The Macroeconomic Implications of Changes in Bank Capital and Liquidity Requirements in Canada: Insights from BoC-GEM-Fin*

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Abstract

The authors rely on simulations within the Bank of Canada's version of the Global Economy Model with financial frictions (BoC-GEM-Fin) to study the macroeconomic effects on Canada of changes in the regulation of banks. More specifically, the authors compute short- and long-run implications for key macroeconomic and financial variables following increases in the minimum capital and liquidity banks that are required to hold. Their results indicate that, while long-run effects on bank loans, lending spreads, investment, and output are modest, the short-run effects are non-negligible. The authors demonstrate that (*i*) the time horizon for implementation of the changes in regulation, (*ii*) the response of monetary policy, and (*iii*) spillovers from changes in regulation in other economies are important factors that have an impact on the size and duration of the economic downturn observed in the short run following the changes in bank regulation.

Key Words: macroprudential rules, bank capital, leverage ratio, liquidity.

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1 Introduction

The aftermath of the 2007−09 financial crisis has prompted policy-makers to discuss macroprudential rules as a way of mitigating the potentially destabilizing effects of procyclical leveraging in the banking system. Two important aspects of the macroprudential rules currently being discussed are the implementation of (*i*) stronger (possibly counter-cyclical) bank capital and (*ii*) liquidity requirements to the banking system. This paper is part of the effort undertaken by the Macroeconomic Assessment Group (MAG) put forward by the Bank for International Settlements (BIS), whereby central banks and other policy institutions worldwide use a diverse set of research protocols to assess the macroeconomic effects of changes in capital and liquidity requirements in their respective economies.[1,2]

More specifically, this paper discusses the macroeconomic impacts on Canada of changes, implemented both in Canada and worldwide, in the capital and liquidity requirements of the banking system. The methodology relies on simulations within the Bank of Canada's version of the Global Economy Model (Lalonde and Muir 2007), a five-sector, five-region dynamic stochastic general-equilibrium (DSGE) model that was recently modified (de Resende, Dib, Lalonde, and Snudden, forthcoming) to include: (*i*) a financial accelerator mechanism à la Bernanke, Gertler, and Gilchrist (1999), and (*ii*) an active banking sector, consisting of optimizing monopolistically competitive banks that interact in an interbank market, following Dib (2010). We refer to this updated version of the model as the BoC-GEM-Fin.

The experiments we describe consist of permanent *increases* in the minimum capital requirement that banks must satisfy. The change is gradually (linearly) implemented over a given time horizon, at the end of which the minimum capital requirement reaches a new permanent value. To capture the (pure) effect of tighter bank capital regulation, one type of experiment considers increases in the minimum capital requirement to satisfy different target levels for its own new steady state value. Another type of experiment focuses instead on the changes in the minimum capital requirement needed to generate a targeted increase in the ratio of liquid assets to total assets held by banks.

Given the structure of the banking system in the model, whereby banks combine funds borrowed in the interbank market with "bank capital" raised from households, there are two *direct* channels through which an increase in the minimum capital requirement affects the economy. The first channel is the effect on the marginal cost of loan supply, as banks need more "input" (capital)

[1] Several central banks, including the Bank of Canada, and the International Monetary Fund are participants in this research program. A number of approaches are being used in the MAG study, such as (*i*) reduced-form empirical examinations of the relationship between bank capital, lending conditions, and growth, (*ii*) "satellite models" to map stylized facts about capital and liquidity positions into forecast paths for credit spreads and bank lending, which can then be used in standard macroeconomic models; and (*iii*) structural (dynamic stochastic general equilibrium models) or semi-structural models used at various central banks.

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to produce one unit of "output" (loans), ceteris paribus. As banks operate in a monopolistically competitive environment, this extra cost is transferred to borrowers through a higher lending rate. This rise in the lending rate has a negative effect on entrepreneurial net worth and, due to the financial accelerator mechanism, leads to an increase in risky spreads, pushing up the firms' external financing costs. This produces a fall in domestic investment and GDP.

The second channel is the direct effect of the increase in the minimum capital requirement on the optimal capital-to-loans ratio chosen by banks. For instance, the more strict capital requirement regulation induces banks to optimally deleverage, which they can do by either reducing the risky loans made to firms or by raising additional bank capital in the market. When banks deleverage by making fewer loans, investment and output fall. The choice about which combination banks will use to deleverage (i.e., reducing loans and/or increasing capital) depends on the relative opportunity costs: banks weigh the marginal loss in revenues from reducing loans with the marginal increase in costs from raising additional bank capital. If bank capital is costly to adjust, households demand a high return to supply a given amount of bank capital to banks, reducing the responsiveness of bank capital to exogenous shocks. Thus, if banks face a change in policy that requires a higher capital-to-loans ratio, when bank capital is costly for households to adjust, the deleveraging process tends to be biased towards the reduction in loans rather than the increase in bank capital.

The global aspect of BoC-GEM-Fin allows for spillover effects on Canada from changes in the bank capital regulation implemented in foreign economies. The spillover effects come from two separate channels that reinforce each other. First, because domestic firms also borrow from foreign banks, when the change in bank capital regulation also occurs in other economies, the cost of providing loans increases not only for domestic banks (as is the case when the change in policy is implemented in Canada only) but also for foreign banks lending to Canadian firms. Second, the increase in the bank capital requirement in other countries leads to a fall in GDP in those economies according to the channels described above. The fall in economic activity abroad reduces the demand for Canadian exports and negatively affects the terms of trade given Canada's net export position on oil and commodities, whose prices are negatively affected by the global fall in output.

Our results suggest that a permanent increase in the minimum capital requirement induces small permanent reductions in bank lending and GDP, as well as modest permanent increases in lending spreads over the policy rate. However, the transition dynamics between the two steady states suggests that the short-term effects are non-negligible. A clear policy recommendation implied by the simulations is that it is best to implement the change in policy over a longer horizon in order to reduce the impact on spreads and on economic activity: as the phase-in period of implementation of the new policy gets longer, the part of the "shock" that is unexpected is reduced, and agents have more time to adjust by smoothing out the effects of several adjustment costs and distortions

they face.

Moreover, the response of monetary policy matters greatly for the implications of the changes in capital and liquidity requirements, as do spillover effects from changes in policy in other economies. When the monetary policy reaction to the fall in inflation resulting from the slowdown in economic activity is temporarily limited, such that the policy rate does not fall as it would otherwise, the resulting higher real interest rate increases the negative effect of the permanent rise in the minimum capital requirement. Similarly, taking into account spillover effects, the temporary fall in Canadian GDP when the changes in the regulatory policy are implemented worldwide is larger compared with the case in which the changes are introduced only in Canada.

The rest of this paper is organized as follows. Section 2 provides a short description of how the banking system is modelled in the BoC-GEM-Fin. Section 3 explains the policy experiments, while section 4 discusses the results, including sensitivity analyses around some key assumptions; and section 5 offers concluding remarks.

2 The BoC-GEM-Fin

The Bank of Canada's version of the Global Economy Model (GEM) with financial frictions (BoG-GEM-Fin) is a five-sector, five-region dynamic stochastic general-equilibrium model which has been adapted from the original GEM developed at the International Monetary Fund (IMF). The latest version of the model has been modified in two important ways to include: (*i*) a financial accelerator mechanism à la Bernanke, Gertler and Gilchrist (1999), and (*ii*) an active banking sector, following Dib (2010). Since previous versions of the model have been extensively documented elsewhere, we focus on a more detailed description of the banking sector, which plays a central role in the simulation exercises discussed in section 3. We keep the description of the other features of the model relatively short and non-technical.[3]

The five regional blocks in the model, encompassing the entire world economy, are: Canada, the United States, emerging Asia, a block for commodity exporting countries, and a residual economy to account for the remaining countries in the global economy.[4] The economy in each of the regional blocks is modelled symmetrically and consists of households, a government, a monetary authority, two types of heterogeneous monopolistically competitive banks that interact in an interbank market, and a multi-tiered production sector that includes risk neutral entrepreneurs, capital producers, monopolistically competitive retail firms, and perfectly competitive wholesale firms.

[3] For the original GEM, see Pesenti (2008). Lalonde and Muir (2007) discuss the first adaptation of GEM to include both (*i*) a separate regional block for Canada and (*ii*) two extra production sectors, namely oil and non-energy commodities. The latest version of the model, including the financial accelerator and a banking sector, is described in de Resende, Dib, Lalonde, and Snudden (forthcoming).

[4] Commodity exporters include OPEC countries, Norway, Russia, South Africa, Australia, New Zealand, Argentina, Brazil, Chile, and Mexico. The "remaining countries" region effectively represents the European Union (EU) and Japan, given the relatively small economic significance of Africa.

Households. There are two types of households in BoC-GEM-Fin, "forward-looking" (or *Ricardian*) and "liquidity-constrained" (or *non-Ricardian*) agents. Both types derive utility from consumption and leisure, supply differentiated labour inputs used by domestic firms, and set nominal wages in a monopolistically competitive way. Wage setting is subject to rigidities in the form of quadratic adjustment costs. To better capture the observed sluggishness in consumption and the labour supply, there is habit persistence in both variables. Forward-looking households, in addition to consumption and leisure, also derive utility from the liquidity services originated in their holdings of bank deposits, which they optimally choose along with their current level of consumption and labour effort. They own all domestic firms and banks, and can optimize inter-temporally by saving part of their income on government bonds, foreign assets, bank deposits, and "bank capital," which they supply to banks. Therefore, the supply of bank capital evolves according to the saving decisions by households. On the other hand, liquidity-constrained agents only optimize intra-temporally (i.e., consumption *versus* leisure), have no access to capital markets, do not hold any assets or liabilities, and consume all their current after-tax labour income and tranfers. The distinction between the two types of households helps the model to capture important non-Ricardian behaviour observed among a significant fraction of consumers, as documented by Campbell and Mankiw (1989) and Evans (1993). Moreover, the presence of non-Ricardian agents is consistent with the failure of the permanent income hypothesis in explaining changes in aggregate consumption (Gali, Lopez-Salido and Valles, 2004) in that it mitigates the importance of Ricardian equivalence (Mankiw, 2000).

Production. There are five productive sectors in the model, providing a rich production structure to capture the transmission of different shocks to the economy. Production technology in all sectors and regions is represented by a constant-elasticity-of-substitution (CES) production function. Monopolistically competitive retail firms operating in two primary sectors – (*i*) Crude oil and (*ii*) non-energy commodities – use capital, labour, and a fixed factor (oil reserves, in the case of oil, and natural resources in the production of commodities) as inputs to produce goods that will either enter the domestic production of refined petroleum (fuel), tradable, and non-tradable goods, or be exported.[5] Capital, labour, and crude oil are also used as inputs by retail producers of (*iii*) fuel, (*iv*) tradable, and (*v*) non-tradable goods, which are also treated as differentiated goods. Firms in the tradable and non-tradable sectors, in addition to capital, labour, and crude oil, also use non-energy commodity as input. The production of tradable goods is partially exported, while the remaining part is sold, along with the production of fuel and non-tradable goods, to two types of competitive wholesale firms. Except for the producers of crude oil outside the commodity exporting region, retailers in all five sectors set their prices as a mark-up over marginal costs, taking

[5] More preciselly, due to a very high calilbrated value for the elasticity of substitution, oil production behaves as perfectly competive in all but the commodity exporting region. That is, oil is assumed to be a homogeneous product across producers and regions, except for the commodity exporting region, where there is some level of product differentiation. This assumption is needed to generate sensible behaviour of global oil prices.

into account quadractic adjustment costs defined on the change of of their nominal prices relative to a target.[6] In addition to this type of nominal rigidity, retailers in the oil and non-energy commodity sectors also face real rigidities in the form of quadractic adjustment costs when changing their usage of capital and labour. In the final stage of production, the wholesale firms aggregate the production of fuel, non-tradable goods, and tradable goods (non-exported domestic production plus imports), using a CES technology, into two types of homogeneous final goods that will be used either for consumption or investment.[7]

Capital producers. For each sector-specific type of physical capital, there is a single, representative, competitive capital producer who combines newly produced equipment (investment goods purchased from wholesalers) with used, undepreciated capital (purchased from entrepreneurs) to produce new capital, which is then re-sold to entrepreneurs to be used in next period's production cycle. The production of new capital is equal to investment, I_t, net of quadratic adjustment costs.[8] The solution to the optimization problem of capital producers generates the following standard Tobin's Q equation where the price of capital, Q_t^k, is determined:

$$\frac{1}{Q_t^k} = \Upsilon_t - \chi_I \left(\frac{I_t}{I_{t-1}} - 1\right)^2 \frac{I_t}{I_{t-1}} + \beta \chi_I E_t \left[\left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2 \frac{Q_{t+1}^k}{Q_t^k}\frac{\lambda_{t+1}}{\lambda_t}\right], \tag{1}$$

where E_t is the expectations operator conditional on information available at time t, Υ_t is a shock to the marginal eficiency of investment, χ_I is the adjustment cost parameter, and λ_t is the marginal utility of consumption from Ricardian households.

