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Abstract

This paper examines the interaction between monetary policy and macroprudential policy and whether policy makers should respond to financial imbalances. To address this issue, we build a dynamic general equilibrium model that features financial market frictions and financial shocks as well as standard macroeconomic shocks. We estimate the model using Canadian data. Based on these estimates, we show that it is beneficial to react to financial imbalances. The size of these benefits depends on the nature of the shock where the benefits are larger in the presence of financial shocks that have broader effects on the macroeconomy.

JEL classification: E42, E50, E60
Bank classification: Monetary policy framework; Financial stability; Financial markets; Economic models

Résumé

Les auteurs examinent les interactions entre la politique monétaire et la politique macroprudentielle ainsi que la question de savoir si les autorités doivent réagir aux déséquilibres financiers. Pour ce faire, ils construisent un modèle d'équilibre général dynamique où les marchés financiers sont soumis à des frictions et qui englobe des chocs tant financiers que macroéconomiques. Le modèle est estimé au moyen de données canadiennes. Les estimations effectuées montrent qu'il est avantageux de réagir aux déséquilibres financiers. L'ampleur des avantages retirés dépend de la nature du choc : le gain de bien être est plus important lorsque le choc financier a des effets étendus dans l'économie.

Classification JEL : E42, E50, E60
Classification de la Banque : Cadre de la politique monétaire; Stabilité financière; Marchés financiers; Modèles économiques

1 Introduction

The recent financial crisis has revived interest in a long-standing question in monetary economics: should the goal of monetary policy be extended beyond price stability? As the events of the past few years have made clear, near-term price stability is sometimes not sufficient to ensure macroeconomic stability. Indeed, most of the advanced economies experienced severe recessions in 2008-2009 even though they all had been pursuing monetary policies focused on price stability for many years. This experience has given fresh significance to an old question: in addition to pursuing the objective of price stability, should central banks also respond to financial imbalances, such as those associated with unsustainable credit expansion and asset-price bubbles?

This paper addresses this question by comparing the performance of a set of policy regimes centered on price stability to another set where policy-makers also respond to emerging financial imbalances, in the context of a standard sticky-price dynamic stochastic general equilibrium (DSGE) model that includes financial market imperfections and a financial shock. The different regimes are ranked using a welfare criterion. Our model-based analysis enables us to examine whether a policy regime that also addresses financial imbalances – characterized as a significant and sustained deviation of asset prices or financial indicators from longer-term trends – can be optimal from a welfare perspective and whether there are trade-offs (compared to a standard Taylor rule) to using monetary policy rules that lean against the build-up of financial imbalances or to using monetary policy rules complemented by macroprudential rules.

We follow FSB-BIS-IMF (2011) in defining macroprudential policy as a policy that uses primarily prudential tools to limit systemic financial risk and hence prevent disruption to key financial services in the economy. In our model, use of the macroprudential tool is triggered by signs of emerging financial imbalances and is assumed to have a direct influence on the funding costs of firms (via the external finance premium). For example, a period of excessive credit expansion would trigger use of the macroprudential tool, leading to an increase in firms' funding costs and a dampening of investment (and hence aggregate economic activity). This mechanism is intended to capture the effects of macroprudential tools such as loan-to-value ratios or the countercyclical capital buffer, a key measure in the recently-approved Basel III package.[1]

Our findings suggest that welfare is higher, compared to a standard Taylor rule, in regimes where policy-makers respond to financial imbalances using the policy rate and/or the macroprudential tool. The welfare gain arises due to the benefits that such regimes offer for macroeconomic stabilization, particularly in the presence of financial shocks. Although the perfor-

[1] See Carney (2011) for a discussion of countercyclical capital buffers as envisioned in Basel III.

mance of the different regimes varies depending on the types of shocks that buffet the economy, our results suggest that the benefits of responding to financial imbalances in the presence of all shocks outweigh the costs.

Several recent papers suggest, in the context of DSGE models with financial frictions, that there may be gains from including financial and credit conditions in monetary policy rules. In their study of optimal Taylor-type interest rate rules, Faia and Monacelli (2007) find that monetary policy should respond to increases in asset prices. However, they find that when monetary policy reacts strongly to inflation, the marginal welfare gain of responding to asset prices vanishes. In a model with frictions in the wage-setting process, Christiano et al. (2007) show that a monetary policy rule that focuses too narrowly on inflation may inadvertently contribute to welfare-reducing boom-bust cycles and that including credit growth into the standard Taylor rule brings the model response to shocks more closely in line with the efficient response. Curdia and Woodford (2010) focus on credit spreads and find that including interest rate spreads can improve upon the standard Taylor rule.

Our paper is more similar to the work of Kannan et al. (2009), Angelini et al. (2011) and Christensen et al. (2011) in that it considers the potential gains from complementing monetary policy rules with macroprudential rules. In Kannan et al. (2009), the authors modify a standard New Keynesian model to create a special role for the housing market and compare the behaviour of their model economy under different policy regimes, assuming that policy-makers have two instruments at their disposal: a nominal short-term interest rate and a macroprudential instrument. Policy regimes are ranked in terms of the evenly weighted variances of the output gap and inflation. They calibrate their model and find that the regime that includes a credit term in the monetary policy reaction function and a macroprudential rule can improve macroeconomic stability in the face of a financial shock but not in the presence of a productivity shock. Angelini et al. (2011) reach a similar conclusion in their study, which uses a DSGE model developed by Gerali et al. (2010) featuring an imperfectly-competitive banking sector and estimated on euro area data: the benefits of introducing macroprudential policy (relative to a "monetary-policy-only world") are modest when the economic cycle is driven by supply shocks but sizeable when financial or housing market shocks are important drivers of the macroeconomy. Moreover, Angelini et al. (2011) find that in all cases, cooperation between the central bank and the macroprudential authority yields superior outcomes. Christensen et al. (2011) focus mainly on the interaction between monetary policy and countercyclical capital buffers. In contrast to our work, their paper features endogenous banking sector riskiness. Our paper differs from these three studies in two key respects. First, we opt to estimate the main structural parameters of our model using Canadian data. Based on these estimates, we conduct simulations under the different regimes and rank them using a welfare criterion instead of an ad hoc loss function.[2] Second, we consider a broader set of monetary policy regimes, including both inflation and price-level targeting. Boivin et al. (2010) also argue that the appropriate response of monetary policy to financial imbalances depends on the nature of the imbalances as well as on the alternative policy instruments available. In particular, they contend that monetary policy may be effective in countering a financial imbalance if such an imbalance has a material aggregate impact and/or suitable macroprudential policy instruments are not available.

This paper is organized as follows. In the next section, we briefly review the literature linking monetary policy and emerging financial imbalances. In Section 2, we present the DSGE model the we use to examine whether a policy regime that also addresses financial imbalances can be optimal. In Section 3, we discuss the data and estimation strategy employed. In Section 4, we present the estimation results and discuss the performance of the estimated model. In Section 5, we use the estimated model to analyze the performance of the different policy regimes considered in reaction to key shocks. In Section 6, we compare the performance of the different policy regimes using a welfare criterion. Section 7 offers some concluding remarks.

2 The Model

To examine whether policy-makers should respond to emerging financial imbalances, we use a standard sticky-price dynamic stochastic general equilibrium (DSGE) model that includes financial market imperfections and a financial shock. In this model, financial and credit conditions play a central role in the propagation of cyclical fluctuations due to a financial accelerator effect. As the financial crisis has underscored, there are significant feedback effects from financial and credit conditions to the real economy and it is important for standard macroeconomic models to captures these effects.[3] We model financial frictions following Bernanke et al. (1999) except that debt contracts are assumed to be written in nominal terms.[4] In this set-up, there is an inverse link between the external finance premium and

[2]In Angelini et al. (2011), the central bank and the macroprudential authority each seek to minimize their respective loss function. The loss function for the central bank includes the variance of inflation and output growth whereas that of the macroprudential authority is based on the variance of the loans-to-output ratio. Christensen et al. (2011) also use a welfare criterion, however, their welfare comparison is based on a calibrated version of their model.

[3]Indeed, estimated models that incorporate a financial accelerator have been found to have a better empirical fit than models without this mechanism. See, for example, Christensen and Dib (2008) who estimate a sticky-price DSGE model with a financial accelerator using U.S. data and find that their model is better able to account for the key features of the U.S. data than the same model without a financial accelerator mechanism. Covas and Zhang (2010) estimate a sticky-price DSGE model that includes debt and equity market frictions using Canadian data and find a similar result.

[4]Other studies have also made this assumption. For examples, Christiano et al. (2003),Gilchrist and Saito (2006), Christensen and Dib (2008) and Covas and Zhang (2010).

firms' net worth. The financial shock is assumed to influence the funding costs of firms (and hence investment and aggregate economic activity) via its effect on the external finance premium.

