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Acknowledgements

Abstract

Using BoC-GEM-Fin, a large-scale DSGE model with real, nominal and financial frictions featuring a banking sector, we explore the macroeconomic implications of various types of countercyclical bank capital regulations. Results suggest that countercyclical capital requirements have a significant stabilizing effect on key macroeconomic variables, but mostly after financial shocks. Moreover, the bank capital regulatory policy and monetary policy interact, and this interaction is contingent on the type of shocks that drive the economic cycle.

Finally, we analyze loss functions based on macroeconomic and financial variables to arrive at an optimal countercyclical regulatory policy in a class of simple implementable Taylor-type rules. Compared to bank capital regulatory policy, monetary policy is able to stabilize the economy more efficiently after real shocks. On the other hand, financial shocks require the regulator to be more aggressive in loosening/tightening capital requirements for banks, even as monetary policy works to counter the deviations of inflation from the target.

JEL classification: E32, E44, E5, G1, G2
Bank classification: Economic models; Financial institutions; Financial stability;
International topics

Résumé

Les auteurs explorent les implications macroéconomiques de différents niveaux de contracyclicité des exigences de fonds propres bancaires en se servant du modèle BOC-GEM-FIN, un modèle d'équilibre général dynamique et stochastique de grande taille qui comporte des frictions réelles, nominales et financières ainsi qu'un secteur bancaire. Les résultats obtenus indiquent que l'instauration d'exigences de fonds propres contracycliques a un effet stabilisateur sur les principales variables macroéconomiques, mais cet effet est surtout notable après un choc financier. En outre, il existe une interaction entre la politique de réglementation des fonds propres bancaires et la politique monétaire, et cette interaction est tributaire du type de chocs qui sont à l'origine des fluctuations économiques.

Enfin, les auteurs analysent des fonctions de perte reposant sur des variables macroéconomiques et financières afin de déterminer le degré de contracyclicité optimal des exigences réglementaires pour un groupe de règles à la Taylor simples et applicables. La politique monétaire est plus efficace que la politique de réglementation des fonds propres bancaires pour stabiliser l'économie après des chocs réels. Les chocs financiers, par contre, obligent l'autorité de réglementation à plus de vigueur dans l'ajustement des exigences de fonds propres, même si la politique monétaire contribue à contrer les écarts de l'inflation par rapport à la cible.

Classification JEL : E32, E44, E5, G1, G2
Classification de la Banque : Modèles économiques; Institutions financières; Stabilité financière; Questions internationales

1 Introduction

The financial crisis of 2008 brought into stark relief the central role that the financial system plays in the economies of most countries. The crisis showed, that after a period of excessive credit growth, accompanied by elevated risk-taking in conditions of unusually low macroeconomic volatility, an economic downturn can result in large losses in the financial system, and the banking sector in particular. Having incurred losses and being constrained by the (a-cyclical) required bank capital, banks will aim to curtail lending and/or de-leverage, exacerbating the economic cycle. As this dynamic became clear, policymakers began to search for a regulatory framework that would not only make the banking sector stronger on average during the economic cycle, but also prevent the amplification of the cycle through excessive risk-taking during booms and de-leveraging during recessions. An example of this is the work by the BIS Macroeconomic Assessment Group, which studied the transitory and long-term effects of raising bank capital requirements (Financial Stability Board and Bank for International Settlements, 2010). There is also growing literature on macroprudential policy focusing on counter-acting the tendency of cyclical shock amplification through leverage in the financial sector (for example, see Galati et al, 2010 for a survey of literature).

Already, a regulatory framework, referred to as Basel III, is being established to address some of the issues that the financial crisis uncovered: it incorporates higher capital requirements, a focus on the leverage ratio, as well as discretionary countercyclical capital buffers, among others. Still, so far the details of implementing countercyclical bank regulations have remained unclear. This reflects several conceptual and practical issues that academic literature and policymakers have yet to resolve.

Mainly, there is currently little consensus on the objectives of macroprudential policies. Even if most agree that the aim should be to foster financial stability, there is little agreement on what the goal of financial stability means in practical terms. Moreover, from the implementation perspective, the definition of the credit cycle that the regulator should target is elusive. A recent consultative document by the Basel Committee on Banking Supervision at the BIS (2010) mentioned several possible measures. While the paper argues for targeting one of them, the ratio of credit to GDP, there are several other plausible measures that can be relevant in different episodes and across countries.

In this context, interest in macroprudential policy within academia has also increased significantly. A recent literature review by Galati et al (2010) shows the progress made in the field of macro-prudential policy in recent years, and the challenges that still remain. Several strands of literature investigate the behaviour of macroprudential policies in DSGE models. One uses financial frictions faced by non-financial borrowers (impatient consumers, entrepreneurs, etc.) to model the credit cycle, but leaves out the financial intermediaries. An example of this approach, Kannan,

Rabanal and Scott (2009) show that a monetary policy that reacts to financial accelerator mechanisms can foster macroeconomic stability. In addition, the authors show that a macroprudential instrument designed specifically to dampen credit market cycles would be useful.

Another strand of literature, which is closer in spirit to our paper, uses an environment with active financial intermediation to study properties of macroprudential policies. In particular, the following papers have studied theoretically the implications of capital regulation for bank behavior and macroeconomic outcomes. Van den Heuvel (2008) models the role of liquidity-creating banks in a standard general equilibrium growth model, and studies the impact of capital requirements on welfare. Covas and Fujita (2009) use a general equilibrium model to gauge the likely importance of bank capital requirements in the macroeconomic setting. They show that output is more volatile, and household welfare is smaller, when capital requirements are procyclical. Zhu (2008) shows that compared to a constant capital rule, a capital requirement that varies according to the risk characteristics of banks leads to much higher capital requirements for small and riskier banks, and much lower requirements for large and less risky banks. He also demonstrates that the negative correlation of risk-based capital standards with the business cycle does not necessarily increase macroeconomic volatility. N'Diaye (2009) finds that countercyclical regulations can help reduce output fluctuations and reduce the risk of financial instability. Using a model that features endogenously set capital buffers and equilibrium loan rates, Repullo and Suarez (2009) analyze the countercyclically-set required bank capital. They show that by adopting countercyclical requirements, credit rationing over the business cycle would be substantially reduced, without affecting the solvency of banks. Meh and Moran (2008) construct a DSGE model in which the balance sheet of banks affects the propagation of shocks. They find that economies whose banking sector remains well-capitalized experience less pronounced downturns due to smaller falls in bank lending, affecting the conduct of monetary policy.

This paper uses a global DSGE (BoC-GEM-FIN) model with financial frictions and an active banking sector based on Dib (2010). It is a large-scale DSGE model that encompasses the world economy, featuring trade and financial linkages between various regions. The model's features also include a financial intermediation sector with an interbank market, with both the demand and supply of credit explicitly modelled. We use BoC-GEM-FIN to study the effects of countercyclical bank capital requirements on macroeconomic stability in the U.S. Furthermore, in the environment of a global DSGE model that incorporates international financial linkages, endogenous second round effects from other regions are taken into account when we evaluate countercyclical policies.

The paper is organized as follows. Section 2 describes the model, Section 3 gives an overview of experiments and their motivation, Section 3 covers the implementation and results and Section 4 concludes.

2 Summary of the Model

The model at the heart of this paper has been described in detail elsewhere.[1] In this section we briefly outline only its most pertinent features. We shall spend more time on the financial intermediation sector, since it plays a central role in the exercises conducted in the paper. Adapted from the original Global Economy Model developed at the International Monetary Fund (IMF), the Bank of Canada's version (BoC-GEM) was recently augmented to incorporate a financial sector and is called BoG-GEM-Fin. The model is a dynamic stochastic general equilibrium model that includes five regions and five production sectors. BoC-GEM-Fin incorporates (i) a financial accelerator mechanism as in Bernanke, Gertler and Gilchrist (1999), and (ii) an active banking sector, following Dib (2010).

The five regions in the model comprise Canada, the United States, emerging Asia, a block for commodity exporting countries, and a region of the remaining countries.[2] In each of the regional blocks the economy is modelled symmetrically and consists of households, a government, a monetary authority, two types of specialized 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.

Production. The five productive sectors in the model make for a rich production structure to capture the transmission of various shocks in the economy. Production technology in all sectors and regions is represented by a constant-elasticity-of-substitution (CES) production function. Monopolistically competitive 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.[3]

Firms producing fuel, tradable and non-tradable goods combine capital, labour, oil and non-energy commodities to produce their corresponding differentiated goods. In turn, tradable and non-tradable goods and gasoline are combined to produce homogeneous consumption and investment goods. Except for oil producers outside the commodity-exporting region, firms are able to exercise some market power and hence set prices as mark-up over the marginal cost, albeit facing quadratic adjustment costs when changing the nominal price relative to the target.[4]

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[1] Consult Pesenti (2008) for the original GEM. The first adaptation of GEM adding a region for Canada and two extra production sectors, namely oil and non-energy commodities, is described in Lalonde and Muir (2007). The latest version of the model, including the financial accelerator and a banking sector, is described in de Resende, Dib, Lalonde, and Snudden (forthcoming).

[2] 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.

[3] The elasticity of substitution in the market for oil is assumed to be very high in all but the commodity-exporting region. Thus, the oil market behaves as if perfectly competitive in all regions except for commodity exporters.

[4] This target is a weighted average of last period's sector-wide price inflation and the economy-wide inflation target.