Entrepreneurs are risk neutral agents who have a finite expected life span, or planning horizon, and are provided with a particular ability to manage capital. At each period t, entrepreneurs rent different types of sector-specific physical capital to the retail firms in a competitive capital market. The supplied capital is purchased at price Q_t^k from capital producers, using both the entrepreneurs' own resources (i.e., net worth) and bank loans. This capital will be used in the production cycle of time $t+1$. Entrepreneurs optimally demand capital up to the level in which the expected marginal return of capital − given by the marginal productivity of capital, r_{t+1}^K, plus the value of one extra unit of undepreciated capital, $(1-\delta)\,Q_{t+1}^k$ − equals the expected marginal external financing cost

$$E_t\left[r_{t+1}^K + (1-\delta)\,Q_{t+1}^k\right] = Q_t^k E_t F_{t+1}. \tag{2}$$

The loan contract between entrepreneurs and banks is introduced through a reduced-form representation of the optimal contract discussed in Bernanke, Gertler and Gilchrist (1999), henceforth refered as BGG. In BGG's framework, entrepreneurs experience idiosyncratic shocks that may be

[6] This target is a weighted average of last period's sector-wide price inflation and the economy-wide inflation target. See Lalonde and Muir (2007), p.28.

[7] There is also a "government services" final good, which aggregates consumption, investment, and non-tradable goods.

[8] The quadratic adjustment cost function is given by $\frac{\chi_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 I_t$.

adversely severe enough to induce them to default on their bank loans. For a given (non-contingent) interest rate on bank loans, the risk-neutral entrepreneurs would demand an infinite amount of loans. However, there would be no corresponding supply since these loans are risky to banks because of asymmetric information: only entrepreneurs, but not banks, observe the realization of the idiosyncratic shocks. To learn about the threshold-level of the idiosyncractic shock that induces default by entrepreneurs, banks need to pay a monitoring cost. In addition, when entrepreneurs default, banks must pay agency costs to retrieve part of the value on the defaulted loan.

Given the asymmetric information problem, no equilibrium is possible unless (*i*) entrepreneurs and banks enter an arrangement whereby the former are constrained in the amount of loans they can receive from the latter, and (*ii*) banks are compensated for the risks involved. This is achieved by a loan contract that maximizes the payoff to the entrepreneurs, subject to the bank earning a rate of return on the risky loan that is enough to cover the expected costs associated with default. BGG show that − given parameter values associated with the monitoring and agency costs, the characteristics of the probability distribution of entrepreneurial returns, and the expected life span of entrepreneurs − the standard loan contract implies an interest rate on loans that includes a premium, rp_t. This risk premium on the external financing cost to entrepreneurs inversely depends on the entrepreneurs' equity stake in a project or, alternatively, on their leverage ratio defined as the ratio between the loans obtained from banks and the entrepreneurs' net worth.[9] Based on BGG, in BoC-GEM-Fin the external finance premium, in real terms, is assumed to have the following functional form:

$$rp_t \equiv \left(\frac{Q_t^k K_{t+1}}{N_t}\right)^{\psi_t} = \left(1 + \frac{L_t}{N_t}\right)^{\psi_t}, \tag{3}$$

where $Q_t^k K_{t+1}$ is the market value of physical capital purchased at time t to be used at time $t+1$, K_{t+1}, and evaluated at the price Q_t^k; N_t is entrepreneurial net worth, L_t is the amount of bank loans, and ψ_t is a time-varying parameter that governs the elasticity of the external finance premium with respect to the entrepreneurs' leverage ratio. Following Christiano, Motto and Rostagno (2009), ψ_t is treated as an aggregate "risk shock" that follows an AR(1) process. A positive innovation to ψ_t, which increases the external financing risk premium, may result from (*i*) an exogenous increase in the standard deviation of the entrepreneurs' idiosyncratic shocks, (*ii*) an exogenous reduction in the entrepreneurs' default threshold, and/or (*iii*) an exogenous increase in monitoring and agency costs.[10]

[9] For a given amount of entrepreneurial net worth, N_t, a higher value of desired purchases of capital means that the borrower increasingly relies on uncollateralized debt (higher leverage) to fund the project. This raises the incentive to misreport the outcome of the project and increases the risk associated with the loan. The cost of borrowing rises, as the loans riskiness increases, because the agency costs also rise due to the increase in the banks' expected losses. The higher external finance premium paid by non-defaulting entrepreneurs compensates for such larger expected losses.

[10] A higher standard deviation on the probability distribution of the entrepreneurs' idiosyncractic shocks implies that is harder for lending banks to distinguish the quality of the entrepreneurs. Morever, a lower threshold for default means that less severe adverse shocks can trigger the payment of agency costs by banks.

Moreover, since net worth tends to be procyclical − due, for example, to the procyclicality of profits and asset prices − and persistent, the premium tends to be counter-cyclical and long lasting. Therefore, changes in net worth tends to amplify and propagate movements in borrowing, investment, and production. As a result, financial frictions may significantly amplify the magnitude and persistence of business cycles − the so-called financial accelerator effect (Bernanke, Gertler, and Gilchrist 1999).

Following Dib (2010), the marginal external financing cost equals the real interest rate on funds borrowed from banks, given by the gross real prime lending rate plus the external finance premium, rp_t:

$$E_t F_{t+1} = E_t \left[\frac{R_t^L}{\pi_{t+1}} rp_t \right], \tag{4}$$

where R_t^L is the gross (nominal) prime lending rate, which is set by lending banks and depends on the marginal cost of "producing" loans, and $\pi_{t+1}$is the next period gross inflation rate.

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

$$N_t = \nu \left[F_t Q_{t-1}^k K_t - E_{t-1} F_t \left(Q_{t-1}^k K_t - N_{t-1} \right) \right] + (1-\nu)\, g_t. \tag{5}$$

Equation (5) shows that both F_t and $E_{t-1}F_t$, respectivelly the *ex post* and *ex ante* real external finance cost matter for the valuation of the current net worth. The former represents the realized (gross) real return on capital, and positively affects net worth. Using the *ex post* version of (2), after uncertainty is resolved at time t, the value of F_t is determined as:

$$F_t = \left[r_t^K + (1-\delta)\, Q_t^k \right] / Q_{t-1}^k. \tag{6}$$

On the other hand, $E_{t-1}F_t$ is pre-determined at time t. It represents the cost entrepreneurs had faced at time $t-1$ when they needed to borrow the amount $Q_{t-1}^k K_t - N_{t-1}$ in order to buy the capital to be used at time t. Note that the nominal interest rate on loans is set at time $t-1$, when the debt contract is signed, to be effective at time t, as shown by the version of (4) lagged of one period.

Government. The government in each region levies labour and capital income taxes, purchases consumption, investment goods, and non-tradable goods (services), and makes tranfers to house-

houlds. Government investment expenditure accumulates into a stock of government capital which positively affects the total factor productivity (TFP).[11] Expenditures in excess of tax revenues are financed by borrowing from domestic households. To insure a well-defined balanced growth path, the net labour tax rate adjusts so that government debt eventually conforms to a constant long-run debt-to-GDP ratio. All domestic debt is exclusively held by domestic forward-looking households, with the exception of the government debt in the United States, which is traded at the (incomplete) international financial market as the only international bond, denominated in U.S. dollars. The interest rate paid on each type of bond is equal to the policy rate in the country that issued the bond plus a country-specific risk premium that depends on the region's net foreign asset position (as a share of GDP) and insures a well-defined balanced growth path, in terms of a constant ratio of net foreign asset holdings to GDP in each region.

Monetary policy is modelled according to a stylized, forward-looking Taylor-type interest rate reaction function. For all regions other than emerging Asia, the monetary authority targets core inflation (defined as the consumer price index excluding fuel and oil prices) through the short-term interest rate. The emerging-Asian monetary authority targets a fixed nominal exchange rate with the United States dollar. The monetary authority can also engage in quantitative easing by providing money injections to lending banks, and in qualitative easing by allowing lending banks to swap a fraction of their risky loans for risk-free government bonds.

As the BoC-GEM-Fin falls into the new Keynesian tradition, there are several region-specific real adjustment costs and nominal rigidities that allow the monetary policy to have real effects on the economy and help to map important elements (i.e., persistence) observed in the data. Along with external habit persistence in consumption and leisure, monopolistic competition in production of intermediate differentiated goods, and factor mobility adjustment costs, which have been already mentioned, additional examples of real rigidities in the model include adjustment costs on investment, on the share of imported goods coming from any specific region, and in the production and usage of oil. The nominal rigidities are of the Rotemberg-Ireland type of wage and price stickiness as mentioned above.

In general, the calibration of the model's parameters is based on data, microeconomic studies, and by drawing on other dynamic stochastic general-equilibrium models. See Lalonde and Muir (2007) and de Resende *et al.* (forthcoming) for a detailed account of the model's calibration. Regarding the calibration of each region's banking sector, international loan flows are calibrated based on recent movements in loans observed in the International Banking Statistics data maintained by the Bank for International Settlements. The calibration of these international loan flows is used to derive the regional composition of loans to firms. The minimum capital requirement ratio is

[11] The effect of public investment on total output is calibrated to be much lower than that of private investment, though.

calibrated at 8% for all regions, according to level defined in the Basel II agreement, except in Canada where we use 10% of minimum capital-to-loans ratio as required by Canadian regulators.

2.1 The Banking System in the BoC-GEM-Fin

The banking sector within BoC-GEM-Fin follows Dib (2010). Without loss of generalization, we separately analyze the optimization problems of banks operating under two situations regarding their net positions in the interbank market.

Banks lending in the interbank market.[12] There is a continuum of monopolistically competitive, profit maximizing banks indexed by $j \in (0,1)$ that collect fully insured deposits ($D_{j,t}$) from households and pay a deposit interest rate $\left(R^D_{j,t}\right)$, which they optimally set as a mark-down over the marginal return of their assets. As in Gerali *et al.* (2009), given the monopolistic competition and imperfect substitution between deposit services provided to households, the j^{th} bank faces an individual deposit supply function that is increasing in (i) the deposit interest rate relative to the market average, R^D_t, and (ii) the total supply of deposits by households, D_t:

$$D_{j,t} = \left(\frac{R^D_{j,t}}{R^D_t}\right)^{\vartheta_D} D_t, \tag{7}$$

where $\vartheta_D > 1$ is the elasticity of substitution between different types of deposits.[13] In setting $R^D_{j,t}$, banks are assumed to face quadratic adjustment costs à la Rotemberg (1982) to varying the deposit interest rate, which allows an interest rate spread that evolves over the business cycle. We assume adjustment costs given by:

$$Ad^{R^D}_{j,t} = \frac{\phi_{R^D}}{2}\left(\frac{R^D_{j,t}}{R^D_{j,t-1}} - 1\right)^2 D_t, \tag{8}$$

where $\phi_{R^D} \geq 0$ is an adjustment cost parameter.[14]

A fraction $s_{j,t}$ of the total deposits is then optimally allocated to provide loans to other banks in the interbank market, while $(1 - s_{j,t})\, D_{j,t}$ is used to buy risk-free government bonds, $B_{j,t}$. When investing in risky assets, by lending in the interbank market, banks must pay a quadratic monitoring cost that depends on the amount lent. At each period there is a probability δ^D_t that borrowing banks in the interbank market will default on their loan contracts. The optimal allocation of the collected deposits between the two instruments, risky interbank loans and risk-free government

[12] Dib (2010) refers to the banks that are net creditors in the interbank market as "savings banks," while banks that borrow in the interbank market to lend to entrepreneurs are called "lending banks."

[13] This supply function is derived from the definition of aggregate supply of deposits, D_t, and the corresponding deposit interest rate, R^D_t, in the monopolistic competition framework, as follows: $D_t = \left(\int_0^1 D_{j,t}^{\frac{1+\vartheta_D}{\vartheta_D}} dj\right)^{\frac{\vartheta_D}{\vartheta_D+1}}$ and $R^D_t = \left(\int_0^1 {R^D_{j,t}}^{1+\vartheta_D} dj\right)^{\frac{1}{1+\vartheta_D}}$, where $D_{j,t}$ and $R^D_{j,t}$ are the supply and deposit interest rate faced by each savings bank $j \in (0,1)$.

