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The Effects of Countercyclical Capital Buffers on Macroeconomic and Financial Stability

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Abstract

We quantitatively study the effectiveness of several forms of countercyclical capital buffers on promoting macroeconomic and financial stability. To do this we introduce banks and a regulatory capital requirement rule to an open economy DSGE model. The capital requirement consists of a fixed part and a countercyclical part. We find that the tighter fixed capital requirements, the better able banks are to handle a financial crisis, but these also reduce long-term consumption and welfare. More importantly, countercyclical buffers that respond to deviation of the observed credit to GDP ratio from its long-term value, or to percentage deviation of the observed credit (or GDP) from its long-term value improve macroeconomic and financial stability and increase welfare. Being forward looking does not pay off. Interestingly, when buffers respond to percentage deviation of asset prices from their long-term values or to credit (or GDP) growth, macroeconomic and financial stability are negatively affected.

Key Words: Capital requirements, countercyclical buffers, financial stability, macroeconomic stability.

JEL Codes: E32, G01, G21, G28.

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1 Introduction

The 2008 global financial crisis proved the need for macroprudential policies targeting the probability of a financial crisis. In this context, Basel III appears with a proposal that is supposed to strengthen the capital of banks taken into account the deficiencies in financial regulation revealed for the 2008 US financial crisis. It recommends higher fixed capital requirements and countercyclical capital buffers.

In that sense, the main objective of this paper is to assess the impact of different forms of countercyclical capital buffers. Hence, we try to contribute to the policy discussing by formally assessing the impact of already debated countercyclical capital buffers on macroeconomic and financial stability and on welfare.

To do so we develop a baseline model. In this model we introduce into an open economy DSGE model banks and regulatory capital requirements. Importantly, since we are not modeling any friction that might lead to inefficient banks' decisions on credit, it is not the interest of this paper to provide a socially optimal capital requirement rule, but rather to focus on the marginal effects of capital requirements or capital buffers.

We incorporate banks as in Gertler and Karadi 2011 (henceforth GKa 2011) in a DSGE model and a regulatory capital requirement rule composed of two parts: The first part consists of a fixed capital requirement. This is, the regulator requires banks to hold as bank net worth a fixed proportion of their total assets. It aims to promote an appropriate level of bank leverage so that the economy will be in good conditions to face a financial crisis. The second part consists of countercyclical capital buffers that responds to the credit spread. In particular, it relaxes the credit constraint (capital requirements) in downturns periods. The role of this part is to reduce real losses once the crisis occurs or equivalently it lessens the effects of the financial crisis whenever it occurs.

In this baseline model, we find that the tighter fixed capital requirements, the better able banks are, and hence economy, to handle a financial crisis; however, it also reduces long-term values of consumption. As a result, as expected tighter fixed capital requirements reduces welfare. Also, we find that countercyclical buffers that respond to credit spread deviations from its long-term value improves macroeconomic and financial stability, i.e., reduces the volatility of macroeconomic and financial cycles, and hence improves welfare.

The main contribution of this work is that after building up our baseline model we propose several additional countercyclical capital buffers and assess their impacts on macroeconomic and financial stability and on welfare. We find that countercyclical buffers that respond to deviations of observed credit to GDP ratio from its long-term value, or to percentage deviations of the observed credit (or GDP) from its long-term value reduce the volatility of macroeconomic and financial cycles and hence raises welfare. While the re-

duction of the volatility of these cycles seems economically important, the welfare increase does not seem, but in contexts of higher uncertainty it might be.

In addition, if buffers respond to the contemporaneous or expected future values of the same indicators, there are not welfare gains. Interestingly, if buffers respond to asset price deviations from its long-term value, macroeconomic and financial stability are negatively affected and welfare decreases. Since asset prices are very volatile, they do not necessarily capture very well the need of the economy for looser or tighter capital requirements. Also, when buffers respond to credit or output growth, volatility of macroeconomic and financial cycles increases and consequently welfare shrinks. This is because the timing of the credit or GDP dynamics might give us a bad indicator of whether regulator must ease or tighten capital requirements.

Finally, as a policy recommendation, according to this work, it seems reasonable to have the observed deviation of bank credit to GDP ratio from its long-term trend or the observed percentage deviation of credit (or output) from its long-term trend as guides to implement countercyclical capital buffers.

The paper is organized as follows: Section 2 presents the relevant literature on this topic. Section 3 describes the baseline model. Section 4 presents the parametrization technique. Section 5 presents the results of the simulations and the different forms of countercyclical capital buffers. Finally, section 6 concludes.

2 Literature Review

This paper is related to the literature that incorporate banks in a DSGE model. Several authors have made efforts leading to the emergence of a new generation of models that attempt to incorporate banks in the analysis. These new models include GKa 2011, Gertler and Kiyotaki (2011) (henceforth GK_i 2011), Gertler Kiyotaki and Queralto (2012) (henceforth GKQ 2012) and Akinici and Queralto (henceforth AQ 2014). In addition to introducing banks, they introduce financial frictions through a moral hazard problem between bankers and households. This raises an incentive constraint where bank equity is crucial on determining the level of bank loans. In particular, bankers can divert a fraction of the resources under their management. As a result, the models provide, among its virtues, an intuitive rationale for market-ruled bank capital requirements.

In particular, in GKa 2011 assume nominal rigidities of prices. The contribution of GK_i 2011 is to allow the existence of different investment opportunity shocks across islands. GKQ 2012 includes the possibility that banks can issue equity (outside equity). In contrast with the previous papers, in this paper the capital requirement rule is given by a regulatory authority. The main contributions of AQ 2014 are that the authors open the economy and

solve the model assuming that the incentive constraint (originated by the moral hazard between bankers and households) is occasionally binding. GKQ 2012 and AQ 2014 solve the model focusing on the stochastic steady state.

We depart from this literature since we do not develop a marked-ruled capital requirement, and instead we assume regulator imposes capital requirements (rule-based capital requirements). Our contribution is to assess the effect of an imposed capital requirement rule on an open economy DSGE model with banks. For simplicity, we abstract from price rigidities, an interbank market and outside equity, and we consider the deterministic steady state instead of the stochastic steady state. In addition, in this version of the paper we assume an always binding capital requirement constraint.

Hence, this paper is also closely related to the literature that study the effects of a regulatory capital requirement rule. This group includes Darracq et al. (2011), Rubi and Carrasco (2014), Benes et al. (2014), and Angeloni and Faia (2013). They develop a DSGE model for closed economies that conclude that countercyclical capital requirements, as in Basel III, are better than Basel II and Basel I. While in this paper, they study one form of countercyclical buffers, the contribution of this document to this literature is to evaluate the different forms of countercyclical buffers.

Respect to regulatory issues, discussions on the potential business cycle amplification effects of Basel II started way before its approval in 2004 by the Basel Committee on Banking Supervision. The argument whereby these effects may occur is well-known. In recessions, losses erode banks' capital, while risk-sensitive capital requirements such as those in Basel II become higher. Thus, if banks cannot quickly raise sufficient new capital, the standard financial accelerator mechanism will take place. In other words, Basel II might incentive large fluctuations of asset prices and real variables in the economy.¹ This conjecture is assessed in DSGE models like Covas and Fujita (2010) and De Walque et al. (2010). Covas and Fujita (2010), comparing output fluctuations under Basel I and Basel II, find that the standard deviation of the second is higher. De Walque et al. (2010) develops a DSGE model and concludes that Basel I reduces long-term values for output and Basel II increases business cycle fluctuations.

Basel III ruled from 2010 requires banks to hold a higher proportion of common equity and "risk-weighted assets". In addition, Basel III introduces "additional capital buffers". In practice, Basel III introduces a series of measures to promote the build-up of capital buffer in good times that can be drawn upon in periods of stress. In this way, Basel III

¹Kashyap and Stein (2004) (henceforth KS 2004) show by simulations and using different methodologies that Basel II capital requirements have the potential to create an amount of additional cyclicality in capital charges, which is economically significant. They explain that in a downturn bank's capital are lower due to higher losses forcing banks to hold more capital. Since it is difficult or costly for banks to raise new capital in bad times, they reduce credits, and this contributes to a worsening of the initial downturn. This describes the deleveraging process observed during the 2007-2009 financial crisis.

looks for “reducing procyclicality and promoting countercyclical buffers”. Some people disagree with this last measure since correcting the potential contractionary effect on credit supply by relaxing capital requirements in bad times may increase bank failure probabilities precisely when, because of high loan defaults, they are largest.

In that respect, Rubio and Carrasco-Gallego (2016) study the interaction between Basel I, II and III with monetary policy. They conclude that the optimal implementation of capital buffers (Basel III) leads to higher financial stability with respect to Basel I and II. By its part, Repullo (2013) (henceforth R 2013) develops a static model to study this trade-off following the framework of KS 2004. In this framework a regulator maximizes the society’s welfare subject to the fixed capital supply where welfare captures the cost of bank failures. It states that capital requirements should be lowered in situations where capital is scarce such as in a recession. And Repullo and Suarez (2012) show that Basel II is more procyclical than Basel I, but makes banks safer. They say Basel III seems to be even better since it increases capital requirement but it is less procyclical. In general, we also find that countercyclical capital buffers leads to smaller fluctuations and hence higher financial stability. However, we depart from this literature since we do not aim to find an optimal capital requirement, but rather to assess effectiveness of different forms of countercyclical buffers.

In addition, there are other papers that measure the effects of capital requirement on welfare. In general, all agree that capital requirements improve welfare, see for instance Begenau (2015), Cristiano and Ikeda (2013), Nguyen (2014) and Collard et al. (2015). In particular, capital requirements tackle a particular inefficiency modeled in each of these papers. Begenau (2015) presents a quantitative dynamic general equilibrium model where households have preferences for safe and liquid assets. It shows that an increased capital requirement can reduce bank funding costs and increase lending. Cristiano and Ikeda (2013) develop a DSGE model with financial intermediaries and an agency problem. It shows that welfare increases when imposing binding capital requirements. In particular, a lower leverage reduces the risk of the creditors, then agency problems are mitigated and the efficiency of the banking system is improved. Nguyen (2014) develops a model with endogenous growth and a dynamic banking sector. It focuses in the distortions that bank bailouts create and the role of capital requirements in mitigating these distortions. In Collard et al. (2015) the interaction of limited liability and deposit insurance create excessive bank risk-taking. This motivates the use of capital requirements to mitigate the risk. This work departs from this literature since we do not model the inefficiency that capital requirements aim to tackle, and so our contribution to this literature is to evaluate the effectiveness of different forms of countercyclical capital buffers on promoting macroeconomic and financial stability.

An empirical paper, Jiménez et al. (2017), using data for Spain shows that counter-

cyclical capital buffers help to smooth credit supply cycles and in downturns those have positive effects on firm credit availability. In this line, Fillat and Montoriol-Garriga J. (2010) argue that if the USA had set aside general provisions in positive states of the economy, this would have been in a better position to absorb loan losses during the recent financial crisis. In the same line, Chan-Lau (2012) shows that countercyclical provisions might help to reduce procyclicality. However, this depends on the characteristics of the banking system of the country. In particular, a dynamic provision scheme as in Spanish would have improved bank's solvency but not reduced the procyclicality. Hence, the contribution of this paper is to formally assess the impact of different forms countercyclical buffers.

3 Baseline Model

3.1 Physical setup

Here we present the basic physical environment. There is a continuum of firms of mass unity. Each firm produces output using an identical constant returns to scale Cobb-Douglas production function with capital K_t and labor L_t as inputs. We can express aggregate output Y_t as:

$$Y_t = A_t K_t^\alpha L_t^{1-\alpha}, 0 < \alpha < 1, \quad (1)$$

where A_t is the aggregate productivity which follows an AR(1) process in logs: $\ln(A_t) = \rho_a \ln(A_{t-1}) + \epsilon_{a,t}$, where $\rho_a \in (0, 1)$ and $\epsilon_a \sim \mathcal{N}(0, \sigma_{\epsilon_a}^2)$. There is a capital in process at t for $t + 1$, S_t , that is the sum of current investment I_t and the stock of undepreciated capital, $(1 - \delta)K_t$:

$$S_t = (1 - \delta)K_t + I_t. \quad (2)$$

Capital in process for period $t + 1$ is transformed into capital for production after the realization of a multiplicative shock to capital quality, ψ_{t+1} ;

$$K_{t+1} = \psi_{t+1} S_t. \quad (3)$$

We introduce the capital quality shock following the finance literature, for instance, Merton (1973), as a way to introduce an exogenous source of variation in the value of capital. As will become clear later, the market price of capital will be endogenous within this framework. The capital quality shock will serve as an exogenous trigger of asset price dynamics. The random variable ψ_{t+1} is best thought of as capturing some form of economic obsolescence, as opposed to physical depreciation.² We assume the log of the capital

²The Appendix B of GKQ 2012 provides an explicit micro-foundation.

quality shock ψ_t follows an AR(1) process:

$$\ln(\psi_t) = \rho_\psi \ln(\psi_{t-1}) + \epsilon_{\psi,t}, \quad (4)$$

where $\rho_\psi \in (0, 1)$ and $\epsilon_\psi \sim \mathcal{N}(0, \sigma_{\epsilon_\psi}^2)$. Firms acquire new capital from capital goods producers. There are convex adjustment costs in the rate of change in investment goods output for capital goods producers.

Our preference structure follows GKQ (2012):

$$\mathbb{E}_t \sum_{i=t}^{\infty} \beta^{i-t} \frac{1}{1-\gamma} (C_i - hC_{i-1} - \frac{\chi}{1+\omega} L_i^{1+\omega})^{1-\gamma}, \quad (5)$$

where \mathbb{E}_t is the expectation operator conditional on information at date t , $\gamma > 0$ is the constant relative risk aversion (CRRA) coefficient, h is the habit parameter, and ω is the inverse Frisch elasticity. The preference specification allows for habit formation and abstracts from wealth effects on labor supply. We include adjustment costs of investment and habit formation since they are standard features of many quantitative macro models. They improve the quantitative performance of the model considerably and can be added at relatively little cost in terms of model complexity. However, to keep the model tractable we abstract from other standard features that help account for employment volatility, such as price and wage rigidities.

