $\xi_t^w = \rho_p \xi_{t-1}^w + \eta_t^w - \mu_w \eta_{t-1}^w$, with $\eta_t^w \sim \mathbb{N}(0,1)$. The MA component describes the high-frequency fluctuations in wages. $w_{mk} = \frac{(1-\xi_w)(1-\beta\gamma\xi_w)}{\xi_w[(\Phi_1 - 1)\kappa_w + 1]}$ represents the speed of adjustment to the expected wage markup. the degree of wage stickiness (ξ_w), the degree of wage indexation (ι_w), and the demand elasticity for labor, which is a function of the steady-state labor market markup $(\Phi_w - 1)$and the curvature of the Kimball (1995) labor market aggregator (κ_w).

CENTRAL BANK

Finally, the central bank follows a generalized Taylor rule in setting the interest rate on the short run (r_t) in response to the lagged interest rate, current inflation, the current level of the output gap, changes in the current level of the output and the output gap, and an exogenous innovation term that is assumed to follow an AR(1) process. The monetary policy rule can be written as follows:

$$r_t = \rho_{r^*} r_{t-1} + \rho_\pi (1-\rho)\pi_t + \rho_y * (1-\rho)(y_t - y_t^p) + \rho_{dy}[(y_t - y_{t-1}) - (y_t - y_{t-1}^p)] + \xi_t^r \quad (17)$$

where $\xi_t^r = \rho_r \xi_{t-1}^r + \eta_t^r$, with $\eta_t^r \sim \mathbb{N}(0,1)$

To obtain the original model without financial frictions, it is sufficient to set the elasticity of the EFP with respect to the leverage ratio as $\omega = 0$ and the steady-state of the leverage ratio as $lev = 1$. Moreover, it is important to note that, unlike the standard DSGE model without financial frictions, the DSGE model with a financial accelerator mechanism incorporates the spread shock and the net worth shock.

DATA AND PRIORS

DATA AND MEASUREMENT EQUATIONS

Our sample data covers the U.S., the U.K., Canada, and the Euro Area. We include the U.K. and the U.S. since they have the highest financial systems in the world. Therefore, we expect they are the most sensitive to financial crises. The Eurozone was included in order to examine the role of the European debt crisis in driving economic fluctuations. Finally, the Canada's financial system was highly resilient during the recent global financial crisis. It is interesting to make a comparative analysis of its business activity during crises with other advanced economies.

The system's stochastic behavior is governed by nine exogenous structural shocks in the theoretic financial frictions model: two technology shocks, one for changes in productivity (ξ_t^a) and the other for the marginal efficiency of investment $\left(\xi_t^i\right)$; one shock for consumption preferences $\left(\xi_t^\beta\right)$; one shock to government expenditure $\left(\xi_t^g\right)$; one shock to monetary policy (ξ_t^r); and two markup shocks, one for inflation determination $\left(\xi_t^p\right)$, and another for wage setting (ξ_t^w). The financial frictions model introduces two additional shocks for the external cost of funding $\left(\xi_t^b\right)$, and the entrepreneur net worth $\left(\xi_t^{n_w}\right)$. The stochastic structure of the exogenous variables evolves according to AR(1) processes.

To identify these shocks, the models estimated with Bayesian techniques use nine quarterly key macroeconomic time series as observable variables. Specifically, the logarithm (log) difference of real GDP (y_t), log of real consumption (c_t), log of real investment (i_t), log of GDP deflator (p_t), log real wages (w_t), log of the total employment level (l_t), the nominal interest rate, the external finance premium ($prem_t$), and net worth (n_t).

The external finance premium was proxied by Bank of America (BofA) ML corporates BBB-AAA rated (C0A4-C0A1 for the U.S, UR40-UR10 for the U.K, F0C4-F0C1 for Canada and ER40-ER10 for the Euro Area). Similarly, the net worth of entrepreneurs in each country is proxied by the value of the stock market price index as in Alpanda and Aysun (2014) and Doojav and Kalirajan (2019) (S&P 500 for the U.S., FTSE 100 for the U.K., SP/TSX for Canada and Dow Jones Euro Stoxx 50 Price Index for the Eurozone). The remaining data series are taken from the Federal Reserve Bank of St. Louis database, the International Financial Statistics of the International Monetary Fund and Bloomberg. Appendix A contains further information regarding the data.[5]

The corresponding measurement equations for the aforementioned variables are given as follows:

$$Y_t = \begin{bmatrix} d\log GDP_t \\ d\log CONS_t \\ d\log INV_t \\ d\log W_t \\ d\log EMP_t \\ d\log P_t \\ INTEREST_t \\ CORPSPREAD_t \\ WORTH_t \end{bmatrix} = \begin{bmatrix} 100(\varepsilon-1) \\ 100(\varepsilon-1) \\ 100(\varepsilon-1) \\ 100(\varepsilon-1) \\ \bar{l} \\ 100\pi \\ 100(\beta^{-1}\varepsilon^{\sigma}\,\overline{\pi}) \\ \\ \end{bmatrix} + \begin{bmatrix} y_t - y_{t-1} \\ c_t - c_{t-1} \\ i_t - i_{t-1} \\ w_t - w_{t-1} \\ l_t \\ \pi_t \\ r^t \\ prem_t \\ n_t \end{bmatrix} \quad (18)$$

In the model without financial frictions, the spread and the entrepreneur net worth are not included among the observable variables.

PRIORS DISTRIBUTION

The Bayesian method utilized in this study has two main advantages. First, the system of linearized equations is estimated simultaneously. Second, Bayesian analysis allows the incorporation of uncertainty and prior information regarding the model's parameterization. However, it should be noted that the choice of the priors is of utmost importance because it might affect the estimates significantly. More exactly, the calibration of priors has a significant effect on the estimates of

[5] See Appendix A for detailed information on the spread definition and calculation.

posteriors using a Bayesian estimation strategy. The main goal of this study is to make a comparative analysis of the effects of financial frictions during financial crises. Different priors across countries can lead to a bias in the posterior estimates. To make useful comparisons among countries, priors are assumed to be the same for all the countries. Because the main objective of our research was to examine the role of frictions on financial markets, we assume that the chosen economies are symmetric. All prior distributions were selected from the normal, beta, gamma and inverse gamma distributions depending on the specific characteristics of the parameters.[6]

All prior distributions are taken directly from Smets and Wouters (2007) and Merola (2015). More specifically, the parameters dealing with the model without financial frictions are extracted from Smets and Wouters (2007) whereas the parameters related to financial frictions are specified as in Merola (2015).

The AR(1) and MA(1) coefficients and the correlation coefficient between output and government spending follow a beta distribution with mean of 0.5 and standard deviation of 0.2. The priors for the standard errors of the shocks follow an inverse gamma with mean of 0.2 and standard deviation of 0.2. The distribution of the structural parameters from the original SW model is consistent with the SW model priors. Parameters for inflation, output level, and output variation are normally distributed with means of 1.5, 0.125 and 0.125 and standard deviations of 0.25, 0.05, and 0.05, respectively. The interest rate smoothing parameter follows a beta distribution with mean of 0.75.

Looking to the model that introduces financial frictions, we set the prior for the elasticity of the entrepreneur external finance premium with respect to the entrepreneur leverage as a gaussian distribution with mean of 0.05 and standard deviation of 0.02. The steady-state of the leverage ratio is also normally distributed in the range [1, 4] with mean of 1.70 and standard deviation of 0.25.

VARIANCE DECOMPOSITION

This section presents the forecast error variance decompositions for real variables (output, consumption, investment, nominal interest rates, inflation, wage, and labor) and financial variables (corporate bond spread and net worth) for Canada, Euro Area, U.K., and U.S. Variance decomposition is employed to understand the main forces driving economic fluctuations during the recent 2007/2008 global financial crisis as well as the 2009 European sovereign debt crisis. Tables 1-4 show the forecast error variance decomposition of the financial and non-financial variables attributed to the nine shocks identified earlier in the paper. On the whole, the variance decomposition confirmed that during the global financial crisis, disturbances triggered by the financial variables have replaced the role of traditional shocks in driving macroeconomic fluctuations.

The DSGE results show that the output is mainly driven by real shocks for models without and with financial frictions in selected economies before the onset of recent financial crises. The contribution of real shocks tends to decrease during financial crises when financial frictions are entered into the model for the Euro Area while the role of real shocks remains important in Canada and the United States. The productivity and wage shocks are the main drivers of consumption variation in the Euro Area and the United States. During periods of relative stability, inflation shock is the main driver of consumption variation in Canada while government expenditure shock is the main driver of consumption variation in the U.K. The risk premium shock produced a significant consumption variation in these economies during the recent financial crises. Finally, our results show that the recent financial crises significantly reduced the impact of real shocks on investment variation in all the economies sampled.

[6] For example, the parameter of habit consumption lies between 0 and 1, and thus, follows a beta distribution. By contrast, the standard deviations of shocks are generally assumed to follow an inverse-gamma distribution.

In the sake of brevity, the following discussion focuses on variance decomposition for output, consumption, investment, and financial variables only. We focus the analysis on the model with financial frictions.[7]

CANADA

OUTPUT

The DSGE estimates suggest that the output is mainly driven by real shocks, especially productivity shock in Canada. This finding is consistent with the neoclassical theory of real business cycles and confirms the resilience of the Canadian economy to financial disturbances.[8]

The contribution of the productivity shock in explaining output variation is 17.21 percent in the model with financial friction (Panel A, Table 1). The predominance of the productivity shock in explaining output variation relies on the commodity dependency of the Canadian economic activity. We can also note that the joint contribution of real shocks $\left(\xi_t^a + \xi_t^\beta + \xi_t^g + \xi_t^i + \xi_t^r + \xi_t^p + \xi_t^w\right)$ to output fluctuation is 83.11 percent during the pre-crisis period (Panel A, Table 1) while the financial shocks $\left(\xi_t^b + \xi_t^{n_w}\right)$ jointly contribute 16.89 percent to output volatility. During the crisis period, the joint effect of real shocks on output variation rises to 98.66 percent while the contribution of financial variables drops to as low as 1.34 percent. Overall, these results imply that the role of real shocks in explaining output variation during the financial crisis is predominant relative to that of financial shocks.

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7 A detailed discussion of the results for the model without financial frictions and the variance decomposition for inflation, wages, labor, and interest rates is available from the authors upon request.