[14] In the current calibration of BoC-GEM-Fin, ϕ_{R^D} is set to zero.

bonds, depends on the returns earned on the riskless government bonds and risky loans, R_t and R_t^{IB} (which are determined by the policy rate and by the equilibrium in the interbank market, respectivelly), as well as on the cost of monitoring the borrowing banks and the probability of default on interbank lending.[15]

Formally, the problem of the j^{th} bank that lends in the interbank market is:

$$\max_{\{s_{j,t},R_{j,t}^D\}} E_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \left\{ \left[s_{j,t} \left(1-\delta_t^D\right) R_t^{IB} + \left(1-s_{j,t}\right) R_t - R_{j,t}^D \right] D_{j,t} - \frac{\chi_s}{2} \left(s_{j,t} D_{j,t}\right)^2 - A d_{j,t}^{R^D} \right\},$$

subject to (7) and (8), taking R_t^{IB}, R_t, and δ_t^D as given. Since forward-looking households are the owners of banks, the stream of profits is discounted by $\beta^t \lambda_t$, where λ_t denotes the marginal utility of consumption; the terms $\frac{\chi_s}{2} \left(s_{j,t} D_{j,t}\right)^2$ represent the quadratic monitoring cost of lending in the interbank market, and $\chi_s > 0$ is a parameter determining the steady-state level of these costs.

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

$$s_t = \frac{\left(1-\delta_t^D\right) R_t^{IB} - R_t}{\chi_s D_t}; \tag{9}$$

$$R_t^D = \frac{\vartheta_D}{1+\vartheta_D} \left[s_t \left(1-\delta_t^D\right) R_t^{IB} + \left(1-s_{j,t}\right) R_t - \chi_s {s_t}^2 D_t - \frac{\Omega_t}{\vartheta_D} + \frac{\beta \lambda_{t+1}}{\lambda_t} \frac{\Omega_{t+1}}{\vartheta_D} \left(\frac{D_{t+1}}{D_t} \right) \right], \tag{10}$$

where

$$\Omega_t \equiv \phi_{R^D} \left(\frac{R_t^D}{R_{t-1}^D} - 1 \right) \frac{R_t^D}{R_{t-1}^D}$$

is the marginal cost of adjusting the deposit interest rate.

Condition (9) describes the share of deposits allocated to interbank lending as decreasing in the probability of default on interbank lending, in the interest rate on government bonds, and in the total supply of deposits, while increasing in the interbank rate. An increase in s_t indirectly leads to an expansion in credit supply available in the interbank market, which will be used to "produce" loans to entrepreneurs. Condition (10) defines the deposit interest rate as a mark-down of the interbank rate.[16]

Banks borrowing in the interbank market combine the funds obtained from other banks, $\widetilde{D}_{j,t} = \left(1-s_t\right) D_t$, with the value of "bank capital" raised from households, $Q_t^Z Z_{j,t}$, to supply loans, $L_{j,t}$, to entrepreneurs. The stock of bank capital, $Z_{j,t}$, priced at Q_t^Z, is held by banks as government bonds that pay the risk-free rate, R_t. To produce loans for entrepreneurs, the j^{th} individual uses the following Leontief technology:

$$L_{j,t} = \min \left\{ \widetilde{D}_{j,t}; \kappa_{j,t} Q_t^Z Z_{j,t} \right\} \Gamma_t, \tag{11}$$

[15] The marginal return of bank deposits depends on the interbank rate, the probability of default on inter-bank borrowing, the policy rate, and on the marginal cost of monitoring borrowing banks, as shown in equation (10).

[16] This equation allows us to derive a "New-Philips curve" type equation for R_t^D.

where Γ_t is a AR(1) shock to the intermediation process (loan production), that represents exogenous factors affecting the bank's balance sheet, perceived changes in creditworthiness, technological changes in the intermediation process due to advances in computational finance and sophisticated methods of sharing risk, among other things.

The return on loans to entrepreneurs is given by the prime loan rate, $R^L_{j,t}$, plus the risk premium, rp_t, that accounts for the costly state verification framework within BGG, as discussed above. The rate $R^L_{j,t}$ is optimally set by bank j in a monopolistically competitive way, as a mark-up over the marginal cost of "producing" loans. When lending to entrepreneurs, bank j face the following Dixit-Stiglitz demand function for loans resulting from the monopolistic competitive set up:

$$L_{j,t} = \left(\frac{R^L_{j,t}}{R^L_t}\right)^{-\vartheta_L} L_t, \tag{12}$$

where $\vartheta_L > 1$ is the elasticity of substitution between different types of loans provided by different lending banks.[17]

As in the problem of setting deposit rates, there are also nominal rigidities in setting $R^L_{j,t}$: banks must pay a cost when adjusting the nominal rate across periods. Again, following Gerali *et al.* (2009), these adjustment costs are modelled à la Rotemberg (1982):

$$Ad^{R^L}_{j,t} = \frac{\phi_{R^L}}{2}\left(\frac{R^L_{j,t}}{R^L_{j,t-1}} - 1\right)^2 L_t, \tag{13}$$

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

The j^{th} individual bank not only can optimally default on a share of its interbank borrowing, but also renege part of the return on the bank capital, R^Z_t. The optimally chosen shares of interbank borrowing and bank capital that the bank defaults on are $\delta^D_{j,t}$ and $\delta^Z_{j,t}$, respectively. When banks default, they must pay convex penalties, Ω^D_t and Ω^Z_t, in the next period. The functional forms are:

$$\Omega^D_t = \frac{\chi_{\delta^D}}{2}\left(\frac{\delta^D_{j,t-1}\widetilde{D}_{j,t-1}}{\pi_t}\right)^2 R^{IB}_{t-1} \text{ and} \tag{14}$$

$$\Omega^Z_t = \frac{\chi_{\delta^Z}}{2}\left(\frac{\delta^Z_{j,t-1}Q^Z_{t-1}Z_{j,t-1}}{\pi_t}\right)^2 R^Z_t, \tag{15}$$

where χ_{δ^D} and χ_{δ^Z} are positive parameters.[18]

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

$$\kappa_{j,t} = L_{j,t}/Q^Z_t Z_{j,t}, \tag{16}$$

[17] This demand function is derived from the definition of aggregate demand of loans, L_t, and the corresponding prime lending rate, R^L_t, in the monopolistic competition framework, as follows: $L_t = \left(\int_0^1 L_{j,t}^{\frac{1-\vartheta_L}{\vartheta_L}} dj\right)^{\frac{\vartheta_L}{1-\vartheta_L}}$ and $R^L_t = \left(\int_0^1 R^{L\,1-\vartheta_L}_{j,t} dj\right)^{\frac{1}{1-\vartheta_L}}$, where $L_{j,t}$ and $R^L_{j,t}$ are the loan demand and lending rate faced by each lending bank $j \in (0,1)$.

[18] This penalty generates a spread over the interbank rate.

but must satisfy a maximum leverage ratio (i.e., a minimum capital requirement) set by regulators:[19][20]

$$\kappa_{j,t} \leq \overline{\kappa}.$$

Before formally stating the optimization problem of banks that borrow in the interbank market, let us make the aditional assumption that well-capitalized banks derive quadratic gains when raising bank capital from households. More specifically, when choosing $\kappa_{j,t} < \overline{\kappa}$ (more bank capital than required by regulators) the quadratic gains are given by:

$$\Omega_t^{\kappa} = \frac{\chi_{\kappa}}{2}\left(\frac{\overline{\kappa} - \kappa_{j,t}}{\overline{\kappa}} Q_t^Z Z_{j,t}\right)^2, \tag{17}$$

where $\chi_{\kappa} > 0$ is a parameter determining the steady-state value of κ_t.

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

$$\max_{\{R_{j,t}^L, \kappa_{j,t}, \delta_{j,t}^D, \delta_{j,t}^Z\}} E_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \left\{ R_{j,t}^L L_{j,t} - (1-\delta_{j,t}^D) R_t^{IB} \widetilde{D}_{j,t} - \left[(1-\delta_{j,t}^Z) R_{t+1}^Z - R_t\right] Q_t^Z Z_{j,t} \right.$$
$$\left. -\Omega_t^D - \Omega_t^Z + \Omega_t^{\kappa} - A d_{j,t}^{R^L} \right\}$$

subject to (11)−(15) and (17).[21]

The first-order conditions of this optimization problem, in a symmetric equilibrium, where all banks take the same decisions, are:

$$\kappa_t = \overline{\kappa}\left[1 - \frac{\Gamma_t \overline{\kappa}(R_t^L - 1)}{\chi_{\kappa} Q_t^Z Z_t}\right]; \tag{18}$$

$$\delta_t^D = E_t\left[\frac{\pi_{t+1} R_t}{\chi_{\delta^D} \widetilde{D}_t}\right]; \tag{19}$$

$$\delta_t^Z = E_t\left[\frac{\pi_{t+1} R_t}{\chi_{\delta^Z} Q_t^Z Z_t}\right]; \tag{20}$$

$$R_t^L = 1 + \frac{\vartheta_L}{\vartheta_L - 1}(\zeta_t - 1) - \frac{\phi_{R^L}}{\vartheta_L - 1}\left(\frac{R_t^L}{R_{t-1}^L} - 1\right)\frac{R_t^L}{R_{t-1}^L}$$
$$+ \frac{\beta \lambda_{t+1}}{\lambda_t}\frac{\phi_{R^L}}{\vartheta_L - 1} E_t\left[\left(\frac{R_{t+1}^L}{R_t^L} - 1\right)\frac{R_{t+1}^L}{R_t^L}\right], \tag{21}$$

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

$$\zeta_t = \Gamma_t^{-1}\left\{R_t^{IB} + \left[R_{t+1}^Z - R_t - (R_t^L - 1)\frac{\overline{\kappa} - \kappa_t}{\overline{\kappa}}\right]\frac{Q_t^Z}{\kappa_t}\right\} \tag{22}$$

[19] The term "bank leverage ratio" usually has a broader interpretation in that it includes the ratio of *total* assets over capital. In this paper, we only consider the risky assets (i.e., loans).

[20] Note that $\kappa_{j,t}$ is the ratio of bank loans to bank capital. Therefore, the minimun bank capital reqirement ratio is $1/\overline{\kappa}$.

[21] Given the assumption that bank capital is held by banks as government bonds, the term $\left[(1-\delta_{j,t}^Z) R_{t+1}^Z - R_t\right] Q_t^Z Z_{j,t}$ denotes the net cost of holding bank capital. It depends on the return paid on non-defaulted bank capital net of the return from holding bank capital as government bonds.

is the marginal cost of producing loans.

Using Leontief technology to produce loans implies perfect complementarity between interbank borrowing and bank capital. Furthermore, the marginal cost of producing loans is simply the sum of the marginal cost of interbank borrowing, R_t^{IB}, and that of raising bank capital (including the shadow price of using capital to satisfy the capital requirement) adjusted by the leverage ratio, given by $\left[R_{t+1}^Z - R_t^{IB} - \left(R_t^L - 1\right)\left(\overline{\kappa} - \kappa_t\right)/\overline{\kappa}\right] Q_t^Z/\kappa_t$.

Therefore, the optimal choice of the leverage ratio, κ_t, direcly affects the cost of lending through its impact on the cost of raising bank capital and the marginal cost of producing loans. In addition, the Leontief technology implies the following implicit demand functions of interbank borrowing and bank capital:

$$L_t = \Gamma_t \widetilde{D}_t; \tag{23}$$

$$L_t = \Gamma_t \kappa_t Q_t^Z Z_t. \tag{24}$$

Equation (18) shows that banks optimally reduce their leverage ratio following a reduction in the regulatory limit, $\overline{\kappa}$. In addition, κ_t is decreasing on the lending rate and increasing in the value of bank capital as a higher R_t^L reduces the demand for loans and a lower $Q_t^Z Z_t$ reduces the net marginal cost of raising bank capital. Equation (19) indicates that the banks' default rate on interbank borrowing, δ_t^D, decreases with the total amount borrowed and increases with both the future inflation and the policy rate. This is because both a higher $\widetilde{D}_t$ and a lower π_{t+1} increase the real marginal value of the penalty in case of default at time t, while a higher $R_t = \lambda_t/\beta\lambda_{t+1}$ implies a higher (discounted value of) marginal cost of default at $t+1$. For similar reasons, condition (20) implies that banks will decrease default on the return on bank capital owned to households when the value of bank capital increases, or when either the future inflation and/or the policy rate decrease. Equation (21) relates the prime lending rate, R_t^L, to the marginal cost of producing loans, ζ_t, and to current costs and future gains of adjusting the prime lending rate.

The law of motion of bank capital, as previously mentioned is determined by the saving decisions of households. Households must pay a quadratic cost in order to adjust their holdings of bank capital, Adj_t^Z, given by:[22]

$$Adj_t^Z = \frac{\chi_z}{2}\left(\frac{\pi_t Z_t}{Z_{t-1}} - \pi\right)^2 Q_t^Z Z_t,$$

where χ_z is an adjustment cost parameter.