3.2 Households

Following GKa 2011, we formulate the household sector in a way that permits maintaining the tractability of the representative agent approach. In particular, there is a representative household with a continuum of members of mass unity. Within the household, there are $1 - f$ “workers” and f “bankers”. Workers supply labor, L_t , and return their wages, W_t , to the household. Each banker manages a financial intermediary (bank) and transfers nonnegative dividends back to the household subject to its flow of fund constraint. There is perfect consumption insurance within the family. Households do not acquire capital and they do not provide funds directly to nonfinancial firms. Rather, they supply funds to banks. It may be best to think of them as providing funds to banks other than the ones they own. Banks offer non-contingent riskless short-term debt (deposits, B_t) to households. Let Z_t be the flow returns at t generated by one unit of the bank’s assets.

The household chooses consumption, labor supply and riskless debt (or domestic bank deposits) (C_t, L_t, B_t) to maximize expected discounted utility, equation (5), subject to the

flow of funds constraint,

$$C_t + B_t = W_t L_t + \Pi_t - T_t + R_t B_{t-1}. \quad (6)$$

Here, Π_t are the net funds from ownership of both banks and capital producing firms. Let u_{C_t} denotes the marginal utility of consumption and $\Lambda_{t,t+1}$ the household's stochastic discount factor. Then, the household's first-order conditions for labor supply and consumption/saving are given by,

$$\mathbb{E}_t u_{C_t} W_t = \chi L_t^\omega (C_t - h C_{t-1} - \frac{\chi}{1+\omega} L_t^{1+\omega})^{-\gamma}, \quad (7)$$

$$\mathbb{E}_t (\Lambda_{t,t+1}) R_{t+1} = 1, \quad (8)$$

respectively, with,

$$u_{C_t} = (C_t - h C_{t-1} - \frac{\chi}{1+\omega} L_t^{1+\omega})^{-\gamma} - \beta h (C_{t+1} - h C_t - \frac{\chi}{1+\omega} L_{t+1}^{1+\omega})^{-\gamma},$$

$$\Lambda_{t,\tau} = \beta^{\tau-t} \frac{u_{C_\tau}}{u_{C_t}}.$$

Because banks may be financially constrained, bankers will retain earnings to accumulate assets. Absent some motive for paying dividends, they may find it optimal to accumulate to the point where the capital requirement constraint is no longer binding. To limit bankers' ability to save to overcome financial constraints, a turnover between bankers and workers is introduced. In particular, there is an i.i.d. probability $1 - \sigma$, that a banker exits next period, (i.e., an average survival time = $\frac{1}{1-\sigma}$). Upon exiting, a banker transfers retained earnings to the household and becomes a worker. Note that the expected survival time may be quite long (in our baseline calibration it is eight years.) It is critical, however, that the expected horizon is finite, in order to motivate payouts while the capital requirements are still binding.

Each period, $(1 - \sigma)f$ workers randomly become bankers, keeping the number in each occupation constant. Finally, because in equilibrium bankers will not be able to operate without any financial resources, each new banker receives a "startup" transfer from the family as a small constant fraction of the total assets of entrepreneurs. Thus, Π_t are net funds transferred to the household; that is, funds transferred from exiting bankers minus the funds transferred to new bankers (aside from small profits of capital producers).

3.3 Nonfinancial Firms

There are two types of nonfinancial firms: goods producers and capital producers.

3.3.1 Goods Producers

Competitive goods producers operate with constant returns to scale technology, with capital and labor as inputs, given by equation (1). Firms choose labor to satisfy,

$$W_t = (1 - \alpha) \frac{Y_t}{L_t}. \quad (9)$$

Since goods producers face zero profits it follows that we may express gross profits per unit of capital Z_t as,

$$Z_t = \frac{Y_t - W_t L_t}{K_t} = \alpha A_t \left(\frac{L_t}{K_t} \right)^{1-\alpha}. \quad (10)$$

Goods producers can commit to pay all the future gross profits to the bank. In particular, we suppose that the bank is efficient at evaluating and monitoring nonfinancial firms and also at enforcing contractual obligations with these borrowers. That is why these borrowers rely exclusively on banks to obtain funds. Then, a goods producer who invests can obtain funds from a bank without any financial friction by issuing new state-contingent securities at the price Q_t . The producer then uses the funds to buy new capital goods from capital goods producers. Each unit of the security is a state-contingent claim to the future returns from one unit of investment:

$$\psi_{t+1} Z_{t+1}, (1 - \delta) \psi_{t+1} \psi_{t+2} Z_{t+2}, (1 - \delta)^2 \psi_{t+1} \psi_{t+2} \psi_{t+3} Z_{t+3}, \dots \quad (11)$$

Through perfect competition, the price of new capital goods is equal to Q_t , and goods producers earn zero residual profits in any state.

3.3.2 Capital Producers

They make new capital using input of final output and subject to adjustment costs. They sell new capital to firms at the price Q_t . Given that households own capital producers, the objective of a capital producer is to choose I_t to solve:

$$\max \mathbb{E}_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau} \{ Q_{\tau} I_{\tau} - [1 + f \left(\frac{I_{\tau}}{I_{\tau-1}} \right)] I_{\tau} \}. \quad (12)$$

where $f \left(\frac{I_{\tau}}{I_{\tau-1}} \right) I_{\tau}$ reflects the physical adjustment costs, with $f(1) = f'(1) = 0$ and $f''(I_t/I_{t-1}) > 0$. From profit maximization, the price of the capital goods is equal to the marginal cost of investment goods as follows:

$$Q_t = 1 + f \left(\frac{I_t}{I_{t-1}} \right) + \frac{I_t}{I_{t-1}} f' \left(\frac{I_t}{I_{t-1}} \right) - \mathbb{E}_t \Lambda_{t,t+1} \left(\frac{I_{t+1}}{I_t} \right)^2 f' \left(\frac{I_{t+1}}{I_t} \right). \quad (13)$$

Profits (which arise only outside of steady state), are redistributed lump sum to households. In particular, we assume,³

$$f\left(\frac{I_\tau}{I_{\tau-1}}\right) = \frac{\varphi_I}{2} \left(\frac{I_\tau}{I_{\tau-1}} - 1\right)^2.$$

3.4 Banks

Every period each bank raises funds by supplying deposits. In addition, the bank has its own net worth accumulated from retained earnings (which we refer to as equity). The bank then uses all its available funds to make loans to goods producers. As noted earlier, there is no friction in transferring funds between a bank and goods producers. Banks finance goods producers by purchasing perfectly state-contingent security. Their total value of loans is equal to the number s_t (credit level) times the price Q_t of the state-contingent security.

For an individual bank, the balance sheet equation implies the value of loans funded within a given period, $Q_t s_t$, must equal the sum of bank net worth n_t , and funds raised from deposits, d_t ,

$$Q_t s_t = n_t + d_t, \tag{14}$$

where,

$$d_t = b_t + b_t^*, \tag{15}$$

where b_t are the external funds that a bank can obtain from domestic households (domestic deposits) and b_t^* are the funds obtained from foreign investors (foreign deposits). Notice that banks raise equity only through retained earnings. Since equity involves management and control of the firm's assets, we suppose it is prohibitively costly for the existing insiders to bring in new ones with sufficient wealth. In particular, the bank's net worth n_t at t is the gross payoff from assets funded at $t - 1$, net of returns to depositors. Let R_{kt} denote the gross rate of return on a unit of the bank's assets from $t - 1$ to t . Then:

$$n_t = R_{kt} Q_{t-1} s_{t-1} - R_t d_{t-1}, \tag{16}$$

with,

$$R_{kt} = \frac{[Z_t + (1 - \delta)Q_t]\psi_t}{Q_{t-1}}. \tag{17}$$

Given that the bank faces a financing constraint, it is in its interest to retain all earnings until the time it exits, at which point it pays out its accumulated retained earnings as dividends. Accordingly, the objective of the bank at the end of period t is the expected

³This functional form is also used in de Groot (2014) and Akinici and Queraltó (2013).

present value of the future terminal dividend,

$$\mathbb{E}_t \left[\sum_{i=t+1}^{\infty} (1 - \sigma) \sigma^{i-t-1} \Lambda_{t,i} n_i \right]. \quad (18)$$

Combining (14) and (16) yields the evolution of n_t as a function of s_{t-1} and n_{t-1} as,

$$n_t = (R_{kt} - R_t) Q_{t-1} s_{t-1} + R_t n_{t-1}. \quad (19)$$

Next, we introduce the regulatory capital requirements.

3.5 Regulatory Capital Requirement Rule

There is a regulatory authority that imposes a capital requirement rule. This rule dictates that banks are required to maintain as net worth (equity), n_t , at least a fraction of the value of their total assets, $Q_t s_t$.

We assume the regulator is efficient at monitoring and ensuring that all banks will satisfy the capital requirement rule and the monitoring costs are negligible. At the same time, if a bank does not satisfy capital requirements, it is charged a huge penalty which will not allow the bank to continue with its activity in the future. Thus, in equilibrium all banks in the market satisfy the capital requirement rule for all t .

The capital requirement rule for each bank is expressed in general as,

$$\kappa_t Q_t s_t \leq n_t, \quad (20)$$

where κ_t is the regulatory capital requirement ratio, which is the sum of a fixed capital requirement ratio, $\kappa^{FCR} > 0$, and a countercyclical capital buffer ratio, κ_t^{CCyB} , i.e.,

$$\kappa_t = \kappa^{FCR} + \kappa_t^{CCyB}, \quad (21)$$

where *FCR* stands for fixed capital requirements and *CCyB* stands for countercyclical capital buffer. The countercyclical capital buffers are defined as follows,

$$\kappa_t^{spread, CCyB} = \kappa^{spread, CCyB} [(E_t R_{kt+1} - R_{t+1}) - (ER_k - R)].$$

The fixed capital requirement ratio aims to promote an appropriate level of bank leverage so that the economy is in good conditions to face a financial crisis. Intuitively, the higher the bank net worth per unit of loans, the higher bank net worth capacity to absorb losses.

This countercyclical capital buffer, κ_t^{CCyB} , is similar to a ‘‘Taylor rule’’. Since there is an infinite number of banks and assuming that they cannot coordinate, bankers know

they cannot affect κ_t^{CCyB} and thus this is taken as given. This rule states that capital requirements will react to any deviation of credit spread from its steady state. We define the credit spread as the difference between the expected return of the assets and the risk-free interest rate, i.e., $E_t R_{kt+1} - R_{t+1}$. We propose a countercyclical capital requirement rule, i.e., we assume $\kappa^{spread,CCyB} < 0$.⁴ The intuition is the following: high spreads, which capture any solvency problem in the banking sector, induce regulator to be more flexible and thus to reduce the minimum amount of capital held for one unit of total assets. Conversely, lower spreads will induce a stronger (precautionary) response from the regulator. Hence, it relaxes the credit constraint (capital requirements) in downturns periods, and increase credit constraint on boom periods. In other words, the role of this part is to reduce real losses once the crisis occurs or equivalently it lessens the effects of the financial crisis whenever it occurs.

As in real life, capital requirements are imposed to provide banks with enough resources to respond to bad unexpected events in the economy. Also, some literature suggests that the capital requirements prevent banks to take excessive risk or equivalently to issue excessive loans (see, Begenau 2015, Cristiano and Ikeda 2013, Nguyen 2014 and Collard et al.2015). Notice, however, that in this paper we are not modeling any friction that might lead to an inefficient allocation and then to an excessive privately optimal level of credit. In other words, if we remove capital requirements, the equilibrium that results from banks decisions is socially optimal. Consequently, since we are not modeling any inefficiency, it is not the interest of this paper to provide a socially optimal capital requirement rule, but rather to focus on effects of capital requirements and on the effects of the effectiveness of different forms of countercyclical capital buffers on improving macroeconomic and financial stability and welfare.

3.6 Bank Optimization Problem

Now, we can continue solving the bank optimization problem. From (18) it follows that, in general, the franchise value of the bank at the end of period $t - 1$ satisfies the Bellman equation,

$$V_{t-1}(s_{t-1}, n_{t-1}) = E_{t-1} \Lambda_{t-1,t} \{ (1 - \sigma)n_t + \sigma \max_{s_t} [V_t(s_t, n_t)] \}, \quad (22)$$

where the right side takes into account that the bank exits with probability $1 - \sigma$ and continues with probability σ . Thus, at each time t , the bank chooses s_t to maximize $V_t(s_t, n_t)$ subject to the capital requirement constraint (20) and the law of motion for net

⁴Notice that $\kappa^{spread,CCyB} < 0$ and the assumption that the rule responds to the expected difference of $R_{kt+1} - R_{t+1}$ and not the observed difference $R_{kt} - R_t$ ensure the model converges.

worth (19). We conjecture the value function,

$$V_t(s_t, n_t) = \mu_{st}Q_t s_t + \nu_t n_t, \quad (23)$$

where μ_{st} and ν_t are time-varying parameters, and verify this guess later. Note that μ_{st} is the marginal value of assets at the end of the period t , and ν_t is the marginal value of bank net worth at the end of the period t . We assume the capital requirements are always binding. In the equilibrium, under reasonable parameter values the constraint always binds within a local region of the deterministic steady state. Then,

$$\kappa_t Q_t s_t = n_t. \quad (24)$$

Equation (20) is a key relation of the banking sector: it indicates that when the borrowing constraint binds, the total quantity of private assets that a bank can intermediate is limited by its net worth, n_t . Let define $\phi_t = \frac{Q_t s_t}{n_t}$ be the ratio of bank assets to net worth (leverage ratio) that satisfies the capital requirement constraint. Then, by construction:

$$\phi_t = \frac{1}{\kappa_t}. \quad (25)$$

Then, after combining the conjectured value function with the Bellman equation, we can verify that the value function is linear in (s_t, n_t) if ν_t and ν_{st} satisfy:

$$\nu_t = E_t(\Lambda_{t,t+1}\Omega_{t+1})R_{t+1}, \quad (26)$$

$$\mu_{st} = E_t[\Lambda_{t,t+1}\Omega_{t+1}(R_{kt+1} - R_{t+1})], \quad (27)$$

where Ω_{t+1} is the shadow value (or marginal value) of a unit of net worth to the bank at $t + 1$ and is given by,

$$\Omega_{t+1} = 1 - \sigma + \sigma[\nu_{t+1} + \phi_{t+1}\mu_{st+1}]. \quad (28)$$