8 The impact of productivity shock on output fluctuations in Canada is less relevant during the pre-crisis period in the model without financial friction than in the model with financial friction. In the model without financial friction, productivity shock explains 15.37 percent of output variation during the pre-crisis.

Table 1. Variance Decomposition, Model with Financial Frictions –Canada–Variance Decomposition is Computed for Different Periods (Pre-Crisis, Crisis), and Different Crises (Global Financial Crisis and European Debt Crisis)

			x_t^a	x_t^b	x_t^b	x_t^g	x_t^i	x_t^r	x_t^p	x_t^w	$x_t^{n_w}$
Panel A	2000Q1-2007Q4	*Output*	17.21	4.22	6.75	16.07	9.85	6.77	15.01	13.98	10.14
		Consumption	3.42	5.58	24.71	11.15	20.91	4.15	5.11	6.87	18.10
		Investment	0.01	0.34	27.73	0.21	29.41	1.56	2.54	11.63	26.57
		Interest Rate	0.15	1.31	14.06	0.82	29.95	2.25	2.33	21.88	27.26
		Inflation	0.04	0.45	3.80	0.42	14.08	0.26	25.63	41.57	13.75
		Wage	1.24	0.67	3.664	0.46	2.22	0.59	34.19	55.34	1.65
		Labor	0.46	0.32	11.77	0.88	22.10	2.55	5.27	36.07	20.56
		Corporate Spread	0.02	0.05	7.03	0.06	43.27	0.27	1.14	15.94	32.23
		Net Worth	0.00	0.27	75.95	0.22	10.31	1.37	0.26	4.56	
Panel B	2000Q1-2014Q4	*Output*	38.17	2.37	0.39	8.92	2.22	2.51	32.39	12.07	0.95
		Consumption	2.71	5.93	5.74	20.17	13.16	3.53	32.84	13.05	2.87
		Investment	0.07	0.17	13.39	0.03	41.44	0.81	21.09	12.88	10.11
		Interest Rate	0.04	0.60	0.73	0.25	4.15	0.70	68.33	24.14	1.06
		Inflation	0.05	0.17	0.22	0.02	1.81	0.25	67.94	29.06	0.48
		Wage	0.64	0.59	0.55	0.93	0.88	0.31	69.14	26.83	0.14
		Labor	0.04	0.32	0.48	0.24	2.05	0.44	74.96	20.83	0.64
		Corporate Spread	0.03	0.06	4.72	0.01	18.31	0.03	35.60	18.75	22.50
		Net Worth	0.01	0.07	67.68	0.11	5.46	1.54	8.97	6.16	10.00
Panel C	2008Q1-2009Q3	*Output*	0.72	0.02	2.84	0.01	0.00	2.04	86.44	0.02	7.90
		Consumption	0.14	0.11	0.63	0.00	0.00	2.40	81.12	0.05	15.54
		Investment	0.02	0.00	7.51	0.00	0.00	1.30	52.30	0.01	38.85
		Interest Rate	0.12	0.00	0.78	0.00	0.00	1.77	72.71	0.04	24.58
		Inflation	0.04	0.00	0.16	0.00	0.00	1.71	93.67	0.02	4.40
		Wage	0.01	0.00	0.05	0.00	0.00	0.27	99.41	0.03	0.23
		Labor	0.07	0.00	0.80	0.00	0.00	0.71	84.20	0.06	14.17
		Corporate Spread	0.00	0.00	0.98	0.00	0.00	0.18	20.04	0.01	78.80
		Net Worth	0.01	0.00	51.82	0.00	0.00	3.34	2.90	0.00	41.93
Panel D	2009Q4-2014Q4	*Output*	28.33	0.92	1.88	18.09	2.74	4.25	0.40	10.91	32.48
		Consumption	1.27	1.40	2.82	8.04	9.37	2.45	0.19	11.11	63.34
		Investment	0.00	0.22	3.92	0.41	9.46	1.76	0.01	8.46	75.75
		Interest Rate	0.03	0.58	0.81	1.08	3.78	2.89	0.04	36.50	54.29
		Inflation	0.04	0.47	0.61	0.97	1.20	0.38	1..27	59.29	35.76
		Wage	0.09	0.08	0.16	0.18	0.76	0.16	1.27	94.39	2.91
		Labor	0.06	0.09	0.55	0.96	3.64	1.71	0.02	28.69	64.27
		Corporate Spread	0.00	0.04	0.75	0.10	4.91	0.30	0.00	25.04	68.85
		Net Worth	0.00	0.18	87.74	0.36	0.85	1.37	0.06	6.18	3.26

Source: Author's calculations.

CONSUMPTION

During the pre-crisis period the risk premium shock $\left(\xi_t^b\right)$ is the most relevant with an impact of 24.71 percent (Panel A, Table 1).[9] However, during the crisis period (Panel B, Table 1) as well as at the peak of the financial crisis from 2008:Q1 to 2009:Q3 (Panel C, Table 1), the inflation shock $\left(\xi_t^p\right)$ is an important driver of consumption volatility. The inflation shock explains 32.84 percent of consumption variation during the 2000Q1 to 2014Q4 entire sample period (Panel B, Table 1) and 81.12 percent during the peak of the financial crisis from 2008Q1 to 2009Q3 (Panel C, Table 1).[10] It is worth noting that the contribution of financial shocks $\left(\xi_t^b + \xi_t^{n_w}\right)$ to consumption variability declines from 42.81 percent during the pre-crisis period (Panel A, Table 1) to only 8.61 percent during the crisis period. At the peak of the financial crisis, however, this decline was only 16.17 percent. During the European debt crisis, however, financial shocks regained tremendous importance in explaining consumption volatility, accounting for as much as 66.16 percent of consumption variation.

INVESTMENT

The investment generally depends on financial market conditions and investment shock.[11] During the pre-crisis period, investment shock $\left(\xi_t^i\right)$ is the dominant driver of investment volatility (Panel A, Table 1). Interestingly, the role of financial shocks $\left(\xi_t^b + \xi_t^{n_w}\right)$ in explaining investment variability drops from 54.30 percent during the pre-crisis period (Panel A, Table 1) to 23.50 percent during the crisis period (Panel B, Table 1). At the peak of the financial crisis, however, financial shocks regained importance by explaining as much as 46.36 percent of investment volatility. These empirical estimates reveal that real shocks from the demand side are significant to stimulate investment in Canada during stability periods. The presence of frictions on credit markets reduces the role of real shocks in explaining investment decisions.

FINANCIAL VARIABLES

During the pre-crisis period and crisis period, real shocks collectively accounted for 60.74 percent and 72.78 percent, respectively, of corporate bond spread volatility (Panels A and B, Table 1). Our results also show that the contribution of the risk premium shock $\left(\xi_t^b\right)$ equal to 75.95 percent (Panel A, Table 1) is the most important determinant of the entrepreneurs' net worth volatility during the pre-crisis period, declining to 67.68 percent during the crisis period (Panel B, Table 1) with net worth shock gaining importance. At the peak of the financial crisis and during the European debt crisis, however, net worth shock was by far the most important driver of financial corporate spread volatility (Panels C and D, Table 1). In August 2011, for example, the Toronto Stock Exchange lost 435.90 points. This was due in part to fears of contagion of the European sovereign debt crisis to Spain and Italy, as well as concerns over the possible worsening of France's current AAA rating and the prospect of sluggish economic growth in the U.S.

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[9] Whereas the dominant determinant of consumption variability during the pre-crisis period in the model without financial friction is the inflation shock (29.50 percent).

[10] In the model without financial friction, inflation shock accounts for 44.82 percent of consumption volatility during the crisis period and 29.50 percent at the peak of the financial crisis.

[11] Investment variability in Canada appears to be driven mostly by government expenditure shock in the model without friction during the pre-crisis period.

EURO AREA

OUTPUT

The occurrence of financial frictions considerably reduces the relevance of real shocks in driving output fluctuations in the Euro Area.[12] The share of productivity shock in explaining output fluctuation dips to 1.96 percent (Panel D, Table 2) whereas net worth shock $\left(\xi_t^{n_w}\right)$ explains as much as 61.08 percent of output fluctuation. Furthermore, the contribution of the risk premium shock $\left(\xi_t^b\right)$ accounts for another 5.80 percent of output variability. In fact, the joint contribution of real shocks $\left(\xi_t^a + \xi_t^\beta + \xi_t^g + \xi_t^i + \xi_t^r + \xi_t^p + \xi_t^w\right)$ to output fluctuation is 33.12 percent whereas the financial shocks $\left(\xi_t^b + \xi_t^{n_w}\right)$ jointly contribute 66.88 percent to output volatility. This result stands in sharp contrast to the pre-crisis period finding which reveals that the joint effect of real shocks on output variation was 68.53 percent (Panel A, Table 2). Taken together, this finding implies that the role of real shocks in explaining output variation during the European debt crisis was clearly supplanted by financial shocks. Indeed, during the European debt crisis, the net worth shock had a significantly greater impact on the error-variance of output (32.48 percent, Panel D, Table 2).

[12] The role played by productivity shock in driving output fluctuations during the European debt crisis in the model without financial friction was more important than in the model with financial friction. In the model without financial friction, productivity shock explains 32.49 percent of the variation in output.