From the optimization problem of households, the law of motion of bank capital is then given by:

$$E_t\left\{\frac{Q_{t+1}^Z}{Q_t^Z}\left[\left(1-\delta_t^Z\right)R_{t+1}^Z + MG_t^Z\right]\right\} = R_t\left[1 + MC_t^Z\right], \tag{25}$$

[22] This cost can be interpreted as payments to brokers or, alternativelly, as costs to collect information about the banks balance sheet. On a more technical point of view, this cost helps avoid an excessive volatility in the stock of bank capital, inducing a more realistic, sluggish behaviour of Z_t.

where:[23]

$$MC_t^Z = -\frac{\partial Adj_t^Z}{\partial Z_t}/Q_t^Z = -\chi_z\left(\frac{\pi_t Z_t}{Z_{t-1}}-\pi\right)\frac{\pi_t Z_t}{Z_{t-1}},$$
$$MG_t^Z = \frac{\partial Adj_{t+1}^Z}{\partial Z_t}/Q_{t+1}^Z = \chi_z\left(\frac{\pi_{t+1} Z_{t+1}}{Z_t}-\pi\right)\left(\frac{Z_{t+1}}{Z_t}\right)^2\pi_{t+1}.$$

Note that households will optimally hold bank capital to equalize the total marginal cost of saving Q_t^Z units of consumption using bank capital at time t with the (present discount value of the) total marginal benefit of the foregone consumption evaluated at time $t+1$. The marginal cost is given by the Q_t^Z units of foregone consumption plus the marginal adjustment cost of changing the current holdings of bank capital at the current price, $Q_t^Z MC_t^Z$. The benefit, which is evaluated at price Q_{t+1}^Z, consists of two parts. The first component is the expected rate of return on bank capital taking into account that a fraction δ_t^Z will be diverted from investors, $\left(1-\delta_t^Z\right)R_{t+1}^Z$. The second component of the benefit is given by the marginal gain,MG_t^Z, that households enjoy by economizing on costs they no longer have to pay for adjusting their holdings of bank capital at time $t+1$, since they already have done so at time t.

3 Policy Experiments

This section describes the experiments we conduct in this paper. We make full use of the global dimension of BoC-GEM-Fin, but we focus on the implications of the different experiments for the Canadian economy. The first set of experiments considers the effect of *permanent* changes in the regulatory policy regarding capital and/or liquidity requirements that are implemented *only* in Canada. A second set of experiments considers the spillover effects on Canada when the regulatory policy also changes in all remaining regions of the global economy.

To study the effects of a stricter bank capital requirement, we permanently reduce the regulatory parameter $\overline{\kappa}$, from the initial value, $\overline{\kappa}_0$, to a new level, $\overline{\kappa}_T$. The reduction in $\overline{\kappa}$ is implemented such that $1/\overline{\kappa}$ *linearly* increases, with equal quarterly changes, over a time-horizon of T years, after which $\overline{\kappa}_T$ becomes the new value for the maximum allowed leverage ratio going forward. We set the initial value of the maximal leverage ratio in Canada to $\overline{\kappa}_0 = 10$, corresponding to a minimum capital requirement ratio of $1/\overline{\kappa}_0 = 10\%$, which mimics the current state of the Canadian banking regulation. For the other regions, following Basel II, we set $1/\overline{\kappa}_0 = 8\%$. Only the first incremental change in $1/\overline{\kappa}$, implemented in 2011Q1, is treated as an unexpected shock. Starting in 2011Q2, the full path of $\overline{\kappa}$ is known and any further increment in $1/\overline{\kappa}$ is fully anticipated. We initially consider six scenarios, in which $1/\overline{\kappa}$ changes only in Canada by 2, 4, and 6 percentage points, from $1/\overline{\kappa}_0$ to new targeted levels of 12%, 14%, and 16%, over phase-in periods of $T = 2, 4$ years. The

[23] The derivative of Adj_t^Z with respect to Z_t includes another term given by $0.5\chi_z\left(\frac{\pi_t Z_t}{Z_{t-1}}-\pi\right)^2 Q_t^Z$, which drops out in linear approximation of (25) around the steady state.

different scenarios for the increase in the capital requirement are indexed by CAi, where $i = 2, 4, 6$ percentage points, while the different horizons (phase-in period) for implementation are indexed by Tj where $j = 2, 4$ refers to 2 and 4 years. For example, $CA2T2$ refers to a scenario in which the minimum capital requirement permanently changes from the initial value of $1/\overline{\kappa}_0 = 10\%$ to 12%, linearly, over a two-year period. On the other hand, scenario $CA4T4$ refers to a permanent change of 4 percentage points in the capital requirement to be completed after 4 years.

Regarding the effects of changes in the regulation of liquidity requirements, we proceed as follows. In BoC-GEM-Fin, the distinction between liquid and illiquid assets is not perfectly clear as all financial assets, including those with implications for the banking system, are one-period assets. However, based on differences in riskiness, we interpret the portion of deposits used to increase the banks' holdings of risk-free government bonds as "liquid," while the remaining part used to provide risky loans in the inter-bank market as "illiquid." Under that interpretation, we consider the ratio of liquid-to-total assets held by banks as:[24]

$$\mu_t = \frac{(1 - s_t) D_t}{(1 - s_t) D_t + L_t}.$$

Since all variables directly affecting the banking system's allocation of assets between liquid and illiquid assets (i.e., s_t, D_t, and L_t) are endogenous to the model, we also implement the liquidity-related experiments through permanent changes in $\overline{\kappa}$. We calibrate the new permanent level of $1/\overline{\kappa}$ such that μ_t permanently increases by 25% and 50% over $T = 2, 4$ years, from its initial value of 18%.[25] The calibrated values of $1/\overline{\kappa}$ that are consistent with the required increases in μ_t are 14% and 18%, respectivelly. The four scenarios for the effects of stricter liquidity requirements are indexed by $LhTj$, where $h = 25, 50$ refers to 25% and 50% permanent increases in the ratio of liquid to total assets, μ_t, respectively. The references to the all alternative scenarios are summarized in Table 1.

Table 1

New value for the capital-to-loans ratio (initial value: $1/\overline{\kappa}_0 = 10\%$)	Phase-in period, years 2	4
+2 percentage points,	CA2T2	CA2T4
+4 percentage points	CA4T2	CA4T4
+6 percentage points	CA6T2	CA6T4
New value for the liquidity ratio (initial value: $\mu_0 = 18\%$)	**Phase-in period, years 2**	**4**
+25%, to 22%	L25T2	L25T4
+50%, to 27%	L50T2	L50T4

[24] In BoC-GEM-Fin, part of the government bonds held by banks in the asset side of the their balance sheet is completely offset by the total amount of bank capital in the liabilities side. This is because the model assumes that bank capital, which banks must hold to satisfy the minimum required by regulators, is held as government securities. As they cancel each other out in terms of banks' balance sheets, we exclude bank capital from the liquidity ratio.

[25] This is the median value of liquidity ratios in the six largest Canadian banks.

Note that permanent changes in $\overline{\kappa}$ imply that the economy will move between two different steady states. In all experiments, we consider a simulation horizon that goes until 2018Q4, over which we compute the effects of the change in regulation on output (measured by the gross domestic product, GDP), investment, headline inflation, the policy interest rate, bank lending, and two interest rate spreads over the policy rate.[26].

3.1 How Changes in $\overline{\kappa}$ Affects the Economy

This subsection discusses the channels through which $\overline{\kappa}$ affects the macro-economy. The first channel is the direct effect of $\overline{\kappa}$ on the marginal cost of producing loans, ζ_t, through (22). Note that an increase in $\overline{\kappa}$, *ceteris paribus*, induces a higher marginal cost to produce loans and, in turn, affects the law of motion of the prime loan rate, R_t^L, according to (21). The increase in R_t^L will negatively affect both the *current* and *future* values of the entrepreneurial net worth. The effect on N_t is a valuation effect: as R_t^L increases, for a given value of the risk premium, investment will cost more and entrepreneurs will demand less capital for the next period. As investment falls at time t, reflecting the reduction in the demand for K_{t+1}, the price of capital also falls, according to (1). The reduction in Q_t^k reduces the *ex post* return on capital, F_t, via (6), and N_t, through (5). On the other hand, the effect of higher R_t^L on N_{t+1} is an expectation effect: the external financial cost entrepreneurs expect to pay at time $t+1$ increases, via (4). The increase in $E_t F_{t+1}$ reduces the next period net worth and increases the future risk premium as seen in the time $t+1$ versions of (5) and (3), respectively. Both effects, on N_t and N_{t+1}, trigger the financial accelerator, with further increases in the risk premium, the expected external financial cost, reductions in net worth, and so on. Therefore, an increase in $\overline{\kappa}$ makes loans more expensive, reducing investment and, thus, output.

The second channel is the indirect effect on ζ_t through the optimal leverage ratio, κ_t, according to equation (18). For example, the more strict capital requirement regulation following the proposed policy experiments (reduction of $\overline{\kappa}$) will induce banks to optimally deleverage, reducing κ_t. From equation (24), abstracting from the exogenous shock Γ_t, banks can deleverage either by reducing the risky loans made to entrepreneurs or by raising additional bank capital in the market. When banks deleverage by making fewer loans to entrepreneurs, investment and output fall.

The choice about which combination of alternatives banks will use to deleverage following a negative shock to $\overline{\kappa}$ (i.e., reducing L_t and/or increasing $Q_t^Z Z_t$) depends on the relative opportunity costs. Banks will weigh the marginal loss in revenues from reducing loans with the marginal increase in costs from raising additional bank capital. One important element in this *trade-off* is the rate of return, R_{t+1}^Z, that banks must pay to households when raising bank capital. This rate depends

[26] The two spreads over the policy rate are computed using the prime loan rate and the external financial cost to entrepreneurs.

on the law of motion of the stock of bank capital, given by equation (25), which is affected by the value of the parameter χ_z. In BoC-GEM-Fin, this parameter is calibrated to match the responses of loans to a diverse set of supply and demand shocks. A higher value of χ_z induces households to demand a higher return R^Z_{t+1} to supply a given amount of bank capital to banks, reducing the responsiveness of bank capital to exogenous shocks. That is, bank capital becomes more costly to adjust and sluggish. If banks are forced to deleverage following a reduction in $\overline{\kappa}$, a high value of χ_z tends to bias the deleveraging process towards the reduction in loans rather than the increase in bank capital, which becomes relatively more costly to raise from households. Since χ_z has crucial implications for the quantitative results discussed in the next section, we provide a sensitivity analysis in section 4.

To summarize, an increase in the minimum capital requirement applied to the domestic banking system affects the economy through the marginal cost of loan supply, as banks need more "input" (capital) to produce one unit of "output" (loans). The higher minimum capital requirement forces banks to reduce loans provided or raise additional bank capital. When banks deleverage by cutting loans, investment is directly affected and falls, followed by GDP. When deleverage implies costly capitalization, the extra cost is transferred to borrowers through a higher lending rate, which has a negative effect on entrepreneurial net worth and leads to an increase in risk premium (spreads), pushing the firms' external financing costs up. This indirect channel also produces a fall in domestic investment and GDP.

4 Results

The results from the different simulations are summarized in Tables 2−4, as well as Charts 1−4. We report results for the following variables: GDP, investment, bank lending, inflation, the loan prime rate spread, the external financing cost spread and the policy rate.[27] Spreads are computed over the policy rate. All variables are expressed in deviations from their balanced growth path (control). We start by focusing on the results for the case where the change in the regulatory policy in implemented *only in Canada*.

4.1 Effects of stronger capital and liquidity requirements when implemented only in Canada

Table 2 displays the changes in steady state values of the selected variables. In response to the higher minimum capital requirement, Canadian banks are forced to deleverage and they do so optimally by accumulating additional capital and/or by reducing loans to entrepreneurs. First,

[27] In BoC-GEM-Fin the risk premium, which adds to the loan prime rate to form the external financing cost, is sector-specific. Here we report the spread observed in the non-tradables sector, which constitutes *55%* of total GDP in the baseline calibration.

note that the permanent increase in the minimum capital requirement does not fully translate into permanent increases in the *actual* capital-to-loans ratios of the same magnitude (columns 2 and 3), which means that banks reduce their capital "buffer" as shown in the top right graphs of Charts 1 and 2.[28] Considering the case where the change in capital/liquidity regulation policy occurs only in Canada, the deleveraging process results in a permanently lower level of bank lending (column 5), by as much as 0.29% in scenarios $L50Tj$. This fall in bank loans to entrepreneurs explains both the permanent increase in the interest rate spreads (columns 7 and 8) and the permanent reduction in GDP (column 4).[29] Since monetary policy is set to react to deviations of inflation from an annual target of 2%, which is invariant to the new policy, no changes are observed in the steady state levels of both inflation and the policy rate. Moreover, as capital requirements become more stringent, the permanent loss in GDP increases, but in a slightly nonlinear way. Note that the largest reductions in GDP are observed in scenarios that imply large increases in capital requirements, from 10% to 16% ($CA6Tj$) or to 18% ($L50Tj$). However, while the change in minimum capital requirement in, say, scenarios $L50Tj$ is four times larger than in scenarios $CA2Tj$, the corresponding fall in GDP is less than three times larger.