Observe that the household discounts the returns by the stochastic factor $\Lambda_{t,t+1}$ while the banker uses a discount factor $\Lambda_{t,t+1}\Omega_{t+1}$. This latter is defined in the literature as ‘‘augmented stochastic discount factor’’. The marginal value of net worth is a weighted average of marginal values for exiting and for continuing banks. If a continuing bank has an additional net worth, it can save the cost of deposits and can increase assets by the leverage ratio ϕ_t , where assets have an excess value equal to μ_{st+1} per unit. Equation (26) claims that the marginal cost of net worth at the end of t is the expected product of the augmented stochastic discount factor and the deposit rate. Similarly equation (27) state that the excess value per unit of assets is the expected product of the augmented stochastic discount factor and the excess return, $R_{kt+1} - R_{t+1}$. Since ϕ_t does not depend on bank-specific factors, we can aggregate equation (24) and (25) to obtain a relation between

the aggregate demand of securities by banks S_t (or the aggregate supply of credit) and the aggregate net worth in the banking sector N_t ,

$$Q_t S_t = \phi_t N_t. \quad (29)$$

As a result, the bank chooses s_t to maximize $V_t(s_t, n_t)$ defined with equations (23), (26) and (27) and n_t defined in the balance sheet equation, subject to the capital requirement constraint, equation (20). Using the Lagrangian,

$$L = \mu_{st} Q_t s_t + \nu_t n_t + \lambda_t [n_t - \kappa_t Q_t s_t], \quad (30)$$

where λ_t is the Lagrangian multiplier with respect to the bank capital requirement constraint, the first order conditions for s_t and λ_t yield, respectively

$$\mu_{st} = \lambda_t \kappa_t, \quad (31)$$

and the first order condition for λ_t yields equation (24)

$$n_t = \kappa_t Q_t s_t, \quad (32)$$

such that $0 < \lambda_t$. Note that banks take κ_t as given. The first order condition for s_t , equation (31), state that the marginal benefit from increasing a unit of asset, μ_{st} , is equal to the marginal cost of tightening the capital requirement constraint $\lambda_t \kappa_t$. Since the incentive constraint binds the excess value of bank assets μ_{st} is positive. In other words, binding capital requirements require banks to accumulate a higher net worth to do so the marginal benefits should be higher, and since marginal return of capital is decreasing, banks also issue less credit. So, compared to the equilibrium without capital requirement constraint, bank credit s_t is smaller and bank net worth n_t is higher. Since bank are identical, this also holds at the aggregate level.

3.7 Evolution of bank net worth

Let total net worth for banks, N_t , equals the sum of the net worth of existing bankers N_{ot} (o for old) and of entering bankers N_{yt} (y for young),

$$N_t = N_{ot} + N_{yt}.$$

Net worth of existing bankers equals earnings on assets held in the previous period net the cost of deposit finance, multiplied by the fraction that survive until the current period, σ ,

$$N_{ot} = \sigma\{[Z_t + (1 - \delta)Q_t]\psi_t S_{t-1} - R_t D_{t-1}\}.$$

We assume that the family transfers to each new banker the fraction $\xi/(1 - \sigma)$ of the total value assets of exiting bankers, implying,

$$N_{yt} = \xi[Z_t + (1 - \delta)Q_t]\psi_t S_{t-1}.$$

Total net worth of bank is now,

$$N_t = (\xi + \sigma)[Z_t + (1 - \delta)Q_t]\psi_t S_{t-1} - \sigma R_t D_{t-1}. \quad (33)$$

Finally, by the balance sheet of the entire banking sector, deposits equal the difference between total assets and bank net worth as follows,

$$D_t = Q_t S_t - N_t. \quad (34)$$

Observe that the evolution of net worth depends on fluctuations in the return to assets. Further, the higher the leverage of the bank, the larger the percentage impact of return fluctuations on net worth will be. Note also that a deterioration of capital quality (a decline in ψ_t) directly reduces net worth.

3.8 International Capital Markets

As it is done in AQ 2014, who follow Schmitt-Grohé and Uribe (2003), we assume that the small open economy is subject to debt-elastic interest rate premium in the international markets,

$$R_t = \frac{1}{\beta} + \varphi \left(e^{\frac{B_t^*}{Y_t} - \bar{b}} - 1 \right) + e^{R_t^* - 1} - 1, \quad (35)$$

where \bar{b} governs the steady state foreign debt to GDP ratio R_t^* is the risk-free world interest rate, which is assumed to follow an AR(1) process in natural logs, $\ln(R_t^*) = \rho_R \ln(R_{t-1}^*) + \epsilon_{R^*,t}$, where $\epsilon_{R^*,t} \sim \mathcal{N}(0, \sigma_{R^*}^2)$.

Equation (35) suggests, turning off the world interest rate shock, that if the foreign debt to GDP ratio is above its long-term value (i.e., above its “sustainable level”), the deposit market assigns a positive country risk premium due to a high risk or a positive probability that the domestic economy fails to honor its foreign debt. As in AQ 2014, we do not model this friction; however, equation (35) aims to capture this issue in a reduced form. In addition, from equation (35) for a given R_t after a negative world interest rate

shock (or a transitory capital inflow shock), the foreign debt to GDP ratio should move above its long-term value.

3.9 Resource Constraint and Market Clearing

To close the model (in the case without government policy), we require market clearing in the market for securities and the labor market. In the market for securities we say that the supply of securities of firms equals the demand of securities of banks. Finally, the condition that labor demand equals labor supply requires that,

$$(1 - \alpha) \frac{Y_t}{L_t} \mathbb{E}_t \left[\frac{u_{C_t}}{(C_t - hC_{t-1} - \frac{\chi}{1+\omega} L_t^{1+\omega})^{-\gamma}} \right] = \chi L_t^\omega. \quad (36)$$

Aggregate output is divided between household consumption C_t , investment expenditures, and net exports NX_t .

$$Y_t = C_t + \left[1 + f \left(\frac{I_t}{I_{t-1}} \right) \right] I_t + G_t + NX_t, \quad (37)$$

where net exports are given by,

$$R_t B_{t-1}^* - B_t^* = NX_t, \quad (38)$$

where $f(\frac{I_t}{I_{t-1}})I_t$ reflects physical adjustment costs. Equations (1, 2, 3, 6, 8, 10, 13, 24, 26, 27, 28, 33, 34, 35, 36, 37, 38) determine the seventeen endogenous variables ($Y_t, L_t, C_t, I_t, S_t, K_t, D_t, B_t^*, Q_t, N_t, R_t, R_{kt}, Z_t, \mu_{st}, \nu_t, \Omega_t, XN_t$) as a function of the state exogenous variables (A_t, ψ_t, R_t^*).

The equilibrium is different from the RBC equilibrium since capital requirements (or the credit constraint), faced by banks, limit investing spending, affecting aggregate real activity. As usual in models with banks that accumulate net worth and face a leverage constraint bank leverage creates an amplification effect.

4 Parametrization

There are twenty parameters for which we need to assign values. Eight parameters are standard preference and technology parameters. These include the discount factor β , the coefficient of relative risk aversion γ , the habit parameter h , the utility weight on labor ξ , the inverse elasticity of the Frisch elasticity of labor supply ω , the capital share parameter α , the deterministic depreciation δ . For these parameters we assign the same values used

in GKQ 2012, see table 1.⁵ The investment adjustment parameter φ_I is set at 1 as in de Groot (2014).

Two additional parameters are specific to financial intermediaries: σ , the quarterly survival probability of bankers, and ξ , the transfer parameter for new bankers. We set $\sigma = 0.975$, implying that bankers survive for ten years on average as in GK1 2011. We set ξ to 0.0013 to have an average credit spread of 100 basis points per year.

There are two parameters associated with the capital requirement rule, κ^{FCR} and $\kappa^{spread,CCyB}$. We set κ^{FCR} to 0.25 to have an aggregate leverage ratio of four in the steady state as in AQ 2014, which is a conservative value. Recall that $\kappa^{spread,CCyB}$ measures the degree of countercyclicality of the capital requirement rule. We are going to start with $\kappa^{spread,CCyB} = -12$. Implying that for 100 basis points (bps) of a positive deviation of spread from its steady state, the regulatory authority reacts reducing the requirement of capital by 12 percent bps. In other words, the regulator requires 0.12 units less of bank net worth per unit of the total value of bank assets. Finally, we set the debt elasticity of world interest rate, φ , to 0.05 and the reference foreign debt to output ratio, \bar{b} , to 60% as in AQ 2014,

We set the persistence of the three shocks (productivity, capital quality and foreign interest rate) to 0.66. The standard deviations of the three shocks in the model are set to 0.0016 so the model delivers realistic values for the (unconditional) volatilities of the business cycles of GDP, consumption and bank credit delivered by the model. This results in $\sigma_y = 2.75\%$, $\sigma_c = 2.66\%$ and $\sigma_s = 4.14\%$, where, in general σ_x in the model is the unconditional standard deviation of $\ln(X)$ in percentages.⁶ The model solved under this parametrization is going to be called the baseline model.

We solve the DSGE model using a second-order approximation around the deterministic steady state in Dynare. The unconditional standard deviations are taken from the theoretical second moments provided by Dynare.

⁵Indeed, these values are similar to those used in the literature, see, for instance, GKa 2011 and GK1 2011

⁶In the data σ_x corresponds to standard deviation of X logged and detrended. For the Canadian economy Mendoza (1991) using annual data for the 1946-1985 period find that σ_y and σ_c are 2.81% and 2.46%, respectively. Also Mendoza (2010) for the Mexican economy using quarterly data for the 1993:I-2005:II period find that σ_y and σ_c are 2.72% and 3.40%. For Chile, Bergoening and Soto (2005) using quarterly data for the 1986:I-2000:IV period document that σ_y and σ_c are 2.2% and 2.43%, respectively. Note that in three previous papers consumption covers private and public. Castillo et al. (2006) for the Peruvian economy using quarterly data for the 1994:II-2005:III period find that σ_y and σ_c are 2.4% and 1.88%, respectively. Finally, Apostoae and Percic (2014) finds that the volatility of the credit cycle is almost two times the volatility of the GDP cycle.

Table 1: Parameter values

Parameters		Values
Risk aversion	γ	2
Discount factor	β	0.99
Capital share	α	0.33
Depreciation rate	δ	0.025
Utility weight of labor	χ	0.25
Inverse Frisch elast. of labor supply	ω	1/3
Investment adjustment costs	φ_I	1
Habit parameter	h	0.75
Survival rate of bankers	σ	0.975
Transfer to entering Banks	ξ	0.0013
Debt elast. of interest rate	φ	0.05
Reference debt/output ratio	b	0.60
Capital requirement rule		
	κ^{FCR}	0.25
	$\kappa^{spread,CCyB}$	-12.0
Shock processes		
Persistence of capital quality	ρ_ψ	0.66
Persistence of productivity	ρ_a	0.66
Persistence of foreign interest rate	ρ_{R^*}	0.66
SD of capital quality	σ_{ϵ_ψ}	0.0016
SD of productivity	σ_{ϵ_A}	0.0016
SD of foreign interest rate	$\sigma_{\epsilon_{R^*}}$	0.0016

In the next section we simulate the model. Since the base of this model is a RBC model many of the dynamics have been already studied, we mainly focus on the effects of the capital requirements. More importantly, next we propose several forms of countercyclical capital buffers and study the second order effects of these on the volatilities of real and financial variables and on welfare. Our welfare measure is given by households' expected discounted utility, equation (5).

5 Simulations and sensitivity analysis

Figures 1 and 2 plot the impulse response functions after a one-time negative shock of capital quality of 1%.⁷ These report the effects of changing the parameter values associated with the fixed capital requirements and with the countercyclical capital buffers,

⁷Notice that since the goal is to observe the implications of tighter or looser capital requirements, for illustrative purposes we are setting a capital quality shock of 1% that represents as around six times the standard deviation of the shock.

respectively.

Figure 1 plots the impulse response functions for the baseline parametrization (solid black lines), which has fixed capital requirement ratio of $\kappa^{FCR} = 1/4$ and yields a leverage ratio of 4. It also plots the impulse responses for a lower fixed capital requirement ratio (blue dashed lines), i.e., $\kappa^{FCR} = 1/8$, and for a higher capital requirement ratio (red dotted lines), i.e., $\kappa^{FCR} = 1/1.5$, that respectively yield to a long-term leverage ratio of 8 and 1.5.⁸

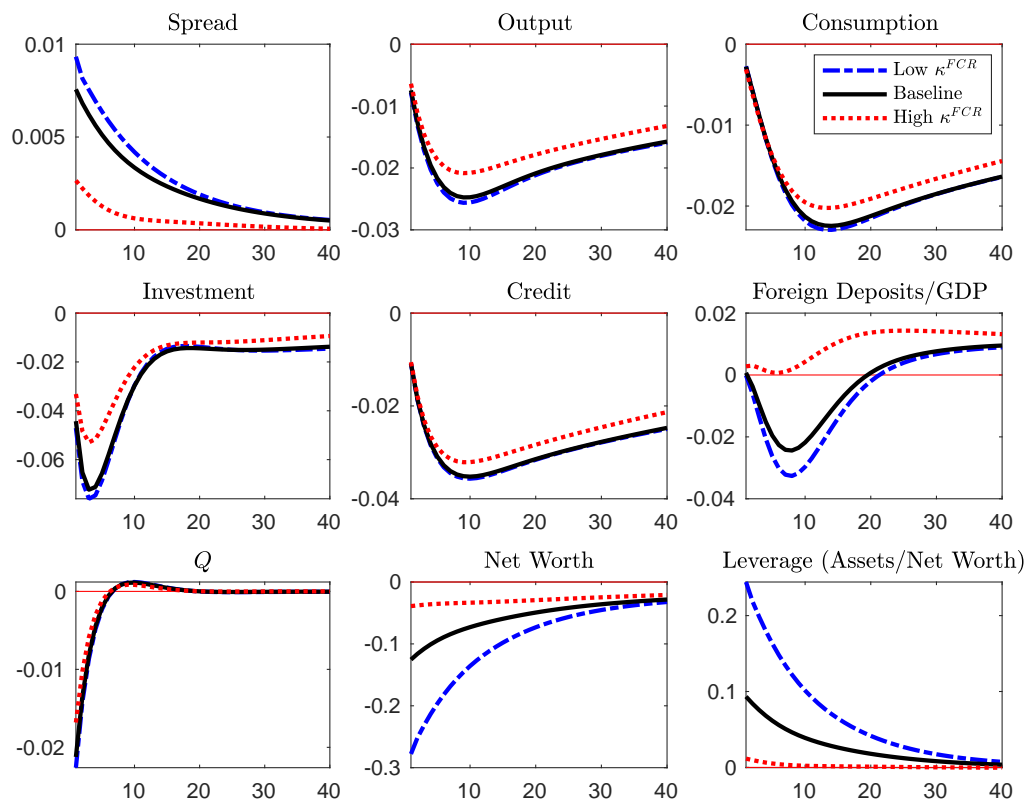
In the baseline model (solid black line) the negative quality capital shock will not only reduce the marginal value of loans but it will also affect bank net worth. Since capital requirements bind, a lower net worth deteriorates bank capacity to lend, which in turn reduces even more the value of the loans, creating an amplification effect of the negative capital quality shock. Quantitatively, in the short-term asset prices shrink by 2.2%, and loans decreases by 1%. These drive the 12% reduction on bank equity.