Table 2. Variance Decomposition, Model with Financial Frictions –Euro Area–Variance Decomposition is Computed for Different Periods (Pre-Crisis, Crisis), and Different Crises (Global Financial Crisis and European Debt Crisis)

			x_t^a	x_t^b	x_t^b	x_t^g	x_t^i	x_t^r	x_t^p	x_t^w	$x_t^{n_w}$
Panel A	2000Q1-2007Q4	*Output*	24.72	7.81	8.04	4.81	17.42	12.87	0.59	0.31	23.43
		Consumption	28.77	20.50	1.52	1.70	8.96	22.54	1.68	1.63	12.70
		Investment	4.30	4.03	14.90	0.36	25.61	3.55	0.01	0.06	47.17
		Interest rate	6.05	14.52	2.30	0.71	43.96	16.44	0.00	2.09	13.93
		Inflation	8.69	18.52	2.63	1.01	39.33	15.34	1.26	2.56	10.66
		Wage	7.67	4.70	0.56	0.14	11.95	8.76	13.30	43.49	9.43
		Labor	0.86	2.92	1.92	0.12	61.09	3.72	0.02	0.52	28.83
		Corp. spread	0.19	1.02	3.24	0.03	30.14	0.53	0.00	0.11	64.74
		Net worth	0.31	0.62	78.48	0.04	10.40	0.36	0.01	0.01	9.77
Panel B	2000Q1-2014Q4	*Output*	48.72	3.33	15.21	2.93	14.56	5.23	1.24	0.13	8.66
		Consumption	28.58	7.94	26.75	2.06	15.11	5.71	1.40	1.07	11.38
		Investment	0.04	1.05	48.73	0.00	28.02	0.10	0.01	0.17	21.88
		Interest rate	0.03	89.57	1.18	0.02	0.50	3.34	4.46	4.46	0.41
		Inflation	0.06	46.66	0.16	0.00	0.49	0.15	22.52	0.10	0.25
		Wage	4.88	3.55	0.59	0.01	3.52	1.30	77.71	0.01	0.94
		Labor	26.05	3.96	18.25	0.20	32.16	1.28	4.01	0.50	13.96
		Corp. spread	0.04	2.99	29.81	0.00	32.23	0.01	0.09	0.04	34.83
		Net worth	0.00	0.24	52.87	0.00	23.85	0.14	0.11	3.11	22.78
Panel C	2008Q1-2009Q3	*Output*	25.55	21.39	1.07	0.28	0.02	1.61	0.00	0.15	49.93
		Consumption	9.33	71.41	0.96	0.06	0.01	0.98	0.00	0.03	17.22
		Investment	15.01	35.60	0.76	0.05	0.01	0.64	0.00	0.00	47.93
		Interest rate	6.02	60.44	0.83	0.12	0.01	0.24	0.00	0.00	32.33
		Inflation	7.70	65.19	0.82	0.13	0.01	0.35	0.00	0.00	25.80
		Wage	13.40	36.05	0.86	0.07	0.01	2.77	0.18	14.85	31.81
		Labor	1.39	26.17	0.60	0.06	0.01	1.28	0.00	0.00	70.49
		Corp. spread	1.16	20.17	0.72	0.04	0.01	0.49	0.00	0.00	77.41
		Net worth	6.30	35.00	9.93	0.06	0.01	0.59	0.00	0.00	48.1
Panel D	2009Q4-2014Q4	*Output*	1.96	7.12	5.80	4.01	8.38	9.06	1.64	0.95	61.08
		Consumption	13.80	6.35	0.14	1.17	0.64	10.11	30.55	26.69	10.55
		Investment	0.05	4.54	7.62	0.59	11.46	5.50	3.03	5.16	62.04
		Interest rate	1.50	2.58	1.01	0.37	9.56	13.94	8.28	17.36	45.41
		Inflation	0.81	5.27	1.14	0.76	6.82	13.86	12.51	21.53	37.30
		Wage	4.67	1.74	0.12	0.28	0.69	1.75	34.89	48.07	7.78
		Labor	10.71	5.06	1.97	0.69	12.94	5.53	1.48	2.74	58.88
		Corp. spread	0.38	1.27	3.34	0.17	20.96	3.21	13.38	9.14	48.15
		Net worth	0.02	0.73	80.85	0.09	4.80	1.25	1.45	1.48	9.32

Source: Authors' calculations.

CONSUMPTION

The most important determinant of consumption variability before the financial crisis is productivity shock.[13] A major component of the variation in consumption is explained by the consumption preference shock $\left(\xi_t^{\beta}\right)$, especially at the peak of the financial crisis. Another interesting finding is that financial shocks $\left(\xi_t^b + \xi_t^{n_w}\right)$ together account for 14.22 percent of consumption variability while real shocks jointly account for as much as 85.78 percent of the variability in consumption (Panel A, Table 2) during the pre-crisis period, declining to only 61.87 percent during the crisis period (Panel B, Table 2). Finally, it is worth noting that while the combined role of financial shocks $\left(\xi_t^b + \xi_t^{n_w}\right)$ in explaining consumption variability increases at the peak of the financial crisis to 18.18 percent (Panel B, Table 2), their contribution decreases significantly to only 10.69 percent during the European debt crisis (Panel D, Table 2). This may be due to the fact that more wealth may have been destroyed at the peak of the financial crisis compared to the European debt crisis period.

INVESTMENT

The investment level depends on financial market conditions and investment shock.[14] The role of this shock in driving investment fluctuations is significantly reduced when the financial accelerator mechanism become operative. The decrease of the role of investment specific shock in explaining investment decisions can be explained by the fact that entrepreneur's net worth shock generates counterfactual effect on asset prices. and the empirical estimates show that financial disturbances (risk premium and net worth) are accorded a substantial role in determining investment variability during the 2008 crisis period. Our empirical estimates suggest that non-financial corporations in the Euro Area significantly adjust their business investments to risk premium shock, especially during financial crises. During the pre-crisis period, the risk premium shock $\left(\xi_t^b\right)$ explained about 14.90 percent of investment variability (Panel A, Table 2). This percentage jumped to 48.73 percent during the crisis period (Panel B, Table 2). Our result also shows that financial shocks $\left(\xi_t^b + \xi_t^{n_w}\right)$ jointly explained 62.07 percent of investment variability during the pre-crisis period (Panel A, Table 2), jumping to an impressive 70.61 percent during the crisis period (Panel B, Table 2) and to 69.66 percent during the European debt crisis. These results are generally consistent with Barkbu et al. (2015) who suggest that the weakness of investment in the Eurozone during the financial crisis was explained by a high cost of capital, financial constraints, and uncertainty.

FINANCIAL VARIABLES

Movements on financial markets are not related to the dynamics of the real sector. Financial shocks $\left(\xi_t^b + \xi_t^{n_w}\right)$ explains a large part of the forecast error variance of financial series (corporate spread and net worth). Specifically, financial shocks explained 67.98 percent of corporate spread fluctuation during the pre-crisis period (Panel A, Table 2), declining moderately to 64.64 percent during the crisis period (Panel B, Table 2) and rising as high as 78.13 percent at the peak of the crisis (Panel C, Table 2).

[13] In the model without financial friction, the productivity shock is more prominent during the crisis period (69.22 percent) compared to the pre-crisis period (61.98 percent). However, at the peak of the financial crisis from 2008:Q1 to 2009:Q3, the wage shock supplanted productivity shock in explaining consumption variability (80.15 percent; =13.77 percent).

[14] However, investment variability is mostly driven by investment shock in the model without frictions in the credit market.

Finally, we note that the contribution of financial shocks to corporate spread volatility stagnates at 51.49 percent during the European debt crisis (Panel D, Table 2). Financial shocks explained as much as 88.25 percent of the entrepreneurs' net worth volatility during the pre-crisis period (Panel A, Table 2), declining to 75.65 percent during the crisis period (Panel B, Table 2). Of all the seven real variables we analyze, only investment shock $\left(\xi_t^i\right)$ appears to be a significant driver for both the corporate spread and net worth during the pre-crisis (30.14 percent and 10.40 percent, respectively, Panel A, Table 2). However, the impact of investment shock on the corporate spread and net worth became more pronounced during the crisis period (32.23 percent and 23.85 percent, respectively, Panel B, Table 2).

U.K.

OUTPUT

The dominant forces behind output developments in the U.K. during the pre-crisis period in both models are government expenditures and inflation shocks $\left(\left(\xi_t^g\right) \text{ and } \left(\xi_t^p\right)\right)$ (Panel A, Table 3). This suggests that the economic activity mainly relies on public spending decisions and inflationary pressures when economic outlook is stable in the United Kingdom. However, during the crisis period, productivity shock (ξ_t^a) in both models becomes the most important driver of output variability. This is consistent with the IMF (2014) which shows that during the 2008 crisis the collapse in the U.K. GDP was largely due to a sharp decline in total factor productivity and, to a lesser extent, reduced labor inputs as well as slower capital accumulation. Moreover, the monetary shock is the most important factor driving output variation at the peak of the crisis (91.67 percent, Panel C, Table 3) and during the European debt crisis (26.05 percent, Panel D, Table 3). Indeed, U.K. monetary policy was significantly expansionary, with the *Bank Rate* reduced from 5.75% in late 2007 to 0.5% in early 2009 in order to support U.K. output and control inflation during the global financial crisis. After reaching the effective lower bound for interest rates, the Bank of England *Monetary Policy Committee* (MPC) began a series of asset purchases, often referred to as quantitative easing, in a further attempt to stimulate U.K. economic activity. As the Euro Area crisis intensified from the late 2011, MPC took further measures to alleviate the increase in U.K. banks' funding costs and the associated tightening of credit conditions.

Table 3. Variance Decomposition, Model with Financial Frictions –U.K.–Variance Decomposition is Computed for Different Periods (Pre-Crisis, Crisis), and Different Crises (Global Financial Crisis and European Debt Crisis)