This model economy is populated by three types of agents: households, entrepreneurs, and retailers. The entrepreneurs produce intermediate goods and face financial frictions. Final goods can be used either for consumption or as capital in production. Retailers bundle together intermediate goods and transform them into final goods – the introduction of retailers allows for the presence of price rigidities.

2.1 Households

The household's problem is fairly standard. The representative household maximizes its expected lifetime utility equation:

$$E_0 \sum_{t=0}^{\infty} \beta^t U\Big(C_t, H_t\Big), \tag{1}$$

with

$$U\Big(C_t, H_t\Big) = e_t \log C_t - \theta \frac{H_t^{1+\gamma}}{1+\gamma}, \tag{2}$$

subject to the following budget constraint:

$$C_t = \frac{W_t}{P_t} H_t + \Pi_t - \frac{B_t - R_{t-1}^n B_{t-1}}{P_t}, \tag{3}$$

where C_t is consumption; $1 - H_t$ is leisure, with $0 < H < 1$; $1/\gamma$ is the elasticity of labour supply; and θ is the weight on leisure in the utility function. The household supplies labour to the entrepreneurs and receive the nominal wage, W_t, in return and owns equity in the retailers receiving the real dividend, Π_t. The household saves by holding a one-period riskless bond B_t; and R_{t-1}^n is the nominal rate of return on the riskless bond held between periods $t-1$ and t.

The variable e_t is an exogenous preference shock, which follows

$$\log\, e_t = \rho_e \log\, e_{t-1} + \epsilon_t^e, \quad \epsilon_t^e \sim i.i.d.\, N(0, \sigma_{\epsilon^e}^2). \tag{4}$$

The first-order conditions include

$$\frac{e_t}{C_t} \frac{1}{R_t^n} = \beta E_t \left[\frac{e_{t+1}}{C_{t+1}} \frac{P_t}{P_{t+1}} \right] \tag{5}$$

and

$$\frac{e_t}{C_t}\frac{W_t}{P_t} = \theta H_t^{\gamma} \tag{6}$$

where P_t is the aggregate price level.

2.2 Entrepreneurs

Entrepreneurs are risk neutral and produce a homogenous intermediate good according to the following production function:

$$F(K_t^j, L_t^j) = \omega_t^j (K_t^j)^{\alpha} (z_t L_t^j)^{1-\alpha} \tag{7}$$

where K_t^j is the capital purchased by entrepreneur j in period t-1; and L_t^j is the labour hired by entrepreneur j. The production of the intermediate good is subject to two types of shocks: ω_t and z_t. The former is an idiosyncratic shock, known only to the entrepreneur.[5] The latter shock is an exogenous technology shock common to all the entrepreneurs, which follows

$$\log\, z_t = \rho_z \log\, z_{t-1} + \epsilon_t^z, \quad \epsilon_t^z \sim i.i.d.\, N(0, \sigma_{\epsilon^z}^2). \tag{8}$$

Given K_t^j, the demand for the two types of labour, household labour (H_t^j) and entrepreneurial labour (H_t^{ej}):

$$L_t^j = (H_t^j)^{1-\Omega} (H_t^{ej})^{\Omega} \tag{9}$$

must satisfy the following first-order conditions:

$$(1-\Omega) F_{H_t}^j = \frac{W_t}{P_{W,t}}, \tag{10}$$

and

$$\Omega F_{H_t^e}^j = \frac{W_t^e}{P_{W,t}}, \tag{11}$$

where W_t and W_t^e are the nominal wages received by households and entrepreneurs, respectively, and $P_{W,t}$ is the nominal price of the intermediate good.

Capital purchased at the end of period t, K_{t+1}^j, is partly financed from the entrepreneur's net worth, N_{t+1}^j, and partly from issuing nominal debt, B_t^j:

$$Q_t K_{t+1}^j = N_{t+1}^j + \frac{B_t^j}{P_t}, \tag{12}$$

[5] The idiosyncratic shock is assumed to be i.i.d. across entrepreneurs and time and to have mean $E[\omega_t^j] = 1$.

where Q_t is the price of capital relative to the aggregate price P_t.

A financial market imperfection arises due to asymmetric information between the borrower and the lender – the idiosyncratic shock is private information for the entrepreneur and is not observed by the lender. The lender has to pay an auditing cost to observe the output. With costly monitoring, the optimal debt contract that gives rise to a risk premium associated with external funds is one in which monitoring only takes place in the case of default. The risk premium associated with external funds, $s(.)$, is defined as the ratio of the entrepreneur's cost of external funds to the cost of internal funds:

$$s_t = \frac{E_t R^k_{t+1}}{E_t\left[R^n_t \frac{P_t}{P_{t+1}}\right]}, \tag{13}$$

where $E_t R^k_{t+1}$ is the expected rate of return of capital, which is equal to the expected cost of external funds in equilibrium, and $E_t[R^n_t \frac{P_t}{P_{t+1}}]$ is the cost of internal funds. The optimal contract implies that the external finance premium, $s(.)$, increases with leverage (i.e., depends on the entrepreneur's balance sheet position), and thus can be characterized at the aggregate level by the following reduced-form equation:

$$s_t = f_t s\left(\frac{Q_t K_{t+1}}{N_{t+1}}\right), \tag{14}$$

where $s^{'}(.) > 0$, $s(1) = 1$ and f_t is an exogenous financial shock common to all the entrepreneurs, which follows

$$\log f_t = \rho_f \log\, f_{t-1} + \epsilon^f_t, \quad \epsilon^f_t \sim i.i.d.\, N(0, \sigma^2_{\epsilon^f}). \tag{15}$$

The supply curve for external financing or the expected marginal cost of external financing can be obtained by rearranging the terms in equation (13):

$$E_t R^k_{t+1} = s_t R^n_t E_t\left[\frac{P_t}{P_{t+1}}\right]. \tag{16}$$

The expected gross return on capital from periods t to $t+1$, $E_t R^k_{t+1}$, depends on the marginal productivity of capital and the capital gain,

$$E_t R^k_{t+1} = E_t\left[\frac{\frac{P^W_{t+1}}{P_{t+1}} F_K + Q_{t+1}(1-\delta)}{Q_t}\right]. \tag{17}$$

The demand for capital depends on both the expected return on capital (equation (17)) and the expected cost of external financing (equation (16)). Entrepreneurs are assumed to have finite lives to ensure that they will never accumulate enough funds to finance capital acquisitions entirely out of net worth. The probability that an entrepreneur survives until the next period is η.

The aggregate net worth of entrepreneurs at the end of period t, N_{t+1}, is the sum of equity held by entrepreneurs surviving from period $t-1$ and wage income:

$$N_{t+1} = \eta\Bigg(R_t^k Q_{t-1} K_t - E_{t-1}[R_t^k](Q_{t-1}K_t - N_t)\Bigg) + (1-\alpha)(1-\Omega) z_t K_t^{\alpha} L_t^{(1-\alpha)\Omega}. \tag{18}$$

Equation (18) suggests that the difference between the realized rate of return on capital in period t, R_t^k, and the expected rate of return on capital in the previous period, $E_{t-1}R_t^k$, is the main source of change in entrepreneurial net worth. Since the debt contract specifies a nominal interest rate, an unanticipated change in inflation will also affect the real cost of debt repayment, and, in turn, the difference between R_t^k and $E_{t-1}R_t^k$. Substituting equation (16) into equation (18), yields

$$N_{t+1} = \eta\Bigg(R_t^k Q_{t-1} K_t - s_{t-1} R_{t-1}^n E_{t-1}\left[\frac{P_{t-1}}{P_t}\right](Q_{t-1}K_t - N_t)\Bigg) + (1-\alpha)(1-\Omega) z_t K_t^{\alpha} L_t^{(1-\alpha)\Omega}, \tag{19}$$

which implies that an unexpected increase (decrease) in inflation reduces (increases) the real cost of debt repayment and, in turn, increases (decreases) net worth.

Entrepreneurs going out of business will consume their residual equity,

$$C_t^e = (1-\eta)\Bigg(R_t^k Q_{t-1} K_t - E_{t-1}[R_t^k](Q_{t-1}K_t - N_t)\Bigg), \tag{20}$$

where C_t^e is the aggregate consumption of the entrepreneurs who exit in period t.