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 quadratic 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.[5]

Households. Two types of households in BoC-GEM-Fin, "forward-looking" (or Ricardian) and "liquidity-constrained" (or non-Ricardian) agents, both value 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 in government bonds, foreign assets, bank deposits, and "bank capital," which they supply to banks. Thus, the supply of bank capital evolves according to the saving decisions by households. On the other hand, liquidity-constrained agents optimize only 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 transfers.[6]

Capital producers. Competitive capital-producers specialize in sector-specific capital. Each type of physical capital is produced by combining newly-produced equipment purchased from wholesalers with used, undepreciated capital purchased from entrepreneurs. The resulting capital 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.

Entrepreneurs. An important role in the model is played by risk-neutral entrepreneurs, who manage firms' investment decisions, financing capital through their accumulated net worth and bank loans. As in Bernanke, Gertler and Gilchrist (1999), entrepreneurs have to compensate banks for taking on risk inherent in lending to entrepreneurs. This premium depends inversely on net worth of entrepreneurs, making the former countercyclical and amplifying the business cycle.

See Lalonde and Muir (2007), p.28.

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

[6] The distinction between the two types of households helps the model to capture important non-Ricardian behaviour observed among a significant fraction of consumers. See Campbell and Mankiw (1989) and Evans (1993). By mitigating the importance of Ricardian equivalence (Mankiw, 2000), the presence of non-Ricardian consumers is consistent with the failure of the permanent income hypothesis to explain changes in aggregate consumption (Gali, Lopez-Salido and Valles, 2004).

2.1 Financial Intermediation in BoC-GEM-Fin

The banking sector within BoC-GEM-Fin follows Dib (2010). There are two sub-sectors in the banking sector: a) savings banks that accept deposits and make loans to the lending banks, and b) the lending banks that lend out funds borrowed from the savings banks to the entrepreneurs. We shall separately analyze the optimization problems of these two classes of banks.

Savings banks - lenders in the interbank market. This class consists of 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 $\left(R_{j,t}^D\right)$, set optimally as a markdown over the marginal return on the portfolio of risk-free government bonds and loans made in the interbank market. The imperfect substitution between deposit services provided to households and the monopolistic competition between banks imply that the jth bank faces an individual deposit supply function, as in Gerali *et al.* (2009):

$$D_{j,t} = \left(\frac{R_{j,t}^D}{R_t^D}\right)^{\vartheta_D} D_t, \tag{1}$$

where $\vartheta_D > 1$ is the elasticity of substitution between different types of deposits. In setting $R_{j,t}^D$, banks face quadratic adjustment costs as in Rotemberg (1982), which allows the interest rate spread that evolves over the business cycle. The functional form of these adjustment costs is given by:

$$Ad_{j,t}^{R^D} = \frac{\phi_{R^D}}{2}\left(\frac{R_{j,t}^D}{R_{j,t-1}^D} - 1\right)^2 D_t, \tag{2}$$

where $\phi_{R^D} \geq 0$ is an adjustment cost parameter.[7]

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, $B_{j,t}$. Lending in the interbank market is risky, hence savings banks must pay a quadratic monitoring cost that depends on the loan size. Each period, with probability δ_t^D, loans made in the interbank market enter default. Thus, the optimal allocation of funds, collected from depositors, between risky interbank loans and risk-free government 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, respectively), as well as on the cost of monitoring the borrowing banks and the probability of default on interbank loans.[8]

Formally, the problem of the jth bank that lends in the interbank market is:

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

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[7]In the current calibration of BoC-GEM-Fin, ϕ_{R^D} is set to 0.

[8]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 (4).

subject to (1) and (2), taking R_t^{IB}, R_t, and δ_t^D as given. The stream of profits is discounted by $\beta^t \lambda_t$, since forward-looking households are the owners of banks. λ_t denotes the marginal utility of consumption by forward-looking households; 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 elasticity of these costs to the amount of lending.

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

$$s_t = \frac{\left(1 - \delta_t^D\right)R_t^{IB} - R_t}{\chi_s D_t}; \tag{3}$$

$$R_t^D = \frac{\vartheta_D}{1 + \vartheta_D}\left[s_t\left(1 - \delta_t^D\right)R_t^{IB} + \left(1 - s_{j,t}\right)R_t - \chi_s s_t^2 D_t - \frac{\Omega_t}{\vartheta_D} + \frac{\beta\lambda_{t+1}}{\lambda_t}\frac{\Omega_{t+1}}{\vartheta_D}\left(\frac{D_{t+1}}{D_t}\right)\right], \tag{4}$$

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 (3) 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 because of higher monitoring costs, 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 (4) defines the deposit interest rate as a mark-down of the average rate of return on savings banks' assets, net of adjustment and monitoring costs.[9]

Lending Banks. Banks in this sector borrow in the interbank market from the savings banks (the amount borrowed is $\widetilde{D}_{j,t} = \left(1 - s_t\right)D_t$), raise bank capital from households, $Q_t^Z Z_{j,t}$. The funds obtained are either lent to the entrepreneurs in the amount $L_{j,t}$, or invested in government bonds that pay the risk-free rate, R_t. The amount of government bonds on the banks' balance sheet is equal to the stock of bank capital, $Z_{j,t}$, priced at Q_t^Z. Lending banks produce loans using Leontief technology:

$$L_{j,t} = \min\left\{\widetilde{D}_{j,t}; \kappa_{j,t}Q_t^Z Z_{j,t}\right\}\Gamma_t, \tag{5}$$

where Γ_t is an AR(1) shock to the intermediation process (loan production), that represents exogenous factors affecting the bank's balance sheet.[10]

The return on loans to entrepreneurs is given by the prime loan rate, $R_{j,t}^L$, plus the risk premium, rp_t, that accounts for the costly state verification framework within Bernanke-Gertler-Gilchrist (BGG) financial accelerator setup. The rate $R_{j,t}^L$ is set by bank j in a monopolistic competition

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

[10]This could be 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.

framework, as a mark-up over the marginal cost of "producing" loans. The demand for loans from bank j follows a Dixit-Stiglitz demand function:

$$L_{j,t} = \left(\frac{R_{j,t}^L}{R_t^L}\right)^{-\vartheta_L} L_t, \tag{6}$$

where $\vartheta_L > 1$ is the elasticity of substitution between different types of loans provided by different lending banks.[11]

When adjusting the prime loan rate, $R_{j,t}^L$, banks pay a cost as in Gerali *et al.* (2009), based on Rotemberg (1982):

$$Ad_{j,t}^{R^L} = \frac{\phi_{R^L}}{2}\left(\frac{R_{j,t}^L}{R_{j,t-1}^L} - 1\right)^2 L_t, \tag{7}$$

where $\phi_{R^L} > 0$ is a parameter.

The jth 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_t^Z. The portion of interbank borrowing and bank capital the bank defaults on are $\delta_{j,t}^D$ and $\delta_{j,t}^Z$, respectively. When bank defaults, it must pay convex penalties, Ω_t^D and Ω_t^Z, in the next period, as given below:

$$\Omega_{t+1}^D = \frac{\chi_{\delta^D}}{2}\left(\frac{\delta_{j,t}^D \widetilde{D}_{j,t}}{\pi_{t+1}}\right)^2 R_t^{IB} \text{ and} \tag{8}$$

$$\Omega_{t+1}^Z = \frac{\chi_{\delta^Z}}{2}\left(\frac{\delta_{j,t}^Z Q_t^Z Z_{j,t}}{\pi_{t+1}}\right)^2 R_t^Z, \tag{9}$$

where χ_{δ^D} and χ_{δ^Z} are positive parameters.[12]

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

$$\kappa_{j,t} = L_{j,t}/Q_t^Z Z_{j,t}, \tag{10}$$

which is constrained to satisfy a maximum leverage ratio (i.e., a minimum capital requirement) set by regulators:[13]

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

Furthermore, we assume that well-capitalized banks derive quadratic gains when the leverage ratio is below the regulatory maximum. When choosing $\kappa_{j,t} < \overline{\kappa}$ (more bank capital than required

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

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

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

by regulators) the quadratic gains are given by:

$$\Omega_t^\kappa = \frac{\chi_\kappa}{2} \left(\frac{\overline{\kappa} - \kappa_{j,t}}{\overline{\kappa}} Q_t^Z Z_{j,t} \right)^2, \tag{11}$$

where $\chi_\kappa > 0$ is a parameter determining the steady-state value of κ_t. The presence of this term ensures that banks optimally choose the leverage ratio that is strictly below the maximum ratio allowed by the regulator.