Table 2
Steady State Comparison (deviations from initial steady state)

Scenarios	Capital-to-loans ratio		GDP	Investment	Bank lending	Inflation	Lending rate spread	External financing cost spread	Policy rate
	Minimum	Actual							
	p.p	*p.p*	%	%	%	*p.p*	*basis points*	*basis points*	*basis points*
Change in regulation only in Canada:									
CA2T*j*	2.0	1.67	-0.03	-0.09	-0.11	0.0	3.3	3.4	0.0
CA4T*j*	4.0	3.43	-0.05	-0.16	-0.18	0.0	5.7	5.8	0.0
CA6T*j*	6.0	5.25	-0.07	-0.20	-0.24	0.0	7.6	7.6	0.0
L25T*j*	4.0	3.43	-0.05	-0.16	-0.18	0.0	5.7	5.8	0.0
L50T*j*	8.0	7.11	-0.08	-0.24	-0.29	0.0	9.0	9.0	0.0
Change in regulation in all regions (spillovers):									
CA2T*j*	2.0	1.67	-0.07	-0.16	-0.17	0.0	3.5	3.5	0.0
Initial steady state	10%	12%	100	100	100	2.0%	3.4%	6.4%	5.1%

While the phase-in period for the implementation of the changes in regulation does not affect the steady state of the model, it has a large influence on the near term dynamics. Charts 1 and 2 display the transition from the initial to the final steady state for the selected variables over the 2011-2018 period, following permanent increases in the minimum capital requirement only in Canada, from 10% to 12% (scenarios $CA2Tj$) and from 10% to 16% (scenarios $CA6Tj$), respectively. Trough

[28] The reason is that, as banks accumulate more bank capital, as required by the new regulation, the marginal cost of raising additional bank capital from households increases. This reduces the marginal incentives for banks to keep a large "buffer" of extra capital over the minimum required.

[29] Note that the loans-to-GDP ratio permanently falls, as loans fall by more than GDP. This higher volatility of loans relative to that of GDP is closely linked to the higher volatility of investment as the demand for loans is directly affected by investment.

values for the GDP, investment, and bank lending, as well as peak values for the lending rate spread over the policy rate are shown in Table 3.

Note that the depth of the recession induced by the higher capital requirement ratio is closely related to the phase-in period. In all scenarios, GDP falls on impact and the recession deepens as the implementation period takes place, reaching a trough two or three quarters before the end of the phase-in period. In both Charts 1 and 2, the effects of the same increase in the minimum required bank capital ratio, implemented over a longer phase-in period (i.e. four years) imply qualitatively similar responses of macro-variables, but the magnitudes are smaller. For example, the trough in GDP in Chart 1 is -0.11%, when the two percent point increase in $1/\overline{\kappa}$ takes place over four years, compared to -0.2%, when $T = 2$ years.

The implementation horizon, T, also dictates the timing and value at which spreads peak: a shorter T leads to a higher and earlier peak value for the spreads, which causes the greater and faster fall in GDP. This is explained by the assumption that $1/\overline{\kappa}$ changes linearly between the two steady states, with equal changes every quarter, but only the initial increment is treated as unanticipated. Therefore, the share of the shock to $1/\overline{\kappa}$ that is unanticipated is twice as large in case $CAiT2$ compared to $CAiT4$ (1 over 8 quarters *versus* 1 over 16 quarters) and both banks and firms are better able to smooth the costs involved in adjusting bank capital and investment, respectively. For example, relative to control, in scenario $CA6Tj$, GDP falls on impact by almost 0.4% when the new policy is implemented over 2 years, but by only about 0.1% when implemented over 4 years, while the annualized lending rate spreads peak at about 400 and 200 basis points, respectively. The smaller response of variables when $T = 4$ is due to the fact that a longer implementation horizon allows agents to adjust to the change in regulatory policy. In particular, banks and firms are better able to smooth the costs involved in adjusting bank capital and investment, respectively.

The observed profiles for the increase in spreads is explained by an increase in the marginal cost of providing loans to entrepreneurs, which follows the changing value of $1/\overline{\kappa}$. When the new permanent level of $1/\overline{\kappa}$ is reached, this channel no longer works and the spreads start to recede. Note that the peak of spreads always occurs exactly when the new capital requirements are fully implemented and the economy reaches the new steady state. As shown in both Charts 1 and 2 and in Table 3, the trough of bank lending always coincides with the peak in spreads when $T = 4$, but comes approximately two years after the peak in spreads when $T = 2$. The reason is that, when the implementation horizon is $T = 2$, there is a large and fast increase in lending rates. This leads to a substantial increase in the external financing cost, which in turn implies a fall in entrepreneurs' net worth that is too large in the short-run. As net worth is a very persistent variable (it takes longer to build it up) loans fall for a longer period. In both cases, this negative co-movement of spreads and bank loans highlights the fact that the change in policy corresponds to a negative shock to the supply of loans, with deleterious effects on investment, consumption, and GDP.

Chart 1
Increase in the Minimum Bank Capital Requirement Ratio from 10% to 12%

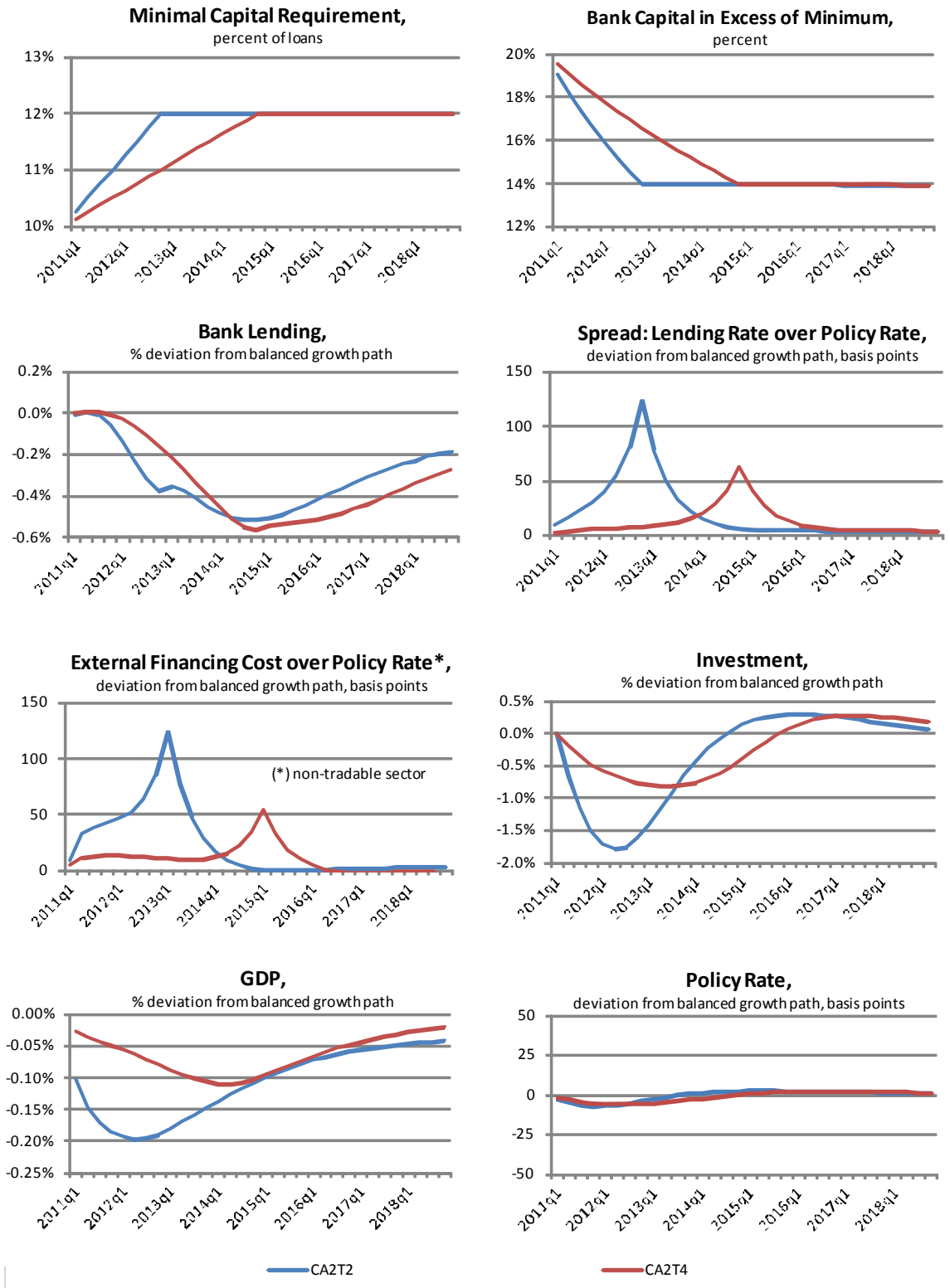


Chart 2
Increase in the Minimum Bank Capital Requirement Ratio from 10% to 16%

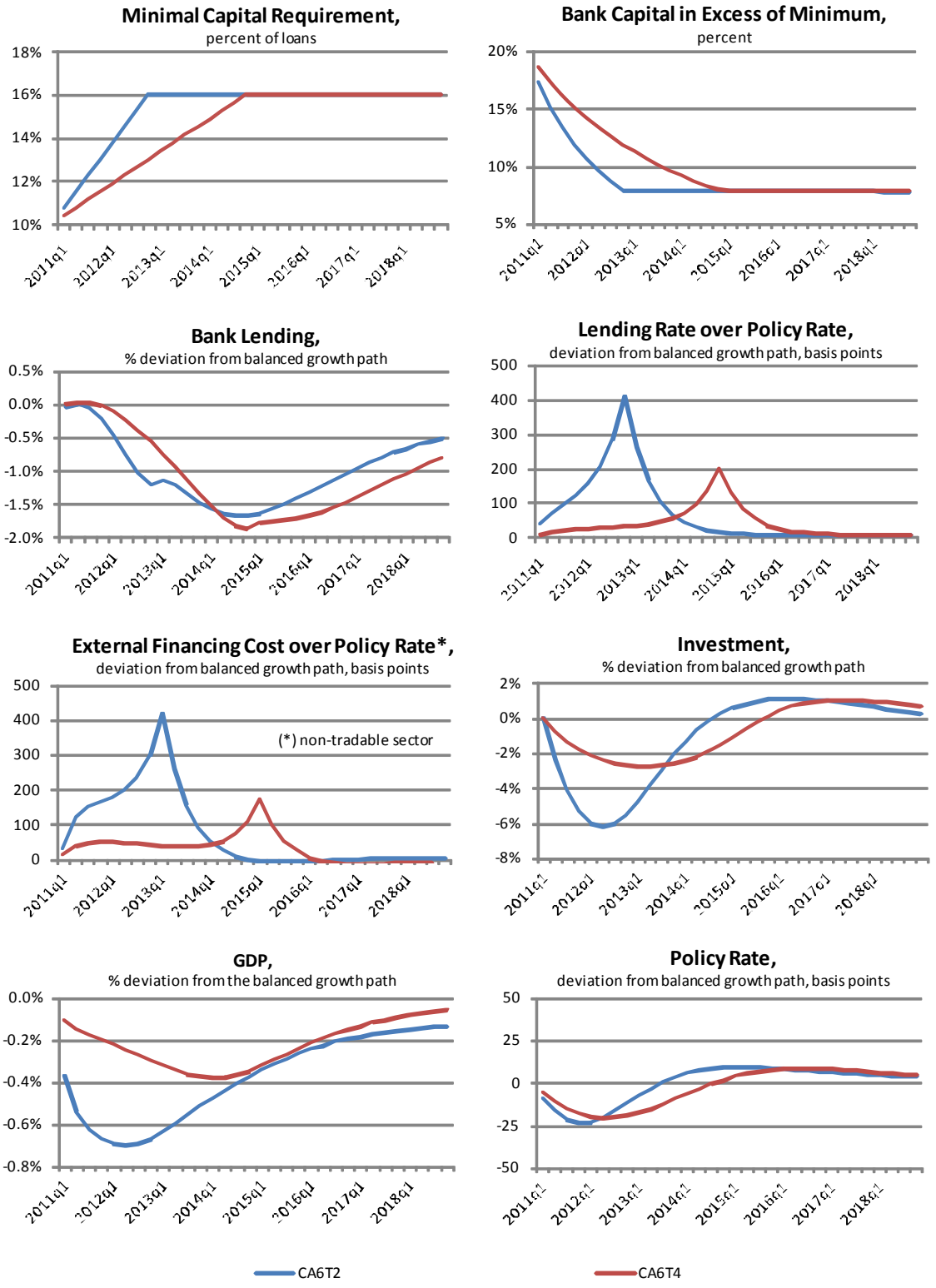


Table 3
Peak/Trough Responses (in deviations from control)