As expected, the higher the fixed capital requirements, the lower the leverage and hence the higher bank's capacity to absorb losses, which in turn leads to a smaller fluctuation in bank net worth and hence to smaller fluctuations of credit and output. Notice that bankers (bank equity) absorb the whole losses (and gains if there are) since depositors receive a risk-free payment. Thus, an economy governed with a more cautious regulatory authority, who impose a higher fixed capital requirement, is in a better position to handle a financial crisis produced by a capital quality shock. However, the higher the fixed capital requirements, the more constrained are banks to issue credit and hence the long-term credit, output and consumption are smaller.⁹ Quantitatively, increasing fixed capital requirements from $1/4$ to $1/1.5$, produces a reduction of asset prices of only 1.7%, which drives a reduction of bank net worth of only 4% rather than 12%. This in turn explains the smaller reduction of bank credit.

⁸In these two latter cases, only κ^{FCR} is modified while keeping the other parameters unchanged.

⁹As, we will see later welfare gains due to smaller fluctuations are dominated by welfare losses of having smaller long-term values of real variables.

Figure 1: Negative capital quality shock and κ^{FCR} sensitivity



IRFs after a one-time negative capital quality shock of 1%. All variables are in log deviations from steady state except Spread. Spread is annualized. Low: $\kappa^{FCR} = 1/8$. Baseline: $\kappa^{FCR} = 1/4$. High: $\kappa^{FCR} = 1/1.5$.

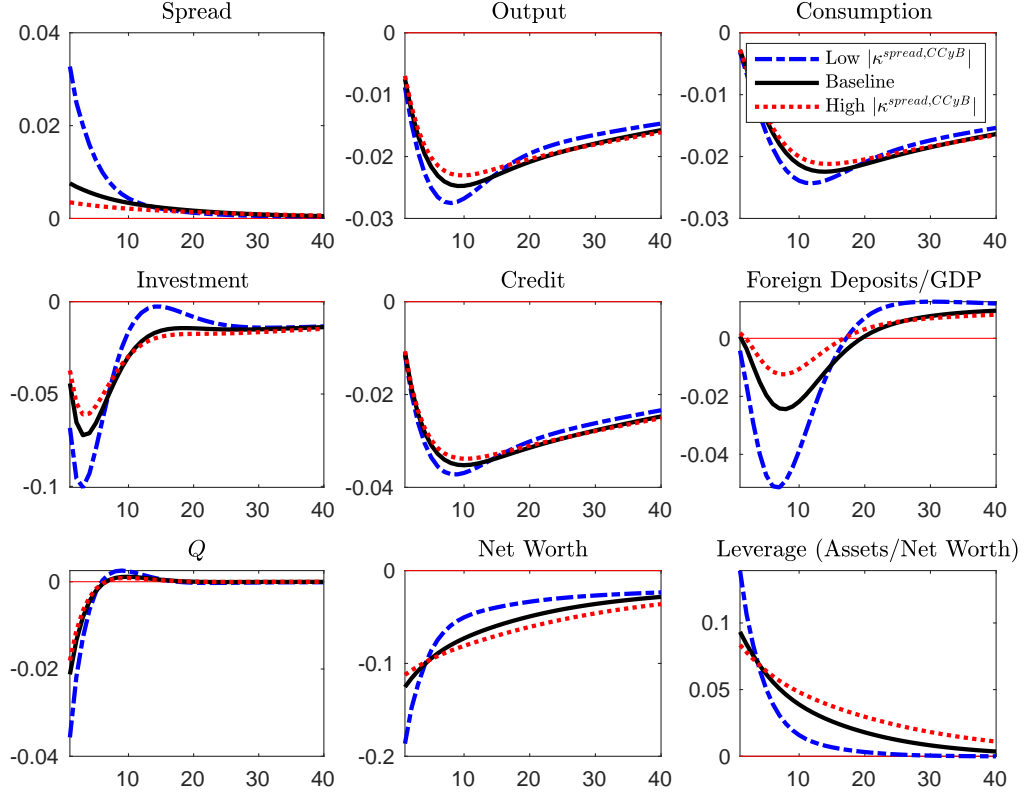
Figure 2 plots the impulse responses for the baseline calibration, where the countercyclical capital buffer ratio is $\kappa^{spread,CCyB} = -12$, for a more countercyclical capital buffers (blue dashed lines), i.e., $\kappa^{spread,CCyB} = -24$, and for a less countercyclical capital buffers (red dotted lines), i.e., $\kappa^{spread,CCyB} = -4$. Notice that moving the countercyclical capital buffer rate does not affect the deterministic steady state of the model since at the steady state buffers, that depends on the cycle, are turned off.¹⁰

In general, economic fluctuations associated with highly countercyclical capital buffers (blue solid lines) are smaller. The intuition is the following. Recall that the countercyclical rule consists of reducing capital requirements each time the credit spread is above its long-term value. This is because the regulator aims to alleviate the bank solvency issues reflected in a higher credit spread. Clearly, after a negative capital quality shock the spread increases, which drives the reduction of capital requirements per unit of assets. This allows banks to lend more for unit of net worth, which diminishes the negative effects on credit produced by the negative capital quality shock. As a result, a more

¹⁰In contrast, the stochastic steady state, which is not studied here, is going to be affected when moving $\kappa^{spread,CCyB}$.

countercyclical capital buffer leads to smaller fluctuations of macroeconomic and financial variables.

Figure 2: Negative capital quality shock and $\kappa^{spread,CCyB}$ sensitivity



IRFs after a one-time negative capital quality shock of 1%. All variables are in log deviations from steady state except Spread. Spread is annualized. Low: $|\kappa^{spread,CCyB}| = 4$. Baseline: $|\kappa^{spread,CCyB}| = 12$. High: $|\kappa^{spread,CCyB}| = 24$.

For completeness, figures 6, 7, 8 and 9 in Appendix A report that higher fixed capital requirements or more countercyclical capital buffers also reduce economic fluctuations in the case of a productivity shock or world interest rate shock.

5.1 Countercyclical capital buffers

Here, we assess the effects of essentially three different forms of countercyclical capital buffers. The first form consists in buffers as suggested in Basel III (BCBS, 2010). Basel III recommends the gap between the credit to GDP ratio and its long-term trend as a guide for setting countercyclical capital buffers, i.e., the capital buffer rate under Basel

III recommendations takes the form of,¹¹

$$\kappa_t^{S/Y,CCyB} = \kappa^{S/Y,CCyB} \left[\frac{S_{t-1}}{Y_t} - \frac{S_{ss}}{Y_{ss}} \right], \quad (39)$$

where the subscript ss denotes steady-state, $\kappa^{S/Y,CCyB} > 0$ and hence the buffers are expected to be countercyclical. This is, if the observed (or realized) credit to GDP ratio is above its long-term value, regulator asks banks to hold more bank net worth per unit of assets or equivalently to reduce their assets given their net worth levels.

The second form of capital buffers we study follows Rubio and Carrasco-Gallego (2016). They propose a capital buffer ratio that responds to percentage deviations of contemporaneous bank credit from its steady state. Similarly, we propose capital buffers that respond to percentage deviations of bank credit, GDP or asset prices from its steady state. To start with, in contrast to Carrasco-Gallego (2016), buffers respond to observed rather than contemporaneous variables. In general, capital buffer ratio takes the following form,

$$\kappa_t^{X,CCyB} = \kappa^{X,CCyB} [ln(X_t) - ln(X_{ss})]. \quad (40)$$

where $X_t \in \{\text{credit } S_{t-1}, \text{ gross domestic product } Y_t, \text{ asset prices } Q_{t-1}\}$ and $\kappa^{X,CCyB} > 0$ and hence buffers are expected to be countercyclical. For instance, for $X_t = S_t$, each time bank credit is above its long-term value, the regulator mandates banks to increase their buffers in proportion to the relative deviation of bank credit from its long-term value.

The third form of capital buffers respond to the observed dynamics of the economy. Formally,

$$\kappa_t^{\Delta X,CCyB} = \kappa^{\Delta X,CCyB} \Delta ln(X_t) = \kappa^{\Delta X,CCyB} [ln(X_t) - ln(X_{t-1})] \quad (41)$$

where $X_t \in \{\text{credit } S_{t-1}, \text{ gross domestic product } Y_t, \text{ asset prices } Q_{t-1}\}$ and $\kappa^{\Delta X,CCyB} > 0$ and again hence buffers are expected to be countercyclical. According to this policy, if $X_t = S_t$ each time economy is experiencing a positive growth on credit, banks are required to hold more capital per unit of equity. Notice that in the long-term, these buffers become zero.

Importantly, the strategy to assess the implications of these countercyclical capital buffer ratios is to add each of these ratios to equation (21). This is to ensure the model always converges to its steady state.¹² For example, in order to assess the effects of

¹¹See Drehmann and Tsatsaronis (2014) for a survey of the criticism of having the credit to GDP ratio as a guide for setting countercyclical capital buffers.

¹²Technically, we do this to ensure Blanchard Kahn conditions are satisfied in order to have a stable equilibrium.

$\kappa_t^{S/Y,CCyB}$, the capital requirement ratio becomes,

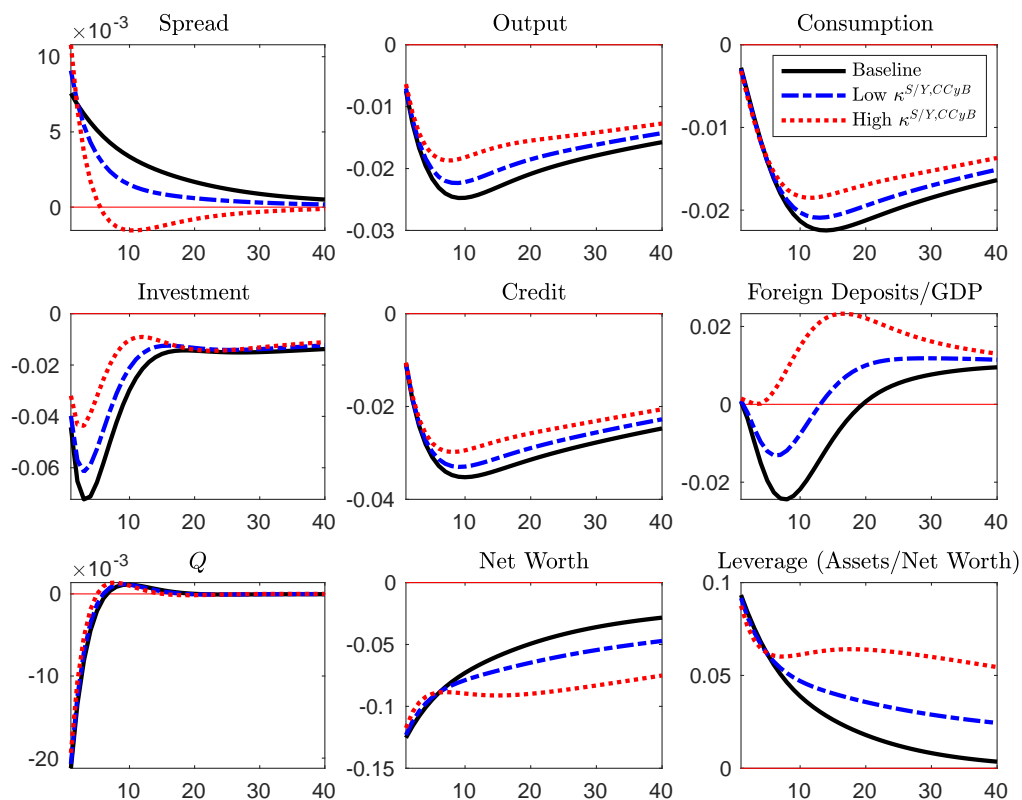
$$\kappa_t = \kappa^{FCR} + \kappa_t^{spread,CCyB} + \kappa_t^{S/Y,CCyB},$$

Notice that the proposed buffers depend on information of variables already observed in the economy and hence easy to obtain; however, we also study if there are gains when the buffers respond to contemporaneous or expected values of the same indicators.

In what follows we discuss the implication of these three forms of countercyclical buffers. Although in the next subsection we quantitatively report the effects of these buffers, the impulse response responses plotted here will help us to illustrate the dynamics of the variables.

Figures 3, 4 and 5 plot the impulse response functions for main variables after a one-time negative capital quality shock of 1%. We evaluate the effects of capital buffers by contrasting them with baseline economy (black solid lines), where there are only fixed capital requirements and CCyB that responds to credit spread.