2.3 Capital producers

Final goods can be used either for consumption or as capital in production, although there are adjustment costs related to installing capital (i.e., capital producers are subject to a quadratic capital adjustment cost, $\frac{\xi}{2}(\frac{I_t}{K_t} - \delta)^2 K_t$). The aggregate capital stock evolves according to

$$K_{t+1} = x_t I_t + (1-\delta) K_t \tag{21}$$

where K is the capital stock, I_t are investment goods purchased from retailers, $x_t I_t$ are efficient investment goods and x_t is an investment-specific shock that follows the following first-order autoregressive process:

$$\log x_t = \rho_x \log x_{t-1} + \epsilon_t^x, \epsilon_t^x \sim i.i.d.N(0, \sigma_{\epsilon^x}^2). \tag{22}$$

Capital producers maximize their profit

$$\Pi_t^k = E_t\left[Q_t x_t I_t - I_t - \frac{\xi}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t\right], \tag{23}$$

yielding the following first-order condition

$$E_t\left[Q_t x_t - 1 - \xi\left(\frac{I_t}{K_t} - \delta\right)\right] = 0. \tag{24}$$

2.4 Retailers

There is a continuum of monopolistically competitive retailers of measure 1 indexed by j who buy intermediate goods from entrepreneurs and differentiate them at no cost. Each retailer j thus sells retail good $Y_t(j)$ at price $P_t(j)$. The final good, Y_t, is the composite of the individual retail goods,

$$Y_t = \left[\int_0^1 Y_{jt}^{\frac{\varepsilon-1}{\varepsilon}} dj\right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{25}$$

and the corresponding price index, P_t, is given by

$$P_t = \left[\int_0^1 P_t(j)^{1-\varepsilon} dz\right]^{\frac{1}{1-\varepsilon}}. \tag{26}$$

The demand function faced by each retailer is given by

$$Y_{jt} = \left(\frac{P_{jt}}{P_t}\right)^{-\varepsilon} Y_t. \tag{27}$$

Each retailer can reoptimize its price only once it receives a random signal, following Calvo (1983). The probability of receiving such a signal is $1-\nu$. Thus, in each period, a fraction $1-\nu$ of retailers reset their prices, while the remaining retailers keep their prices fixed. Each retailer selects its price in order to maximize its expected real total profit over the periods during which its price remains fixed:

$$E_t \Sigma_{i=0}^{\infty} \nu \Delta_{i,t+i}\left[\left(\frac{P_{jt}}{P_{t+i}}\right) Y_{jt+i} - mc_{t+i} Y_{jt+i}\right], \tag{28}$$

where $\Delta_{t,i} \equiv \beta^i C_{t+i}/C_t$ is the stochastic discount factor and the real marginal cost, mc_t, is the price of the intermediate good relative to the price of the final good $(P_{W,t}/P_t)$. Let P_t^* be the optimal price chosen by all firms adjusting at time t. The first-order condition is:

$$P_t^* = \left(\frac{\varepsilon}{\varepsilon - 1}\right) \frac{E_t \sum_{i=0}^{\infty} \nu^i \Delta_{i,t+i} mc_{t+1} Y_{t+i} (\frac{1}{P_{t+i}})^{-\varepsilon}}{E_t \sum_{i=0}^{\infty} \nu^i \Delta_{i,t+i} Y_{t+i} (\frac{1}{P_{t+i}})^{1-\varepsilon}} \tag{29}$$

and the aggregate price level evolves according to:

$$P_t = [\nu P_{t-1}^{1-\varepsilon} + (1-\nu)(P_t^*)^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}}. \tag{30}$$

2.5 Equilibrium characterization

The resource constraint for final goods is

$$K_t^{\alpha}(z_t L_t)^{1-\alpha} = C_t + C_t^e + I_t + \frac{\xi}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t. \tag{31}$$

In this model, price stickiness induces price dispersion across final goods, and this price dispersion is inefficient and causes output loss. Thus, when aggregating, some adjustment needs to be made to take this inefficiency into account. To illustrate this point, consider the equilibrium condition at the firm level:

$$F(K_{jt}, L_{jt}) = (C_t + C_t^e + I_t + \frac{\xi}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t)\left(\frac{P_{jt}}{P_t}\right)^{-\varepsilon}. \tag{32}$$

Integrating over all firms yields the following:

$$F(K_t, L_t) = (C_t + C_t^e + I_t + \frac{\xi}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t) \int_0^1 \left(\frac{P_{jt}}{P_t}\right)^{-\varepsilon}. \tag{33}$$

Let $\Gamma_t \equiv \int_0^1 \left(\frac{P_{jt}}{P_t}\right) dj$. It can be shown that the following holds:

$$\Gamma_t = (1-\nu)\left(\frac{P_t^*}{P_t}\right)^{-\varepsilon} + \nu \pi^{\varepsilon} \Gamma_{t-1}.^6 \tag{34}$$

Thus, the resource constraint in the model is given by

$$F(K_t, L_t) = (C_t + C_t^e + I_t + \frac{\xi}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t)\Gamma_t, \tag{35}$$

[6] See Schmitt-Grohe and Uribe (2006) for details.

where Γ_t summarizes the resource costs induced by the relative price dispersion.[7]

2.6 Monetary policy and macroprudential rules

We compare the behaviour of our model economy under four different monetary policy /macro-prudential regimes. Our baseline policy regime is a standard Taylor rule with interest-rate smoothing (standard Taylor rule). The second policy regime is an augmented Taylor rule in which the baseline policy rule is augmented to allow the policy interest rate to also react to changes in nominal credit (augmented Taylor rule); or in other words, the central bank can also use the policy rate to lean against the build-up of emerging financial imbalances. The third regime combines a macroprudential rule with a standard Taylor rule (macroprudential regime with a standard Taylor rule), and the fourth regime combines a macroprudential instrument with the augmented Taylor rule (macroprudential regime with an augmented Taylor rule).

2.6.1 Standard Taylor rule

Our baseline policy regime is a standard Taylor rule with interest-rate smoothing, a standard way to characterize monetary policy under an inflation-targeting regime such as the one the Bank of Canada has been following over the past two decades. According to the Taylor rule, the central bank adjusts the nominal interest rate, R_t^n, in response to deviations in inflation, π_t and Y_t from their steady-state values, π, and Y. It is assumed that the central bank smooths interest rates, adjusting them gradually to the desired value. This behaviour is widely observed in practice and has been shown by Woodford (2003) to be a desirable outcome in a model for optimizing private sector behaviour, because it can help to steer private sector expectations of future policy. The baseline policy rule thus takes the following form:

$$\frac{R_t^n}{R^n} = \left(\frac{R_{t-1}^n}{R^n}\right)^{\phi_R} \left(\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{Y_t}{Y}\right)^{\phi_Y}\right)^{1-\phi_R} e^{\epsilon_t^m}, \tag{36}$$

where ϕ_π, ϕ_Y and ϕ_r are policy coefficients chosen by the central bank, and ε_t^m is a monetary policy shock, which follows

$$\varepsilon_t^m \sim i.i.d.\, N(0, \sigma_{\varepsilon^m}). \tag{37}$$

[7] Schmitt-Grohe and Uribe (2006) show that Γ_t is bounded below by 1 and has first-order real consequences for the stationary distribution of the endogenous variables if the steady-state inflation is positive.

2.6.2 Augmented Taylor rule

In the second policy regime we consider, the central bank follows a Taylor rule under which it can also lean against the build-up of emerging financial imbalances. More specifically, the baseline policy rule is augmented to allow the policy interest rate to also react to deviations in credit growth from its steady-state value as follows:

$$\frac{R_t^n}{R^n} = \left(\frac{R_{t-1}^n}{R^n}\right)^{\phi_R} \left(\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{Y_t}{Y}\right)^{\phi_Y} \left(\frac{cg_t}{cg_{ss}}\right)^{\phi_c}\right)^{1-\phi_R} e^{\epsilon_t^m}, \tag{38}$$

where

$$cg_t = \frac{B_t}{B_{t-1}} \tag{39}$$

and cg_t is the growth rate of nominal credit, cg_{ss} is the steady-state value of cg_t and ϕ_c is the policy coefficient chosen by the central bank that captures the extent to which it responds to deviations in credit growth.

We use deviations of credit growth from its steady state as the variable that triggers an interest rate response from the central bank given that credit variables have been found to provide useful leading indicators of asset prices busts (IMF (2009)). Indeed, large booms in credit have often been precursors to financial crises, including the most recent crisis.

2.6.3 Macroprudential regime with a standard Taylor rule

The third policy regime combines a macroprudential rule with a standard Taylor rule. In this regime, it is assumed that policy-makers have both interest rates and the macroprudential instrument at their disposal to stabilize the macroeconomy. We follow Kannan et al. (2009) in modelling the macroprudential tool as an exogenous component of the external finance premium as follows:

$$s_t = f_t s\left(\frac{Q_t K_{t+1}}{N_{t+1}}\right)\tau_t, \tag{40}$$

where

$$\tau_t = (\frac{cg_t}{cg_{ss}})^{\rho_\tau}, with\ \tau(.) > 0,$$

and ρ_τ is the policy coefficient chosen by the policy-makers, which may or may not be the central bank. Thus, in our model, use of the macroprudential tool is triggered by signs of emerging financial imbalances (as proxied by deviations in credit growth from its steady-state value) and is assumed to have a direct influence on the funding costs of firms (via the external finance premium). For example, a period of excessive credit expansion would trigger use of the macroprudential tool, leading to an increase in firms' funding costs and a dampening of investment (and hence aggregate economic activity).