Scenarios (change implemented only in Canada)	Trough						Peak	
	GDP (% deviation)		Investment (% deviation)		Bank lending (% deviation)		Lending Rate spread (basis points)	
	Value	Date			Value	Date	Value	Date
CA2T2	-0.20%	2012Q2	-1.79%	2012Q1	-0.51%	2014Q4	122.5	2012Q4
CA2T4	-0.11%	2014Q2	-0.81%	2013Q2	-0.57%	2014Q4	61.9	2014Q4
CA4T2	-0.43%	2012Q2	-3.86%	2012Q1	-1.08%	2014Q3	261.2	2012Q4
CA4T4	-0.24%	2014Q1	-1.72%	2013Q1	-1.20%	2014Q4	129.0	2014Q4
CA6T2	-0.70%	2012Q2	-6.18%	2012Q1	-1.67%	2014Q3	411.1	2012Q4
CA6T4	-0.38%	2014Q1	-2.73%	2013Q1	-1.87%	2014Q4	198.7	2014Q4
L25T2	-0.43%	2012Q2	-3.86%	2012Q1	-1.08%	2014Q3	261.2	2012Q4
L25T4	-0.24%	2014Q1	-1.72%	2013Q1	-1.20%	2014Q4	129.0	2014Q4
L50T2	-1.00%	2012Q2	-8.71%	2012Q1	-2.28%	2014Q3	569.0	2012Q4
L50T4	-0.53%	2014Q1	-3.82%	2012Q4	-2.57%	2014Q4	269.6	2014Q4
CA2T2 with alternative assumptions for the monetary policy response								
Full response	-0.20%	2012Q2	-1.79%	2012Q1	-0.51%	2014Q4	122.5	2012Q4
reduced response for 1 year	-0.34%	2011Q4	-2.29%	2012Q1	-0.58%	2014Q4	124.1	2012Q4

Note: control variables correspond to the balanced growth path (a linear trend, in the cases of GDP and bank lending, and a constant value for the lending rate spread)

As in the comparison between steady states described above, the short-run dynamics also shows that a larger change in policy has a nonlinearly larger effect on the economy, regardless of the phase-in period for policy implementation. For example, comparing Charts 1 and 2 for a given T, notice that a change in the capital requirement of 6 percentage points (scenarios $CA6Tj$, Chart 2) produces spikes in the lending rate spreads that are more than 3 times larger than those observed in scenarios $CA2Tj$ (Chart 1) for which the capital requirement increases by only 2 percentage points. The (slightly) nonlinear effect is also observed in both the immediate and trough responses of GDP, investment and lending (by factors of about 3.5 or more).

Results regarding the liquidity requirement are qualitatively similar to those described above, as we also used a shock to $\overline{\kappa}$ in order to generate the scenarios. In particular, an increase in the liquidity ratio by 25% (scenario $L25Tj$) is obtained with a change in the minimum capital requirement from 10% to 14%, which is identical to scenarios $CA4Tj$. On the other hand, scenarios $L50Tj$ (increase in liquidity ratio by 50%) implies an increase in the minimum capital requirement from 10% to 18%, which is larger than in scenario $CA6Tj$. In Chart 3, we only show the corresponding increase in the liquidity ratio, μ_t. Some quantitative effects of the increase in the liquidity requirement are shown in Tables 2, 3, and 4.

Table 4 shows the conditional standard deviations of the selected variables, measured by the average squared deviation from the corresponding (initial) balanced growth path values. This statistic summarizes the dynamic path of these variables over the time period from 2011 until

convergence to the new balanced growth path when the change in $1/\overline{\kappa}$ is implemented only in Canada. Note that a longer implementation period has less of a destabilizing effect on GDP, inflation and both interest rate spreads, as indicated by lower conditional standard deviations. For bank lending, on the other hand, the opposite occurs. As the implementation period increases from 2 to 4 years, bank lending becomes more volatile. However, a further increase in the implementation period to 6 years (not shown) leads to lower standard deviations.

Chart 3
Increase in the Liquidity ratio Requirement
Ratio of government securities to risky assets (loans)

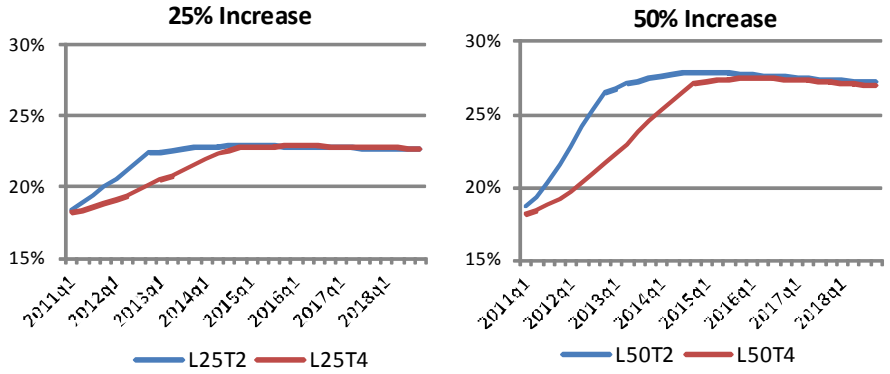


Table 4
Conditional Standard Deviations

Scenarios	GDP	Investment	Bank lending	Inflation	Lending rate spread	External financing cost spread	Policy rate
CA2T2	0.06%	0.34%	0.18%	0.01%	0.14%	0.15%	0.01%
CA2T4	0.04%	0.21%	0.19%	0.01%	0.08%	0.07%	0.01%
CA4T2	0.12%	0.72%	0.35%	0.02%	0.30%	0.33%	0.03%
CA4T4	0.07%	0.44%	0.37%	0.02%	0.16%	0.14%	0.03%
CA6T2	0.19%	1.15%	0.51%	0.04%	0.49%	0.53%	0.05%
CA6T4	0.11%	0.69%	0.56%	0.03%	0.25%	0.22%	0.04%
L25T2	0.12%	0.72%	0.35%	0.02%	0.30%	0.33%	0.03%
L25T4	0.07%	0.44%	0.37%	0.02%	0.16%	0.14%	0.03%
L50T2	0.26%	1.61%	0.68%	0.05%	0.68%	0.76%	0.06%
L50T4	0.15%	0.95%	0.75%	0.04%	0.34%	0.30%	0.06%
CA2T2 with Alternative assumptions for the monetary policy response							
Full response	0.06%	0.34%	0.18%	0.01%	0.14%	0.15%	0.01%
reduced response for 1 year	0.09%	0.43%	0.19%	0.02%	0.14%	0.16%	0.01%
Countercyclical capital requirements, response to an aggregate temporary technology shock							
A-cyclical	0.15%	0.18%	0.13%	0.13%	0.01%	0.02%	0.03%
Weakly countercyclical	0.14%	0.11%	0.11%	0.13%	0.04%	0.04%	0.03%
Strongly countercyclical	0.13%	0.08%	0.17%	0.13%	0.08%	0.07%	0.03%

Note: values correspond to the average square deviation from control.

To summarize the findings discussed so far regarding the implementation of stronger capital and liquidity standards: (i) larger increases in the capital requirement ratio produce larger effects

on the selected variables, but in a slightly nonlinear way, (*ii*) long-run effects are modest, but transition costs are important, and (*ii*) a longer implementation period reduces the severity of the transition costs, in terms of deviations of output from its balanced growth path.

4.1.1 Higher adjustment cost on bank capital

The simulation results shown so far are based on the baseline calibration of the BoC-GEM-Fin. In particular, the adjustment cost parameter, χ_z, is calibrated to match the responses of loans to a several shocks during the recent financial crisis. As χ_z is crucial to the dynamics of loans following the change in the minimum bank capital requirement, and since there is some uncertainty around its calibrated value, Chart 4 provides results for the scenario $CA2T2$ when χ_z is multiplied by factors of two (blue line) and five (red line). Note that the same reduction in $\overline{\kappa}$, when combined with a higher value of χ_z, induces the deleveraging process by banks to be less based on the (more costly) accumulation of bank capital. This, in turn, implies that the reduction in loans must be larger, with larger increases in spreads and larger reductions in both investment and GDP.

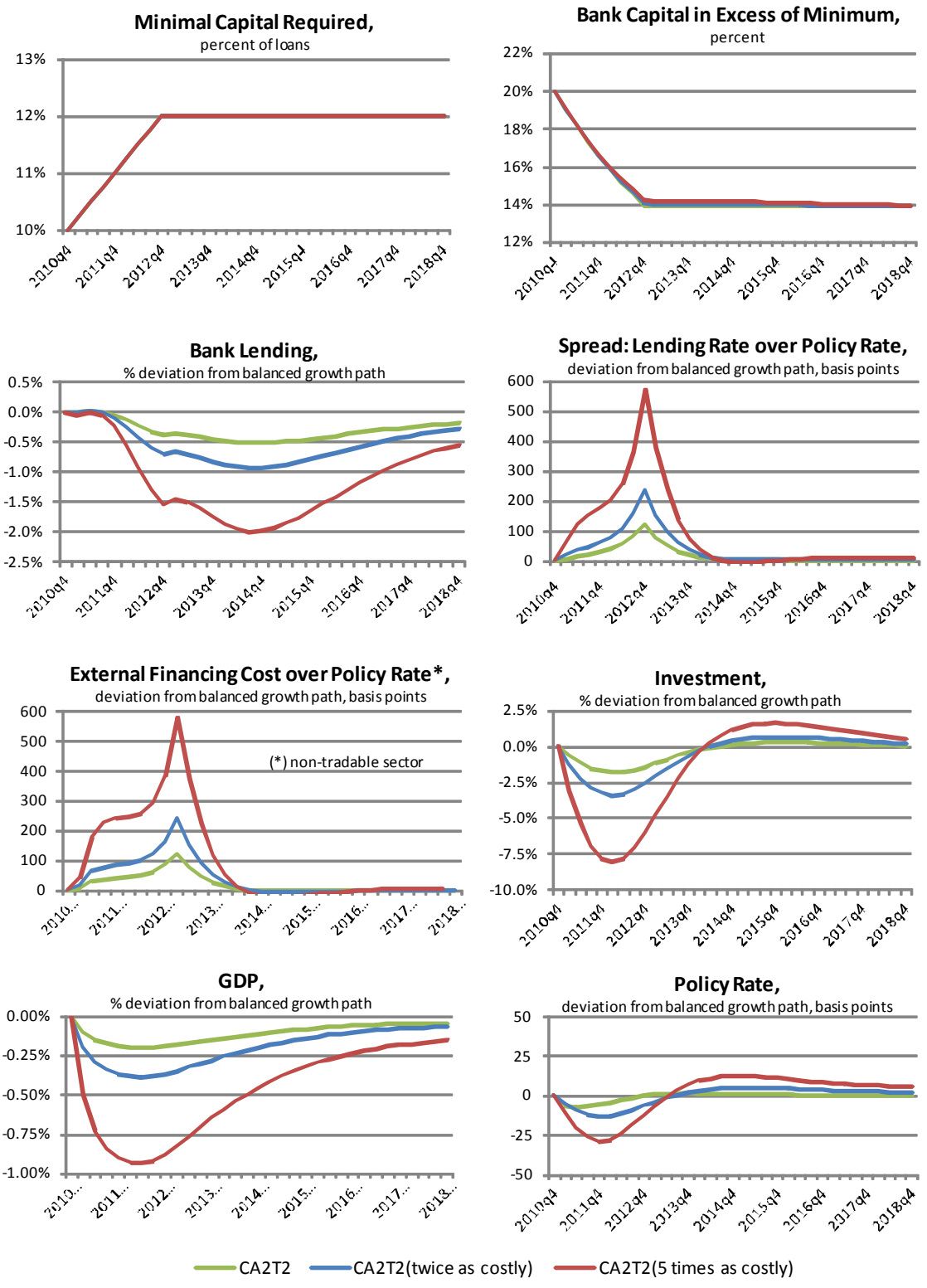
4.1.2 Counter-cyclical capital requirement

Another underlying assumption in the scenarios discussed above is that the regulatory parameter $\overline{\kappa}$ is constant over the business cycle. In this subsection, we discuss the effects of a counter-cyclical rule that relaxes the capital requirements during recessions and make it more strict during booms. We consider two cases: (*i*) an a-cyclical rule whereby the minimum capital requirement ratio is constant at $1/\overline{\kappa} = 10\%$ and (*ii*) counter-cyclical rules whereby the minimum capital requirement ratio responds to deviations of output from its balanced growth path according to $1/\overline{\kappa}_t = 0.1\,(y_t/y_t^*)^{\omega}$, where y_t is GDP, y_t^* is GDP's balance growth path level, and ω is a parameter for the elasticity of the capital requirement to the output gap. Note that when $y_t = y_t^*$, the capital requirement is equal to the value in the a-cyclical case, $1/\overline{\kappa}_t = 10\%$.

