Macroprudential rules in a small open economy: a DSGE approach

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Abstract

This paper analyses the interaction between macroprudential instruments using a dynamic stochastic general equilibrium (DSGE) for a small-open-economy with financial and nominal frictions. Using different objectives for the monetary authority, we try to find the optimal policy rules involving dynamic capital and reserve requirements.

Given the frictions present in the model, the gains from adapting reserve and capital requirements to economic conditions are substantial, especially if financial stability is included as an objective of the Central Bank. Regarding the differences between the two instruments, the most important is that, contrary to capital requirements, an increase in reserve requirements leads to higher inflation and has an ambiguous impact on output. Finally, in the scenario of a financial stability objective and strict separation of tasks by instrument, reserve requirements provide a slightly better response to the exogenous shocks in the economy than capital requirements.

Keywords: Macroprudential Policy, Capital Requirements, Reserve Requirements
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I. Introduction

The onset of the 2008 global financial crisis heightened the importance of a macroprudential approach to banking regulation. Policymakers are now more aware of the tight relationship between macroeconomic and financial stability. In this context, macroprudential tools are useful to target specific sources of financial imbalances, overcoming most of the limitations of traditional monetary policy. However, experience and knowledge on the effectiveness of macroprudential policies, their calibrations, performance under different financial distortions, and interactions between the different macroprudential tools and with monetary policy ones, are still limited (Claessens and Valencia (2013)).

In the past decade, new prudential regulation has been established focusing especially on strengthen bank capital and liquidity requirements. The most prominent example are the fundamental reforms known as Basel III, introduced by the Basel Committee with the purpose of addressing the market failures exposed during the crisis. Regarding capital requirements and the inherent procyclicality of the financial cycle, they suggest the construction of capital buffers in "good times" that can absorb unexpected losses in periods of economic stress, when the buffers have to be released without delay. This countercyclical capital buffer still offers the additional benefit of moderating credit growth during booms, by raising its cost (Ferreira et al. (2015), Basel III (2010)).

Regarding liquidity regulation, a tool that has been used extensively is reserve requirements, which can be thought as a Basel III liquidity requirement[1] (Agénor et al. (2018)). Although there is still an ongoing discussion about the correct use of reserve requirements, many emerging economies have been using them as a financial stability tool, rather than as an unconventional monetary policy tool for price stability - in particular, when the interest rate policy is constrained by the zero lower bound (Gray (2011), Glocker and Towbin (2012)).

The literature, however, is still silent on the appropriate mix of macroprudential policy instruments. As the application of these instruments generates second order costs, an excessive use of macroprudential tools can also generate significant costs for the financial system in terms of efficiency. In this sense, it is essential to discuss the appropriate

[1] Basel III introduced a minimum standard for managing liquidity risk: the liquidity coverage ratio (LCR), which requires each bank to hold a sufficient quantity of highly-liquid assets to survive a 30-day period of market stress. It also introduced another minimum standard for managing liquidity risk, the net stable funding ratio (NSFR), which is viewed as complementary to the LCR.

combination of macroprudential regulatory instruments, so that the desired objective is obtained but at the lowest possible cost.

In this sense, we analyze the interaction between macroprudential instruments using a dynamic stochastic general equilibrium (DSGE) for a small-open-economy with a banking sector and a central bank. In particular, we are interested in understanding if countercyclical capital and reserve requirements complement or offset each other in stabilizing an economy facing different types of shocks. One of the most important steps to answer this is to find the optimal policy rules (aggregate variables should these instruments respond), given a set of instruments and particular objectives of the monetary or financial regulator. To our knowledge, this is the first study that focuses on the interaction between these two macroprudential instruments from either a theoretical or empirical perspective.

Our work relates mainly to fours strands of the literature. First, we contribute to the literature about countercyclical bank capital requirements. These requirements can prove useful when facing certain financial frictions, as for example the moral hazard problem between bankers and depositors, developed by Gertler and Karadi (2011). Standard capital requirements introduce important feedback loops between the real and financial sides of the economy (Gerali et al. (2010)). On the one hand, during expansions, bank earnings tend to rise, and thus capital accumulation, leading to an increase in loans (and a more dramatic expansion). As macroeconomic conditions deteriorate, banks profits and hence capital might be negatively hit; depending on the nature of the shock that hits the economy, banks might respond by reducing the amount of loans they are willing to extend to the private sector, thus exacerbating the original contraction. Recently, Lozej et al. (2018) evaluates different countercyclical capital buffers rules in a small open economy where monetary policy is completey shut off. Ferreira et al. (2015) focuses on the the anchor variable for the capital buffer using a DSGE model estimated for Brazil. They find that credit growth is the variable that performs best.