			x_t^a	x_t^b	x_t^b	x_t^g	x_t^i	x_t^r	x_t^p	x_t^w	$x_t^{n_w}$
Panel A	2000Q1-2007Q4	Output	9.82	9.32	13.03	19.05	15.03	9.16	18.57	0.78	4.34
		Consumption	2.20	9.06	23.82	15.79	23.40	6.79	12.89	0.46	5.58
		Investment	0.00	0.03	43.07	0.00	45.34	0.12	0.14	0.02	11.28
		Interest rate	0.08	9.43	21.75	1.28	27.62	6.97	14.90	6.87	11.10
		Inflation	0.13	1.08	5.04	0.25	7.58	1.58	73.08	7.88	3.37
		Wage	0.56	0.89	0.92	0.09	1.26	1.04	44.95	49.98	0.31
		Labor	0.23	2.00	32.45	1.58	40.55	3.19	4.72	1.59	13.70
		Corp. spread	0.00	0.01	43.65	0.00	26.50	0.00	0.03	0.06	29.75
		Net worth	0.00	0.06	49.30	0.01	20.96	0.34	0.57	0.08	28.68
Panel B	2000Q1-2014Q4	Output	42.59	20.79	1.17	19.21	2.22	11.21	1.39	0.14	1.28
		Consumption	11.76	29.37	11.21	21.18	9.43	11.46	1.34	0.25	3.99
		Investment	0.03	0.14	40.01	0.01	40.44	1.10	0.05	0.03	18.20
		Interest rate	2.25	18.46	18.37	2.83	16.69	28.44	1.70	3.93	7.33
		Inflation	0.07	0.57	0.65	0.00	0.95	1.77	87.96	7.47	0.55
		Wage	0.60	0.87	0.96	0.14	1.10	0.54	30.47	64.85	0.46
		Labor	1.83	33.53	14.60	2.53	13.90	24.39	0.95	4.02	4.25
		Corp. spread	0.01	0.01	41.36	0.00	23.35	0.42	0.02	9.17	34.61
		Net worth	0.05	0.28	42.44	0.05	17.36	1.16	0.20	0.11	38.2
Panel C	2008Q1-2009Q3	Output	0.18	0.11	0.01	3.44	2.17	91.67	0.06	0.06	2.30
		Consumption	0.02	0.38	0.00	0.17	0.21	98.63	0.15	0.03	0.41
		Investment	0.05	0.12	0.05	0.12	11.18	68.42	0.06	0.00	20.01
		Interest rate	0.04	0.07	0.01	0.10	3.01	88.53	0.08	0.01	8.15
		Inflation	0.02	0.03	0.00	0.07	0.66	97.47	0.18	0.02	1.55
		Wage	0.02	0.05	0.00	0.05	0.65	88.11	0.41	10.34	0.37
		Labor	0.04	0.03	0.01	0.20	2.62	89.82	0.08	0.01	7.19
		Corp. spread	0.02	0.05	0.03	0.08	8.65	49.19	0.54	0.02	41.41
		Net worth	0.04	0.10	2.12	0.12	4.97	79.21	0.15	0.00	13.29
Panel D	2009Q4-2014Q4	Output	11.12	0.53	0.85	22.66	9.28	26.05	5.06	10.92	13.53
		Consumption	3.82	0.43	0.60	5.55	9.04	16.54	4.29	29.47	30.46
		Investment	0.39	0.97	1.80	0.02	22.38	22.51	0.17	1.49	50.27
		Interest rate	0.12	0.21	0.00	0.01	0.03	60.70	0.06	38.21	0.67
		Inflation	0.38	0.52	0.00	0.02	0.09	31.75	20.03	46.54	0.68
		Wage	1.19	0.03	0.00	0.00	0.16	1.75	39.51	56.20	1.15
		Labor	0.15	0.80	0.18	0.72	4.80	23.75	0.49	32.62	36.50
		Corp. spread	0.02	0.68	0.53	0.01	8.52	13.52	0.10	21.32	55.30
		Net worth	0.08	0.62	63.51	0.01	3.23	13.33	0.65	4.57	14.00

Source: Authors' calculations.

CONSUMPTION

The risk premium shock is the most important determinant of consumption variation[15] with an impact of 23.82 percent (Panel A, Table 3). A major component of the variation in consumption is explained by the consumption preference shock, especially during the crisis period (Panel B, Table 3). However,

[15] The most important determinant of consumption variability during the pre-crisis period in the model without financial friction is government expenditure shock.

at the peak of the financial crisis from 2008:Q1 to 2009:Q3, the monetary policy shock (ξ_t^r) outpaces risk premium shock by explaining as much as 98.63 percent of consumption variability (Panel C, Table 3). The large expansionary monetary policy adopted by the central bank stimulate households to borrow to finance their private consumption. Another interesting finding is that financial shocks $\left(\xi_t^b + \xi_t^{n_w}\right)$ jointly account for 29.40 percent of consumption variability while real shocks jointly account for as much as 70.60 percent of the variability in consumption (Panel A, Table 3) during the pre-crisis period, increasing to 84.80 percent during the crisis period (Panel B, Table 3). Finally, it is worth noting that the combined role of financial shocks $\left(\xi_t^b + \xi_t^{n_w}\right)$ in explaining consumption variability decreases dramatically to 0.41 percent during the peak of the financial crisis (Panel C, Table 3) but regains relative importance during the European debt crisis by explaining as much as 31.01 percent of consumption volatility (Panel D, Table 3).

INVESTMENT

During the pre-crisis period, investment shock is the most important determinant of investment variability.[16] During the pre-crisis period, financial shocks account for 54.35 percent investment variability (Panel A, Table 3) increasing to 58.29 percent during the crisis period (Panel B, Table 3). This is consistent with Akbar et al. (2013) who examine how shocks to the supply of credit during the global financial crisis affected British companies. Their findings suggest that credit contraction has negatively affected the performance and investment of private firms. We note, however, that monetary policy shock supplants financial shocks in explaining investment volatility at the peak of the financial crisis (68.42 percent, Panel C, Table 3). Interestingly, financial shocks regain great importance in explaining investment variation during the European debt crisis (52.07 percent, Panel D, Table 3).

FINANCIAL VARIABLES

Financial shocks $\left(\xi_t^b + \xi_t^{n_w}\right)$ explain a large part of the forecast error variance of financial variables (corporate spread and net worth). Precisely, financial shocks explain 73.40 percent of corporate spread fluctuation during the pre-crisis period (Panel A, Table 3), rising to 75.97 percent during the crisis period (Panel B, Table 3) and decreasing to as low as 41.44 percent at the peak of the crisis (Panel C, Table 3) seemingly replaced with monetary policy shock which now explain as much as 49.19 percent of corporate spread variability (Panel C, Table 3). This can be explained by the fact that low interest rates resulting from the massive expansionary monetary policy adopted by the U.K. central bank has significantly contributed to reduce the external finance premium. Furthermore, we note that financial shocks explain as much as 77.98 percent of the entrepreneurs' net worth volatility during the pre-crisis period (Panel A, Table 3), increasing to 80.64 percent during the crisis period (Panel B, Table 3). However, monetary policy shock largely determines entrepreneurs' net worth volatility at the peak of the 2008 financial crisis (79.21 percent, Panel C, Table 3). Finally, it can be seen that financial shocks regain dominance during the European debt crisis by explaining as much as 77.51 percent of net worth variability.

[16] However, the contribution of investment shock to investment variability is more pronounced in the model without financial friction (64.32 percent) compared to the model with financial friction (45.34, Panel A Table 3).

U.S.

OUTPUT

Inflation and wage shocks $\left((\xi_t^p), (\xi_t^w)\right)$ are the main drivers of output variation during the pre-crisis period in the U.S. The joint contribution of these two shocks to output variation is 42.50 percent[17] (Panel A, Table 4). During the crisis period, however, productivity shock (ξ_t^a) becomes the main driver of output fluctuation in both models (Panel B, Table 4). In fact, productivity shock alone accounts for 56.80 percent in the model with financial friction.[18] These results reveal that when the economic activity is stable in the U.S., firms adjust their production regarding the private earnings of households and their power purchase which mirror the demand that they face. During an economic crisis period, non-financial companies limit their production so that the productivity shock is the main driver of output fluctuations. However, the presence of financial friction clearly dampens the impact of real shocks irrespective of the period considered.

[17] The joint contribution is 46.44 percent in the model without financial friction.
[18] And 58.26 percent of output variation in the model without financial friction.

Table 4. Variance Decomposition, Model with Financial Frictions –U.K.–Variance Decomposition is Computed for Different Periods (Pre-Crisis, Crisis), and Different Crises (Global Financial Crisis and European Debt Crisis)

			x_t^a	x_t^b	x_t^b	x_t^g	x_t^i	x_t^r	x_t^p	x_t^w	$x_t^{n_w}$
Panel A	2000Q1-2007Q4	*Output*	9.34	4.19	5.04	10.19	7.00	15.56	19.36	23.14	6.19
		Consumption	5.92	12.51	1.01	0.41	6.24	14.32	8.23	43.44	7.94
		Investment	0.47	0.11	14.98	0.00	29.97	6.26	15.22	2.78	30.21
		Interest rate	0.95	1.68	0.23	0.01	3.77	4.80	20.31	62.42	5.83
		Inflation	0.60	0.40	0.07	0.00	1.41	12.61	34.12	48.53	2.26
		Wage	3.18	1.15	0.13	0.00	1.34	5.34	77.41	9.95	1.50
		Labor	0.62	0.19	0.27	0.09	1.88	2.01	6.97	85.15	2.83
		Corp. spread	0.04	0.00	0.95	0.00	2.31	0.59	0.24	2.95	92.93
		Net worth	0.01	0.02	76.24	0.00	1.49	3.03	0.13	0.47	18.62
Panel B	2000Q1-2014Q4	*Output*	56.80	12.07	0.93	11.92	1.39	11.31	0.89	1.95	2.74
		Consumption	30.62	17.75	5.82	10.12	10.94	9.74	0.51	5.90	8.60
		Investment	0.15	0.26	22.67	0.01	36.57	3.94	0.53	1.42	34.46
		Interest rate	4.61	6.60	3.66	0.53	15.18	30.17	5.59	22.87	10.80
		Inflation	0.14	0.04	0.10	0.18	0.14	0.03	58.92	39.67	0.77
		Wage	1.83	1.29	0.83	0.18	4.52	0.65	15.62	71.04	4.06
		Labor	3.27	12.00	1.83	0.80	15.14	12.09	1.90	46.19	6.79
		Corp. spread	0.06	0.04	4.25	0.00	9.99	0.10	0.08	1.92	83.56
		Net worth	0.09	0.14	77.66	0.01	2.48	1.12	0.05	0.33	18.12
Panel C	2008Q1-2009Q3	*Output*	28.65	7.04	3.62	6.48	1.35	52.82	0.00	0.03	0.01
		Consumption	17.79	17.15	1.51	2.66	1.67	59.07	0.01	0.14	0.00
		Investment	26.54	17.21	5.52	4.33	2.07	44.30	0.00	0.01	0.02
		Interest rate	14.17	22.04	8.68	6.41	5.06	43.62	0.00	0.01	0.02
		Inflation	12.53	17.07	5.97	4.93	2.91	56.55	0.01	0.03	0.01
		Wage	60.17	3.14	0.77	1.25	1.05	31.85	0.39	1.37	0.00
		Labor	7.68	11.69	4.80	3.43	2.39	69.95	0.00	0.04	0.02
		Corp. spread	5.41	14.34	10.73	4.16	11.61	53.69	0.00	0.01	0.05
		Net worth	7.85	10.23	40.72	2.80	7.26	31.12	0.00	0.01	0.01
Panel D	2009Q4-2014Q4	*Output*	3.35	0.76	4.77	11.38	56.65	0.29	0.05	17.47	5.27
		Consumption	1.58	5.07	0.28	1.44	89.08	0.68	0.08	1.14	0.64
		Investment	0.66	1.46	0.30	20.87	33.13	0.07	0.00	32.16	11.35
		Interest rate	5.01	5.56	1.21	7.43	45.14	0.17	0.04	18.48	16.96
		Inflation	2.42	3.10	0.67	2.10	77.81	3.08	0.11	6.75	3.95
		Wage	1.52	0.24	0.07	1.20	21.96	36.64	35.58	0.88	1.91
		Labor	1.43	1.06	0.38	5.15	71.53	0.13	0.03	8.55	11.74
		Corp. spread	0.3	0.42	0.09	8.09	15.65	0.26	0.04	28.12	47.01
		Net worth	0.08	0.14	0.03	0.58	3.49	0.00	0.00	94.41	1.28

Source: Authors' calculations.