We look at two calibrated values for ω. In a weakly counter-cyclical case, we set ω such that, following a temporary one standard deviation (about 0.7%) technology shock, the maximum deviation of $1/\overline{\kappa}$ from its a-cyclical counterpart is 1 percentage point. Similarly, we consider a strongly counter-cyclical rule whereby the minimum capital requirement ratio does not go above 12% or below 8%.

The results are in the bottom of Table 4. Note that a counter-cyclical rule can reduce the volatility of both GDP and investment, at the expense of more volatile spreads. For a weakly counter-cyclical capital requirement rule, loans also become less volatile due to a greater reduction in the volatility of entrepreneurial net worth. When we move to the strongly counter-cyclical policy, this effect is outweighed by the effects of the BGG financial accelerator on spreads (notice that the volatility of spreads increases greatly in this case).

Chart 4
Sensitivity to the Adjustment Cost of Bank Capital, χ_z

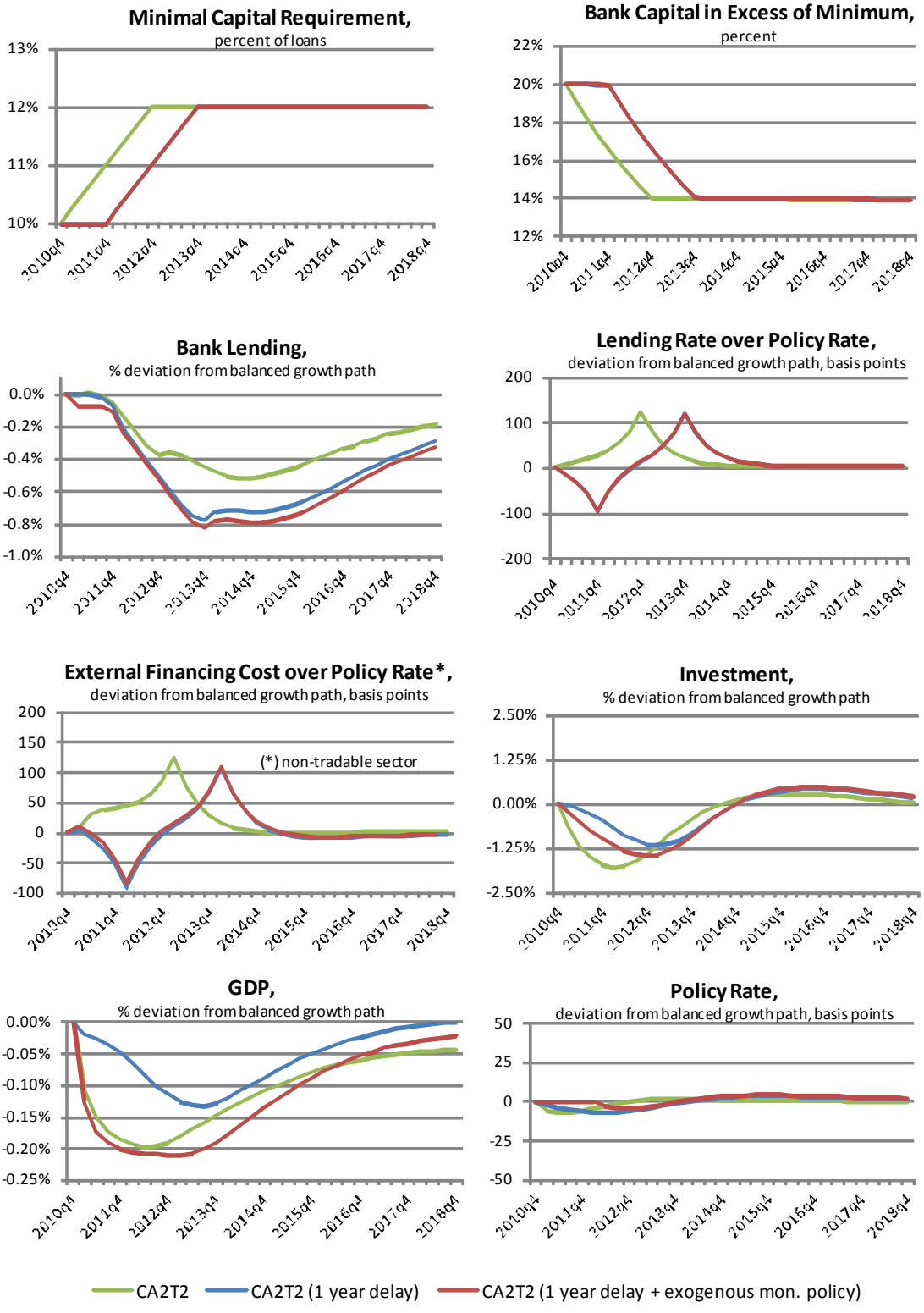


4.1.3 Pre-announcement of the change in policy

In all scenarios discussed so far, the increase in the bank capital requirement is implemented without announcement. Given that the current discussions about the changes in regulatory policy are fairly public, this may not be a realistic assumption. We have already pointed out that a longer phase-in period allows more time for economic agents to smooth out the distortions and costs resulting from the higher capital and liquidity requirement standards. As the unexpected aspect of the change in policy gets diluted on a longer implementation period, the negative effects on lending, investment, and output become smaller. The same principle applies when agents know in advance that the change in regulatory policy *will be* implemented some time in the future. Chart 5 shows that announcing the change in policy one year in advance (blue line) can reduce the trough of the GDP response to the higher capital requirement ratio by almost half, compared to the baseline $CA2T2$ scenario (green lines).

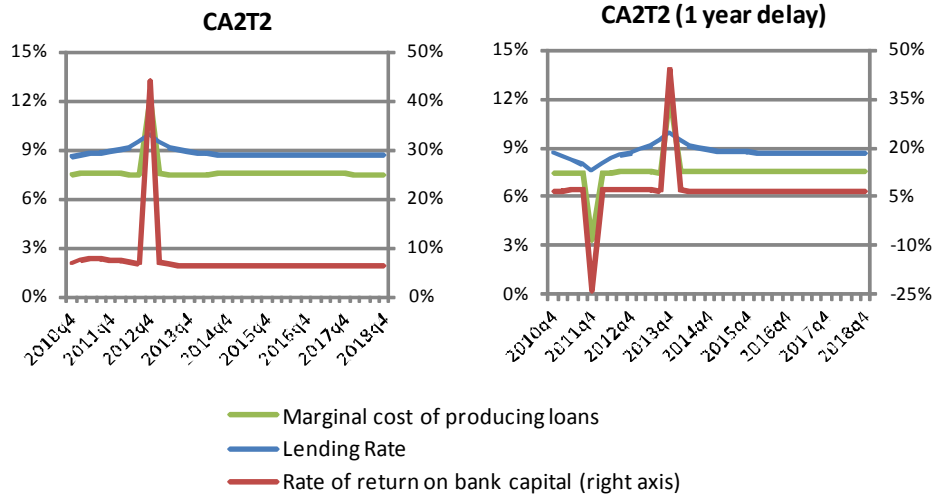
Note that, differently from the case where the policy is implemented as an unexpected shock, the spreads fall during the time the policy has been announced but not implemented. Chart 6 helps us understand why. It shows the behaviour of the lending rate, R_t^L, and that of one of its main determinant, the marginal cost of producing loans, ζ_t, which in turn depends on the expected rate of return on bank capital, R_{t+1}^Z through equation (22). The left graph on Chart 6 shows that, in the baseline scenario $CA2T2$, the higher capital requirement ratio induces a spike in the marginal cost of loan supply that coincides with the end of the phase-in period, by the time the new policy is fully implemented. Moreover, that graph shows that while this spike in ζ_t is fully explained by a similar spike in R_{t+1}^Z, it does cause the lending rate to spike. Instead, R_t^L increases smoothly until reaching the peak at the same time as ζ_t and R_{t+1}^Z. The reason for this one time rise in both R_{t+1}^Z and ζ_t is easy to see from equation (25). When the phase-in period begins, both Z_t and Z_{t+1}increase in a way that MC_t^Z and MG_t^Z offset each other. As R_t, Q_{t+1}^Z/Q_t^Z, and δ_t^Z do not react by much, the balance between MC_t^Z and MG_t^Z implies that R_{t+1}^Z does not need to change much. However, at the last quarter in the phase-in period, Z_t and Z_{t+1}both stop rising, while Z_{t-1} has been rising. This affects MC_t^Z, which increases, but not MG_t^Z. As MC_t^Z dominates MG_t^Z, the increase in the cost of saving using bank capital induces households to demand a higher return on their investment.The jump in both R_{t+1}^Z and ζ_t is anticipated by banks, which will transfer the cost increase to costumers by raising R_t^L. Since there are costs in adjusting R_t^L, banks smooth them out by spreading out the increase in R_t^L over the phase-in period.

Chart 5
Effect of a Pre-Announced Change in the Bank Capital Requirement Ratio



The same logic explains why R_t^L initially falls when agents know in advance that a higher capital requirement ratio will be in effect one year in the future. The difference is that, in this case: (i) MC_t^Z and MG_t^Z offsett each other during the pre-announcement period (so R_{t+1}^Z stays constant); (ii) MG_t^Z dominates MC_t^Z at the exact date when the policy starts being implemented (Z_{t+1} increases, but not Z_t or Z_{t-1}, such that R_{t+1}^Z falls for one period); (iii) MC_t^Z and MG_t^Z once again offsett each other during phase-in period; and (iv) MC_t^Z dominates MG_t^Z at the last period of the implementation of the new capital standards. These movements in R_{t+1}^Z imply similar changes in the marginal cost of producing loans, which is passed on to borrowers through changes in R_t^L. The initial reduction in R_t^L mitigates the fall in investment and GDP, as shown on Chart 5.

Chart 6
Effect of an Increase in the Capital Requirement Ratio on the Determinants of the Lending Rate



4.2 Reponse of Monetary Policy and Spillover Effects

In the simulations discussed above, we assume that: (i) the monetary policy is set to react to inflation outcomes using an interest rate rule, and (ii) the change in the regulation policy is implemented only in Canada, keeping the minimum capital requirement at the level recommended by the Basel II committee in all other regions of the global economy. To investigate the effect of these assumptions on the results, we provide a sensitivity analysis using scenario $CA2T2$ as the baseline case.

First, consider the difference between the two scenarios represented by the blue and red lines in Chart 5. The former refers to the case where monetary policy endogenously reacts, according to a Taylor-type interest rate rule, to the fall in inflation that results from the slowdown in economic activity after the stricter bank regulation policy is implemented. The latter refers to the case where

monetary policy does not respond to inflation outcomesfor one year.[30] We refer to this case as one of "exogenous" monetary policy.[31] The comparison between the two cases suggests that "purging" the results from the effects of the monetary policy reaction implies a deeper recession following the change in the regulation policy. Since the monetary authority does not reduce the nominal interest rate to react to the fall in inflation resulting from the recession, the real interest rate becomes higher than it would be otherwise, which induces a larger fall in GDP. The bottom part of Table 3 shows that in the case monetary policy is free to fully respond to the fall in inflation resulting from the changes in the minimum capital requirement, the trough response of GDP is of -0.2%, implying a shallower recession than the -0.34% observed in the alternative case. Table 4 shows that full response by the monetary authority also results in lower conditional standard deviations in GDP, investment, bank loans, inflation, and lending spreads.

Regarding the assumption that the change in the regulation policy is implemented only in Canada, first consider the row in Table 2 that refers to the case in which the baseline scenario $CA2T2$ is modified to allow for changes in regulation policy that are implemented globally. Note that the permanent fall in lending is more than 50% larger than that in the scenario $CA2T2$, while the permanent reduction observed in both GDP and investment are about twice as large, despite the small additional permanent increase in spreads.