2.6.4 Macroprudential regime with the augmented Taylor rule

The final policy regime combines the augmented Taylor rule with the macroprudential instrument. In this regime, it is assumed that policy-makers have both interest rates and the macroprudential instrument at their disposal to stabilize the macroeconomy according to equation (40). Moreover, it is assumed that the policy rate reacts to credit growth according to equation (38).

3 Data and estimation strategy

We estimate the model using a Bayesian approach. We use data for the following five variables in our estimation: output, investment, the nominal interest rate, inflation and the external finance cost. Output is measured by real GDP excluding government expenditures.[8] Investment is the sum of gross fixed capital formation and investment in inventories. The nominal interest rate used is the overnight rate. Core CPI is used for our measure of inflation.[9] And the real external finance cost is measured using an index of real Canadian corporate yields.[10] All data series are quarterly and are for the Canadian economy over the period from 1997Q1 to 2009Q3. The output and investment series are expressed in per capita terms, and are are logged and linearly detrended. The series for the nominal interest rate, inflation, and the real external finance cost are demeaned.

As is standard when estimating DSGE models using a Bayesian approach, some parameters are set prior to estimation, because the data does not contain sufficient information to estimate them. Table 1 lists the parameters we calibrate and the values assigned. The discount factor β is set to 0.99, which implies an annual steady-state real interest rate of 4%. The steady-state depreciation rate, δ, is assigned a value of 0.025. The parameter representing the capital share in the Cobb-Douglas production function, α, is set to one-third. The steady-state price markup $\varepsilon/(\varepsilon-1)$ is set to 1.2.[11] We set $\gamma = 1$ so that the implied labour supply elasticity is $1/\gamma = 1$.[12] The weight of leisure in the utility function, θ, is set to 5.75, implying that

[8] We exclude government expenditures in our measure of output because there is no government spending in the model.

[9] Core CPI is total CPI excluding eight of the most volatile components as well as the effect of changes in indirect taxes on the remaining components. The Bank of Canada uses the core CPI as a guide to its policy actions.

[10] We use the *Canadian Corporate Index Yield to Maturity* series from Merrill Lynch (series F0C0). Although this series only starts in 1997, we use it because we believe it's the best proxy available for the external finance costs of Canadian firms.

[11] This value is consistent with Leung (2008) who finds that the mark-up for major Canadian industries is 1.346, whereas that for Canadian manufacturing industries is 1.15.

[12] Existing studies suggest that the individual elasticity of labour is about 0.1, while the aggregate elasticity

households spend one-third of their time working. The survival rate of entrepreneurs, η, is set at 0.9728, as in Bernanke et al. (1999); this implies that the average working life for entrepreneurs is 36 quarters and also implies that the steady-state risk premium is 1.0177. The steady-state inflation rate is set to $\pi = 1.02$ per year. Following King and Santor (2008), the steady-state ratio of net worth to capital is set to 0.6.

Table 1: Parameter calibration

Parameters	Definition	Values
β	Discount factor	0.99
δ	Capital depreciation rate	0.025
α	Capital share in production function	1/3
ε	Intermediate-good elasticity of substitution	6
γ	Inverse of labor supply elasticity	1
θ	Weight on leisure in the utility function	5.75
η	Survival rate of entrepreneurs	0.9728
π	Gross steady-state inflation rate	1.005
n/k	Steady-state ratio of net worth to capital	0.6
s	Gross steady-state risk premium	1.0177

The remaining parameters are estimated using a Bayesian approach. The information on the priors for these parameters is given in Table 2.[13] We use previous studies to guide us in establishing our priors. The elasticity of the external finance premium with respect to firm leverage, χ, is set to have a gamma distribution with a mean of 0.05 (the value suggested by Bernanke et al. (1999)). The rest of the priors are fairly standard. For the monetary policy rule, we set the prior of the reaction on inflation, ϕ_π, to have a gamma distribution with a mean of 1.5 and a standard deviation of 0.1. The coefficient of the reaction on the output gap, ϕ_Y, is assumed to have a normal distribution of mean 0.1 and a standard deviation of 0.05. The interest rate smoothing parameter is assumed to have a Beta distribution of mean 0.85 and a standard deviation of 0.05. For the priors of the shocks affecting the economy, we set the autoregressive coefficients of the technology shocks, investment-specific shocks, preference and financial shock to have a beta distribution with a mean of 0.80 and a standard deviation of 0.05. The standard deviations of the innovations are assumed to follow an inverse-gamma distribution with a mean of 0.01. Finally, the parameter ξ, which determines the degree

is about 0.9, with most of the difference due to the extensive margin (i.e., participation and employment). See Fiorito and Zanella (2009) for more details.

[13] As the results can be sensitive to the prior distributions selected when using the Bayesian method, we use loose priors whenever possible and aim to keep the priors on the stochastic processes as harmonized as possible.

of capital adjustment costs, is set to have a normal distribution with a mean of 0.25 and a standard deviation of 0.05. The Calvo probability, ν, is assumed to be around 0.67, suggesting an average length of price contract of three quarters.

Table 2: Estimation results

	Prior distribution			Posterior distribution			
Coef.	Density	Mean	StD	Mode	Mean	5%	95%
$\boldsymbol{\chi}$	G	0.05	0.02	0.0594	0.0615	0.0339	0.0881
$\boldsymbol{\xi}$	N	0.25	0.05	0.2603	0.2608	0.1804	0.3363
$\boldsymbol{\nu}$	B	0.67	0.05	0.4824	0.4819	0.4320	0.5288
$\boldsymbol{\phi_\pi}$	G	1.50	0.10	1.7062	1.7256	1.5625	1.8762
$\boldsymbol{\phi_Y}$	N	0.10	0.05	0.0776	0.0771	0.0361	0.1126
$\boldsymbol{\phi_r}$	B	0.85	0.05	0.7145	0.7057	0.6516	0.7667
$\boldsymbol{\rho_f}$	B	0.80	0.05	0.7980	0.7920	0.7251	0.8569
$\boldsymbol{\rho_z}$	B	0.80	0.05	0.8342	0.8347	0.7684	0.9002
$\boldsymbol{\rho_x}$	B	0.80	0.05	0.8810	0.8792	0.8355	0.9271
$\boldsymbol{\rho_p}$	B	0.80	0.05	0.9546	0.9512	0.9365	0.9656
$\boldsymbol{\sigma_f}$	IG	0.01	—	0.0018	0.0018	0.0015	0.0022
$\boldsymbol{\sigma_z}$	IG	0.01	—	0.0060	0.0065	0.0049	0.0079
$\boldsymbol{\sigma_e}$	IG	0.01	—	0.0021	0.0022	0.0018	0.0026
$\boldsymbol{\sigma_x}$	IG	0.01	—	0.0050	0.0052	0.0038	0.0065
$\boldsymbol{\sigma_p}$	IG	0.01	—	0.0211	0.0211	0.0171	0.0250

We use Dynare 3.065 to estimate the model. We use the Metropolis-Hastings algorithm to perform the simulations. To check for convergence, we run two difference chains starting from dispersed points. For each chain, the total number of draws is $20,000$ and the first 20% of the draws are discarded. A step size of 0.5 resulted in an acceptance rate of 0.33.

4 Estimation results

4.1 Parameter estimates

Along with the priors, Table 2 also reports the parameter estimates, displaying the mode, the mean, and the 5 and 95 percentiles of the posterior distribution of the parameters. In what follows, we report the posterior modes, as they are very close to the posterior means. The elasticity of the risk premium with respect to leverage, χ, is estimated to be around 6%. The persistence of the financial shock is 0.798 and the standard deviation is estimated at 0.0018.[14]

[14]Given the importance of the parameters related to financial frictions and the financial shock in our study, it is useful to compare our estimates of these parameters to those from previous studies. Our estimate of χ is close to the estimates ($\chi = 0.04$) in Christensen and Dib (2008) and Covas and Zhang (2010). For the financial shock, we compare our estimates with those in Dib et al. (2008), a paper that also estimates a DSGE model with a financial shock for the Canada economy. The volatilities of the estimated financial shock from

Among the shocks, the preference shock is the most persistent and volatile.

Now turning to the other parameters. The estimated value of the monetary policy parameter, ϕ_π, the coefficient that captures the response of monetary policy to a deviation of inflation from its steady state, is 1.7. The coefficient that measures the response of monetary policy to the output gap, ϕ_Y, is 0.077. This estimate suggests that monetary policy does not react very strongly to the output gap. The interest rate smoothing parameter is estimated at 0.71. The estimate of the capital adjustment cost, ξ, is 0.2603, which is close to the estimate in Covas and Zhang (2010). The estimate of the sticky price parameter, ν, is 0.48, suggesting that the average duration of price contracts is about two quarters.