Formally, the problem of the jth 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 $(5)-(9)$ and (11).[14]

The first-order conditions of this optimization problem, in a symmetric equilibrium, are:

$$\kappa_t = \overline{\kappa} \left[1 - \frac{\Gamma_t \overline{\kappa} (R_t^L - 1)}{\chi_\kappa Q_t^Z Z_t} \right]; \tag{12}$$

$$\delta_t^D = E_t \left[\frac{\pi_{t+1} R_t}{\chi_{\delta^D} \widetilde{D}_t} \right]; \tag{13}$$

$$\delta_t^Z = E_t \left[\frac{\pi_{t+1} R_t}{\chi_{\delta^Z} Q_t^Z Z_t} \right]; \tag{14}$$

$$R_t^L = 1 + \frac{\vartheta_L}{\vartheta_L - 1} (\zeta_t - 1) - \frac{\phi_{R^L}}{\vartheta_L - 1} \left(\frac{R_t^L}{R_{t-1}^L} - 1 \right) \frac{R_t^L}{R_{t-1}^L}$$
$$+ \frac{\beta \lambda_{t+1}}{\lambda_t} \frac{\phi_{R^L}}{\vartheta_L - 1} E_t \left[\left(\frac{R_{t+1}^L}{R_t^L} - 1 \right) \frac{R_{t+1}^L}{R_t^L} \right], \tag{15}$$

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

$$\zeta_t = \Gamma_t^{-1} \left\{ R_t^{IB} + \left[R_{t+1}^Z - R_t - (R_t^L - \zeta_t) \frac{\overline{\kappa} - \kappa_t}{\overline{\kappa}} \right] \frac{1}{\kappa_t} \right\} \tag{16}$$

is the marginal cost of producing loans. The term $\left[R_{t+1}^Z - R_t - (R_t^L - 1) \frac{\overline{\kappa} - \kappa_t}{\overline{\kappa}} \right] \frac{Q_t^Z}{\kappa_t}$ is the net cost of raising bank capital, which pays interest rate R_{t+1}^Z to households and is invested in government bonds earning R_t.

Using Leontief technology to produce loans implies perfect complementarity between interbank borrowing and bank capital. Thus, 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

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[14]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.

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shadow price of using capital to satisfy the capital requirement) adjusted by the leverage ratio, given by $\left[R_{t+1}^Z - R_t - (R_t^L - 1)(\overline{\kappa} - \kappa_t)/\overline{\kappa}\right] Q_t^Z / \kappa_t$. The leverage ratio chosen by banks, κ_t, affects the cost of lending through its impact on the cost of raising bank capital and ultimately through the marginal cost of producing loans.

In addition, the Leontief technology implies the following implicit demand functions of interbank borrowing and bank capital:

$$L_t = \Gamma_t \widetilde{D}_t; \tag{17}$$

$$L_t = \Gamma_t \kappa_t Q_t^Z Z_t. \tag{18}$$

Equation (12) shows that κ_t is decreasing in the lending rate and increasing in the regulatory maximum leverage and the value of bank capital. Any increase in R_t^L reduces the demand for loans thus reducing leverage, while a lower $Q_t^Z Z_t$ reduces the net marginal cost of raising bank capital. Equation (13) indicates that the banks' default rate on interbank borrowing, δ_t^D, decreases with the total amount borrowed and increases with the policy rate. A higher $\widetilde{D}_t$ increase the real marginal value of the penalty in case of default at time t, while a higher R_t implies a lower (discounted value of) marginal cost of default at t. The problem of the bank capital default rate is similar (14). Equation (15) 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.

Concluding this section, we describe more fully the channels through which $\overline{\kappa}$ affects the macro-economy. First, there is a direct effect of $\overline{\kappa}$ on the marginal cost of producing loans, ζ_t, through a reduction in the capital buffer above the regulatory requirement in (16). An increase in $\overline{\kappa}$, *ceteris paribus*, affects the law of motion of the prime loan rate, R_t^L, according to equation (15). The increase in R_t^L will negatively affect both the current and future values of the entrepreneurial net worth, N_t, and thus investment through the financial accelerator mechanism.

The second channel is the indirect effect on ζ_t through the optimal leverage ratio, κ_t, according to equation (12). A stricter capital requirement (reduction of $\overline{\kappa}$) will induce banks to optimally deleverage, reducing κ_t. From equation (17), 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 combination of alternatives that 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 cost. Banks will weigh the marginal loss in revenues from reducing loans with the marginal increase in costs from raising additional bank capital.

The level of bank capital 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:

$$Adj_t^Z = \frac{\chi_z}{2}\left(\frac{\pi_t Z_t}{Z_{t-1}} - \pi\right)^2 Q_t^Z Z_t, \tag{19}$$

9

where χ_z is an adjustment cost parameter. The adjustment cost influences the rate of return, R_t^Z, that households require in compensation for supplying new capital. In particular, if households foresee that in the next period capital would have to increase, they are willing to accept a lower return on bank capital now, in order to increase the level of capital they hold, to smooth out the transition. On the other hand, if they anticipate that bank capital would have to fall in the next period, they would demand higher rates now, to begin drawing down the level of capital today. This generates the negative correlation between expected changes in the level of bank capital and the required rate of return on it, and thus the marginal cost of lending.

2.2 Countercyclical Requirements: Implementation

As explained above, the measure of credit cycle in the countercyclical capital requirement is a matter of debate. After considering several alternatives, the BIS consultative paper (Basel Committee on Banking Supervision, BIS, 2010) proposes a particular measure. In the view of the BIS, the primary objective of the countercyclical buffer would be to achieve the macroprudential goal of protecting the banking sector from periods of excess credit growth that have been associated with a system-wide risk build-up. Therefore, the BIS advocates for use of a ratio of credit to GDP, taken in deviations from trend.[15] The introduction of an explicit link between credit and the business cycle recognizes that it is lending in excess of what is warranted by real economic developments that the regulator should target.

Our study also takes the view that the regulator should focus on bank lending, while keeping in mind the macroeconomic backdrop. We focus on a weighted average of bank lending and GDP, both in deviations from the balanced growth path. To understand why, let us consider the sources of financial distortions arising in the model. One type is related to imperfect competition in the banking sector as well as defaults by the lending banks, leading to a spread between the policy rate and the lending rate. Another is the informational asymmetry between lending banks and entrepreneurs, which results in a wedge between the financing cost for entrepreneurs and the lending rate absent such distortion.[16] Both supply factors that influence the prime lending rate excluding risky spreads, and demand factors related to the entrepreneurial net worth (such as risky spreads, see 15)[17] determine the amount of credit extended to the entrepreneurs by the banking sector. Consequently, the co-movement between credit and macroeconomic aggregates depends on the interaction between these supply and demand factors. Therefore, depending on the focus of

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[15]Other variables considered in the paper included other aggregate macroeconomic variables, measures of equity prices and risky spreads, all in deviations from long-term trends. The paper concluded that the ratio of credit to GDP be used because of a) its smooth behaviour and data availability, and b) easy interpretation.

[16]For the U.S., given the current calibration of BoC-GEM-Fin, the annualized spread between the nominal lending rate and the policy rate is approximately 3.5%, while the spread between the policy rate and the external financing cost for entrepreneurs is 6.8%.
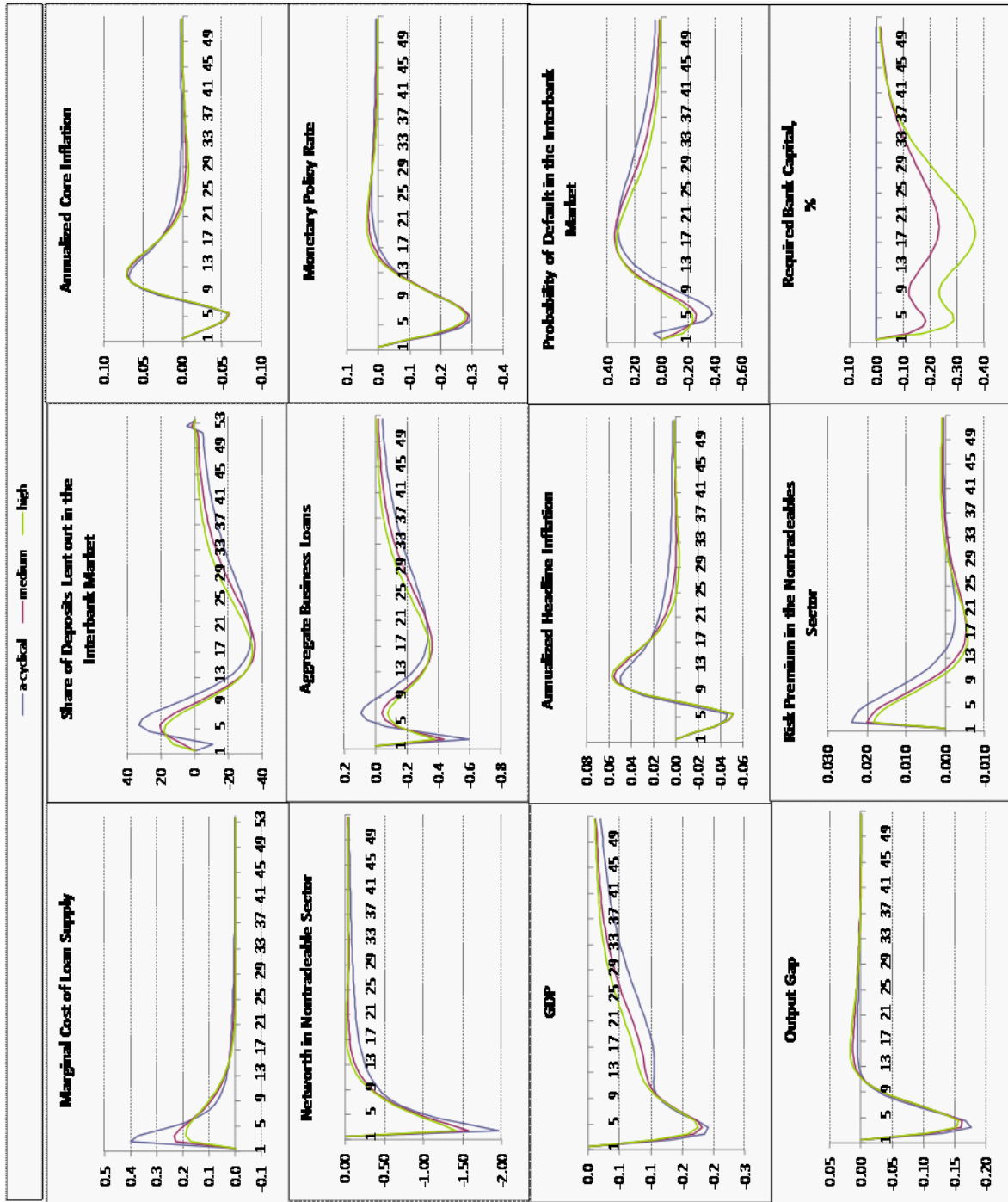
[17]Another group of factors is related to the demand for investment goods, which is influenced by the persistence of investment demand in the face of adverse shocks to the entrepreneurial net worth.

macroprudential policies, it may be better to target the risky spread for entrepreneurs (demand for credit), the spread between the bank prime lending rate (supply of credit), or the volume of loans. The latter is an equilibrium aggregate that masks the underlying determinants that could potentially be relevant for the regulator. we argue that some combination of loans and output would help to disentangle the supply and demand effects.