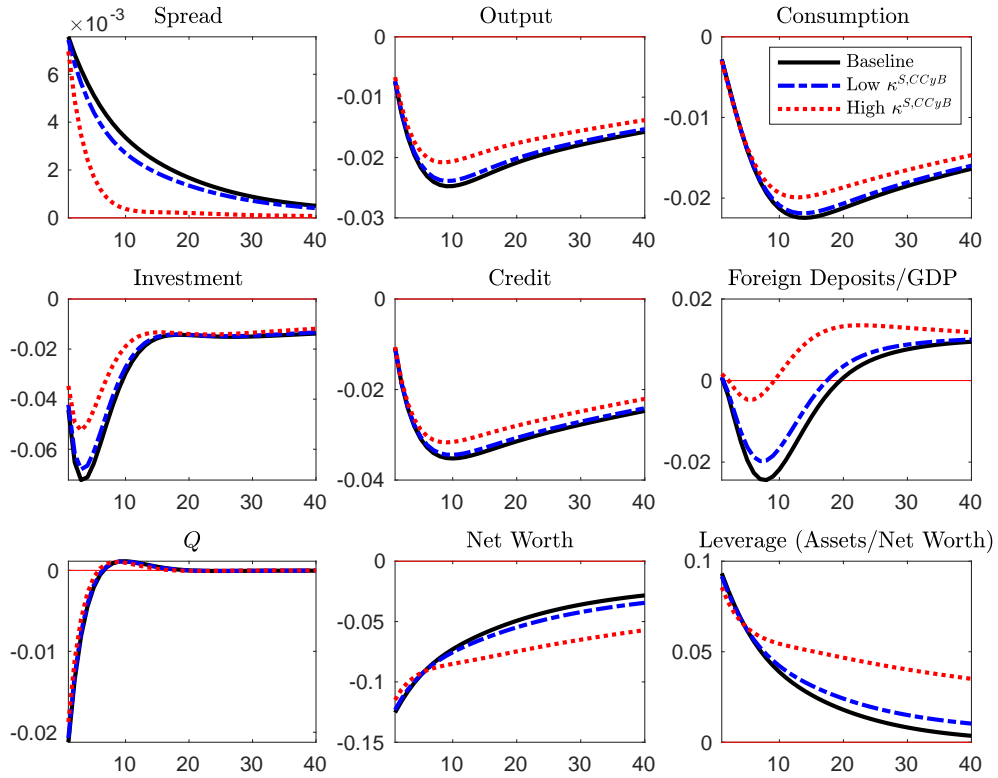
Figure 3: Negative capital quality shock and $\kappa^{S/Y,CCyB}$ sensitivity



IRFs after a one-time negative capital quality shock of 1%. All variables are in log deviations from steady state except Spread. Spread is annualized. Baseline: $\kappa^{S/Y,CCyB} = 0$. High: $\kappa^{S/Y,CCyB} = 0.20$. Low: $\kappa^{S/Y,CCyB} = 0.08$.

In figure 3 we observe the effects of capital buffers that respond to the observed credit to GDP deviations from its steady state. It reports the effects of a more and less countercyclical additional capital buffer, i.e., $\kappa^{S/Y,CCyB} = 0.20$ and $\kappa^{S/Y,CCyB} = 0.08$, respectively. In general, this additional capital buffer reduces the cyclicality. Thus, the more countercyclical the additional buffer (i.e., the larger $\kappa^{S/Y,CCyB}$), the higher the reduction of the fluctuations of real and financial variables. If we consider buffers that respond to the observed total value of loans to GDP ratio, results hold, see figure 14 in Appendix A.

Figure 4: Negative capital quality shock and $\kappa^{S,CCyB}$ sensitivity

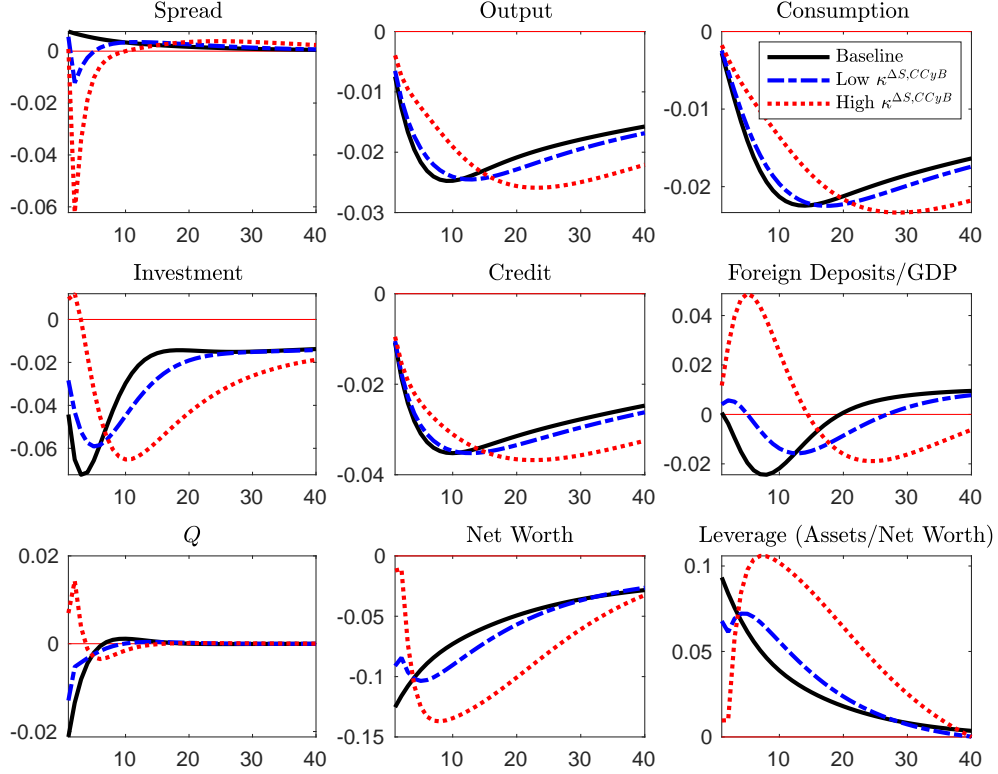


IRFs after a one-time negative capital quality shock of 1%. All variables are in log deviations from steady state except Spread. Spread is annualized. Baseline: $\kappa^{S,CCyB} = 0$. High: $\kappa^{S,CCyB} = 0.40$. Low: $\kappa^{S,CCyB} = 0.08$.

Figure 4 reports the effects of capital buffers that responds to the observed percentage deviations of bank credit from its steady state. We set $\kappa^{S,CCyB} = 0.40$ and $\kappa^{S,CCyB} = 0.08$ in order to see a more and less countercyclical capital buffer, respectively. The results are, qualitatively speaking, similar when studying the buffers that responds to credit to GDP deviations. The same occurs when studying the buffers that responds to the observed percentage deviations of GDP from its steady state, see figure 10 in Appendix A. This is, the more countercyclical the buffers (i.e., the larger $\kappa^{S,CCyB}$ or $\kappa^{Y,CCyB}$), the smaller the fluctuations of real and financial variables. However, when assessing the buffers that respond to the percentage deviations of asset price from its steady state, figure 11 in

Appendix A, the results are inconclusive. In other words, it is not clear if the more countercyclical buffers (i.e., the larger $\kappa^{Q,CCyB}$) leads to smaller economic fluctuations. The intuition is provided in the following subsection.

Figure 5: Negative capital quality shock and $\kappa^{\Delta S,CCyB}$ sensitivity



IRFs after a one-time negative capital quality shock of 1%. All variables are in log deviations from steady state except Spread. Spread is annualized. Baseline: $\kappa^{\Delta S,CCyB} = 0$. High: $\kappa^{\Delta S,CCyB} = 20$. Low: $\kappa^{\Delta S,CCyB} = 5$.

Figure 5 evaluate the effects of adding buffers that responds to credit growth. For a low policy response (i.e., $\kappa^{S,CCyB} = 5$), we observe dynamics similar to the baseline economy. And for a strong policy response (i.e., $\kappa^{S,CCyB} = 20$) it is not clear if buffers promote real and financial stability. Since this rule depends on the dynamics and hence when the economy is going back to its normal state it shows positive credit growth, then buffers respond by requiring more capital, when the economy is still recovering from the shock and hence is below its long-term trend. Extrapolating this to real life, it seems that buffers are more effective when responding to the excessive credit growth rather than to credit growth. This result is aligned with the literature that suggests excessive credit growth as an early indicator of a financial crisis (see, e.g., Alessi, 2018). This literature hence implicitly suggests the need of countercyclical capital buffers. According to figures 12 and 13 in Appendix A, conclusions hold with buffers that responds to observed GDP growth, while it is clear that buffers that respond to capital price growth do not improve real and

financial stability.

5.2 Second Moments and Second Order Effects on Welfare

Tables 2-5 summarize indicators of macroeconomic stability (columns 1-2) and financial stability (columns 3-4) when implementing different capital requirements. It also shows the second order effects on welfare (column 6) and total welfare gains (column 7) of implementing these capital requirements. The measures of macroeconomic stability are the variability of output and consumption, while the measures that we take as a proxy for financial stability are the variability of credit and the variability of the spread. As standard in the literature we measure welfare losses in terms of consumptions equivalent units.¹³

The capital buffers studied here are those defined in subsection 5.1, which respond to observed indicators, but also we study the cases when buffers respond to contemporaneous and expected indicators.¹⁴ For example, buffers might also respond to the contemporaneous credit to GDP ratio deviation, $\mathbb{E}_t\{S_t/Y_{t+1} - S_{ss}/Y_{ss}\}$, or the expectation of future credit to GDP ratio deviation, $\mathbb{E}_t\{S_{t+1}/Y_{t+2} - S_{ss}/Y_{ss}\}$. Similarly, buffers might respond to the contemporaneous relative deviations of credit, $\ln(S_{t+1}) - \ln(S_{ss})$, or the expectation of future relative deviation of credit, $\mathbb{E}_t\{\ln(S_{t+1}) - \ln(S_{ss})\}$. Accordingly, table 2 reports for each form of buffer, the cases when it responds to the observed, the contemporaneous and the expected indicator.

In practice, it is not easy to implement the two latter cases since it requires a deeper understating of the economy's features from the regulator side, for example, to know the uncertainty level (shocks volatilities). Recall that we assume that banks take capital buffer ratios as given. Notice that if banks can internalize the effects of their decisions on buffers, they might ex-ante take more risk since they know if a crisis occurs, regulator is going to relax capital requirements, and hence it might reduce regulation effectiveness. However, in this paper we assume that banks cannot coordinate and hence since there is a large number of banks, they take countercyclical capital buffer rates as given.

We find that:

- From table 2, higher fixed capital requirements (lower leverage) allows banks to better handle a crisis and hence promote macroeconomic and financial stability. This is captured by the small volatility of the business cycle of macroeconomic and fi-

¹³This consumption equivalents, derived from the second-order approximation of the model, are defined as a permanent fixed relative reduction in consumption so the new unconditional mean of welfare yields to its baseline.

¹⁴For completeness we report the cases when considering the total asset value ($Q_{t-1}S_{t-1}$) or capital ($K_t = \psi_t S_{t-1}$) instead of credit level (S_{t-1}).

financial variables (columns 1-4) and the positive second order effect on welfare (i.e., $Mean - DSS$ in column 5 raises from -0.004 to 0.012). However, when considering both first and second order effects, tighter fixed capital requirements produce welfare losses, measured as consumption equivalents, of 7.7% (column 7). Due to the first order effects, higher fixed capital requirements decrease long-term credit, consumption and hence welfare, which clearly dominates the second order effects. Notice that the opposite occur with looser fixed capital requirements.¹⁵

- While the fixed capital requirements might have first and second order effects on the macroeconomic and financial variables, countercyclical capital buffers proposed here by definition do not have first order effects, but second order effects. As a result, when assessing the effect of some countercyclical buffers on welfare, welfare gains (column 7) only capture the second order effects of buffers on welfare. In general, second order component of welfare (column 6) is very small, e.g., in the baseline this is less than 0.01%.¹⁶ This implies that even though some countercyclical capital buffers might significantly affect this second order component and hence significantly improve macroeconomic and financial stability as it is reported in tables 2-5, welfare gains are very small. In contexts of high uncertainty (i.e., high shock volatilities) countercyclical buffers might be an important tool to significantly improve society welfare. Whether the impact on welfare is economically significant or not, we can still qualitatively evaluate the effectiveness of the different buffers forms on reducing economic fluctuations, which is the main interest of this paper.
- As suggested before, table 2 reports that a higher $|\kappa^{spread,CCyB}|$ produces positive second order effects on welfare and hence welfare gains. The opposite happens with looser CCyB buffers.
- Table 2 suggests that adding CCyB that respond to the deviation of observed credit to GDP (S_{t-1}/Y_{t-1}) from its long-term value enhances macroeconomic and financial stability and leads to welfare gains. For example, for a $\kappa^{S/Y,CCyB} = 0.20$ the standard deviations of the GDP cycle and credit cycle decrease from 2.75% to 2.14%, and from 4.14% to 3.39%, respectively. Notice that being forward looking does not improve the economy at all. Similarly, according to table 4 and table 5, considering total assets value ($Q_{t-1}S_{t-1}$) or capital (K_t) instead of credit level does not increase the positive effects on stability and hence on welfare.
- Similarly, buffers that respond to the percentage deviation of observed credit are also effective in reducing volatility of macroeconomic and financial variables (see

¹⁵With looser fixed capital requirements, macroeconomic and financial stability is weakened and consequently there are second order welfare losses, but the first order welfare gains are much more important.

¹⁶This is obtained with the formula: (column 6)/(column 5 + column 6).

table 2) and hence increase welfare. This holds when buffers respond to percentage deviations of observed GDP (see table 3), total credit value (see table 4) or capital (see table 5); however, the welfare gains are a bit smaller. For example, when adding buffers respond to observed credit, GDP, total credit value or capital, the volatility of the GDP cycle becomes 2.36%, 2.50%, 2.36% and 2.36%, respectively, for a $\kappa = 0.40$, and so we notice a smaller volatility for observed credit. As before, being forward looking does not improve the economy at all. Interestingly, if buffers respond to the percentage deviation of asset prices (see table 3), we observe that macroeconomic and financial stability are negatively affected. Since asset prices are very volatile, they do not necessarily capture very well the need of the economy for looser or tighter capital requirements.

- When buffers respond to observed credit growth (see table 2) or output growth (see table 3), volatility of macroeconomic and financial cycles increases and hence buffers diminish welfare. As suggested before, the timing of the credit or GDP dynamics might give us a bad indicator of whether regulator must ease or tighten capital requirements. For example, volatility of the credit cycle increases from 4.14% to 4.95% and from 4.14% to 4.59%, when buffers respond to observed credit and output growth, respectively, for a $\kappa = 20$. Conclusions hold for the asset prices growth (see, table 3) and also holds when considering total credit value and capital (see, tables 4 and 5). As expected, the conclusions hold if buffers respond to contemporaneous or expected values of the same indicators.