4.2 The behaviour of the estimated model under the baseline policy regime

In this section, we use the estimated model with the baseline policy regime (i.e., the standard Taylor with interest-rate smoothing) to analyze the effects of key shocks in our model economy using both impulse response functions (IRFs) and variance decomposition. This section is intended to show that the performance of the estimated model in response to key shocks is reasonable as well as to provide some intuition regarding the key mechanisms at play in the model.

4.2.1 Impulse-response analysis

Figures 1 and 2 in Appendix A plot the IRFs of the estimated model for two key shocks: a financial shock and a technology shock. All impulse responses are for a temporary one standard deviation shock. The financial shock is modelled as a negative shock to the external risk premium. It is a simple way to proxy for an expansionary financial shock that could be the result of, for example, a relaxation in lending standards. The technology shock is fairly standard and is modelled as a positive shock to z_t, the aggregate technology term in the production function.

We first consider the response of our estimated model economy to an expansionary financial shock. As shown in Figure 1, an expansionary financial shock leads to a positive output gap, a rise in inflation and an increase in credit growth. The intuition is as follows. The fall in the risk premium leads to a decline in the external finance cost and an increase in the demand for capital. This in turn leads to higher asset prices and higher net worth, leading to a higher demand for credit. Hours increase as well since firms hire more labour, leading to the rise in output.

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our paper and Dib et al. (2008) are similar, although our results suggests the financial shock is less persistent.

Inflation also rises following the expansionary financial shock due to an increase in marginal cost, resulting from an increase in real wages and a fall in the marginal productivity of labour. This is because marginal cost is determined by the ratio of the real wage W_t/P_t to the marginal productivity of labour $(1-\Omega)F_{H_t}$ in the model. This can be seen by rewriting the following equation:

$$(1-\Omega)F_{H_t} = \frac{W_t}{P_{W,t}}, \tag{41}$$

as

$$mc_t = \frac{P_{W,t}}{P_t} = \frac{W_t/P_t}{(1-\Omega)F_{H_t}}. \tag{42}$$

Real wages rise following the financial shock because the increase in hours pushes up the marginal disutility of labour. The marginal productivity of labour decreases as hours worked increase immediately whereas the capital stock adjust gradually, resulting in a decline in the capital-labour ratio.

Figure 2 depicts the response of key variables in the model following a positive technology shock. As shown, output, consumption, and investment all rise and inflation declines, which is consistent with the responses in a standard New-Keynesian model. In terms of the response of financial variables, both asset prices and nominal credit growth increase as enterpreneurs invest more and the demand for capital rises. Although the net worth of enterpreneurs' rises, the demand for capital increases even more, resulting in an increase in leverage, and in turn, a higher risk premium.

4.2.2 Variance Decomposition

Table 3 shows the contribution of each of the shocks to the variability of the key variables in the model. Our estimation results suggest that the preference shock is the most persistent and the most volatile shock, and thus it is not surprising that the preference shock appears to be the main source of the fluctuations in output and consumption. The financial shock is the least persistent and the least volatile of the shocks considered, but it plays an important role in explaining the variation in some key variables in the model due to the financial accelerator effects. In particular, the financial shock accounts for 30 percent of the fluctuations in inflation, 60 percent of those in investment, 75 percent of those in the risk premium and 43 percent of variation in the policy rate. Technology and investment-specific shocks explain a significant amount of the variation in investment and output (i.e., 25 percent and 11 percent, respectively). As expected, the monetary policy shock in an important driver of inflation, accounting for 55 percent of its total variation.

Table 3: Variance Decomposition

	Technology	Monetary	Investment	Preference	Financial
Output	10.95	1.57	1.05	81.63	4.80
Inflation	6.09	55.30	4.91	2.84	30.87
Consumption	5.81	0.16	1.74	86.46	5.82
Investment	14.19	5.78	10.55	9.62	59.86
Policy Rate	13.98	0.25	8.46	33.33	43.97
Risk Premium	0.51	0.11	7.07	16.97	75.34

5 The Performance of Different Policy Regimes in Reaction to Key Shocks

In this section, we examine the behaviour of our estimated economy under the four different policy regimes discussed in Section 3 in response to the same two shocks discussed above: an expansionary financial shock and a positive technology shock.

5.1 Expansionary financial shock

Figure 3 in Appendix B compares the responses of the key variables in our model economy to an expansionary financial shock under the four different policy regimes considered. All of the parameters in our baseline policy rule are estimated, as discussed in the previous section (and shown in Table 2). For the augmented Taylor rule, we take the estimated parameters from the standard Taylor rule for $\phi_r = 0.71$, $\phi_\pi = 1.7$ and $\phi_y = 0.08$ and we set $\phi_c = 0.5$, where ϕ_c is the policy coefficient chosen by the central bank that captures the extent to which it responds to deviations in credit growth.

Compared to the standard Taylor rule (solid blue line), the impact of the financial shock is dampened when the central bank follows a Taylor rule under which it also responds to deviations in credit growth (solid red line). Output and inflation still rise in the latter policy regime, but by less. The responses of the financial variables are dampened as well, as nominal credit growth, asset prices and net worth all rise by less. The dampened response works through the expectation channel. In a regime where policy-makers respond to deviations in credit conditions, agents expect the policy rate to react more aggressively in the presence of an expansionary financial shock than it would in the standard Taylor rule regime. Forward-looking agents take the potential rise in the policy interest rate (and the associate rise in the cost of external finance) into account and hence reduce their borrowing accordingly. This dampens the responses in output and inflation, and the ex post policy rate rises by less compared to the standard Taylor rule. Thus, in response to a financial shock, our results suggest that a policy regime in which the central bank responds to deviations in credit conditions would result in less volatility in both inflation and financial market conditions compared to the standard Taylor rule.

Inflation and output are further stabilized in response to a financial shock under the regime that combines a standard Taylor rule with a macroprudential tool ($\rho_\tau = 0.5$, dashed blue line). Under this regime, policy-makers have the macroprudential instrument at their disposal and can use it to directly offset the effects of the expansionary financial shock on the external finance premium. Thus, following an expansionary financial shock, the external risk premium does decline, as in the Taylor rule regime, but by less because policymakers use the countercyclical macroprudential instrument to partially offset the fall in the external risk premium. This smaller decline in the external risk premium results in more muted increases in investment and credit demand. This, in turn, dampens the response in inflation and output and the ex post policy rate rises by less compared to the standard Taylor rule. The responses of inflation and output are also more muted under the macroprudential regime compared to the augmented Taylor rule regime, as policymakers have at their disposal a macroprudential tool that directly influences the risk premium in the latter regime whereas in the augmented Taylor rule regime, monetary policy influences the risk premium indirectly via the expectation channel.

In the fourth regime considered, policy-makers have two instruments at their disposal to offset the effects of financial imbalances: the policy rate and the macroprudential tool ($\phi_c = 0.5,$, $\rho_\tau = 0.5$). In the presence of a financial shock, the macroprudential regime with an augmented Taylor rule (dashed red line) offers similar benefits in terms of macroeconomic stabilization as does the regime that combines a standard Taylor rule with the macroprudential instrument. Indeed, the responses of the key variables are similar under the two macroprudential regimes, suggesting that the macroprudential instrument may be a more effective tool for macroeconomic stabilization in the presence of a financial shock than the policy rate.

5.2 Positive technology shock

As made clear in the previous section, macroeconomic stabilization is better served in the presence of a financial shock under regimes where policy-makers respond to financial imbalances (using either the policy rate and/or a macroprudential instrument) compared to a standard Taylor rule regime. However, this result may not hold in the face of other types of shocks. To examine this issue, we now compare how the economy would respond to a positive technology shock under the different policy regimes considered.

Figure 4 in Appendix B compares the responses of the key variables in our model economy to a positive technology shock under the four different policy regimes considered. In contrast to the case of a financial shock, the responses of inflation and output are fairly similar across the four regimes. Thus, all four regimes yields similar results in terms of macroeconomic stabilization. However, the means by which this result are achieved differ across the regimes. In the standard Taylor rule regime (blue line), the central bank eases monetary policy in response to the fall in inflation resulting from the positive technology shock and hence the policy rate declines. Under the augmented Taylor rule regime (red line), the policy rate also falls but the decline is larger on impact because agents expect the central bank to increase the policy rate in response to the increase in credit growth resulting from the technology shock. Thus, the required response in the policy rate following a technology shock is larger when the central bank also responds to deviations in credit conditions compared to the case where it follows a standard Taylor rule. Under the two macroprudential regimes (dashed red and blue lines), policy-makers will use the macroprudential tool to offset the effects of rising credit growth that arise following the positive technology shock and this will lead to an increase in the risk premium, which will counteract to some extent the effects of the easing in monetary policy. Thus, monetary policy will have to be eased further and the policy rate will need to decline by more in the regimes that feature the macroprudential tool compared to the standard Taylor rule regime.