Second, our work contributes to understanding the theoretical affects of reserve requirements from a macroprudential perspective[2]. Among these studies, Glocker and Towbin (2012) considered required reserves as an additional policy instrument and variations in loans as an additional target into an open-economy model with nominal rigidities and financial frictions. Their results imply that reserve requirements favor the price stability objective only if financial frictions are nontrivial and are more effective if there is a financial stability

[2]See for example Prada-Sarmiento (2008), Bianchi (2011), Kashyap and Stein (2012), Mimir et al. (2013), Alper et al. (2014), and Guzman and Roldos (2014).

objective and debt is denominated in foreign currency. Areosa et al. (2013) find a similar result by augmenting the model of Gertler and Karadi (2011) to include a compulsory reserve requirement ratio. They estimate a new-Keynesian DSGE model for the Brazilian economy, with financial financial intermediaries facing endogenous balance sheet constraints. The authors conclude that the effect of a monetary policy shock to the interest rate is much stronger than the one to the reserve requirement, despite both shocks yielding similar dynamics in the macroeconomic aggregates. More recently, Bustamante and Hamann (2015) also resort to a DSGE model to shed lights on the effectiveness of reserve requirements in mitigating business cycle fluctuations. Using a framework with risk-averse financial intermediaries and heterogeneous agents facing uninsurable idiosyncratic risks, they find that reserve requirements help reducing consumption volatility only if banks are sufficiently risk averse.

Moreover, most of the papers that introduce macroprudential policies in general equilibrium models focus on the interaction between these tools and traditional monetary policy (e.g., Angelini et al. (2011), Agénor et al. (2013), Kannan et al. (2012), Quint and Rabanal (2013), Suh (2012), Cecchetti and Kohler (2012), Carvalho and Castro (2017)). Nevertheless, there has been recent efforts to study the interaction between different macroprudential tools, as in Frache et al. (2017). The authors perform a realistic assesment of two macroprudential tools: countercyclical capital buffers and dynamic provisions[3], using a DSGE model estimated with data for Uruguay. Carvalho et al. (2014), on the other hand, try to understand the transmission mechanism of capital and reserve requirements under traditional and matter-of-fact financial frictions in Brazil, and find that both instruments have important quantitative effects. However, they do not evaluate countercyclical capital requirements[4] and consider only a closed economy, ignoring external financial and trade shocks that are important drivers in the business-cycle of emerging economies.

Lastly, we contribute to the overall literature about the recent application of macroprudential tools, mostly in emerging economies. Since the GFC, more and more countries are using prudential instruments to complement their current regulatory frameworks. As indicated by Lim et al. (2011), two thirds of the countries that responded to a survey prepared by the IMF have implemented this type of policy since 2008. Likewise, it is the

[3]The underlying principle behind dynamic provisioning is that loan loss provisions should be set in line with estimates of long-run, or through-the-cycle expected losses, breaking pro-cyclicality and creating countercyclical provision buffers (Mahapatra (2012)).

[4]They only consider Basel I and Basel II-type of requirements, which are not sensitive to the business-cycle. In particular, bank minimum capital requirements are modeled as an AR(1) process with a very high persistence.

emerging countries that have used these tools to a greater extent than developed countries. The authors suggest that the latter is due to the fact that emerging countries need to mitigate certain market failures as a result of their lower financial development as well as the usual dominance by banks in the relatively small financial sector. As argued by Rey (2015), domestic monetary policy through interest rates may be ineffective in emerging markets with strong global capital flows, so instruments such as reserve requirements can therefore be useful.

The remainder of this paper is organized as follows: Section 2 describes the model and calibration. Section 3 provides a first glance to how discretionary changes to macroprudential instruments affect the banking sector and the economy. Section 4 discuss the main results and provides an application, while Section 5 concludes.

II. The Model

The model is largely based on the work by Glocker and Towbin (2012), who incorporate reserve requirements to a relatively standard small open-economy model with investment, sticky prices, and a financial accelerator mechanism. In order to accurately capture the dynamics of the banking sector, we introduce banking capital and balance sheet constraints into the model following Gerali et al. (2010). As it will be discussed later, this provides an additional financial friction, and further scope for macroprudential policy. The model is solved by log-linearization around the steady-state[5].

Household savings have to be intermediated through banks in order to reach firms. Banks make loans to entrepreneurs to finance their capital stock. They are subject to reserve and capital requirements set by the government[6]. Households consume a bundle of home and foreign goods and have access to an internationally traded bond.