Our results suggest that it seems a reasonable strategy to implement countercyclical capital buffers that respond to the observed credit to GDP ratio, or to observed credit or output percentage deviations from its long-term value. At least in this framework being forward looking does not payoff. Also, with the goal of being very cautious or conservative it is not a good idea having rules that depends of asset prices. This might also suggest that we should prefer buffers that respond to the credit to GDP ratio rather than total credit value-to-GDP ratio.

Consequently, the policy recommendation delivered in this work is that it seems reasonable to have the observed deviation of bank credit to GDP ratio from its long-term trend or the observed percentage deviation of credit (or output) from its long-term trend as guides to implement countercyclical capital buffers.

Table 2: Second moments and second order effects: Capital buffers based on Credit Level

κ		σ_y^2	σ_c^2	σ_s^2	σ_{spread}^2	Welfare			
						DSS	Mean-DSS	Gains	
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Baseline		2.750	2.657	4.144	0.343	-65.596	-0.004	0.0000	
I. Fixed Capital Requirements (κ^{FCR})									
Low	1/8	2.829	2.711	4.232	0.420	-61.975	-0.009	1.7706	
High	1/1.5	2.222	2.249	3.480	0.091	-79.686	0.012	-7.6889	
II. Countercyclical Capital Buffers ($\kappa^{spread,CCyB}$)									
Low	-4	2.690	2.604	4.015	0.983	-65.596	-0.018	-0.0074	
High	-24	2.749	2.655	4.179	0.195	-65.596	0.009	0.0062	
III. Other Countercyclical Capital Buffers that respond to:									
III.a. Deviation of Credit to GDP ratio ($\kappa^{S/Y,CCyB}$)									
		$\frac{S_{t-1}}{Y_t} - \frac{S_{ss}}{Y_{ss}}$	2.474	2.439	3.794	0.312	-65.596	-0.001	0.0012
Low	0.08	$\mathbb{E}_t \left\{ \frac{S_t}{Y_{t+1}} - \frac{S_{ss}}{Y_{ss}} \right\}$	2.479	2.443	3.802	0.282	-65.596	-0.001	0.0012
		$\mathbb{E}_t \left\{ \frac{S_{t+1}}{Y_{t+2}} - \frac{S_{ss}}{Y_{ss}} \right\}$	2.483	2.446	3.808	0.266	-65.596	-0.001	0.0012
		$\frac{S_{t-1}}{Y_t} - \frac{S_{ss}}{Y_{ss}}$	2.141	2.174	3.387	0.396	-65.596	-0.002	0.0009
High	0.20	$\mathbb{E}_t \left\{ \frac{S_t}{Y_{t+1}} - \frac{S_{ss}}{Y_{ss}} \right\}$	2.151	2.182	3.402	0.296	-65.596	-0.002	0.0010
		$\mathbb{E}_t \left\{ \frac{S_{t+1}}{Y_{t+2}} - \frac{S_{ss}}{Y_{ss}} \right\}$	2.159	2.189	3.415	0.247	-65.596	-0.002	0.0009
III.b. Percentage deviation of Credit from its steady state ($\kappa^{S,CCyB}$)									
		$\ln(S_{t-1}) - \ln(S_{ss})$	2.662	2.587	4.035	0.312	-65.596	-0.002	0.0010
Low	0.08	$\ln(S_t) - \ln(S_{ss})$	2.664	2.589	4.037	0.307	-65.596	-0.002	0.0010
		$\mathbb{E}_t \{ \ln(S_{t+1}) - \ln(S_{ss}) \}$	2.665	2.590	4.039	0.304	-65.596	-0.002	0.0010
		$\ln(S_{t-1}) - \ln(S_{ss})$	2.361	2.350	3.663	0.229	-65.596	0.003	0.0032
High	0.40	$\ln(S_t) - \ln(S_{ss})$	2.367	2.355	3.671	0.206	-65.596	0.003	0.0031
		$\mathbb{E}_t \{ \ln(S_{t+1}) - \ln(S_{ss}) \}$	2.372	2.359	3.679	0.192	-65.596	0.003	0.0031
III.c. Bank Credit growth ($\kappa^{\Delta S,CCyB}$)									
		$\Delta \ln(S_{t-1})$	2.868	2.753	4.319	0.357	-65.596	-0.007	-0.0016
Low	5	$\Delta \ln(S_t)$	2.858	2.745	4.299	0.346	-65.596	-0.008	-0.0020
		$\mathbb{E}_t \{ \Delta \ln(S_{t+1}) \}$	2.845	2.733	4.276	0.290	-65.596	-0.008	-0.0020
		$\Delta \ln(S_{t-1})$	3.282	3.087	4.947	1.234	-65.596	-0.022	-0.0094
High	20	$\Delta \ln(S_t)$	3.245	3.058	4.881	1.312	-65.596	-0.021	-0.0087
		$\mathbb{E}_t \{ \Delta \ln(S_{t+1}) \}$	3.191	3.014	4.789	0.912	-65.596	-0.020	-0.0081

“Welfare, DSS” gives us the deterministic steady state of household welfare. “Welfare, Mean-DSS” captures the second order effects on welfare and hence it shows the difference between the mean and the deterministic steady-state value for households’ welfare. In general, the unconditional standard deviations is defined as $\sigma_x^2 = \mathbb{E}\{[\ln(X_t) - \mathbb{E}\{\ln(X_t)\}]^2\}$ and are reported in %. We solve the model using a second-order approximation in Dynare. The mean and standard deviation of welfare reported correspond to the first and second theoretical moments provided by Dynare. *Welfare gains are measured in consumption equivalents in %, if this positive there are gains, otherwise, there are losses. In the baseline model $\kappa^{FCR} = 1/4$, $\kappa^{spread,CCyB} = -12$, and there are not additional capital buffers.

6 Conclusions

In this document we quantitatively assess the implications of countercyclical capital buffers. To do so we introduce banks and a regulatory capital requirement rule to an open economy DSGE model. The capital requirements consist of a fixed capital requirement ratio and a countercyclical capital buffer ratio. We find that the tighter fixed capital requirements, the better able banks are, and hence economy, to handle a financial crisis and hence improves macroeconomic and financial stability. However, as expected these tighter capital requirements reduces long-term consumption, which reduces welfare.

We then suggest additional countercyclical capital buffers, many of them already debated by policy makers. We find that, buffers that respond to observed credit to GDP ratio from their long-term values, or to percentage deviations of the observed credit (or GDP) from its long-term values promote macroeconomic and financial stability and improve welfare. When buffers respond to the contemporaneous or the expected future value of the same indicators, there are not welfare gains. Interestingly, when buffers respond to percentage deviation of asset prices or to credit or output growth, macroeconomic and financial stability are negatively affected.

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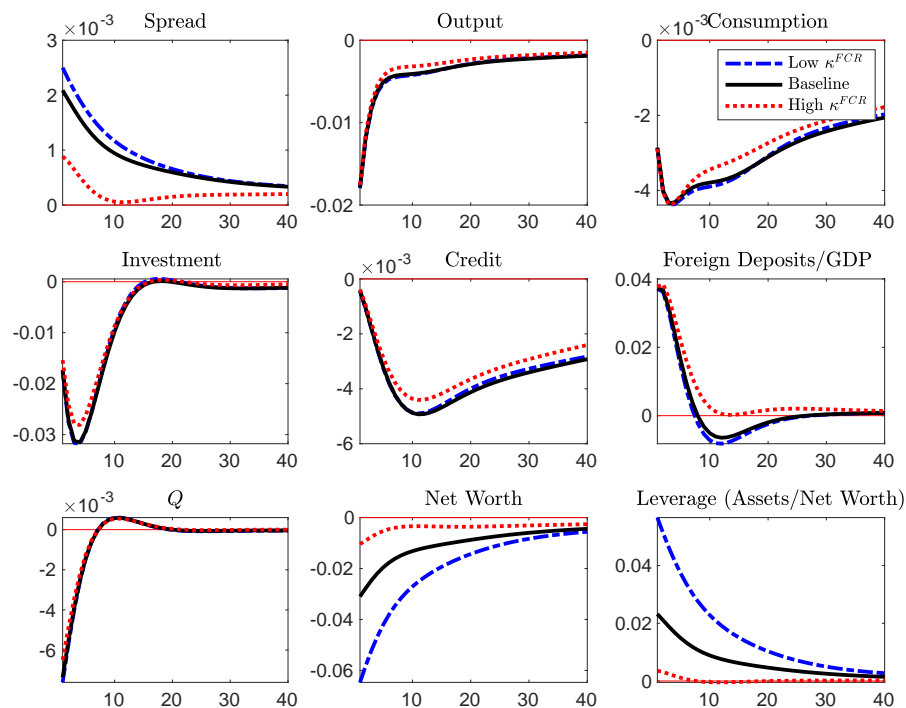
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Appendices

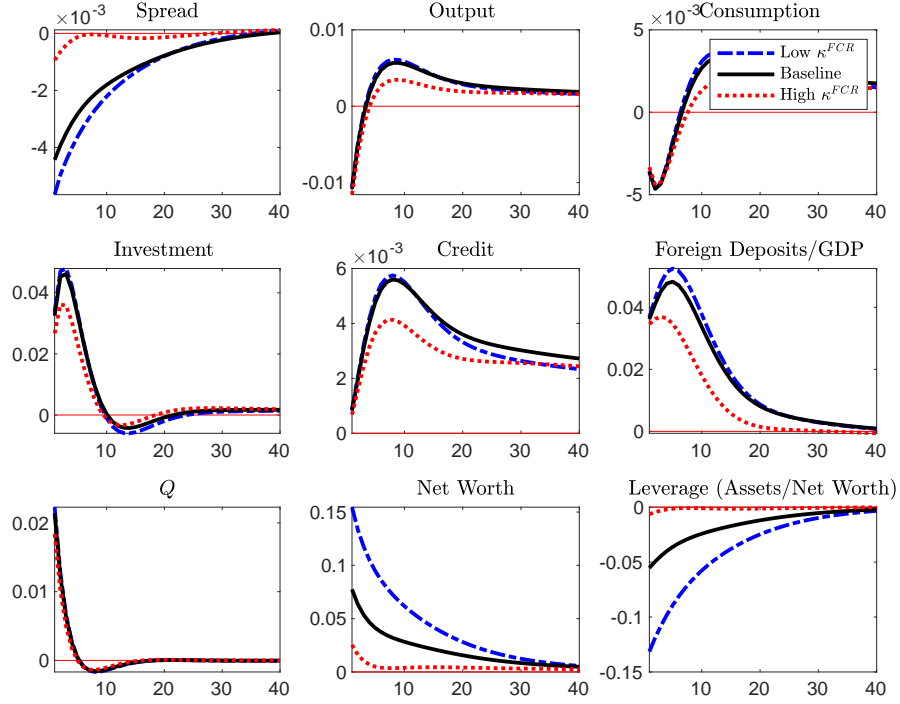
A Additional figures

Figure 6: Negative productivity shock and κ^{FCR} sensitivity



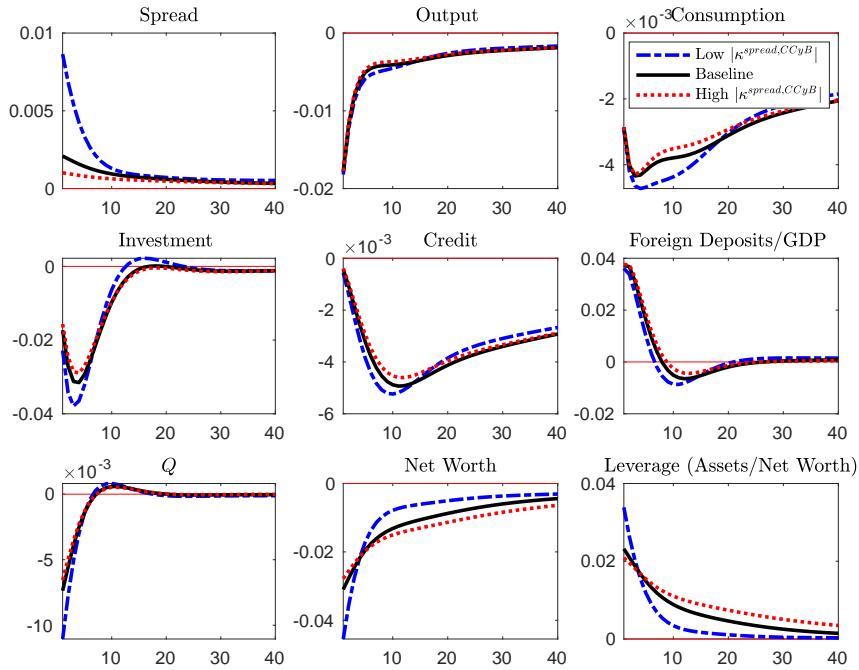
IRFs after a one-time negative productivity shock of 1%. All variables are in log deviations from ss except Spread. Spread is annualized. Low: $\kappa^{FCR} = 1/8$. Baseline: $\kappa^{FCR} = 1/4$. High: $\kappa^{FCR} = 1/1.5$.

Figure 7: Negative foreign interest rate shock and κ^{FCR} sensitivity



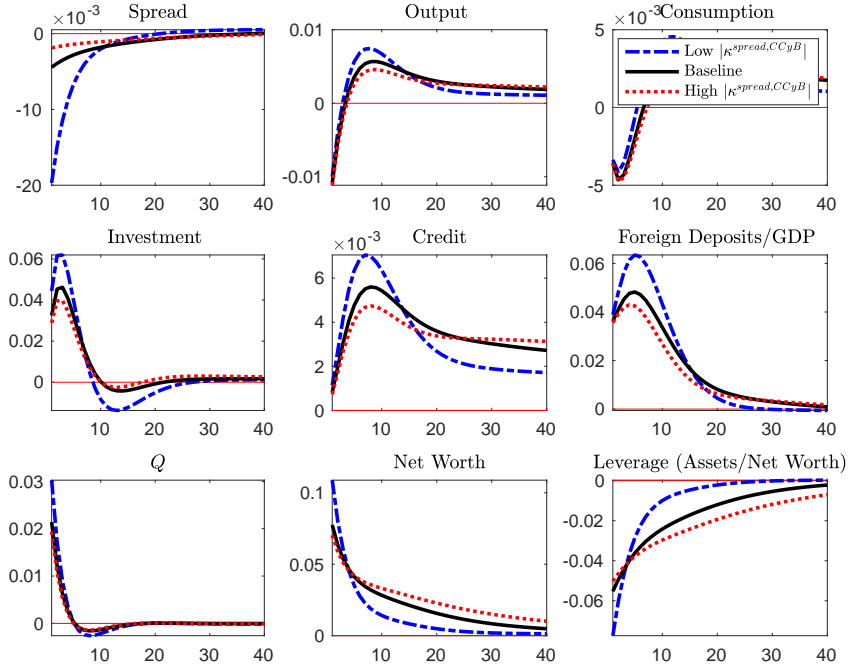
IRFs after a one-time negative world rate shock of 1%. All variables are in log deviations from ss except Spread. Spread is annualized. Low: $\kappa^{FCR} = 1/8$. Baseline: $\kappa^{FCR} = 1/4$. High: $\kappa^{FCR} = 1/1.5$.