5.3 Interest-rate smoothing

Our baseline policy rule is a standard Taylor rule where it is assumed that the central bank smooths the policy rate, as is widely observed in practice. Appendix C depicts the key results for the various policy regimes considered in the case where it is assumed that the central bank follows a standard Taylor rule *without* smoothing the interest rate. As shown, the results do not change in a material way. There are only minor differences in the estimated parameters for the smoothing and non-smoothing cases (Table 12). The results of the variance decomposition reveal that the preference shock plays a less dominant role in explaining variation in output and consumption when the central banks doesn't smooth the interest rate. Indeed, as shown in Table 13, although the preference shock continues to be the main source of the fluctuations in output and consumption, it explains relatively less of the variation in these variables compared to the smoothing case and technology shocks explain relatively more. Preference shocks also explain less of the variation in the policy rate, although they explain more of the variation in inflation and the risk premium in the non-smoothing case. Moreover, the key variables in the model respond to shocks in a similar fashion in the smoothing and non-smoothing cases. However, in the presence of an expansionary financial shock, the responses of the key variables are generally more muted when the central bank does not smooth the interest rate, whereas in the presence of a technology shock, it is mainly the response of inflation that is more muted.

6 Welfare Analysis

In this section, we compare the performance of our four policy regimes using a welfare criterion. In conducting our welfare analysis, we assume that the behavioural parameters and the parameters governing the exogenous shocks are the same across all regimes. The values for the estimated parameters are taken from the mode estimates reported in Table 2. In each regime, the optimal policy rules are those whose policy coefficients maximize the following equation:

$$E_0 \sum_{t=0}^{\infty} \beta^t U\Big(C_t, H_t\Big). \tag{43}$$

In order words, the optimal policy coefficients in each regime are those that yield the paths for consumption and hours worked that achieve the highest level of unconditional lifetime utility.[15] The change in welfare associated with a particular policy regime is captured by the compensating variation, which measures the percentage change in consumption in the deterministic steady-state that would give households the same unconditional expected utility in the stochastic economy. Therefore, a negative figure indicates a welfare cost and a positive figure indicates a welfare gain, and the gain of the alternative regimes over the standard Taylor regime is the percentage difference between the two regimes.[16]

Table 4 reports the optimal policy coefficients in each regime, and Table 5 reports the welfare costs associated with the optimal policy in each regime as well as the welfare gain of each regime over the standard Taylor rule regime. The results in these tables suggest that it is welfare-improving for policy-makers to respond to financial imbalances. In fact, welfare is highest in the regime where policy-makers respond to financial imbalances using both the policy rate and the macroprudential tool (i.e., the macroprudential regime with the

[15]For the optimal rule coefficients, we perform a grid search for ϕ_π, ϕ_Y, ϕ_c and ρ_τ (keeping ϕ_r fixed at 0.71). To ensure the local uniqueness of the rational expectation equilibrium, we limit our attention to policy coefficients in the interval (1, 3] for ϕ_π and in the interval [0, 0.5] for ϕ_Y. In the former case, we follow Schmitt-Grohe and Uribe (2007) in setting the upper bound to 3 given that a policy parameter larger than 3 would be difficult to communicate to the public. For parameters ϕ_c and ρ_τ, we restrict them to be within the interval [0,1]. We set the size of the intervals for all the coefficients to 0.1.

[16]For example, as shown in Table 5, under the standard Taylor rule regime, the welfare in utils is -73.0897, which corresponds to a welfare cost (relative to the deterministic economy) of 0.0906% of steady-state consumption. Under the augmented Taylor rule regime, the corresponding values for welfare and welfare cost are -73.0855 and -0.0864% of steady-state consumption, respectively. Thus, the gain associated with the augmented Taylor rule regime (relative to the baseline regime) is 0.0042% (i.e., -0.0864 - (-0.0906)) of steady-state consumption.

augmented Taylor rule). We provide intuition for this key result below.

Table 4: Optimal Rules Under Different Regimes

	Optimal coefficients			
	ϕ_π	ϕ_Y	ϕ_c	ρ_τ
Standard Taylor regime	3	0.1	-	-
Augmented regime	3	0.1	1	-
Macroprudential regime	3	0.1	-	1
Augmented Macroprudential regime	3	0.1	0.9	1

Note: We keep ϕ_r fixed at 0.71.

Table 5: Welfare Comparison across Different Regimes

	Welfare	Welfare cost	Relative gain
Standard Taylor regime	-73.0897	-0.0906	-
Augmented regime	-73.0855	-0.0864	0.0042
Macroprudential regime	-73.0836	-0.0845	0.0061
Augmented Macroprudential regime	-73.0830	-0.0839	0.0067

Notes: (1) Welfare is measured in utils. (2) The welfare cost is measured in terms of steady-state consumption (in percentage) and relative to the deterministic economy. (3) The welfare gain is relative to the standard Taylor rule regime.

6.1 Macroprudential regime with standard Taylor rule

The results in Tables 4 and 5 suggest that it is optimal for policy-makers to use the macroprudential tool and that the welfare gain associated with this regime, compared to the standard Taylor rule, is about 0.0061% of steady-state consumption. To provide intuition for this result, we also compute the optimal monetary policies assuming the economy is only subject to a financial shock or a technology shock. This exercise is useful given that the performance of the different policy regimes in reaction to the two keys shocks differs, as discussed in Section 6.

As shown in Table 6, in an economy where the financial shock is the only shock buffeting the economy, it is optimal for policymakers to use the macroprudential tool agressively (i.e., $\rho_\tau = 1$); the associated welfare gain, compared to the standard Taylor rule regime, is about 0.0048% of steady-state consumption. The welfare gain arises because the macroprudential tool significantly reduces the volatility in the key macro variables in the presence of a financial shock. As discussed in Section 6, following an expansionary financial shock, the external

Table 6: Optimal Rules and Welfare Gains Under Macroprudential Regimes

	ϕ_π	ϕ_Y	ϕ_c	ρ_τ	Welfare	Relative gain
All shocks	3	0.1	-	1	-73.0836	0.0061
	3	*0.1*	-	-	*-73.0897*	-
Financial shock only	3	0.2	-	1	-72.9999	0.0048
	3	*0.5*	-	-	*-73.0047*	-
Technology shock only	3	0	-	0.1	-72.9963	4.84313E-05
	3	*0*	-	-	*-72.9964*	-
Thought experiment						
Technology shock only	3	0.2	-	1	-72.9974	-0.0010
	3	*0*	-	-	*-72.9964*	-

Notes: (1) See notes for Table 5. (2) The numbers in italics correspond to the standard Taylor rule regime.

risk premium declines, leading to higher demand for credit and investment. Both inflation and output rise, calling for tighter monetary policy. A countercyclical macroprudential tool increases the external risk premium, leading to a dampening in investment and credit demand. This stabilization effect increases welfare. However, this aggressive use of the macroprudential tool is not optimal when other shocks buffet the economy. As shown in Table 6, in the presence of a technology shock, the optimal coefficient on the macroprudential tool becomes very small.

In fact, aggressive use of the macroprudential tool will reduce welfare if the economy is only subject to a technology shock. This result is shown in the last row of Table 6. In this thought experiment, we assume that the economy is only subject to a technology shock but that policy-makers adopt the policy rule that is optimal in the presence of a financial shock, which involves an aggressive use of the macroprudential tool. Welfare decreases under this rule. The intuition is as follows. Following a positive technology shock, output and credit rise but inflation declines. This creates a tension between two instruments, the policy rate and the macroprudential tool. The policy rate needs to decline to bring inflation back to target. However, the rise in nominal credit growth calls for a tightening in the macroprudential tool (i.e., a rise in the risk premium), which reduces the effectiveness of monetary policy. In this case, monetary policy has to be eased further to compensate for the effect of the macroprudential tool, leading to higher volatility in the policy rate and inflation, which reduces welfare.

6.2 Augmented Taylor rule regime

As the results in Tables 4 and 5 suggest, it is optimal for monetary policy to respond to financial imbalances and the welfare gain associated with the augmented Taylor rule, compared to the standard Taylor rule, is about 0.0042% of steady-state consumption. To understand the source of this welfare gain, we conduct similar experiments for the augmented Taylor rule regime as we did for the macroprudential regime. The results are presented in Table 7.

Table 7: Optimal Rules and Welfare Gains Under Augmented Regimes

	ϕ_π	ϕ_Y	ϕ_c	Welfare	Relative gain
All shocks	3	0.1	1	-73.0855	0.0042
	3	*0.1*	-	*-73.0897*	-
Financial shock only	3	0.3	1	-73.0026	0.0021
	3	*0.5*	-	*-73.0047*	-
Technology shock only	3	0	0.1	-72.9964	1.62004E-06
	3	*0*	-	*-72.9964*	-
Thought experiment					
Technology shock only	3	0.3	1	-72.9985	-0.0021
	3	*0*	-	*-72.9964*	-

Notes: See notes for Table 6.