As an illustration of the importance of considering the determinants of credit fluctuations, Chart 1 shows the impulse response to a *negative shock to the loan production function* in the U.S., Γ_t. Such a shock creates a temporary exogenous decline in lending and is akin to a diminished intermediation capacity in the banking sector, not unlike that experienced during the recent crisis. In particular, the shock decreases the amount of loans that can be produced from a given combination of capital and interbank borrowing in the Leontief production function (5). The blue line shows the a-cyclical capital requirement policy, which we will concentrate on for now. As the shock hits, the marginal cost of producing loans immediately rises, leading to an increase in the lending rate through the effect on the marginal cost in the banking sector (16, 15). The rise in the lending rate, in turn, depresses the entrepreneurial net worth and, coupled with investment rigidities that keep investment from falling, the price of capital initially falls. This produces a fall in the value of assets on the entrepreneurs' balance sheets. Initially, this implies less lending required to finance these assets. However, as investment begins to adjust, the price of capital starts to rise and the value of assets that need to be financed increases. Consequently, loans rise above their steady state level four quarters after the initial shock.[18]

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[18] In all figures we concentrate on the non-tradable goods sector due to its large size in the economy, but the same holds for the tradable goods sector as well.

Chart 1. Banking Shock.

In such a situation, what should the aim of the countercyclical capital policy be? Even as loans start to increase several quarters after the shock, credit conditions remain less than accomodative. The bank lending rate and risky spreads remain above the steady state level. An expansion of both the quantity and the price of loans implies an increase in demand for loans which is not being fully accomodated by the supply. The actual response of the regulator to this shock would depend on the measure of the credit cycle that the policy targets.

If the quantity of loans or the ratio of loans to GDP are targeted, and assuming there is no delay in the targeting rule, the required capital ratio should initially fall below the steady state level, but then rise and remain above it for an extended period of time. Both measures would push GDP even lower in the medium term, thus making net worth decline even more and financing cost for entrepreneurs rise even higher. Furthermore, marginal cost of loan production would be higher, hurting the banking sector's profitability in the midst of a recession.

On the other hand, the spirit of countercyclical capital requirements is "to ensure that the banking sector in aggregate has the capital on hand *to help maintain the flow of credit in the economy without its solvency being questioned*, when the broader financial system experiences stress after a period of excess credit growth..." (BIS 2010). Two elements are highlighted: maintaining the flow of credit in periods of stress and safeguarding the solvency of the financial system.

In BoC-GEM-Fin, there is no insolvency in the banking sector. Banks are compensated for the losses they incur through sufficiently high spreads and penalties they impose.

Regarding the flow of credit, it is important to differentiate between the demand for and supply of credit. As the financial crisis has made policy-makers aware, efforts to increase the flow of credit will only be successful if there is demand for it. In other words, maintaining the supply of credit adequate for the level of demand and conditional on the solvency of the banking system, should be the aim of countercyclical bank capital requirement.

We concentrate on the following macroeconomic measure of the credit cycle, CC_t:

$$CC_t = \upsilon \widetilde{GDP}_t + (1 - \upsilon)\widetilde{Loans}_t, \tag{20}$$

where υ is set at 0.5, and GDP is in deviations from potential output, while loans are in deviations from the steady state.

In our model, reacting to both the quantity of loans and a measure of the macroeconomic cycle, in the form of GDP deviations from potential, can help to distinguish supply and demand for credit. Consider the scenario when loans increase and GDP falls and thus the rise in CC_t is relatively small. Roughly, this implies that demand for credit likely is pushing loans higher. This is due to a) falling net worth and b) investment demand rigidities. In this case, consistent with the ultimate goal of countercyclical capital requirements, the banking sector should accommodate increased demand, as long as the stability of the banking sector is not in question. The prudential regulator would

not raise the required capital significantly by targeting CC_t, compared to measures based solely on credit, or those that assume a "normal" *ratio* of credit to macroeconomic variables, e.g. GDP. *In particular, the latter measures imply tighter capital requirements when aggregate demand for credit rises in order to smooth over a temporary recessionary shortfall in revenues, for example to sustain investment plans.* [19]

Other alternative scenarios and the regulator's responses are summarized in Table 1 below.

The functional form for the time-varying maximum allowed leverage ratio, the inverse of the required level of capital, is as follows:

$$\overline{\kappa}_t = \overline{\kappa}_{t-1}^{\psi} \left[\overline{\kappa} \cdot [CC_t]^{-\phi} \right]^{1-\psi}, \tag{21}$$

where $\overline{\kappa}_t$ is the time-varying maximum ratio and $\overline{\kappa}$ is the steady state maximum capital ratio set at 12.5. The coefficient ψ determines the amount of smoothing in the rule and is set to 0.7 in our applications, while $-\phi$ is the short-run elasticity of the maximum leverage ratio to CC_t. In addition, below we will compare other alternative policy targets, such as a spread between the bank lending rate and the monetary policy rate and GDP deviation from trend.

Table 1. Illustration of CC_t behaviour and regulatory response.

		Loans, deviation from steady state	
		-0.5%	0.5%
GDP, deviation from potential	-0.5%	-0.5%, supply < demand, required capital falls	0.0%, supply >= demand, no change to required capital
	0.5%	0.0%, supply >= demand, no change to required capital	0.5%, supply > demand, required capital rises

3 Results

3.1 Experiment Set-up

The policy experiments we discuss in this paper are meant to address the following questions. First, what effect do countercyclical requirements have in the face of various shocks? Second, what is the optimal sensitivity of capital requirements to the selected target variable, a linear combination of bank loans and GDP? Third, is there interaction between monetary policy and a countercyclical

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[19] This discussion highlights an important point: the measure of the credit cycle has to be consistent with the overall objective of countercyclical capital buffers.

capital requirement? Finally, what should the "optimal" policy be, both for the Central Bank and the financial regulator?

We examine three shocks: a shock to the production function for loans (5), a shock to the level of productivity in the tradable and non-tradable goods sectors, and a shock to consumption demand. For each shock we consider a dynamic response of the system as a function of three parameters: the sensitivity of the countercyclical policy to the measure of credit cycle, ϕ, the sensitivity of the Taylor rule to core inflation, ω_π, and the sensitivity of the Taylor rule to the output gap, ω_y. The values we consider for these parameters are summarized in the following table:

Table 2.

Parameter	Values
ϕ	Between 0 and 30, increments of 3.
ω_π	Between 0.3 and 3, increments of 0.3; and 10.
ω_y	Values: 0.0, 0.01, 0.6.

Following each of the shocks, given a combination of parameters from the above table, we calculate the impulse response of the system and a value of a loss function that depends on GDP in deviations from potential output, and total inflation deviation from its steady state, in percentage terms, with the following form:

$$L_t = \sum_t^\infty \left[\alpha \widetilde{\pi}_s^2 + (1 - \alpha) \widetilde{GDP}_s^2 \right], \tag{22}$$

For a set value of α, we compare loss functions for all alternative parameter combinations. We do not focus on a particular loss function and instead consider a family of loss functions indexed by α, because a set of weights in practice would depend on the Central Bank's and the regulator's aversion to output and inflation deviations. Moreover, setting α at either zero or one we can compare, respectively, GDP and total inflation outcomes among policy parameter combinations.

Below, we also investigate loss functions that are tied solely to financial variables, such as the risky spread in the nontradable sector and the default rate in the interbank market. The choice of these alternative targets is natural. The default rate in the interbank market is the only determinant of the interbank spread in our model, thus it is the only source of the inefficiency in the supply of funds from the savings to lending banks. The risky spread is a wedge arising from the information asymmetry between lending banks and entrepreneurs. Therefore, loss functions based on one of these measures have focus on inefficiencies at different stages of the lending cycle.

Finally, an important point to underscore is that while the monetary authority targets core inflation, the loss function above takes into account total inflation. The latter is more relevant for welfare analysis, which can be approximated by minimizing the loss function (22), as shown in Rotemberg and Woodford (1997) and Woodford (2002).

3.2 Simulation Results

The results of our simulations are presented below in tables 3 through 5. Each table shows the results of optimization for a set of loss functions described in the previous section. In addition, the two right-most columns show loss functions that depend only on financial variables - the risky spread in the nontradables sector, or the default rate in the interbank market.