Figure 8: Negative productivity shock and $\kappa^{spread,CCyB}$ sensitivity



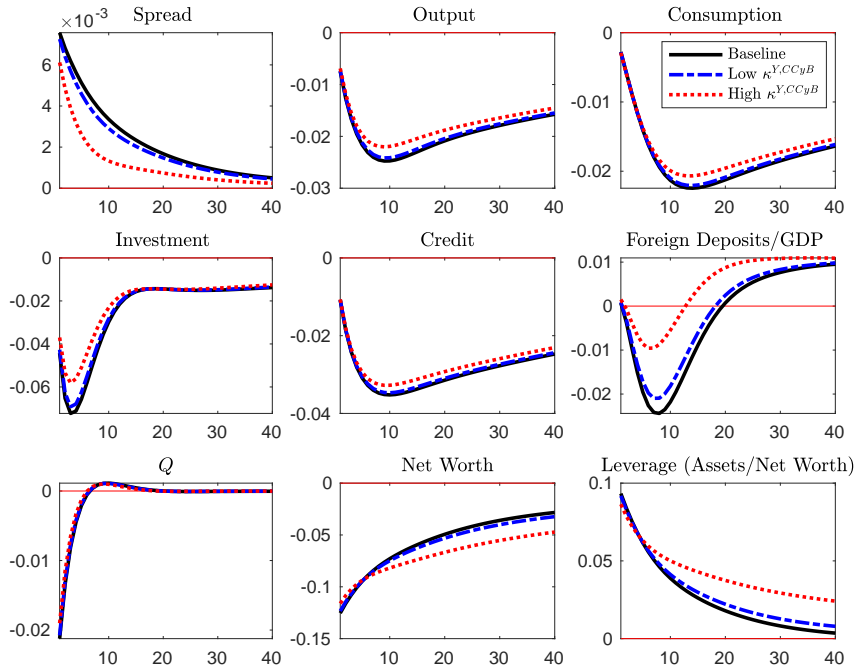
IRFs after a one-time negative productivity shock of 1%. All variables are in log deviations from ss except Spread. Spread is annualized. Low: $|\kappa^{spread,CCyB}|=4$. Baseline: $|\kappa^{spread,CCyB}|=12$. High: $|\kappa^{spread,CCyB}|=24$.

Figure 9: Negative world interest shock shock and $\kappa^{spread,CCyB}$ sensitivity



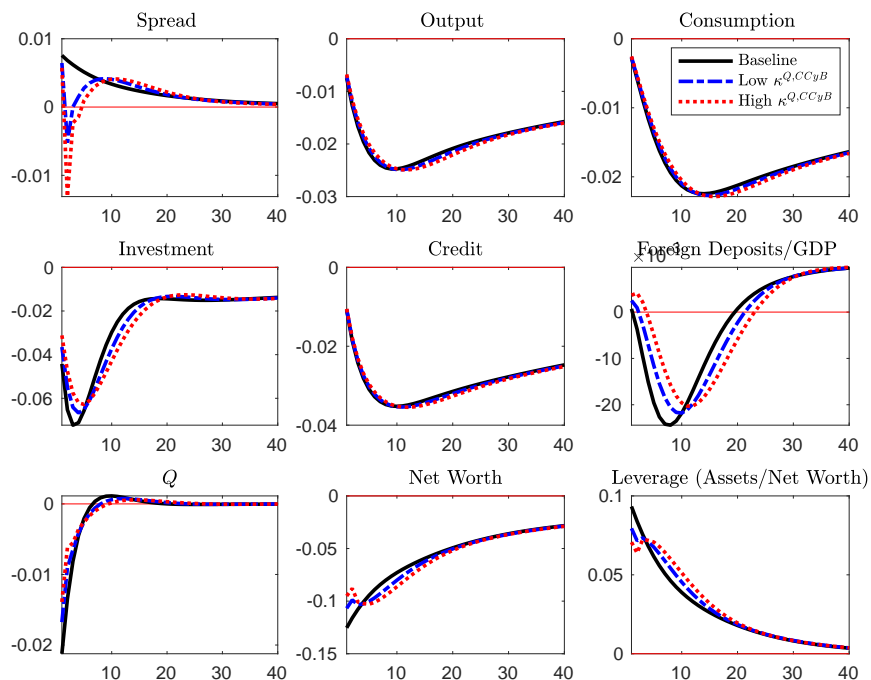
IRFs after a one-time negative world interest rate shock of 1%. All variables are in log deviations from ss except Spread. Spread is annualized. Low: $|\kappa^{spread,CCyB}|=4$. Baseline: $|\kappa^{spread,CCyB}|=12$. High: $|\kappa^{spread,CCyB}|=24$.

Figure 10: Negative capital quality shock and $\kappa^{Y,CCyB}$ sensitivity



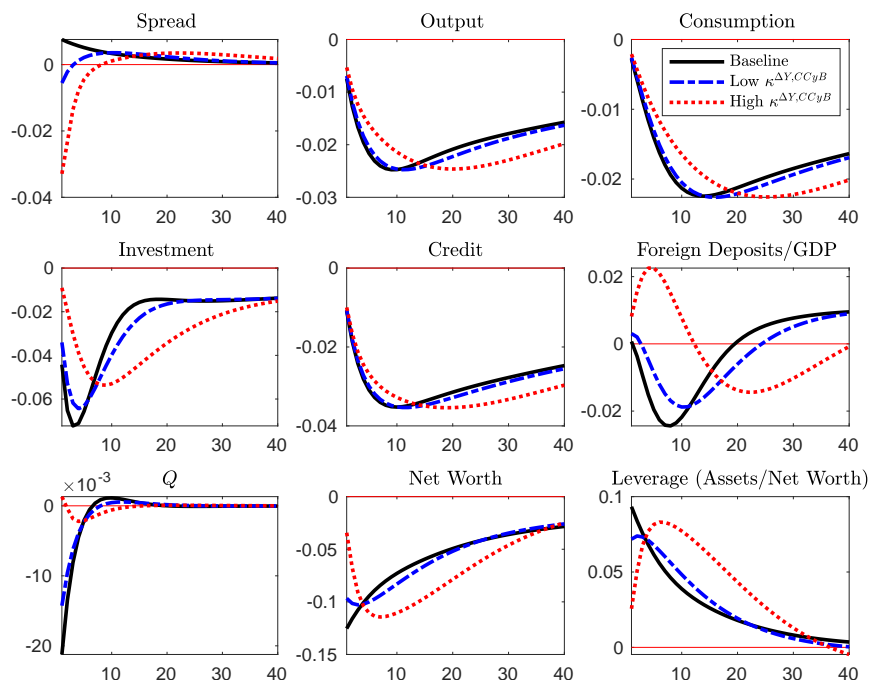
IRFs after a one-time negative capital quality shock of 1%. All variables are in log deviations from steady state except Spread. Spread is annualized. Baseline: $\kappa^{Y,CCyB} = 0$. High: $\kappa^{Y,CCyB} = 0.40$. Low: $\kappa^{Y,CCyB} = 0.08$.

Figure 11: Negative capital quality shock and $\kappa^{Q,CCyB}$ sensitivity



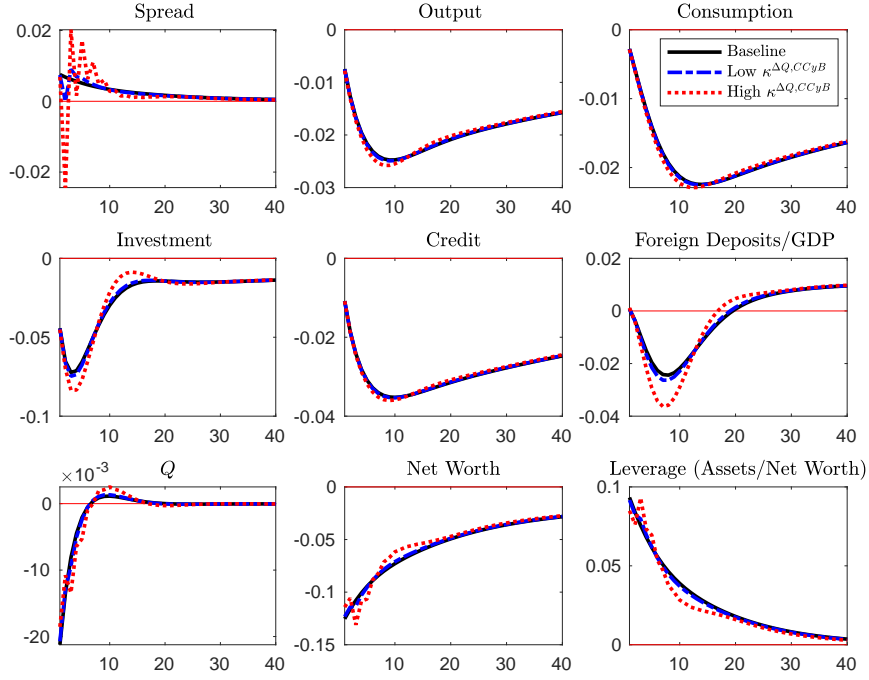
IRFs after a one-time negative capital quality shock of 1%. All variables are in log deviations from ss except Spread. Spread is annualized. Baseline: $\kappa^{Q,CCyB} = 0$. High: $\kappa^{Q,CCyB} = 4$. Low: $\kappa^{Q,CCyB} = 2$.

Figure 12: Negative capital quality shock and $\kappa^{\Delta Y,CCyB}$ sensitivity



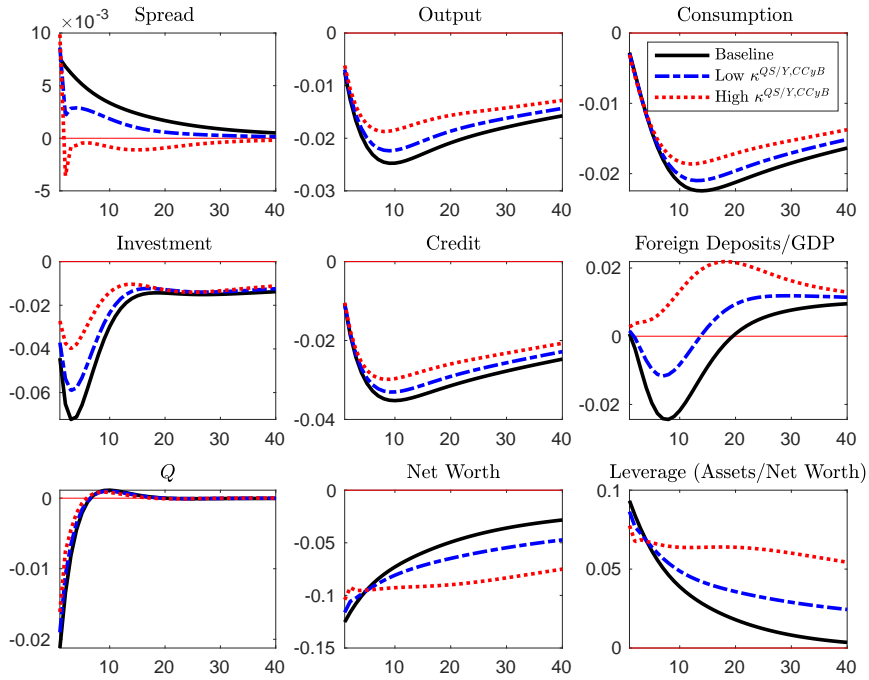
IRFs after a one-time negative capital quality shock of 1%. All variables are in log deviations from ss except Spread. Spread is annualized. Baseline: $\kappa^{\Delta Y,CCyB} = 0$. High: $\kappa^{\Delta Y,CCyB} = 20$. Low: $\kappa^{\Delta Y,CCyB} = 5$.

Figure 13: Negative capital quality shock and $\kappa^{\Delta Q, CCyB}$ sensitivity



IRFs after a one-time negative capital quality shock of 1%. All variables are in log deviations from ss except Spread. Spread is annualized. Baseline: $\kappa^{\Delta Q, CCyB} = 0$. High: $\kappa^{\Delta Q, CCyB} = 5$. Low: $\kappa^{\Delta Q, CCyB} = 1$.

Figure 14: Negative capital quality shock and $\kappa^{QS/Y, CCyB}$ sensitivity



IRFs after a one-time negative capital quality shock of 1%. All variables are in log deviations from ss except Spread. Spread is annualized. Baseline: $\kappa^{QS/Y, CCyB} = 0$. High: $\kappa^{QS/Y, CCyB} = 0.20$. Low: $\kappa^{QS/Y, CCyB} = 0.08$.