Table 7 suggests that if the financial shock is the only shock buffeting the economy, it is optimal for the central bank to react aggressively to deviations in nominal credit growth (i.e., $\phi_c = 1$). As suggested in Section 6, this is due to the expectation channel. Following an expansionary financial shock, under the augmented Taylor rule, agents expect the policy rate to react more aggressively than they would if the central bank followed a standard Taylor rule. Agents take these potential rises in the interest rate and external finance cost into account, and reduce borrowing accordingly. This dampens the responses in output and inflation, leading the ex post policy rate to rise by less compared to the standard Taylor rule. Thus, under the augmented Taylor rule, the volatility of the key variables is reduced in the presence of a financial shock and this improves welfare. However, this result may not generalize to other types of shocks. As suggested in Section 6, the volatility in the policy rate increases in the presence of a technology shock if the central bank responds aggressively to deviations in credit growth. As shown in the last row of Table 7, in an economy that is buffeted only with a technology shock, an aggressive response to deviations in credit growth (that would be appropriate for an economy facing only a financial shock) will lead to a decline in welfare.

It is worth noting that the welfare gain associated with the augmented Taylor rule regime is not as large as that associated with the macroprudential regime (i.e., 0.0042 versus 0.0061). The larger welfare gain in the latter regime is due to the fact that the macroprudential tool works directly on the source of the financial imbalance as opposed to addressing it indirectly via the expectation channel.

6.3 Macroprudential regime with augmented Taylor rule

As shown in Table 8, when policy-makers have both the policy rate and the macroprudential tool at their disposal to stabilize the macroeconomy, it is optimal for them to use both instruments. Compared to the standard Taylor rule, the welfare gain is the highest under the macroprudential regime with the augmented Taylor rule, representing about 0.0067% of steady-state consumption. The results also suggest that once policy-makers adopt the macroprudential tool, the policy rate will react to deviations in credit growth less aggressively (i.e., $\phi_c = 0.9$ compared to $\phi_c = 1$ for all shocks in the augmented regime; and $\phi_c = 0.6$ compared to $\phi_c = 1$ for the financial shock in the augmented regime).

Table 8: Optimal Rules and Welfare Gains Under Augmented Macroprudential Regimes

	ϕ_π	ϕ_Y	ϕ_c	ρ_τ	Welfare	Relative gain
All shocks	3	0.1	0.9	1	-73.0830	0.0067
	3	*0.1*	-	-	*-73.0897*	-
Financial shock only	3	0	0.6	1	-72.9997	0.0049
	3	*0.5*	-	-	*-73.0047*	-
Technology shock only	3	0	0	0.1	-72.9963	4.84313E-05
	3	*0*	-	-	*-72.9964*	-

Notes: See notes for Table 6.

6.4 Price-level targeting

We also consider whether policy-makers should respond to financial imbalances in a price-level targeting (PLT) regime. The PLT regime is defined as follows. It is assumed that, by targeting the price level, the central bank adjusts the nominal interest rate, R_t^n, in response to deviations of the price level, P_t, from the targeted price level, $\overline{P_t}$, and deviations of output from its steady-state level:

$$\frac{R_t^n}{R^n} = \left(\frac{R_{t-1}^n}{R^n}\right)^{\phi_R} \left(\left(\frac{P_t}{\bar{P}_t}\right)^{\phi_P} \left(\frac{Y_t}{Y_{ss}}\right)^{\phi_Y}\right)^{1-\phi_R} e^{\epsilon_t^m}, \tag{44}$$

where $\overline{P_t} = \pi^t P_0$, and $P_0 = 1$.

Table 9 presents the optimal policy rules for the different regimes considered for the case of PLT as well as a welfare comparison between IT and PLT. The results suggest that it is optimal for policymakers to respond to financial imbalances by using either the policy rate and/or the macroprudential tool under a PLT regime as was the case under an IT regime. Consistent

Table 9: Optimal Coefficients and Welfare Under Different Regimes: PLT

	Optimal coefficients				Welfare cost	Relative gain
	ϕ_P	ϕ_Y	ϕ_c	ρ_τ		
Standard Taylor-type regime	3	0.5	-	-	-0.0555 *(-0.0906)*	0.0351
Augmented regime	3	0.5	0.5	-	-0.0553 *(-0.0864)*	0.0311
Macroprudential regime	3	0.5	-	0.3	-0.0550 *(-0.0845)*	0.0295
Macroprudential augmented regime	3	0.5	0.6	0.3	-0.0548 *(-0.0839)*	0.0291

Notes: (1) See notes from Table 5. (2) The welfare gain is relative to the corresponding IT regime (shown in parenthesis).

with previous work, we found a welfare gain of PLT over IT across all the regimes. The welfare gain arises due to the history dependence feature in PLT. History dependence refers to the expectation that future deflation (inflation) will immediately depress (spur) inflation when shocks buffet the economy. Introducing history dependence in a forward-looking model stabilizes expectations and delivers lower macroeconomic variability and higher welfare. In general, key macroeconomic variables are less volatile under a PLT regime, compared to an IT regime.

Table 10 quantifies the welfare gain of the different regimes over the standard Taylor type regime under PLT. As shown, both the augmented Taylor rule regime and the macroprudential regime outperform the standard Taylor rule in a PLT regime. However, compared to IT, the gains are smaller. For example, under IT, the welfare gain associated with the macropudential regime over the standard Taylor rule is about 0.0061% of steady-state consumption. While under PLT, the corresponding gain is just about 0.0005% of steady-state consumption. Under IT, the welfare gain associated with the augmented Taylor rule, over the standard Taylor rule, is about 0.0042% of steady-state consumption. Under PLT, the corresponding gain is about 0.0002% of steady-state consumption. The smaller welfare gain arises because under PLT, the volatility of the key macro variables is already low when the central bank follows a standard Taylor-type rule due to the benefits of history dependence. Therefore, the benefits of further stabilization by adopting a policy regime where policy-makers respond to financial imbalances, using the policy rate and/or the macroprudential tool, is marginal.

Table 10: Welfare Comparison Across Different Regimes: PLT

	Welfare cost	Gain relative to standard Taylor rule
Standard Taylor-type	-0.0555	-
Augmented	-0.0553	0.0002
		(0.0042)
Macroprudential	-0.0550	0.0005
		(0.0061)
Macroprudential augmented	-0.0548	0.0007
		(0.0067)

Notes: (1) See notes for Table 9. (2) The relative gains over the standard Taylor rule for IT regimes are shown in parenthesis.

7 Concluding Remarks

This paper studies whether it is optimal for policy-makers to respond to financial imbalances in the context of a model, estimated on Canadian data, that features both financial frictions and financial shocks. Our findings suggest that welfare is higher, compared to a standard Taylor rule, in regimes where policy-makers respond to financial imbalances using the policy rate and/or a macroprudential tool. The welfare gain arises due to the benefits that such regimes offer for macroeconomic stabilization, particularly in the presence of financial shocks. Although the performance of the different regimes varies depending on the types of shocks that hit the economy, our results suggest that the benefits of responding to financial imbalances in the presence of all shocks outweigh the costs.

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Appendix A: Impulse-Response Functions for the Estimated Model under the Baseline Policy Regime