CONSUMPTION

In the U.S., wage shock (ξ_t^w) is the dominant driver of consumption fluctuation during the pre-crisis period. The mean impact of wage shock on consumption is 42.41 percent (Panel A, Table 4). This is intuitive and consistent with Stephens (2001), who shows that households are able to smooth their consumption in response to earnings shocks. Stephens also finds that large changes in earnings result in small changes in household consumption in the short run. In the long run, however, he documents that household consumption is still affected significantly but not to the same magnitude as earnings. During the crisis period, productivity shock becomes the predominant determinant of consumption variability, accounting for 30.62 percent of consumption variation (Panel B, Table 4). The risk premium shock $\left(\xi_t^b\right)$ had no information content to forecast the consumption error-variance during the pre-crisis period (1.01 percent, Panel A, Table 4). This confirms Gilchrist and Zakrajsek (2009) results who found that corporate credit spreads have essentially no information content for future consumption spending on both durable and non-durable goods from 1990:Q2 to 2008:Q2. The combined effect of financial shocks $\left(\xi_t^b + \xi_t^{n_w}\right)$ grew from 8.95 percent during the pre-crisis period (Panel A, Table 4) to 14.42 percent during the crisis period. However, at the peak of the financial crisis from 2008:Q1 to 2009:Q3, the monetary policy shock (ξ_t^r) became the most important driver of consumption explaining as much as 59.07 percent of consumption variation. Finally, it is worth noting that investment shock $\left(\xi_t^i\right)$ became the most important driver of consumption variation, explaining about 89.08 percent of consumption variation (Panel D, Table 4).

INVESTMENT

During the pre-crisis period, investment shock is a significant driver of investment variation. Financial shocks also play a relevant role in the U.S. investment fluctuations. During the pre-crisis period, it explained 14.98 percent of investment variation (Panel A, Table 4b) growing to 22.67 percent during the crisis period (Panel B, Table 4). This result reveals that linkages between credit markets frictions and the real sector strengthens during the crisis period and is in line with Gilchrist and Zakrajsek (2009) who find that high-yield bond spread can be used to forecast total investment spending. The combined financial shocks $\left(\xi_t^b + \xi_t^{n_w}\right)$ account for 45.19 percent of the forecast error-variance of investment (Panel A, Table 4) during the pre-crisis period, increasing to 57.13 percent during the crisis period (Panel B, Table4). However, we observe that movements in business investment at the peak of the financial crisis are primarily driven by the monetary policy shock, productivity shock, and consumption shock which explained, respectively, 44.30 percent, 26.54 percent, and 17.21 percent of investment variability (Panel C, table 4). The high contribution of the monetary policy shock is consistent with the massive quantitative easing adopted by the FED to support the U.S. economy during the global financial crisis.

FINANCIAL VARIABLES

The dynamics on assets and credit markets is disconnected to the real sector when there is a tranquility in the economy. However, it seems that central bank decisions are able to reduce the stress on financial markets in the U.S. during a great turmoil. The DSGE estimates show that the forecast error variance of financial variables is largely explained by risk premium and net worth shocks. Specifically, these financial shocks together explain 93.88 percent of corporate spread fluctuation during the pre-crisis period (Panel A, Table 4), declining to 87.81 percent during the crisis period (Panel B, Table 4) and to as low as 10.78 percent at the peak of the crisis (Panel C, Table 4). Thus, financial shocks are replaced with monetary policy shock at the peak of the crisis since monetary policy shock explains as much as 53.69 percent of corporate spread variability at the peak of the crisis (Panel C, Table 4). Moreover, we observe that financial shocks explain as much as 94.86 percent of the entrepreneurs' net worth volatility during the pre-crisis period (Panel A, Table 4), rising to 95.78 percent during the crisis period (Panel B, Table 4). This is consistent with Suh and Walker (2016) who find that non-financial variables explain less than 5 percent of risk spread, and bank spread in the United States.

HOW DOES THE FINANCIAL FRICTION MODEL INTERPRET RECENT FINANCIAL CRISES?

Using historical decompositions, we document how the 2008 global financial crisis and the European debt crisis are interpreted by the version of the model that accounts for financial friction. These decompositions show the contribution of each structural shock to changes in specific variables. The individual contributions of each structural shock to the dynamics of output, investment and consumption over the sample period are based on the estimates of the various shocks in the DSGE model with financial friction. These decompositions are useful as they shed light on how the estimated model interpreted specific movements in the observed data, especially during the crucial period of 2007–2013.

Given the estimates of the model parameters and the structural shocks we can calculate the contribution of the $j-th$ structural shock $\varepsilon_t = (\varepsilon_{j,1}, \varepsilon_{j,2}, \ldots, \varepsilon_{j,t})$ to $k-th$ variable $X_k = X_{k,1}, X_{k,2}, \ldots, X_{k,t}$ by assuming $\varepsilon_{\forall l \neq h} = 0$ in the above MA representation. To obtain the historical decomposition from DSGE models, posteriors are estimated with Canada, the Euro Area, U.K., and U.S. data from 2000:Q1 to 2014:Q4.

CANADA

OUTPUT

Although Canada was not at the epicenter of the 2008 global financial crisis, our empirical estimates show that their contagion effects operate through various transmission channels. Canada has experienced a recession that was less severe and shorter than in the other advanced economies. Between the 2008:Q3 and 2009:Q1, Canada slid into a deep recession. The drop in Canada's GDP that occurs over those three quarters (Figure 1) is shorter than the four to six quarters of contraction in the other economies. The productivity shock is the most important determinant of recession during 2008:Q4-2009:Q3. Figure 1 shows that it contributes to a large fraction of the downfall in output (roughly 60%).

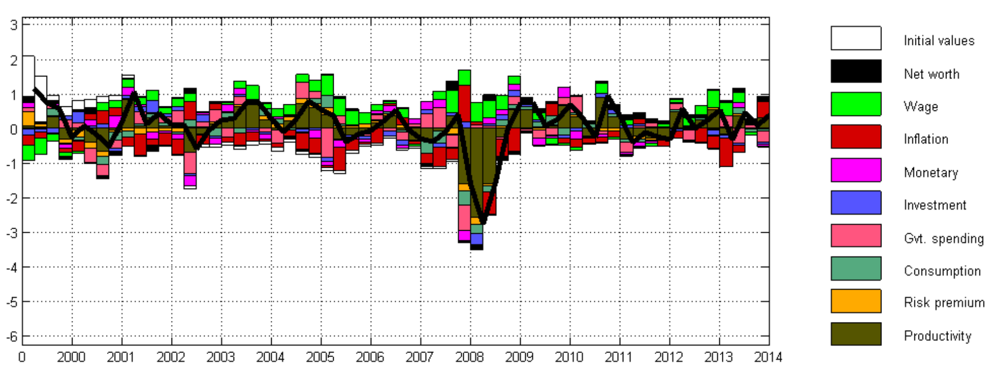

Figure 1. Historical Decomposition, Changes in Output, Deviation from Trend (%) –Canada–
Source: Authors' calculations.

Figure 1 depicts the historical decomposition to examine the contribution of each structural shock to changes in the Canadian output. The estimates are based on the DSGE model with financial friction.

INVESTMENT

Shocks related to financial friction, most notably the risk premium shock, play a significant role in investment movements in Canada. The contraction in investment during the global financial crisis is mostly driven by the risk premium shock. The net worth shock also explains an important share of investment downfall, although this role is less prominent. Thus, the risk premium provides a better explanation of co-movement between investment and the capital price during the 2008 crisis than investment shock (Figure 2).[19]

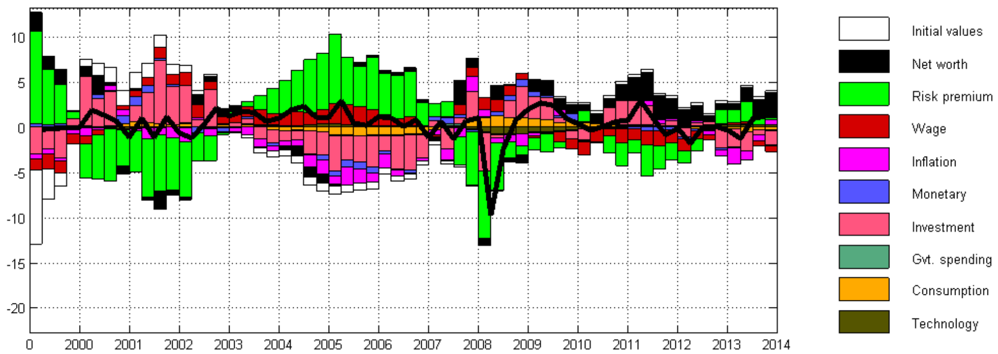

Figure 2. Historical Decomposition, Changes in Investment, Deviation from Trend (%) –Canada–
Source: Authors' calculations.

Figure 2 depicts the historical decomposition to examine the contribution of each structural shock to changes in the Canadian investment. The estimates are based on the DSGE model with financial friction.

CONSUMPTION

Decline in household consumption during 2008:Q1-2008:Q4 is mainly driven by demand shocks, notably consumption shock, inflation shock, and government spending shock (Figure 3). This suggests that the expansionary fiscal policy adopted to support the economy during the global financial crisis has mainly operated through the consumption channel. In contrast, the role played by financial shocks in the consumption downfall is mostly insignificant.