First, we would like to provide the reader with a preview of results. In terms of loss functions based on a weighted average of business loans and output, countercyclical policy is most useful in the context of financial shocks. When the economy is hit with a financial intermediation (banking) shock, the countercyclical policy is very helpful in order to stabilize macroeconomic variables. On the other hand, when the economy is hit with real shocks - supply (e.g. productivity in the tradable and nontradable sectors) or demand (e.g. a shock to consumption preferences) - the benefits of countercyclical bank capital requirement are very small. In particular, the reduction in the usual loss functions based on GDP and inflation is very small, compared to a sizeable fall in losses after a financial shock. When we consider loss functions based on financial variables, the countercyclical capital requirements are much more useful, producing sizeable falls in volatility of these measures.

Table 3 presents the results of a shock to the banks' production function for loans. The row titled "Overall best" shows the minimum value of the loss function and the combination of coefficients that achieves it, given the weight on inflation. The order of coefficients is a) (countercyclical) sensitivity of the required bank capital ratio to the target variable, b) the inflation coefficient in the monetary policy rule, and c) the output gap coefficient in the monetary policy rule. For example, in Table 3, when the weight on inflation, α, is 0, the minimum value of the function is 0.012, and the optimized value of ϕ is 30, ω_π is 10 and ω_y is 0.56. In the the same row, the higher is the weight on inflation in the loss function, the less the overall aggressiveness of the countercyclical policy becomes (notice the decline of ϕ from 30 to 0).

We will now look at the results in Table 3 in more detail. Rows below the first show the optimal combinations of monetary policy coefficients conditional on a given value for ϕ, from 0 to 30. It also demonstrates the ratio of the value of the loss function conditional on a combination of parameters, to the overall best for that variant of the loss function. With ϕ set to 0 capital requirements are a-cyclical. With ϕ set to 30, the regulator is very actively responding to a measure of credit and business cycle by varying the capital requirement. In the table, the cells with the minimum loss function level are highlighted in grey, as can be seen from the ratio of the value of the loss function to the minimum of that loss function at the top (the ratio equals to one in all grey-shaded cells).

First, we focus on the "typical" loss functions that weigh inflation and output deviations from the respective steady states. Table 3 contains several key messages. First, α, the weight placed on inflation in the loss function, critically determines the optimal sensitivity of the countercyclical policy to the measure of credit and business cycle. As the weight on inflation increases above 0.6

the optimal sensitivity of the countercyclical policy falls to zero. The reason is that inflation is not very sensitive to changes in bank capital requirements, even as the latter have an effect on the output gap.

Second, the inflation coefficient in the monetary policy rule remains at the maximum, 10, regardless of the shares of output and inflation in the loss function. This is because inflation and the output gap move in the same direction following a banking shock, implying no trade-off between inflation and output loss components in the monetary policy rule. The strongest response is best in this situation.

Furthermore, even though the inflation coefficient is 10, the coefficient on the output gap remains at the maximum. This is because in our model monetary policy targets core inflation, in accord with the stated or implicit practice of central banks, while the loss function is specified in terms of total inflation. The latter is more relevant for welfare of households. The output gap is more correlated with the total inflation, so stabilizing the output gap helps to smooth out the remaining deviations of the headline inflation. This effect, however, is only second order, compared to the effect of core on headline inflation.

Third, the differences between the overall and constrained minima of the loss function are substantial. For example, at α equal to 0, the a-cyclical capital requirement is 11% more costly than a very aggressive bank capital policy.[20]

In the case of loss functions based on financial variables, the optimal policy depends significantly on the type of the function. As explained above, we consider two variables, the risky financing spread in the non-tradable sector, and the default rate in the interbank market. In both cases counter-cyclical bank capital policy is helpful in stabilizing target variables: an aggressive loosening of capital requirements stabilizes the interbank default rate and prevents prime lending rate from rising as much, improving net worth and hence risky spreads. The optimal combination of monetary policy coefficients, on the other hand, is sensitive to the loss function specification. The optimal combination of coefficients in the policy rule is determined by the dynamic properties of the associated target variable (output gap and core inflation), in particular their correlation with the interbank default rate.

Looking further, first, let us focus on the interbank market default rate. Notice that the default rate falls initially after a negative banking shock (chart 1). This is because this shock is an exogenous decline in the banks' productivity. If the demand for loans does not fall sufficiently, the decline in productivity may lead to an increase in demand for interbank borrowing, an input into the Leontief's loan production function. This effect depends on the elasticity of demand for loans. An initial rise in interbank borrowing implies a fall in the interbank default rate, ceteris paribus (see equation 13), as the penalty for default increases.

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[20]In terms of GDP, the improvement is approximately 0.01 per cent.

Given the basic mechanism, it is not surprising that the maximum coefficient in countercyclical policy is required to stabilize the interbank default rate. The tightening and loosening of capital requirements aims to keep business loans stable, which helps to stabilize the denominator of the equation for the default rate (see equation 13).

On the other hand, monetary policy can make the default rate more volatile. First, the real policy rate falls, which increases the discounted cost of default and reduces the probability of default (see equation 13). Second, *ceteris paribus*, a *larger* fall in the *real* monetary policy rate causes the interbank rate to fall further, encouraging more borrowing by the lending banks in the interbank market. Both effects imply a lower default rate in the first two years. The situation is symmetrical for the case of a larger increase in the real rate. In particular, increasing the coefficient on inflation in the policy rule makes the real policy rate first fall more and then rise more, making the probability of default more volatile through the discounted cost of default channel (equation 13, above).

On the other hand, the coefficient on the output gap is at the maximum value considered. Since a fall in the output gap leads to a fall in the entrepreneurial net worth, which requires more borrowing by the entrepreneurs in the short term in order to finance sticky investment, as well as leads to higher external financing cost, reducing the volatility of the output gap is helpful in itself. Furthermore, increasing the output gap coefficient in the policy rule significantly reduces the volatility of the output gap without creating persistent policy rate deviations. This is because, after the banking shock, the output gap is less persistent than inflation, thus necessitating a less persistent response.

Considering the loss function based on the risky spread, the coefficients are at the maximum both on the output gap and the inflation rate. This is because when the negative shock hits, the net worth of entrepreneurs falls and the risky spread rises. So the lower the policy rate falls, the less the risky spreads increase, explaining why both coefficients are at the maximum. In addition, even if the core inflation rate is stabilized, there still is a benefit in reacting to the output gap in order to stabilize the headline inflation due to the debt deflation phenomenon.

Table 3.

Banking Shock			Weight on Inflation in the Loss Function, α						Financial	
			0	0.2	0.4	0.6	0.8	1	Spread	Default
	Overall Best	Value	0.012	0.011	0.010	0.009	0.008	0.007	0.021	0.000
		Policy Coefficients	30, 10, 0.56	30, 10, 0.56	30, 10, 0.56	30, 10, 0.56	0, 10, 0.56	0, 10, 0.56	30, 10, 0.56	30, 0.3, 0.56
Counter-cyclical coefficients, φ	0	Value/Overall Min	1.11	1.08	1.05	1.01	1.00	1.00	1.43	1.41
		Policy Coefficients	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	0.3, 0.56
	6	Value/Overall Min	1.05	1.04	1.02	1.00	1.01	1.04	1.31	1.36
		Policy Coefficients	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	0.3, 0.56
	12	Value/Overall Min	1.02	1.02	1.01	1.00	1.03	1.07	1.22	1.28
		Policy Coefficients	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	0.3, 0.56
	18	Value/Overall Min	1.01	1.01	1.01	1.01	1.04	1.09	1.14	1.19
		Policy Coefficients	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	0.3, 0.56
	24	Value/Overall Min	1.01	1.01	1.01	1.01	1.04	1.10	1.07	1.10
		Policy Coefficients	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	0.3, 0.56
	30	Value/Overall Min	1.00	1.00	1.00	1.00	1.03	1.09	1.00	1.00
		Policy Coefficients	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	0.3, 0.56

Next we examine a temporary positive technology shock in both the tradable and non-tradable sectors. This shock is an example of an economy-wide supply shock, and a priori it is not clear what the role of countercyclical policy would be. Chart 2 shows impulse responses for this shock. As the shock hits, GDP rises, but potential output rises even more, producing initially negative output gap and lower inflation. Investment rises, and with it rises demand for loans. The lending rate falls, remaining below the steady state value for over 10 years. The latter effect can be explained by i) a fall in the policy rate, and ii) a temporary fall in the required return on bank capital. The latter is due to falling opportunity cost of adjusting the bank capital, as faced by the forward-looking consumers.

As Table 4 shows, the optimal countercyclical policy is either very aggressive (the coefficient is 30), or the requirement is a-cyclical (the coefficient is 0). However, as the ratio of loss functions demonstrates, the overall optimal combination of coefficients is not very different in terms of the loss function value. When policymakers are only concerned about GDP losses, at α equal to zero, the minimum loss function is achieved with strongly countercyclical policy, a relatively weak response to inflation and a strong response to the output gap. The capital requirements are preferred to be countercyclical in this case, since the output gap is initially negative while business loans increase. The overall effect on capital requirements is approximately zero in the first few quarters, since the weighted average of loans and output gap is roughly zero. The required capital increases later on, when the output gap switches sign and loans remain persistently above their steady state. The increase in the countercyclical capital produces a fall in bank capital adjustment costs in the first

few quarters of the shock. This is due to a short term negative correlation between the marginal cost of lending and the changes in bank capital, because of the adjustment costs on bank capital (see equation 19 and the discussion that follows it).