B Additional tables

Table 3: Second order effects under different capital requirement rules: Capital buffers based on GDP and Asset Prices

κ		σ_y^2	σ_c^2	σ_s^2	σ_{spread}^2	Welfare		
						DSS	Mean-DSS	Gains
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
Baseline		2.750	2.657	4.144	0.343	-65.596	-0.004	0.0000
Percentage deviation of Output from its steady state ($\kappa^{Y,CCyB}$)								
	$\ln(Y_t) - \ln(Y_{ss})$	2.695	2.613	4.077	0.318	-65.596	-0.002	0.0008
Low	0.08 $\mathbb{E}_t \{\ln(Y_{t+1}) - \ln(Y_{ss})\}$	2.696	2.614	4.078	0.315	-65.596	-0.002	0.0007
	$\mathbb{E}_t \{\ln(Y_{t+2}) - \ln(Y_{ss})\}$	2.697	2.615	4.079	0.314	-65.596	-0.002	0.0007
	$\ln(Y_t) - \ln(Y_{ss})$	2.497	2.458	3.834	0.247	-65.596	0.002	0.0028
High	0.40 $\mathbb{E}_t \{\ln(Y_{t+1}) - \ln(Y_{ss})\}$	2.501	2.461	3.839	0.229	-65.596	0.002	0.0027
	$\mathbb{E}_t \{\ln(Y_{t+2}) - \ln(Y_{ss})\}$	2.504	2.464	3.844	0.218	-65.596	0.002	0.0026
Percentage deviation of Asset Price from its steady state ($\kappa^{Q,CCyB}$)								
	$\ln(Q_{t-1}) - \ln(Q_{ss})$	2.774	2.678	4.178	0.331	-65.596	-0.005	-0.0008
Low	2 $\ln(Q_t) - \ln(Q_{ss})$	2.768	2.672	4.167	0.314	-65.596	-0.006	-0.0011
	$\mathbb{E}_t \{\ln(Q_{t+1}) - \ln(Q_{ss})\}$	2.760	2.665	4.153	0.297	-65.596	-0.005	-0.0006
	$\ln(Q_{t-1}) - \ln(Q_{ss})$	2.794	2.695	4.206	0.465	-65.596	-0.007	-0.0016
High	4 $\ln(Q_t) - \ln(Q_{ss})$	2.786	2.688	4.190	0.448	-65.596	-0.007	-0.0020
	$\mathbb{E}_t \{\ln(Q_{t+1}) - \ln(Q_{ss})\}$	2.772	2.675	4.167	0.380	-65.596	-0.006	-0.0013
GDP growth ($\kappa^{\Delta Y,CCyB}$)								
	$\Delta \ln(Y_t)$	2.817	2.711	4.230	0.380	-65.596	-0.007	-0.0019
Low	5 $\mathbb{E}_t \{\Delta \ln(Y_{t+1})\}$	2.827	2.719	4.247	0.704	-65.596	-0.006	-0.0013
	$\mathbb{E}_t \{\Delta \ln(Y_{t+2})\}$	2.809	2.704	4.217	0.321	-65.596	-0.007	-0.0018
	$\Delta \ln(Y_t)$	3.074	2.920	4.588	1.204	-65.596	-0.017	-0.0070
High	20 $\mathbb{E}_t \{\Delta \ln(Y_{t+1})\}$	3.102	2.943	4.645	2.746	-65.596	-0.009	-0.0026
	$\mathbb{E}_t \{\Delta \ln(Y_{t+2})\}$	3.040	2.893	4.534	0.822	-65.596	-0.018	-0.0071
Asset Price growth ($\kappa^{\Delta Q,CCyB}$)								
	$\Delta \ln(Q_{t-1})$	2.747	2.654	4.139	0.376	-65.596	-0.004	-0.0003
Low	1 $\Delta \ln(Q_t)$	2.746	2.653	4.137	0.375	-65.596	-0.004	-0.0003
	$\mathbb{E}_t \{\Delta \ln(Q_{t+1})\}$	2.745	2.652	4.137	0.413	-65.596	-0.003	0.0004
	$\Delta \ln(Q_{t-1})$	2.737	2.644	4.115	0.924	-65.596	-0.007	-0.0018
High	5 $\Delta \ln(Q_t)$	2.727	2.635	4.104	0.869	-65.596	-0.007	-0.0018
	$\mathbb{E}_t \{\Delta \ln(Q_{t+1})\}$	2.716	2.627	4.095	1.034	-65.596	0.003	0.0033

“Welfare, DSS” gives us the deterministic steady state of household welfare. “Welfare, Mean-DSS” captures the second order effects on welfare and hence it shows the difference between the mean and the deterministic steady-state value for households’ welfare. In general, the unconditional standard deviations is defined as $\sigma_x^2 = \mathbb{E}\{[\ln(X_t) - \mathbb{E}\{\ln(X_t)\}]^2\}$ and are reported in %. We solve the model using a second-order approximation in Dynare. The mean and standard deviation of welfare reported correspond to the first and second theoretical moments provided by Dynare. *Welfare gains are measured in consumption equivalents in %, if this positive there are gains, otherwise, there are losses. In the baseline model $\kappa^{FCR} = 1/4$, $\kappa^{spread,CCyB} = -12$, and there are not additional capital buffers.

Table 4: Second order effects under different capital requirement rules: Capital buffers based on total bank assets value (total credit value)

κ		σ_y^2	σ_c^2	σ_s^2	σ_{spread}^2	Welfare			
						DSS	Mean-DSS	Gains	
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Baseline		2.750	2.657	4.144	0.343	-65.596	-0.004	0.0000	
III.a. Deviation of Bank Assets to GDP ratio ($\kappa^{QS/Y,CCyB}$)									
Low	0.08	$\frac{Q_{t-1}S_{t-1}}{Y_t} - \frac{Q_{ss}S_{ss}}{Y_{ss}}$	2.481	2.445	3.803	0.262	-65.596	-0.002	0.0009
		$\mathbb{E}_t \left\{ \frac{Q_t S_t}{Y_{t+1}} - \frac{Q_{ss} S_{ss}}{Y_{ss}} \right\}$	2.484	2.447	3.807	0.218	-65.596	-0.002	0.0007
		$\mathbb{E}_t \left\{ \frac{Q_{t+1} S_{t+1}}{Y_{t+2}} - \frac{Q_{ss} S_{ss}}{Y_{ss}} \right\}$	2.485	2.448	3.810	0.226	-65.596	-0.002	0.0008
High	0.20	$\frac{Q_{t-1}S_{t-1}}{Y_t} - \frac{Q_{ss}S_{ss}}{Y_{ss}}$	2.152	2.184	3.400	0.366	-65.596	-0.003	0.0003
		$\mathbb{E}_t \left\{ \frac{Q_t S_t}{Y_{t+1}} - \frac{Q_{ss} S_{ss}}{Y_{ss}} \right\}$	2.158	2.188	3.410	0.264	-65.596	-0.003	0.0001
		$\mathbb{E}_t \left\{ \frac{Q_{t+1} S_{t+1}}{Y_{t+2}} - \frac{Q_{ss} S_{ss}}{Y_{ss}} \right\}$	2.162	2.191	3.417	0.215	-65.596	-0.003	0.0003
III.b. Percentage deviation of Bank Assets from its steady state ($\kappa^{QS,CCyB}$)									
Low	0.08	$\ln(Q_{t-1}S_{t-1}) - \ln(Q_{ss}S_{ss})$	2.663	2.588	4.036	0.303	-65.596	-0.002	0.0010
		$\ln(Q_t S_t) - \ln(Q_{ss} S_{ss})$	2.664	2.589	4.038	0.297	-65.596	-0.002	0.0009
		$\mathbb{E}_t \{ \ln(Q_{t+1} S_{t+1}) - \ln(Q_{ss} S_{ss}) \}$	2.665	2.590	4.039	0.299	-65.596	-0.002	0.0009
High	0.40	$\ln(Q_{t-1}S_{t-1}) - \ln(Q_{ss}S_{ss})$	2.364	2.353	3.668	0.194	-65.596	0.003	0.0031
		$\ln(Q_t S_t) - \ln(Q_{ss} S_{ss})$	2.369	2.357	3.674	0.161	-65.596	0.002	0.0029
		$\mathbb{E}_t \{ \ln(Q_{t+1} S_{t+1}) - \ln(Q_{ss} S_{ss}) \}$	2.373	2.360	3.679	0.168	-65.596	0.002	0.0029
III.c. Bank Assets growth ($\kappa^{\Delta QS,CCyB}$)									
Low	1	$\Delta \ln(Q_{t-1}S_{t-1})$	2.770	2.673	4.172	0.348	-65.596	-0.005	-0.0006
		$\Delta \ln(Q_t S_t)$	2.767	2.670	4.167	0.339	-65.596	-0.005	-0.0006
		$\mathbb{E}_t \{ \Delta \ln(Q_{t+1} S_{t+1}) \}$	2.763	2.667	4.162	0.369	-65.596	-0.004	0.0000
High	5	$\Delta \ln(Q_{t-1}S_{t-1})$	2.860	2.745	4.301	0.860	-65.596	-0.008	-0.0025
		$\Delta \ln(Q_t S_t)$	2.842	2.730	4.271	0.762	-65.596	-0.009	-0.0030
		$\mathbb{E}_t \{ \Delta \ln(Q_{t+1} S_{t+1}) \}$	2.816	2.709	4.234	0.678	-65.596	-0.003	0.0004

“Welfare, DSS” gives us the deterministic steady state of household welfare. “Welfare, Mean-DSS” captures the second order effects on welfare and hence it shows the difference between the mean and the deterministic steady-state value for households’ welfare. In general, the unconditional standard deviations is defined as $\sigma_x^2 = \mathbb{E}\{[\ln(X_t) - \mathbb{E}\{\ln(X_t)\}]^2\}$ and are reported in %. We solve the model using a second-order approximation in Dynare. The mean and standard deviation of welfare reported correspond to the first and second theoretical moments provided by Dynare. *Welfare gains are measured in consumption equivalents in %, if this positive there are gains, otherwise, there are losses. In the baseline model $\kappa^{FCR} = 1/4$, $\kappa^{spread,CCyB} = -12$, and there are not additional capital buffers.

Table 5: Second order effects under different capital requirement rules: Capital buffers based on capital

κ			σ_y^2	σ_c^2	σ_s^2	σ_{spread}^2	Welfare		
							DSS	Mean-DSS	Gains
			(1)	(2)	(3)	(4)	(5)	(6)	(7)
Baseline			2.750	2.657	4.144	0.343	-65.596	-0.004	0.0000
III.a. Deviation of Capital to GDP ratio ($\kappa^{K/Y,CCyB}$)									
Low	0.08	$\mathbb{E}_t \left\{ \frac{K_t}{Y_t} - \frac{K_{ss}}{Y_{ss}} \right\}$	2.477	2.442	3.800	0.279	-65.596	-0.001	0.0011
		$\mathbb{E}_t \left\{ \frac{K_{t+1}}{Y_{t+1}} - \frac{K_{ss}}{Y_{ss}} \right\}$	2.481	2.444	3.805	0.262	-65.596	-0.001	0.0012
		$\mathbb{E}_t \left\{ \frac{K_{t+2}}{Y_{t+2}} - \frac{K_{ss}}{Y_{ss}} \right\}$	2.484	2.447	3.811	0.253	-65.596	-0.001	0.0011
High	0.20	$\mathbb{E}_t \left\{ \frac{K_t}{Y_t} - \frac{K_{ss}}{Y_{ss}} \right\}$	2.148	2.180	3.399	0.345	-65.596	-0.002	0.0009
		$\mathbb{E}_t \left\{ \frac{K_{t+1}}{Y_{t+1}} - \frac{K_{ss}}{Y_{ss}} \right\}$	2.155	2.186	3.410	0.270	-65.596	-0.002	0.0009
		$\mathbb{E}_t \left\{ \frac{K_{t+2}}{Y_{t+2}} - \frac{K_{ss}}{Y_{ss}} \right\}$	2.162	2.191	3.420	0.237	-65.596	-0.002	0.0009
III.b. Percentage deviation of Capital from its steady state ($\kappa^{K,CCyB}$)									
Low	0.08	$\ln(K_t) - \ln(K_{ss})$	2.663	2.588	4.035	0.308	-65.596	-0.002	0.0010
		$\mathbb{E}_t \{ \ln(K_{t+1}) - \ln(K_{ss}) \}$	2.664	2.589	4.037	0.305	-65.596	-0.002	0.0010
		$\mathbb{E}_t \{ \ln(K_{t+2}) - \ln(K_{ss}) \}$	2.665	2.590	4.039	0.303	-65.596	-0.002	0.0010
High	0.40	$\ln(K_t) - \ln(K_{ss})$	2.363	2.352	3.666	0.211	-65.596	0.003	0.0032
		$\mathbb{E}_t \{ \ln(K_{t+1}) - \ln(K_{ss}) \}$	2.368	2.356	3.673	0.196	-65.596	0.003	0.0031
		$\mathbb{E}_t \{ \ln(K_{t+2}) - \ln(K_{ss}) \}$	2.373	2.360	3.680	0.186	-65.596	0.003	0.0031
III.c. Capital growth ($\kappa^{\Delta K,CCyB}$)									
Low	5	$\Delta \ln(K_t)$	2.859	2.746	4.303	0.337	-65.596	-0.007	-0.0018
		$\mathbb{E}_t \{ \Delta \ln(K_{t+1}) \}$	2.847	2.735	4.281	0.281	-65.596	-0.007	-0.0018
		$\mathbb{E}_t \{ \Delta \ln(K_{t+2}) \}$	2.837	2.727	4.264	0.270	-65.596	-0.007	-0.0019
High	20	$\Delta \ln(K_t)$	3.234	3.048	4.870	1.331	-65.596	-0.019	-0.0075
		$\mathbb{E}_t \{ \Delta \ln(K_{t+1}) \}$	3.185	3.008	4.787	0.883	-65.596	-0.018	-0.0073
		$\mathbb{E}_t \{ \Delta \ln(K_{t+2}) \}$	3.149	2.979	4.723	0.643	-65.596	-0.018	-0.0072

“Welfare, DSS” gives us the deterministic steady state of household welfare. “Welfare, Mean-DSS” captures the second order effects on welfare and hence it shows the difference between the mean and the deterministic steady-state value for households’ welfare. In general, the unconditional standard deviations is defined as $\sigma_x^2 = \mathbb{E}\{[\ln(X_t) - \mathbb{E}\{\ln(X_t)\}]^2\}$ and are reported in %. We solve the model using a second-order approximation in Dynare. The mean and standard deviation of welfare reported correspond to the first and second theoretical moments provided by Dynare. *Welfare gains are measured in consumption equivalents in %, if this positive there are gains, otherwise, there are losses. In the baseline model $\kappa^{FCR} = 1/4$, $\kappa^{spread,CCyB} = -12$, and there are not additional capital buffers.