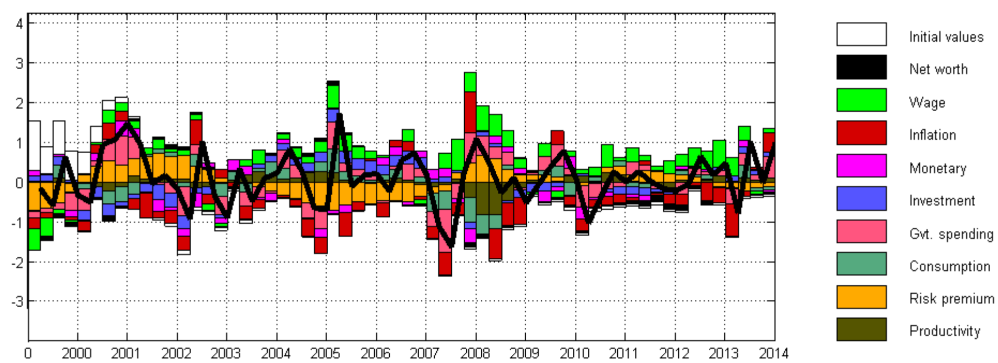

Figure 3. Historical Decomposition, Changes in Consumption, Deviation from Trend (%) –Canada–
Source: Authors' calculations.

[19] Suh and Walker (2016) report a similar finding for the U.S.

Figure 3 depicts the historical decomposition to examine the contribution of each structural shock to changes in the Canadian consumption. The estimates are based on the DSGE model with financial friction.

EURO AREA

OUTPUT

The spread shock is suitable to account for output fluctuations in Euro Area during the pre-crisis and the crisis periods (Figure 4). Between 2001 and 2003, the recession was caused by risk premium shock. Although the main driving force of output collapse in 2008 was productivity shock, the historical decomposition of output shows that financial shocks, especially net worth shock, played a significant role in output collapse during the 2008/2009 recession.

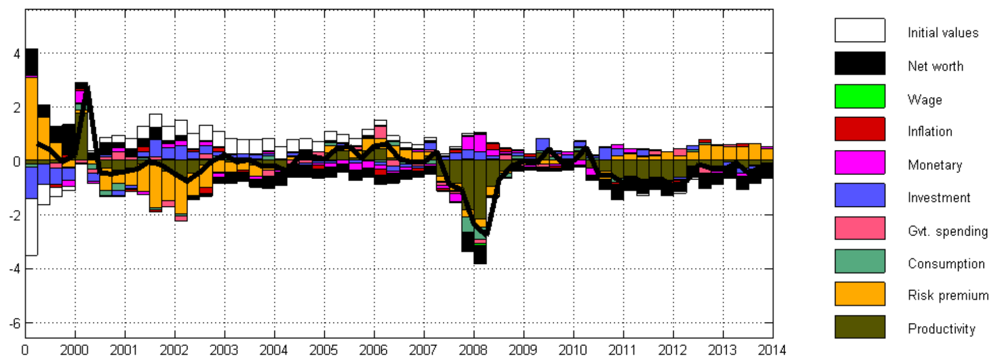

Figure 4. Historical Decomposition, Changes in Output, Deviation from Trend (%) –Euro Area–
Source: Authors' calculations.

Figure 4 depicts the historical decomposition to examine the contribution of each structural shock to changes in the Euro Area output. The estimates are based on the DSGE model with financial friction.

INVESTMENT

The risk premium shock has a significantly expansionary effect on investment during 2005-2007 (Figure 5). However, by 2008:Q1, the risk premium shock's impact on investment fluctuation had turned negative. Figure 5 shows that the link between the financial sector and the real economy operates via investment as in Merola (2015). The expansion of investment in 2004-2007 and the contraction observed in 2008:Q1 was driven mostly by the risk the premium shock and net worth shock. During the European debt crisis, fluctuations in investment were essentially caused by risk premium shocks and net worth shocks.

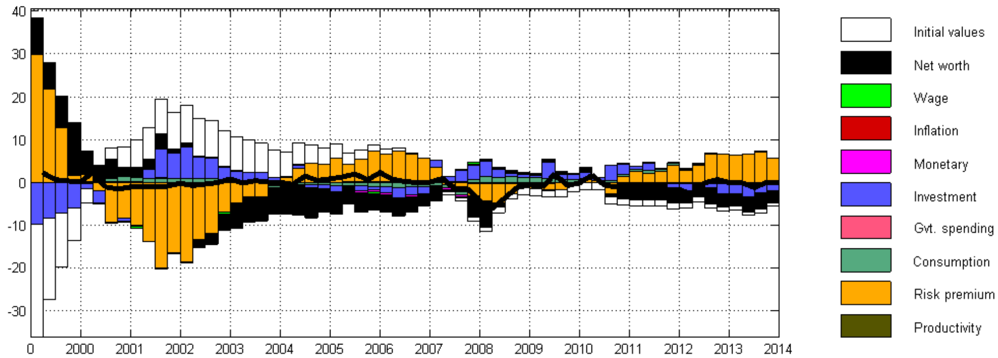

Figure 5. Historical Decomposition, Changes in Investment, Deviation from Trend (%) –Euro Area–
Source: Authors' calculations.

Figure 5 depicts the historical decomposition to examine the contribution of each structural shock to changes in the Euro Area investment. The estimates are based on the DSGE model with financial friction.

CONSUMPTION

Figure 6 shows that fluctuations in consumption were driven mostly by productivity and consumption shocks during 2008 global financial crisis. However, during the European debt crisis, the risk premium shock replaced consumption shock. This is due to the fact that household debt rose and consumption contracted significantly during the European debt crisis. Since the beginning of 2010, tensions in the sovereigns of many countries in the Eurozone have distorted monetary and credit conditions, hindering the ECB monetary policy transmission mechanism and raising the cost of funding to non-financial companies and households causing a significant decrease in private consumption.

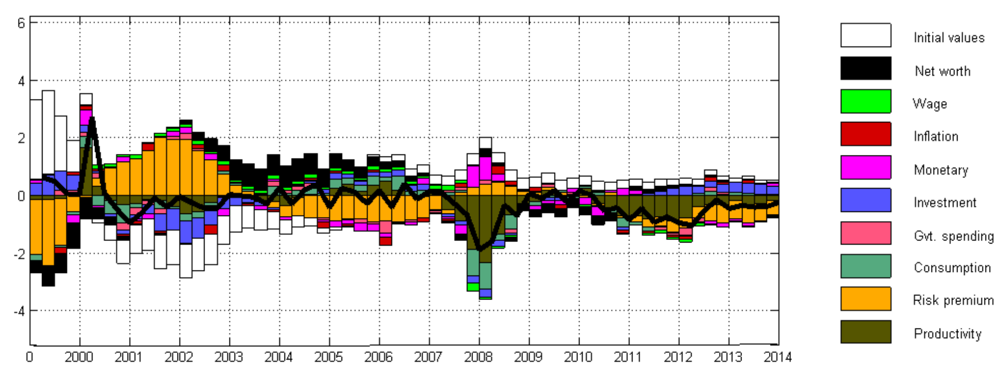

Figure 6. Historical Decomposition, Changes in Consumption, Deviation from Trend (%) –Euro Area–
Source: Authors' calculations.

Figure 6 depicts the historical decomposition to examine the contribution of each structural shock to changes in the Euro Area consumption. The estimates are based on the DSGE model with financial friction.

U.K.

OUTPUT

Figure 7 shows that the global financial crisis caused the U.K. to slip into recession in 2008. This turning point coincided with the collapse of Northern Rock bank in 2007:Q4 which was followed by partial nationalization of several other banks. This led to panic among depositors who feared that their savings might not be available if Northern Rock went into receivership.

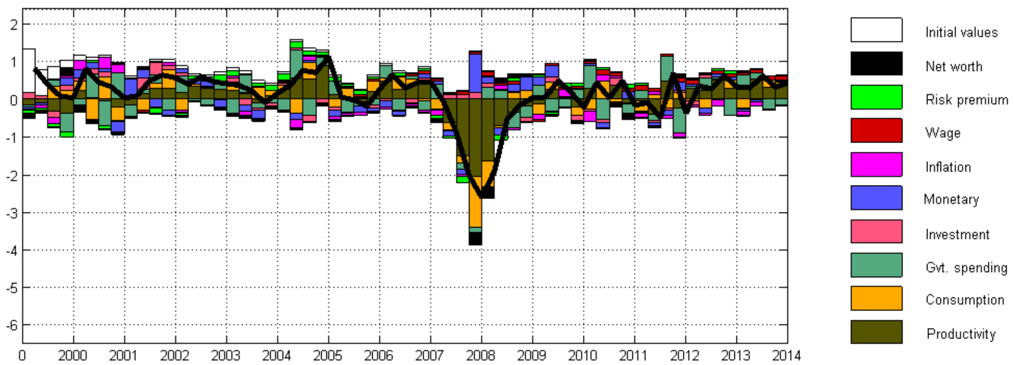

Figure 7. Historical Decomposition, Changes in Output, Deviation from Trend (%) -United Kingdom-
Source: Authors' calculations.

Figure 7 depicts the historical decomposition to examine the contribution of each structural shock to changes in the U.K. output. The estimates are based on the DSGE model with financial friction.

U.K. output shrink in 2008 and 2009 (Figure 7). During this recession period, the historical decomposition shows that productivity and consumption shocks explain the collapse of output. This is in line with the downturn observed in labor productivity at the peak of the crisis (See figure 8).

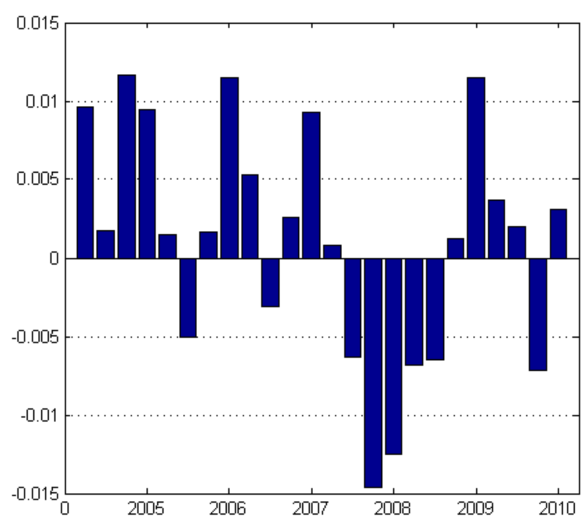

Figure 8. Labor Productivity[20] Growth –United Kingdom–
Source: Authors' calculations from International Financial Statistics

[20] Labor productivity is defined as output per worker (i.e., real gross domestic product (GDP) divided by total employment).