This initially implies a lower lending rate for entrepreneurs, which causes their net worth to increase, making them demand fewer loans in the long term. The overall effect of countercyclical policy is then to reduce the amount of borrowing and risky spreads, while not affecting the real macroeconomic aggregates.

As the weight on total inflation increases, the optimal response to inflation in the monetary policy rule rises as well, while the output gap coefficient eventually falls to zero, because reacting to the output gap makes monetary policy less effective in bringing inflation back to the target, given differences in persistence between inflation and output gap. Furthermore, in all cases, countercyclical capital requirement does not reduce the loss function significantly. This is because there is almost no effect on GDP or inflation from changes in capital requirements.

Table 4.

Technology Shock			Weight on Inflation in the Loss Function, α						Financial	
			0	0.2	0.4	0.6	0.8	1	Spread	Default
	Overall Best	Value	0.216	0.237	0.208	0.153	0.083	0.006	0.027	0.001
		Policy Coefficients	30, 0.3, 0.56	0, 0.9, 0.56	0, 0.9, 0.56	30, 2.1, 0.02	30, 2.7, 0	30, 10, 0	30, 2.1, 0.56	30, 0.3, 0
Counter-cyclical coefficients, φ										
	0	Value/Overall Min	1.01	1.00	1.00	1.01	1.00	1.23	1.88	1.60
		Policy Coefficients	0.3, 0.56	0.9, 0.56	0.9, 0.56	2.1, 0.02	2.7, 0	10, 0	10, 0.56	0.3, 0.56
	6	Value/Overall Min	1.00	1.00	1.00	1.01	1.00	1.16	1.72	1.46
		Policy Coefficients	0.3, 0.56	0.9, 0.56	0.9, 0.56	2.1, 0.02	2.7, 0	10, 0	10, 0.56	0.3, 0.56
	12	Value/Overall Min	1.00	1.01	1.00	1.01	1.00	1.11	1.56	1.33
		Policy Coefficients	0.3, 0.56	0.9, 0.56	0.9, 0.56	2.1, 0.02	2.7, 0	10, 0	10, 0.56	0.3, 0
	18	Value/Overall Min	1.00	1.01	1.01	1.00	1.00	1.06	1.37	1.20
		Policy Coefficients	0.3, 0.56	0.9, 0.56	0.9, 0.56	2.1, 0.02	2.7, 0	10, 0	2.7, 0.56	0.3, 0
	24	Value/Overall Min	1.00	1.01	1.01	1.00	1.00	1.03	1.17	1.09
		Policy Coefficients	0.3, 0.56	0.9, 0.56	0.9, 0.56	2.1, 0.02	2.7, 0	10, 0	2.7, 0.56	0.3, 0
	30	Value/Overall Min	1.00	1.01	1.00	1.00	1.00	1.00	1.00	1.00
		Policy Coefficients	0.3, 0.56	0.9, 0.56	0.9, 0.56	2.1, 0.02	2.7, 0	10, 0	2.1, 0.56	0.3, 0

Finally, we look at a temporary positive shock to consumption preferences. Broadly speaking, this shock leads to a boost in consumption, imports and GDP, and also features falling investment, and hence business loans.

In Chart 3, the profiles of inflation and output gap illustrate why countercyclical policy is useful when inflation weight is not too large. The output gap returns to the equilibrium following an initial positive hump-shaped response to the shock. Inflation, on the other hand, remains persistently above the steady state level. The marginal cost of lending for banks increases immediately and

follows the shape of the policy rate, remaining above the steady state level for a significant time period. The fall in loans dominates the increase in output, which requires the regulator to loosen capital requirements. When faced with a decrease in required capital, banks optimally adjust their level of capital. Due to the presence of adjustment costs, marginal cost of lending initially increases above the a-cyclical response. This means that looser capital requirements are less effective immediately, than in the medium term. For this shock, such behaviour favours responding to the output gap, which is zero in the medium term, just when lower requirements are most effective, and positive in the short term, when marginal cost of lending is high. On the other hand, inflation is above equilibrium in the short and medium term, making countercyclical policy less useful when the loss function places a large weight on inflation.

Table 5 corroborates this: countercyclical capital requirements are most effective on output stabilization, as we explain above (the overall mimima of loss functions that include a significant weight on the output gap are at least 5 per cent and up to 30 per cent lower than the constrained optima along the a-cyclical policy row). When inflation is the sole objective, the policy is not very effective – the differences between constrained and global minima are very small.

Loss functions that focus on financial variables require a strong countercyclical response. This is because for this shock, the regulator is mostly reacting to falling loans, which the regulator targets by lowering the required bank capital. Initially, this leads to a higher increase in the marginal cost of loan supply relative to the a-cyclical rule, which makes external financing for entrepreneurs more expensive, making their net worth fall relatively more. This is analogous to the case of a technology shock, where marginal cost initially falls when required capital begins to increase. Eventually, marginal cost of lending falls below the a-cyclical case as the full effect of lower capital requirement is felt by the banks.

Table 5.

Consumption Shock			Weight on Inflation in the Loss Function, α						Financial	
			0	0.2	0.4	0.6	0.8	1	Spread	Default
	Overall Best	Value	0.018	0.024	0.027	0.024	0.017	0.008	0.094	0.001
		Policy Coefficients	30, 0.9, 0.56	30, 0.9, 0.56	30, 1.5, 0.56	30, 2.7, 0.56	30, 10, 0.56	0, 10, 0.56	30, 1.5, 0.56	30, 0.3, 0
Counter-cyclical coefficients, φ	0	Value/Overall Min	1.30	1.19	1.14	1.11	1.05	1.00	1.60	1.39
		Policy Coefficients	0.9, 0.56	0.9, 0.56	1.5, 0.56	2.7, 0.56	10, 0.56	10, 0.56	10, 0.56	0.3, 0
	6	Value/Overall Min	1.25	1.16	1.12	1.09	1.05	1.04	1.48	1.30
		Policy Coefficients	0.9, 0.56	0.9, 0.56	1.5, 0.56	2.7, 0.56	10, 0.56	10, 0.56	10, 0.56	0.3, 0
	12	Value/Overall Min	1.18	1.12	1.09	1.07	1.04	1.07	1.36	1.22
		Policy Coefficients	0.9, 0.56	0.9, 0.56	1.5, 0.56	2.7, 0.56	10, 0.56	10, 0.56	10, 0.56	0.3, 0
	18	Value/Overall Min	1.12	1.08	1.06	1.05	1.03	1.10	1.24	1.14
		Policy Coefficients	0.9, 0.56	0.9, 0.56	1.5, 0.56	2.7, 0.56	10, 0.56	10, 0.56	1.5, 0.56	0.3, 0
	24	Value/Overall Min	1.06	1.04	1.03	1.02	1.01	1.12	1.11	1.07
		Policy Coefficients	0.9, 0.56	0.9, 0.56	1.5, 0.56	2.7, 0.56	10, 0.56	10, 0.56	1.5, 0.56	0.3, 0
	30	Value/Overall Min	1.00	1.00	1.00	1.00	1.00	1.13	1.00	1.00
		Policy Coefficients	0.9, 0.56	0.9, 0.56	1.5, 0.56	2.7, 0.56	10, 0.56	10, 0.56	1.5, 0.56	0.3, 0

An important conclusion from the simulations we have presented is that the countercyclical capital requirements are much more effective at stabilizing output and financial variables, as opposed to inflation, and that it is much better at responding to shocks that originate in the banking sector (or financial shocks in general), as well as demand shocks, than supply shocks. Finally, implementing countercyclical bank capital regulations may significantly reduce the volatility of output and risky spreads.

A note of caution is that since we are focusing on single shocks, the optimal values for the coefficients on inflation and output gap, as well as the measure of the credit and business cycle in the policy functions are at the limits of the ranges we consider. Ultimately, the optimal policy should depend on the joint distribution of shocks, resulting in more moderate coefficient values.

3.3 Reacting to the Lending Rate Spread

In this section we briefly look at the specification of the countercyclical policy where the target variable is the spread between the lending rate and the policy rate. As was mentioned above, consistent with an emphasis on the "uninterrupted supply of credit", the regulator may want to react to an aggregate that is most closely related to the supply of credit. In our model, banks set the price of credit in the form of the lending rate, a mark-up over the marginal cost, while the quantity of loans is determined by demand for credit given that rate. Hence, the spread between the lending rate and the monetary policy rate, which excludes the risky spread, is the most natural indicator for the regulator to target. When the lending rate spread increases above its equilibrium

level, supply of credit becomes too restrictive. Hence, the regulator would want to counteract that by lowering the required capital ratio, which would lead to a decline in the marginal cost of lending and reduce the spread.

We test the new specification using the same structural shocks as in the previous section. Table 6 shows the results for the bank lending shock. The main difference is that the for all loss functions the optimal capital requirement policy is very aggressive, unlike in Table 3, where as the weight on inflation increases the countercyclical policy becomes less useful. In this case, the differences in loss functions are substantial: the a-cyclical capital buffers are more than 50 per cent worse, judging by the loss function, than the aggressive countercyclical buffers. In this case the countercyclical requirements target precisely the root of the problem – an exogenous increase in the cost of producing loans which requires the banks to raise their lending spread.