Figure 1: Response of Key Variables to an Expansionary Financial Shock

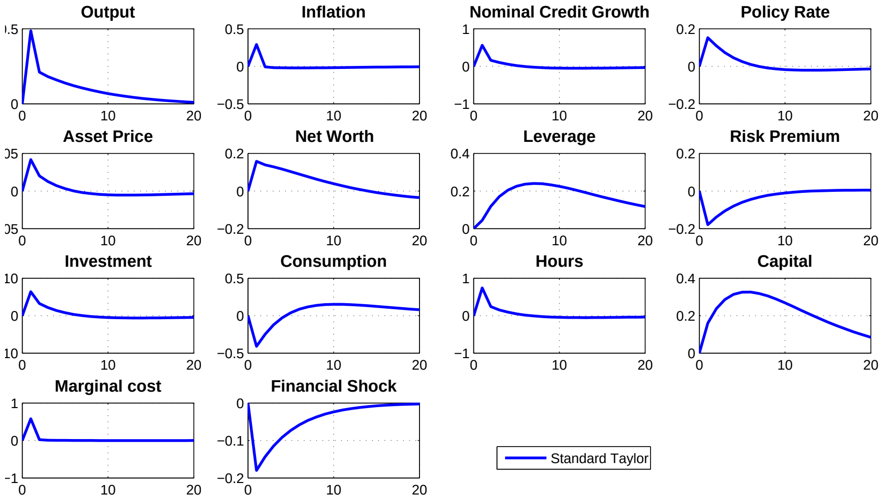
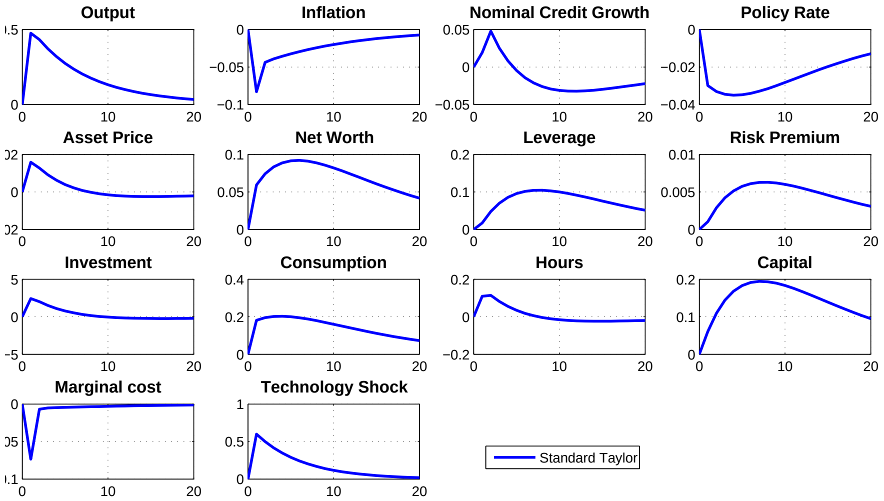


Figure 2: Response of Key Variables to a Positive Technology Shock



Appendix B: The Performance of Different Policy Regimes in Response to Key Shocks

Figure 3: Effects of an Expansionary Financial Shock

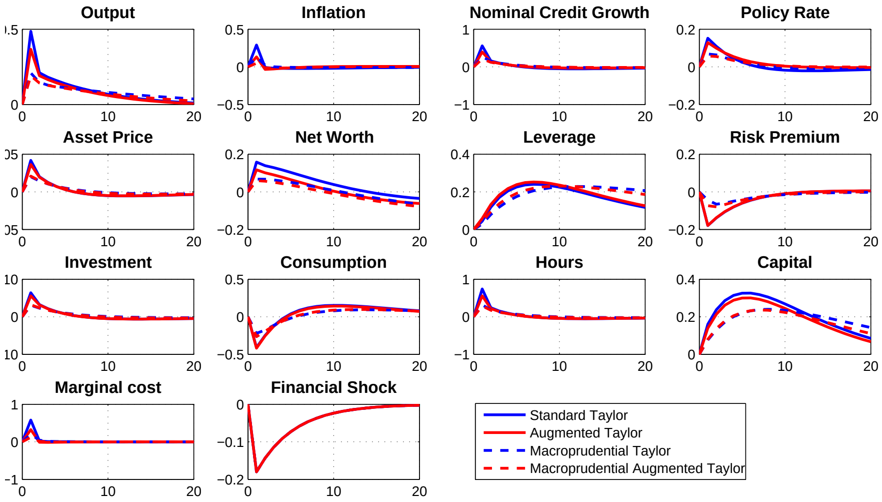
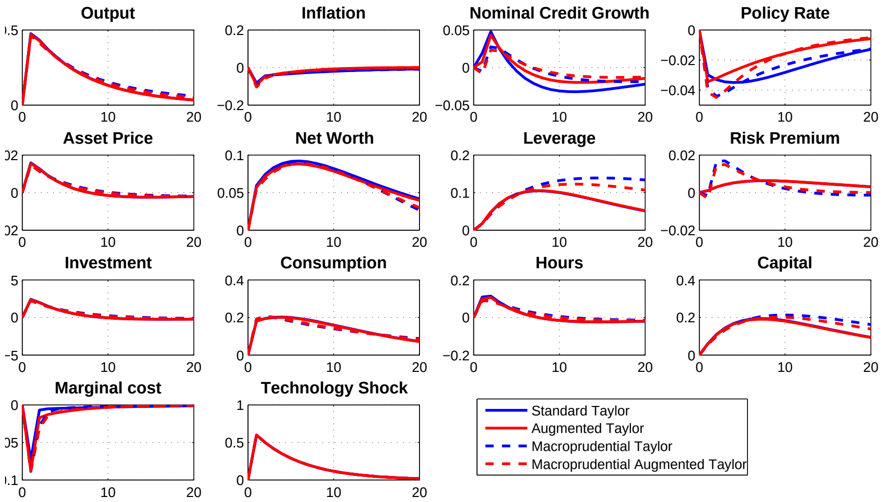


Figure 4: Effects of a Positive Technology Shock



Appendix C: Key Results for the Non-Smoothing Case

Table 11: Estimation results: Non-smoothing case

	Prior distribution			Posterior distribution			
Coef.	Density	Mean	StD	Mode	Mean	5%	95%
$\boldsymbol{\chi}$	G	0.05	0.02	0.059	0.063	0.031	0.090
$\boldsymbol{\xi}$	N	0.25	0.05	0.252	0.248	0.171	0.331
$\boldsymbol{\nu}$	B	0.67	0.05	0.461	0.462	0.417	0.509
$\boldsymbol{\phi_\pi}$	G	1.50	0.10	1.818	1.829	1.668	1.985
$\boldsymbol{\phi_Y}$	N	0.10	0.05	0.057	0.049	0.008	0.085
$\boldsymbol{\rho_f}$	B	0.80	0.05	0.822	0.809	0.735	0.883
$\boldsymbol{\rho_z}$	B	0.80	0.05	0.857	0.863	0.792	0.934
$\boldsymbol{\rho_x}$	B	0.80	0.05	0.886	0.885	0.840	0.930
$\boldsymbol{\rho_p}$	B	0.80	0.05	0.946	0.934	0.897	0.963
$\boldsymbol{\sigma_f}$	IG	0.01	—	0.0014	0.0015	0.0012	0.0017
$\boldsymbol{\sigma_z}$	IG	0.01	—	0.0079	0.0087	0.0064	0.0109
$\boldsymbol{\sigma_e}$	IG	0.01	—	0.0056	0.0058	0.0048	0.0068
$\boldsymbol{\sigma_x}$	IG	0.01	—	0.0057	0.0053	0.0039	0.0066
$\boldsymbol{\sigma_p}$	IG	0.01	—	0.0188	0.0179	0.0121	0.0227

Table 12: Variance Decomposition: Non-smoothing case

	technology	monetary	investment	preference	financial
output	30.67	0.91	1.08	64.55	2.78
inflation	10.44	59.40	4.87	5.50	19.79
consumption	17.26	0.09	2.37	74.46	5.82
investment	34.90	3.20	10.73	10.73	40.44
policy rate	11.03	0.07	11.58	29.75	47.57
risk premium	1.33	0.07	11.22	19.36	68.03

Figure 5: Effects of an Expansionary Financial Shock (non-smoothing case)

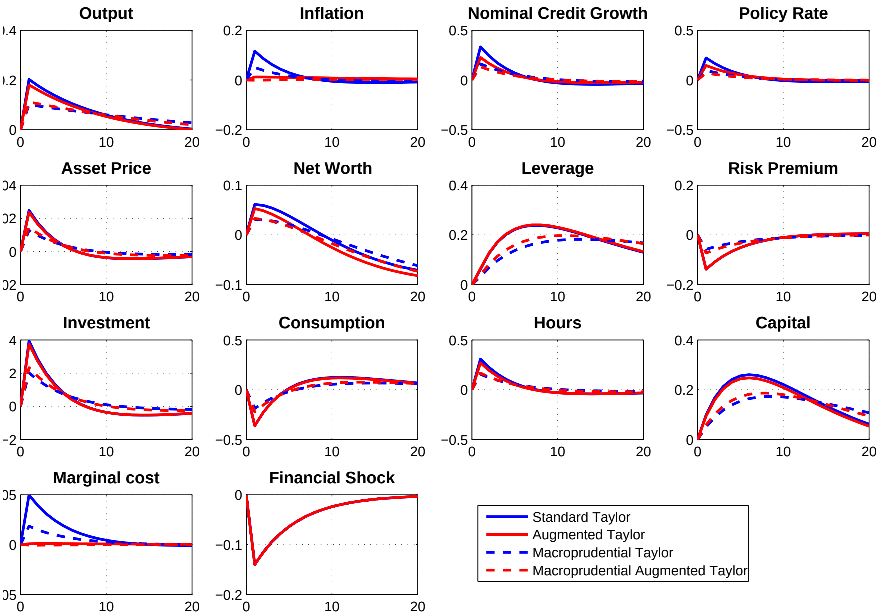


Figure 6: Effects of a Positive Technology Shock (non-smoothing case)