Figure 8 shows that the labor productivity has considerably collapsed during the 2008 global financial crisis in the United Kingdom.

The historical decomposition shows that interest rate shocks limit the decrease of real GDP. This is consistent with the accommodative monetary policy in the U.K. in 2008:Q1-2009:Q3. In response to the global crisis, the monetary authority implemented a massive expansionary policy. the Bank of England's Monetary Policy Committee (MPC) cut the bank rate in a sequence of steps, from 5% in October 2008 to 0.5% in March 2009.

INVESTMENT

The contraction in investment during 2008:Q4-2009:Q1 is almost completely due to risk premium and net worth shocks (Figure 9). This shows the negative impact that the worsening of credit markets has on firms' investment during the 2008 global financial crisis in the U.K. (Akbar, 2013). In the presence of capital market imperfections, the availability of finance (internal or external) becomes an important determinant of firm's investment. In a banking crisis situation like in 2008, the availability of finance becomes constrained for bank-dependent firms, leading to a misallocation of finance and hence investment across businesses. Figure 9 also shows that investment shock and monetary policy shock moderate the collapse of investment between 2008:Q1 and 2009:Q2.

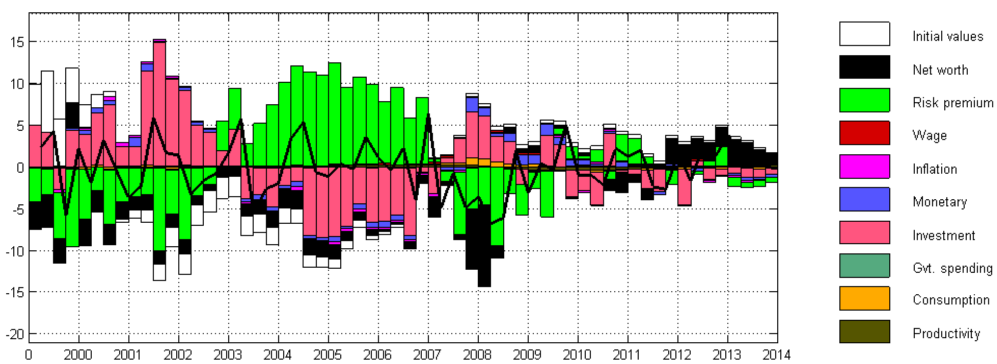

Figure 9. Historical Decomposition, Changes in Investment, Deviation from Trend (%) –U.K.–
Source: Authors' calculations.

Figure 9 depicts the historical decomposition to examine the contribution of each structural shock to changes in the U.K. investment. The estimates are based on the DSGE model with financial friction.

CONSUMPTION

The decline in consumption at the peak of the crisis is mainly due to productivity and consumption shocks (Figure 10). Between 2008:Q2 and 2009:Q2, these two shocks account for more than 50% of household consumption collapse. This finding is not surprising, suggesting that private consumption expenditures mainly depend on the availability of products in the economy on which households exert their preferences.

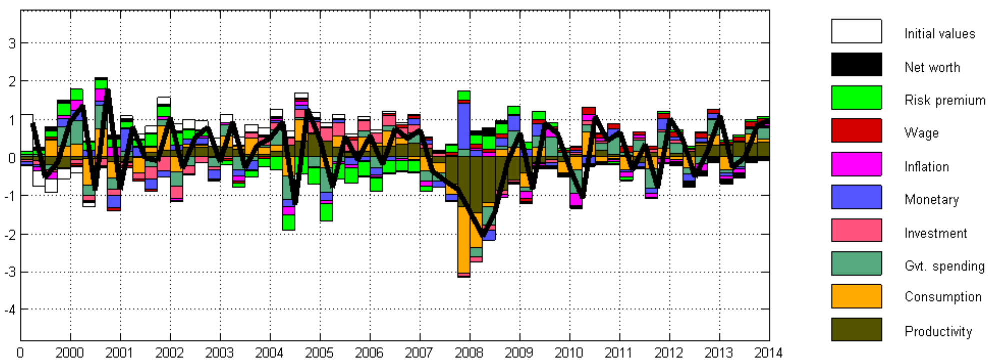

Figure 10. Historical Decomposition, Changes in Consumption, Deviation from Trend (%) –U.K.–
Source: Authors' calculations.

Figure 10 depicts the historical decomposition to examine the contribution of each structural shock to changes in the U.K. consumption. The estimates are based on the DSGE model with financial friction.

U.S.

OUTPUT

In 2008/2009, the U.S. economy has experienced a crisis that was led by the derivatives market and the subprime mortgage crisis. The empirical estimates show that the net worth shock account for a significant portion of the decline in output at the peak of the crisis (Figure 11). Historical decomposition of output accords well with the considerable damage that the financial crisis inflicted to the U.S. economy between 2007:Q3–2009:Q1. However, the model is unable to explain the tightening of credit that has dramatically impeded GDP growth as in Merola (2015) and Suh and Walker (2016). Figure 11 shows that productivity shock is the most important driver of the downturn in output during 2008:Q4.

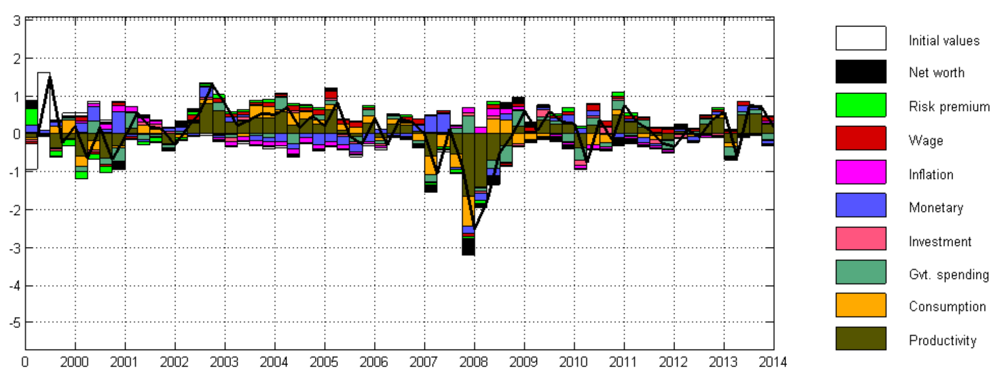

Figure 11. Historical Decomposition, Changes in Output, Deviation from Trend (%) –United States–
Source: Authors' calculations.

Figure 11 depicts the historical decomposition to examine the contribution of each structural shock to changes in the U.S. output. The estimates are based on the DSGE model with financial friction.

INVESTMENT

Figure 12 shows that financial shocks play a vital role in explaining investment fluctuation before and during the financial crisis period. The historical decomposition in Figure 12 reveals that the net worth shocks impacts investment negatively both during the pre-crisis period of 2004:Q2–2006:Q1 and during the crisis. In fact, the role of investment specific shocks in explaining investment is considerably reduced because of their counterfactual effect on asset prices. By contrast, the risk premium shock impacts investment positively during the pre-crisis period and negatively during the crisis period. Overall, these findings align with those of Suh and Walker (2016) who show that the risk premium provides a better explanation of co-movement between investment and the price of capital during the 2008 crisis than investment shock.

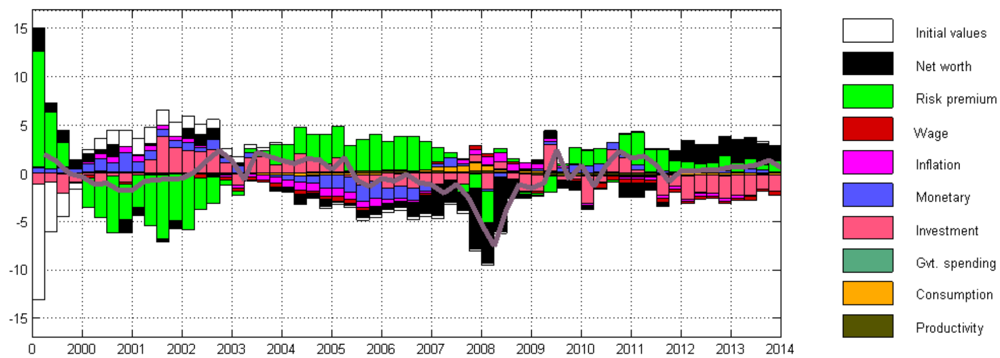

Figure 12. Historical Decomposition, Changes in Investment, Deviation from Trend (%) -US-
Source: Authors' calculations.

Figure 12 depicts the historical decomposition to examine the contribution of each structural shock to changes in the U.S. investment. The estimates are based on the DSGE model with financial friction.

CONSUMPTION

Consumption shock and productivity shock play a significant role in consumption contraction in 2008:Q4 (Figure 13). The contribution of consumption shock reflects the sharp increase in the desire of households to save for precautionary reasons rather than spend. Our historical decomposition results are similar to those of Hall (2010) which suggest that consumption of nondurables fell sharply in 2008. Because of decreased incomes, many consumers decided to cut back on cash outlays for durables and new houses. This is consistent with the finding of Lee et al. (2010) who show that the U.S household consumption rate has declined in late 2008 as the savings rate rose to around 6 percent of disposable personal income from nearly 5 percent in 2009. Compared to the pre-crisis years (2003-07), this savings rate implies a decline in U.S private-sector demand.