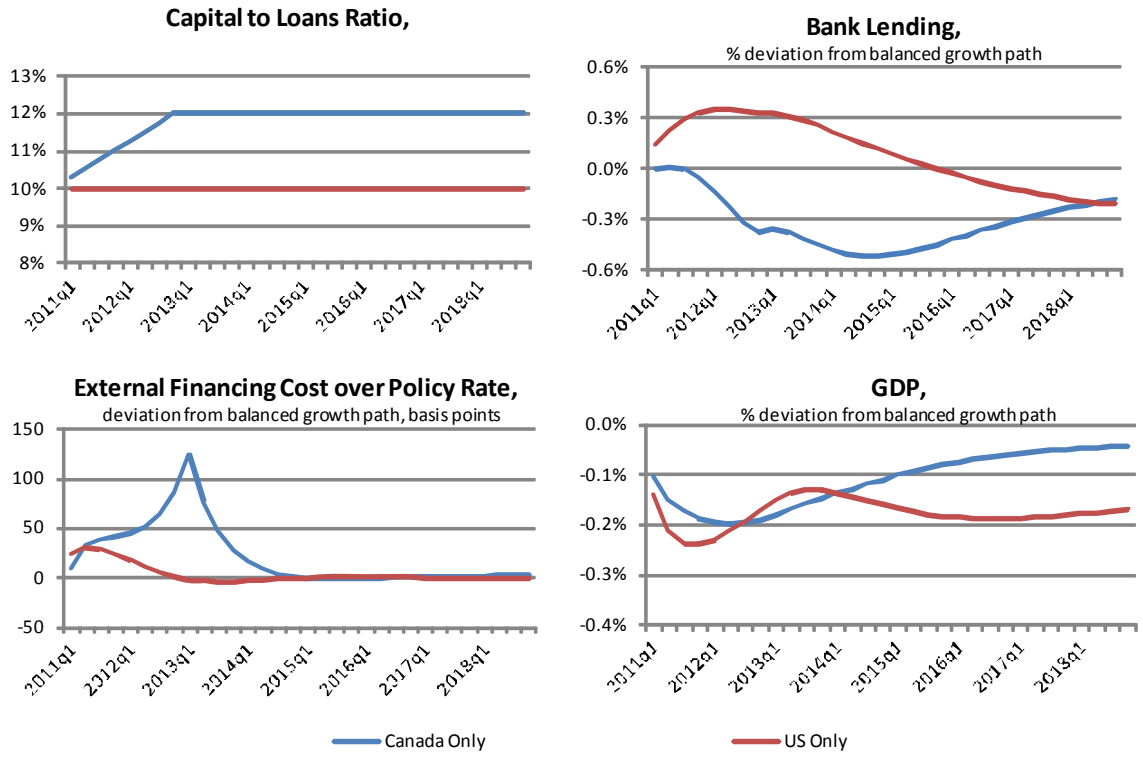
Chart 7 shows the impact on Canada of a similar two percentage point permanent increase in the minimum capital requirement implemented *only in the United States*. In terms of the calibrated values in BoC-GEM-Fin, this experiment means that only the United States adjusts the minimum capital requirement from 8% to 10%, while $1/\overline{\kappa}$ remains fixed at 10% in Canada. The implications of this experiment for Canada are compared to those observed under scenario $CA2T2$. Note that when the change in policy is implemented only in the U.S. (red lines), total loans in Canada increase, rather than fall as in the baseline case. This is explained by a combination of four factors: (*i*) the tighter regulation in the U.S. induces a higher fall in net worth of entrepreneurs in the U.S. and, therefore, higher increases in the risk premium and spreads in that country, compared to Canada; (*ii*) this large fall in net worth in the U.S. will be transmitted to Canada through trade linkages, commodity prices, and cross-border lending from U.S. banks to Canadian firms in the tradable sector, (*iii*) the higher external financing cost in the United States directly reduces the net worth

[30] This assumption could be taken as representing a situation where, at the start of the simulation period, the policy interest rate is already at the effective lower bound and the monetary authority also chooses not use alternative instruments. During the recent financial crisis, even though the policy interest rates were reduced to the effective zero lower bound, the Bank of Canada was able to retain considerable flexibility in the conduct of monetary policy. Several other instruments than the interest rates were available to the Bank of Canada, such as a conditional commitment to maintain the overnight rate at 1/4 per cent for a considerable period of time, as well as additional stimulus through quantitative and/or credit easing.

[31] We reduce the coefficient of (core) inflation in the interest rate rule by a factor of 0.01 and increase the smoothing factor to 0.99 over the longest possible time period such that the model could still satisfy the "Taylor Principle," and produce sensible results. This means that the monetary policy response is fixed for one year, from 2011Q1 to 2012Q1.

of Canadian firms that borrow from U.S. banks, and (*iii*) the sluggish downward adjustment of physical capital due to adjustment costs implies that the fall in net worth leads to higher demand for loans.

Chart 7
Spillovers From a Two Percentage Point Increase in the Minimun Capital Ratio in the United States



The higher sensitivity of net worth and the risk premium in the United States, compared to Canada, is conditional on the current calibration of BoC-GEM-Fin, based on data from the International Banking Statistics from the BIS. More specifically, (at the steady state) only 9.2% of total loans received by domestic firms in the United States come from foreign banks, compared to 44% in Canada. To better understand this point, let us start with the situation in which only Canada implements the increase in the minimun required bank capital-to-loans ratio. As regulation gets tighter in Canada, but not the U.S., Canadian firms will still borrow a relatively large amount of loans from foreign banks at a lower cost, given that the marginal cost of producing loans increases in Canada, but does not change in the U.S. and other economies. Therefore, the average cost of borrowing in Canada does not increase as much for the same increase in the marginal cost of producing loans faced by Canadian banks. When only the U.S. implements the increase in $1/\overline{\kappa}$, on the other hand, as firms rely more heavily on domestic banks for loans, borrowing costs to entrepreneurs increase by more for the same rise in marginal cost of loans in the event of a similar change in regulatory policy. Compared to Canada, the larger increase in the marginal cost of loan

production in the U.S. means equally larger increases in both the lending rate and the expected external financial cost and, as previously explained, larger decreases in current and future net worth through equation (5) and larger increases in the risk premium through equation (3).

The sluggish adjustment of physical capital, due to adjustment costs, combined with a large reduction in net worth increases the demand for loans by the entrepreneurs, as well as increases corporate spreads. The greater increase in spreads results in a larger reduction in GDP in the U.S. (not shown) compared to Canada when only the latter implements the change in policy.[32] This large fall in U.S. GDP, transmitted to Canada through trade linkages, commodity prices, and cross-border lending from U.S. banks to Canadian firms in the tradable sector, implies a large fall in Canadian net worth. Since investment in Canada also faces a sluggish adjustment, the fall in net worth explains the increases in spreads at the same time that Canadian firms demand more loans to finance their investment projects. When both Canada and other regions implement changes in the minimum bank capital requirement the same spillover effect to Canadian banks occurs and for the same reason: a larger fall in the net worth of Canadian entrepreneurs forces them to borrow more to finance their ongoing investment projects.

Table 5 summarizes the effect on Canadian GDP of a set of policy experiments that consider a two percentage point increase in the minimum required capital-to-loans ratio, under different assumptions about where the change in policy will take place (only in Canada *versus* globally), the response of monetary policy (endogenous *versus* no response for one year), and the phase-in period (two, four, or six years). The results shown in Table 5, based on simulations with BoC-GEM-Fin over the period from 2010Q4 to 2018Q4, suggest that a permanent increase in the minimum capital requirement implies a reduction in GDP that outlasts the phase-in period. This fall in GDP is explained by the increase in spreads, followed by a fall in investment as discussed in subsection 3.1. The results also imply that spillover effects to Canada from changes in policy in foreign economies are substantial and should not be neglected. They may increase the average negative effect of the change in regulation on Canadian GDP by as much as 0.9 percentage points (when comparing scenarios 1 and 7). When considering the average of all scenarios, spillover effects increase the average negative effect on GDP by 0.2 percentage points. These spillovers come from two separate channels. First, the cost of providing loans increases not only for Canadian banks (as in the case of changes in policy only domestically implemented) but also foreing banks, which means that foreign bank lending to Canadian firms also becomes more expensive. Second, the increase in the bank capital requirement in other countries leads to a fall in economic activity abroad, which reduces the demand for Canadian exports and negatively affects the terms of trade. For instance, as a net exporter of oil and commodities, Canada is negatively affected since the global fall in output puts

[32] The fact that Canada is calibrated as a net importer of investiment goods in the BoC-GEM-Fin also plays a role in the smaller reduction in Canadian GDP compared to the United States, given the high sensitivity of investment decisions to the increase in the marginal cost of producing loans and to the increase in spreads.

downward pressure on the prices of these goods.

Table 5

Effect of a Two Percentage Point Increase in the Minimum Capital Requirement Ratio on the Canadian GDP [1]

Scenario	Change in capital regulation	Monetary policy [2]	Phase-in	2013Q1	2015Q1	2017Q1	2018Q4	average 2011-2018	trough
1	only Canada	exogenous	2 years	-0.27%	-0.15%	-0.09%	-0.07%	-0.18%	-0.34%
2	only Canada	exogenous	4 years	-0.16%	-0.13%	-0.07%	-0.04%	-0.12%	-0.18%
3	only Canada	exogenous	6 years	-0.04%	-0.07%	-0.07%	-0.04%	-0.05%	-0.08%
4	only Canada	endogenous	2 years	-0.18%	-0.10%	-0.06%	-0.04%	-0.11%	-0.20%
5	only Canada	endogenous	4 years	-0.09%	-0.10%	-0.04%	-0.02%	-0.06%	-0.11%
6	only Canada	endogenous	6 years	-0.01%	-0.06%	-0.06%	-0.03%	-0.04%	-0.07%
7	global (spillovers)	exogenous	2 years	-0.76%	-0.59%	-0.52%	-0.46%	-0.68%	-1.24%
8	global (spillovers)	exogenous	4 years	-0.41%	-0.49%	-0.44%	-0.39%	-0.44%	-0.51%
9	global (spillovers)	exogenous	6 years	0.04%	-0.09%	-0.15%	-0.11%	-0.06%	-0.17%
10	global (spillovers)	endogenous	2 years	-0.49%	-0.44%	-0.42%	-0.38%	-0.47%	-0.69%
11	global (spillovers)	endogenous	4 years	-0.15%	-0.23%	-0.18%	-0.15%	-0.17%	-0.26%
12	global (spillovers)	endogenous	6 years	0.05%	-0.09%	-0.15%	-0.11%	-0.05%	-0.17%
Spillover effects									
Comparison of scenarios:									
1 and 7		exogenous	2 years	-0.49%	-0.44%	-0.43%	-0.39%	-0.50%	-0.90%
2 and 8		exogenous	4 years	-0.25%	-0.35%	-0.37%	-0.35%	-0.32%	-0.33%
3 and 9		exogenous	6 years	0.08%	-0.02%	-0.08%	-0.07%	0.00%	-0.09%
4 and 10		endogenous	2 years	-0.30%	-0.33%	-0.37%	-0.34%	-0.36%	-0.49%
5 and 11		endogenous	4 years	-0.07%	-0.14%	-0.14%	-0.13%	-0.10%	-0.15%
6 and 12		endogenous	6 years	0.06%	-0.03%	-0.09%	-0.08%	-0.01%	-0.10%
average across scenarios				-0.16%	-0.22%	-0.24%	-0.23%	-0.22%	-0.34%

(1) Effects are computed as percent deviation of the balanced growth path.

(2) Exogenous monetary policy means that the response to inflation has been delayed for one year.

Moreover, Table 5 shows that the response of monetary policy in Canada matters greatly for the implications of the changes in capital requirements. If monetary policy does not initially react to inflation outcomes, the effects of the change in capital regulation policy are much stronger. Considering the average of all scenarios, a nonresponsive monetary policy increases the average negative effect on GDP by 0.1 percentage points. Finally, results in Table 5 confirm that the phase-in period for the implementation of the new regulatory policy also matters. Reducing the implementation period from four to two years may imply an extra 0.3 percentage point fall in GDP (scenarios 11 and 10), on average (-0.16 percentage points, considering the average of all scenarios). On the other hand, increasing the phase-in period to six years reduces the average fall in GDP across scenarios by 0.15 percentage point.

5 Conclusion

This paper examines the effects of changes in bank capital and liquidity requirements on selected macroeconomic variables in Canada, using the Bank of Canada's version of the Global Economy Model modified to include optimizing banks and a financial accelerator mechanism. Our results suggest that:

- A permanent increase in both the minimum capital requirement and in the liquidity requirement would produce small, permanent reductions in bank lending and GDP, and permanent increases in both the spreads of the lending rates and the external financing cost over the policy rate.
- The transition dynamics between the initial steady state and the new one suggests that larger changes in policy regarding the regulation of the banking system imply non-linearly larger effects on the trough responses of GDP and bank lending, and the peak response of lending spreads.
- The response of monetary policy matters greatly for the implications of the changes in capital and liquidity requirements. If the reaction of monetary policy to the fall in economic activity and inflation is limited, the effect of the change in regulation is much stronger.
- To minimize the impact on spreads and the negative effect on economic activity, the change in policy should be extended over a longer implementation horizon. Moreover, the pre-announcement of a change in policy also reduces the overall impact on GDP.
- Spillover effects to Canada from changes in policy in other economies, especially the United States, are substantial and should not be neglected.
- The responsiveness of bank capital to the change in regulatory policy is quantitatively very important for the size of the resulting recession: the more sluggish the bank capital's response to change in policy, the deeper the recession tends to be, since banks will have to deleverage by heavily cutting loans made to entrepreneurs.
- Following a temporary technology shock, counter-cyclical minimum capital requirements are able to attenuate loan fluctuations for a weakly counter-cyclical policy, but not for a very strong counter-cyclical policy, owing to its effects on spreads via the financial accelerator. In both situations, however, the volatility of macroeconomic variables such as investment and GDP is reduced.

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