Unlike in the previous section, when the economy experiences a broad technology shock and the regulatory capital depends cyclically on the prime lending rate spread, the optimal policy is to be very aggressive (see Table 7). For all combinations of inflation and output in the loss function, the optimal coefficient on the lending spread is 30, the maximum we allow. The choice of aggressive policy is explained by a closer correlation between the prime lending rate spread and the displacement of inflation and output from their trends. A caveat is that the loss function is fairly flat, so the outcomes are not very different with or without countercyclical buffers. On the other hand, the coefficients in the monetary policy rule are changing quite intuitively: as the weight on inflation in the loss function increases, the weight on inflation gap in the monetary policy rule increases as well, while the weight on the output gap falls from 0.56 to 0.

Finally, when faced with a consumption shock the optimal specification for the countercyclical capital requirements is very aggressive for all loss functions (see Table 8). However, the countercyclical policy in general is not very effective, since the difference between a-cyclical and very aggressive countercyclical policies is small in terms of macroeconomic-based loss functions.

As in the previous subsection, when loss functions are based on financial variables, the optimal policy is very countercyclical. In most cases, the differences in loss functions are not very pronounced, but regardless off the size of the improvement, having an aggressive countercyclical policy is at least neutral in most cases and beneficial when the shocks are financial in nature.

4   Conclusion

In this paper we looked at the optimal countercyclical bank capital requirements. We examined several specifications for countercyclical bank capital rules under various conditions . The main points of discovery can be summarized as follows:

- regardless of the specification, reacting to credit and GDP, or to the lending spread, strongly

countercyclical response to financial shocks is best;

- for the rule specification based on credit and GDP, the aggressiveness when facing the supply shocks increases in the weight on inflation in the loss function; for the demand shocks, as long as there is some weight on output gap the optimal policy is to adjust capital requirements very aggressively;

- when reacting to the bank prime lending rate spread, facing demand shocks, the countercyclical policy needs to be very aggressive regardless of the weights on inflation and output gap in the loss function;

- when reacting to the lending spread after supply shocks, the countercyclical policy has to be uniformly aggressive;

- finally, for many shocks, the difference in macroeconomic loss function outcomes is fairly small;

- for loss functions based on financial variables - risky spread or the probability of default in the interbank market, a very aggressive countercyclical policy is required, regardless of the measure of the credit market that is used to vary the capital requirements.

References

Basel Committee on Banking Supervision, BIS, 2010. "Countercyclical Capital Buffer Proposal", Consultative Document.

Bernanke, B., M. Gertler, and S. Gilchrist. 1999. "The Financial Accelerator in a Quantitative Business Cycle Framework." In Taylor, J.B., & Woodford, M., eds. Handbook of Macroeconomics. Bodmin: North-Holland Publishing.

Covas, F and S Fujita (2009), "Time-varying capital requirements in a general equilibrium model of liquidity dependence". Working Papers 09-23, Federal Reserve Bank of Philadelphia.

Christiano, L., R. Motto, and M. Rostagno. 2010. "Financial Factors in Economic Fluctuations." ECB Working Paper Series No. 1192.

de Resende, C., A. Dib, R. Lalonde, and S. Snudden., 2010. "The Bank of Canada's Version of the Global Economy Model with Financial Frictions (BoC-GEM-Fin)." Bank of Canada technical Report, forthcoming.

Dib, A., 2010. "Banks, Credit Market Frictions, and Business Cycles." Bank of Canada Working Paper, 2010-24.

Evans, P. 1993. "Consumers Are Not Ricardian: Evidence from Nineteen Countries." *Economic Inquiry* 31 (4): 534–48.

Galati, G., R. Moessner, 2011. "Macroprudential Policy - a Literature Review" BIS Working Papers No 337.

Gali, J., J. D. López-Salido, and J. Vallés. 2004. "Rule-of-Thumb Consumers and the Design of Interest Rate Rules." NBER Working Papers 10392.

Gerali, A., S. Neri, S., L. Sessa, and F. M. Signoretti. 2010. "Credit and Banking in a DSGE Model of the Euro Area." Bank of Italy Temi di Discussione No. 740.

Kannan, P., P. Rabanal and A. Scott, 2009. "Monetary and Macroprudential Policy Rules in a Model with House Price Booms", IMF Working Paper WP/09/251.

Lalonde, R., and D. Muir. 2007. "The Bank of Canada's Version of the Global Economy Model (BoC-GEM)." Bank of Canada Technical Report No. 98.

Pesenti, P., 2008. "The Global Economy Model: Theoretical Framework." *IMF Staff Papers* Vol. 55, No. 2.

Rotemberg, Julio J., and Michael Woodford (1997), "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy", in B.S. Bernanke and Rotemberg (eds.), NBER Macroeconomic Annual 1997, Cambridge, MA: MIT Press. 297-346.

Rotemberg, J. 1982. "Monopolistic Price Adjustment and Aggregate Output." *Review of Economic Studies* 49: 517-31.

Van den Heuvel, S. (2008), "The welfare cost of bank capital requirements", Journal of Monetary Economics 55, p. 298-320.

Woodford, M. 2002. "Inflation Stabilization and Welfare", The B.E. Journal of Macroeconomics, Volume 2, Issue 1, Article 1.

Zhu, H (2008), "Capital Regulation and Banks' Financial Decisions", International Journal of Central Banking, 4(1), pp. 165-211.
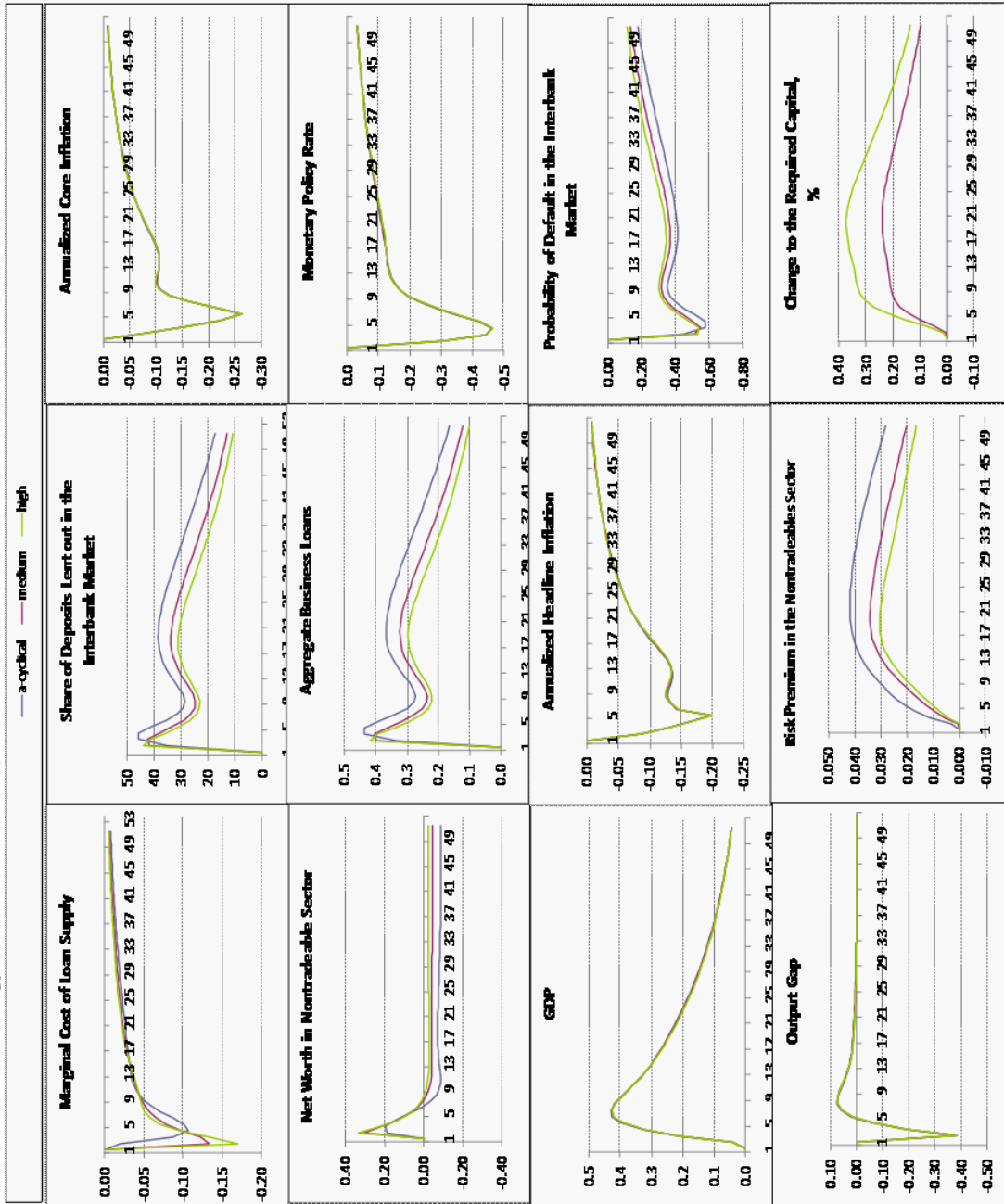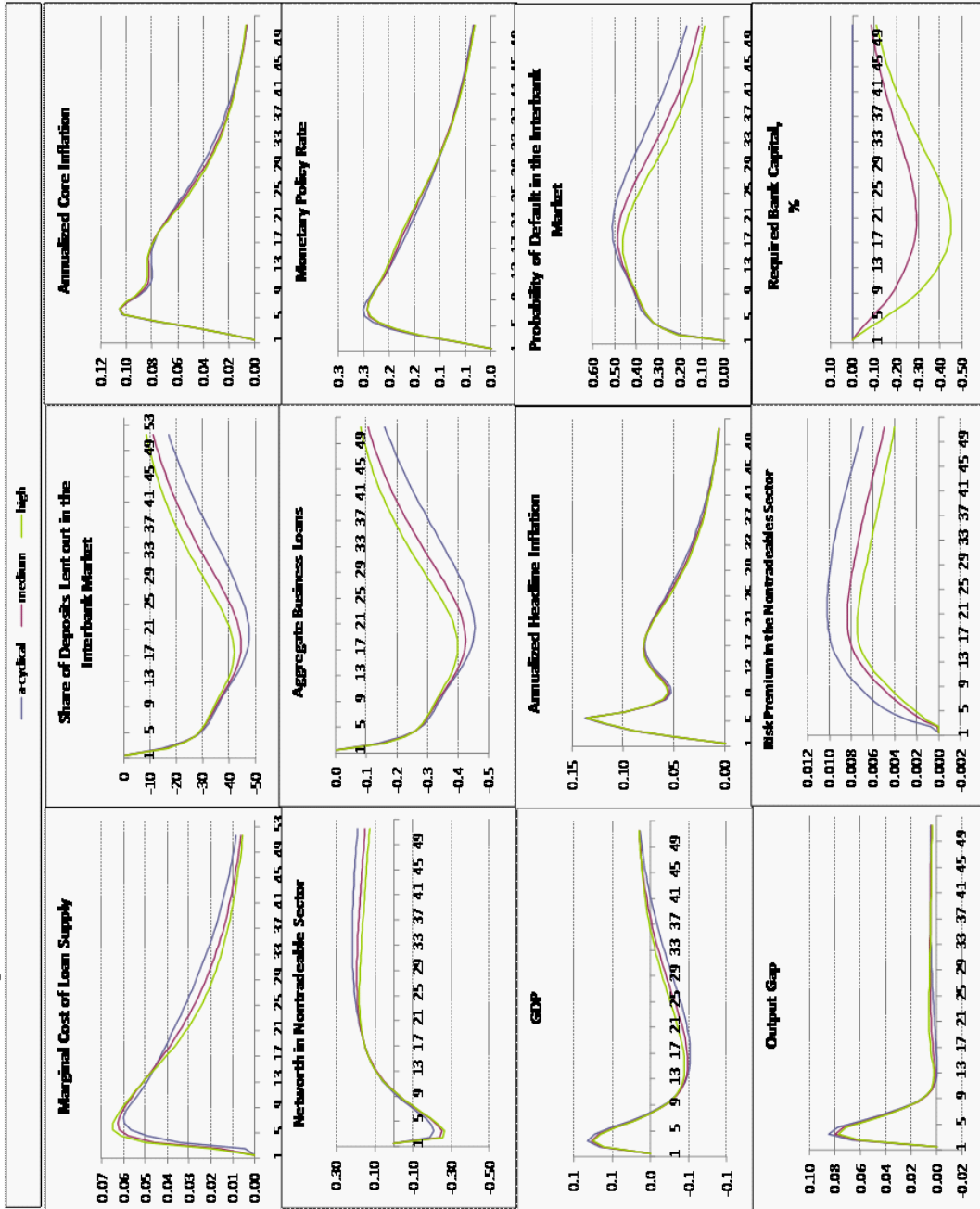
Chart 2: Technology Shock