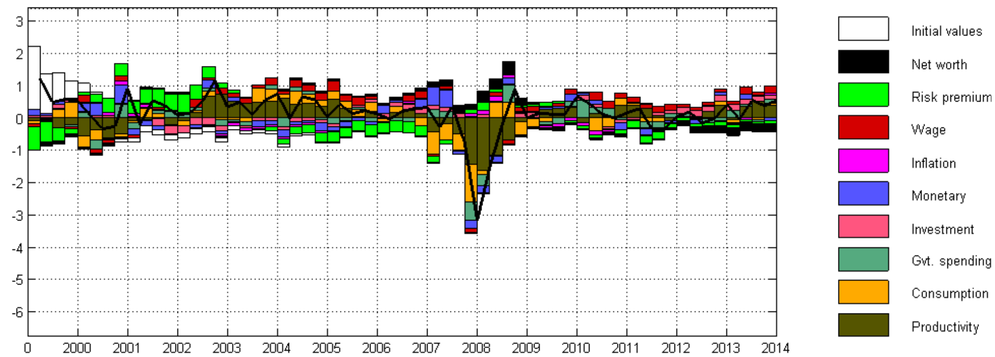

Figure 13. Historical Decomposition Changes in Consumption, Deviation from Trend (%) –United States–

Source: Authors' calculations.

Figure 13 depicts the historical decomposition to examine the contribution of each structural shock to changes in the U.S. consumption. The estimates are based on the DSGE model with financial friction.

MAIN FINDINGS ACROSS THE WORLD

A major result concerns the fact that during the crisis period, financial frictions raise investment adjustment costs significantly across the world but the magnitude is not the same. We find that the increase is more pronounced in the Euro Area (31.52%) and U.S. (28.98%) than in Canada (24.86%) and the U.K. (17.56%). This finding implies that corporate investment in the Euro Area and U.S. was more exposed to the worsening condition in the credit market during the 2008 global financial crisis.

Another important finding is that, during the financial crises, the effects of financial shocks are more pronounced in driving investment than output across the world. By contrast to the study of Merola (2015), we introduce the net worth shock in our DSGE model. The results show that the contribution of this shock to investment fluctuations tend to supplant that of the risk premium shock because of their counterfactual effects on asset prices. This finding is similar to that of Christiano et al. (2014), showing that, in the presence of financial frictions, a good share of investment variance in the United States is explained by the net worth shocks. The downfall observed in the historical decompositions of output is mainly attributed to a negative productivity shock. Private consumption is mainly explained by preferences shocks and productivity shocks. The impact relatively increases during the crisis period, suggesting that households make their adjustment whether to spend or not when economic outlook is not good. In addition, the importance of productivity shock increases since the output's contraction constraint the choices of consumers.

We can see in our empirical estimates that financial shocks play a more important role in the Euro Area and U.S. than in Canada during the recent crises. The joint contribution of the risk premium shock and net worth shock in investment variation increases more in the Euro Area and U.S. during the crises. This is in line with the losses related to the U.S. sub-prime mortgages. A number of financial institutions in the United States and elsewhere either went bankrupt or received government support. Banks became increasingly wary of lending to each other due to fear that other institutions will be unable to repay their loans, thereby raising the cost of inter-bank loans. The higher cost of raising cash, coupled with the need to make their balance sheets look better, resulted in reduced bank lending less and higher interest rates. This "credit crunch" in turn led a sharp decline in in consumption and investments, giving rise to fears of a worldwide recession. The heavy exposure of a number of Euro Area countries to the U.S. sub-prime saga is clearly revealed in the summer of 2007 when BNP Paribas froze redemptions for three investment funds, citing its inability to value structured products.

Compared to other industrialized countries such as the U.S., Canada's financial system was relatively less affected by the global financial crisis. One main reason is that the regulatory framework for the Canadian financial sector is both more responsive and more prudent, in some respects, than that of the United States. Compared to their American counterparts, Canadian banks were less active in the sub-prime lending and securitization activities that were at the center of the financial crisis. For example, sub-prime loans accounted for less than 5% of new mortgages in Canada in 2006 compared to 22% in the U.S.

CONCLUSION

The objective of the paper was to examine whether the recent financial crises enhanced the role played by financial frictions and financial shocks on business fluctuations in Canada, the Euro Area, the U.K., and the U.S. using an improved version of the DSGE methodology described in Merola (2015). We found that lenders became more sensitive to the deterioration of corporate balance sheets during the recent financial crises and reacted by raising the EFP for high-risk corporate firms globally. This situation worsened credit market conditions by dampening the quantity of credit available to borrowers and increasing borrowing costs. Investment was the macroeconomic variable most affected by the deterioration of financial market frictions. Variance decomposition results show that the contribution of financial friction and financial shocks in driving investment increased notably during the crisis period. The historical decomposition was able to replicate the effects of financial shocks on investment but not necessarily on output during the 2008 global crisis. This result is consistent with the findings of Akbar et al. (2013) who analyzed how shocks to the supply of credit during the global financial crisis affected the financing and investment policies of private businesses in the U.K. and found that credit contraction had negatively impacted the performance and investment of private firms. Finally, this study found that financial friction and financial shocks significantly affected international businesses through investment.

Our empirical estimates show that financial frictions did not exert significant effects on the macroeconomy in Canada during the recent financial crises and this may be because of Canada's restrictive regulatory rules of the financial sector. One policy implication of this finding is that restrictive regulatory rules in the financial sector can be helpful in protecting the economy against financial shocks during financial crises. Moreover, our results seem to imply that governments may be able to boost the economy by making important investments during periods of financial crises. More specifically, our empirical findings suggest that financial frictions mainly impact the real economy through the investment channel. It follows, therefore, that additional public investments should be encouraged since they can substantially temperate the recession effects of financial frictions when there are restrictive constraints on the financial markets.

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APPENDIX

A.1) Data Description and Sources

	Variables	Description	Data source
U.S.	*Output*	*Gross Domestic Product, Seasonally Adjusted, Annualized Rate- National Currency*	*International Financial Statistics*
	Consumption	*Household Consumption Expenditure, incl. NPISHs, Nominal, Seasonally Adjusted, Annualized Rate- National Currency*	*International Financial Statistics*
	Investment	*Gross Fixed Capital Formation, Seasonally Adjusted, Annualized Rate- National Currency*	*International Financial Statistics*
	Wage	*Hourly Earnings: Manufacturing for the United States, Index 2010=1, Seasonally Adjusted*	*Federal Reserve Bank of St. Louis*
	Labor	*Employment, Number of persons*	*International Financial Statistics*
	Deflator	*Gross Domestic Product, Deflator, Seasonally Adjusted*	*International Financial Statistics*
	Short-Term Nominal Interest Rate	*Money Market Rate*	*International Financial Statistics*
	Corporate Spread	*C0A4-C0A1 BofA ML US Corporates BBB-AAA, Rated*	*Federal Reserve Bank of St. Louis*
	Net Worth	*S&P 500 index*	*Bloomberg*
U.K.	*Output*	*Gross Domestic Product, Seasonally Adjusted, Annualized Rate- National Currency*	*International Financial Statistics*
	Consumption	*Household Consumption Expenditure, incl. NPISHs, Nominal, Seasonally Adjusted, Annualized Rate- National Currency*	*International Financial Statistics*
	Investment	*Gross Fixed Capital Formation, Seasonally Adjusted, Annualized Rate- National Currency*	*International Financial Statistics*
	Wage	*Hourly Earnings: Manufacturing for the United States, Index 2010=1, Seasonally Adjusted*	*Federal Reserve Bank of St. Louis*
	Labor	*Employment, Number of persons*	*International Financial Statistics*
	Deflator	*Gross Domestic Product, Deflator, Seasonally Adjusted*	*International Financial Statistics*
	Short-Term Nominal Interest Rate	*Money Market Rate*	*International Financial Statistics*
	Corporate Spread	*UR40-UR10 BofA ML Sterling Corporates BBB-AAA Rated*	*Federal Reserve Bank of St. Louis*
	Net Worth	*Footsie 100 index*	*Bloomberg*

Canada	*Output*	*Gross Domestic Product, Seasonally Adjusted, Annualized Rate- National Currency*	*International Financial Statistics*
	Consumption	*Household Consumption Expenditure, incl. NPISHs, Nominal, Seasonally Adjusted, Annualized Rate- National Currency*	*International Financial Statistics*
	Investment	*Gross Fixed Capital Formation, Seasonally Adjusted, Annualized Rate- National Currency*	*International Financial Statistics*
	Wage	*Hourly Earnings: Manufacturing for the United States, Index 2010=1, Seasonally Adjusted*	*Federal Reserve Bank of St. Louis*
	Labor	*Employment, Number of persons*	*International Financial Statistics*
	Deflator	*Gross Domestic Product, Deflator, Seasonally Adjusted*	*International Financial Statistics*
	Short-Term Nominal Interest Rate	*Money Market Rate*	*International Financial Statistics*
	Corporate Spread	*F0C4-F0C1 BofA ML Canadian Corporates BBB-AAA, Rated*	*Bloomberg*
	Net Worth	*S&P/TSX index*	*Bloomberg*
Euro Area	*Output*	*Gross Domestic Product, Seasonally Adjusted, Annualized Rate- National Currency*	*International Financial Statistics*
	Consumption	*Household Consumption Expenditure, incl. NPISHs, Nominal, Seasonally Adjusted, Annualized Rate- National Currency*	*International Financial Statistics*
	Investment	*Gross Fixed Capital Formation, Seasonally Adjusted, Annualized Rate- National Currency*	*International Financial Statistics*
	Wage	*Hourly Earnings: Manufacturing for the United States, Index 2010=1, Seasonally Adjusted*	*Federal Reserve Bank of St. Louis*
	Labor	*Employment, Number of persons*	*International Financial Statistics*
	Deflator	*Gross Domestic Product, Deflator, Seasonally Adjusted*	*International Financial Statistics*
	Short-Term Nominal Interest Rate	*Money Market Rate*	*International Financial Statistics*
	Corporate Spread	*UR40-UR10 BofA ML Sterling Corporates BBB-AAA Rated*	*Bloomberg*
	Net Worth	*Dow Jones Euro Stoxx 50 index*	*Bloomberg*

A.2) Definition of Data Variables

$Output = [LN(GDP/GDPDEF)] \times 100$
$Consumption = [LN(CONS/GDPDEF)] \times 100$
$Investment = [LN(INV/GDPDEF)] \times 100$
$Inflation = [LN(GDP/GDP(-1))] \times 100$
$Interest\ rate = Market\ money\ rate/4$
$Real\ wage = LN(HOUREAQIS/GDPDEF)$
$Labor = LN(Employment)$
$External\ finance\ premium = BBB - AAA\ Corporate\ spread/4$
$Net\ worth = [LN(FINDEX/GDPDEF)] \times 100$