Chart 3: Consumption Shock

Table 6. Lending Spread-based Capital Requirement Rule.

Banking Shock			Weight on Inflation in the Loss Function, α						Financial	
			0	0.2	0.4	0.6	0.8	1	Spread	Default
Overall Best		Value	0.00696	0.00633	0.00570	0.00507	0.00444	0.00351	0.03886	0.00067
		Policy Coefficients	30, 10, 0.56	30, 10, 0.56	30, 10, 0.56	30, 10, 0.56	30, 10, 0.56	30, 2.7, 0.56	30, 0.3, 0.56	30, 0.3, 0.56
Counter-cyclical coefficients, φ	0	Value/Overall Min	1.80	1.76	1.71	1.65	1.56	1.50	1.30	1.27
		Policy Coefficients	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	2.7, 0.56	10, 0.56	0.3, 0.56
	6	Value/Overall Min	1.55	1.53	1.49	1.45	1.40	1.36	1.24	1.20
		Policy Coefficients	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	2.7, 0.56	10, 0.56	0.3, 0.56
	12	Value/Overall Min	1.36	1.35	1.33	1.30	1.27	1.25	1.17	1.14
		Policy Coefficients	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	2.7, 0.56	2.7, 0.56	0.3, 0.56
	18	Value/Overall Min	1.22	1.21	1.20	1.18	1.17	1.15	1.12	1.09
		Policy Coefficients	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	2.7, 0.56	2.7, 0.56	0.3, 0.56
	24	Value/Overall Min	1.10	1.09	1.09	1.08	1.08	1.07	1.06	1.04
		Policy Coefficients	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	2.7, 0.56	0.3, 0.56	0.3, 0.56
	30	Value/Overall Min	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Policy Coefficients	10, 0.56	10, 0.56	10, 0.56	10, 0.56	10, 0.56	2.7, 0.56	0.3, 0.56	0.3, 0.56

Table 7. Lending Spread-based Capital Requirement Rule.

Technology Shock			Weight on Inflation in the Loss Function, α						Financial	
			0	0.2	0.4	0.6	0.8	1	Spread	Default
Overall Best		Value	0.21	0.22	0.20	0.15	0.08	0.01	0.07	0.0021
		Policy Coefficients	30, 0.3, 0.56	30, 0.3, 0.56	30, 0.9, 0.56	30, 1.5, 0.02	30, 2.7, 0	30, 10, 0	30, 10, 0.56	30, 0.9, 0
Counter-cyclical coefficients, φ	0	Value/Overall Min	1.02	1.01	1.01	1.01	1.00	1.00	1.11	1.02
		Policy Coefficients	0.3, 0.56	0.3, 0.56	0.9, 0.56	1.5, 0.02	2.7, 0	10, 0	10, 0.56	0.9, 0
	6	Value/Overall Min	1.01	1.01	1.01	1.00	1.00	1.00	1.08	1.02
		Policy Coefficients	0.3, 0.56	0.3, 0.56	0.9, 0.56	1.5, 0.02	2.7, 0	10, 0	10, 0.56	0.9, 0
	12	Value/Overall Min	1.01	1.00	1.00	1.00	1.00	1.00	1.05	1.01
		Policy Coefficients	0.3, 0.56	0.3, 0.56	0.9, 0.56	1.5, 0.02	2.7, 0	10, 0	10, 0.56	0.9, 0
	18	Value/Overall Min	1.00	1.00	1.00	1.00	1.00	1.00	1.03	1.01
		Policy Coefficients	0.3, 0.56	0.3, 0.56	0.9, 0.56	1.5, 0.02	2.7, 0	10, 0	10, 0.56	0.9, 0
	24	Value/Overall Min	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.00
		Policy Coefficients	0.3, 0.56	0.3, 0.56	0.9, 0.56	1.5, 0.02	2.7, 0	10, 0	10, 0.56	0.9, 0
	30	Value/Overall Min	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Policy Coefficients	0.3, 0.56	0.3, 0.56	0.9, 0.56	1.5, 0.02	2.7, 0	10, 0	10, 0.56	0.9, 0

Table 8. Lending Spread-based Capital Requirement Rule.

Consumption Shock			Weight on Inflation in the Loss Function, α						Financial	
			0	0.2	0.4	0.6	0.8	1	Spread	Default
	Overall Best	Value	0.02112	0.02388	0.02566	0.02147	0.01704	0.01257	0.18055	0.00218
		Policy Coefficients	30, 0.3, 0.56	30, 0.9, 0.56	30, 1.5, 0.56	30, 10, 0.56	30, 10, 0.56	30, 10, 0.02	30, 10, 0	30, 10, 0
Counter-cyclical coefficients, φ										
	0	Value/Overall Min	1.02	1.02	1.01	1.00	1.01	1.01	1.04	1.02
		Policy Coefficients	0.3, 0.56	0.9, 0.56	1.5, 0.56	10, 0.56	10, 0.56	10, 0.02	10, 0	10, 0
	6	Value/Overall Min	1.01	1.01	1.01	1.00	1.00	1.01	1.03	1.02
		Policy Coefficients	0.3, 0.56	0.9, 0.56	1.5, 0.56	10, 0.56	10, 0.56	10, 0.02	10, 0	10, 0
	12	Value/Overall Min	1.01	1.01	1.01	1.00	1.00	1.01	1.02	1.01
		Policy Coefficients	0.3, 0.56	0.9, 0.56	1.5, 0.56	10, 0.56	10, 0.56	10, 0.02	10, 0	10, 0
	18	Value/Overall Min	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01
		Policy Coefficients	0.3, 0.56	0.9, 0.56	1.5, 0.56	10, 0.56	10, 0.56	10, 0.02	10, 0	10, 0
	24	Value/Overall Min	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.00
		Policy Coefficients	0.3, 0.56	0.9, 0.56	1.5, 0.56	10, 0.56	10, 0.56	10, 0.02	10, 0	10, 0
	30	Value/Overall Min	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Policy Coefficients	0.3, 0.56	0.9, 0.56	1.5, 0.56	10, 0.56	10, 0.56	10, 0.02	10, 0	10, 0