A. The Banking Sector

Banks attract funding from households and lend to entrepreneurs. For ease of exposition, we analyze the tasks of lending and funding separately and consider lending units and deposit units. This separation is convenient especially to evaluate the effectiveness of our

[5]The log-linearized equations of the model can be found in the annex.

[6]We assume that there are no other means of external finance. Possibilities to circumvent banks would obviously weaken the effects of reserve and capital requirements.

two macroprudential tools: deposit units will be subject to reserve requirements, while lending units will face capital requirements. Households' savings are remunerated at the deposit rate, while deposit units lend to lending units at the (risk-free) interbank rate. Lending units make risky loans to entrepreneurs[7].

A.1. Deposit Units

Deposit units collect deposits from households and rent a fraction to lending units on the interbank market and keep the rest as reserves with the central bank. They operate in perfectly competitive input and output markets, and their profits accrue to households since they are the owners of the deposit units.

The representative deposit unit collects deposits D_t from households and pays a gross deposit interest rate i_t^D. Next, the bank has two possibilities to use the deposits. It allocates a fraction $1 - \varsigma_t$ of deposits to lending in the interbank market and earns a gross return equal to $i_t^I B$. The remaining fraction of funds $Res_t = \varsigma_t D_t$ is put into an account at the central bank, which is remunerated at the reserve rate i_t^R. The bank optimally chooses the composition of its assets, taking into account the minimum reserve requirement ratio ς^{MP} imposed by the monetary authority. The balance sheet of the deposit unit reads

$$Res_t + D_t^{IB} = D_t \tag{1}$$

where $D_t^{IB} = (1 - \varsigma) D_t$ is interbank lending. Deposit units face convex costs in holding reserves G_t^{ς}:

$$G_t^{\varsigma} = \psi_1 (\varsigma_t - \varsigma_t^{MP}) + \frac{\psi_2}{2} (\varsigma_t - \varsigma_t^{MP})^2 \tag{2}$$

where ψ_1 and ψ_2 are cost function parameters. The first linear term determines steady-state deviations from the required reserve ratio. Holding excess reserves may generate some benefits, for example, because it reduces the costs of liquidity management. In addition, the central bank may impose a fee for not fulfilling the reserve requirement. Both motivations imply that $\psi_1 < 0$. On the other hand, the quadratic term with $\psi_2 > 0$ guides the dynamics around the steady state. Glocker and Towbin (2012) discuss several motivations for such convex costs. First, the benefits from holding excess reserves may decline because of

[7] Note that an alternative would be to consider banks that collect savings and lend at the same time. The opportunity cost of attracting an additional unit of deposit would then correspond to the interbank rate.

decreasing returns to scale. Second, the central bank may punish large negative deviations from its target with a larger penalty rate and phase out the remuneration of excess reserves at the same time.

The problem that the deposit unit faces is to maximize its profits, taking i_t^{IB}, i_t^D, and i_t^R as given, and subject to equation (2):

$$\max_{\{\varsigma_t, D_t\}} \Pi_t^S = \left[(1-\varsigma_t)i_t^{IB} + \varsigma i_t^R - i_t^D - G_t^{\varsigma}\right] D_t \tag{3}$$

The first-order conditions of the optimization problem are:

$$-(i_t^{IB} - i_t^R) - \psi_1 = \psi_2(\varsigma_t - \varsigma_t^{MP}) \tag{4}$$

$$i_t^D = (1-\varsigma_t)i_t^{IB} + \varsigma_t i_t^R - G_t^{\varsigma} \tag{5}$$

The bank's actual reserve ratio, ς_t, is determined by equation (5). It is decreasing in the spread between the interbank rate and the reserve rate and increasing in the required reserve ratio ς_t^{MP}. On the other hand, equation (6) shows that the deposit rate is a weighted average of the rates received from lending and reserve holdings, net of operating costs. Deposit units face opportunity costs by investing part of their assets in reserves, which is captured by the interest rate differential $i_t^{IB} - i_t^R \geq 0$. Therefore, it is possible to think of reserve requirements as a tax on the banking system. An increase in the monetary authority's target value of reserve requirements increases the opportunity costs. As a consequence, the spread between deposit and interbank rates rises[8].

A.2. Lending Units

Lending units do not interact with households. They finance themselves through the interbank market and with their own banking capital, so they do not hold any deposits from households. Given this, they are not subject to reserve requirements, but to capital requirements.

Lending units operate in perfectly competitive input and output markets. They supply loans to entrepeneurs at the lending rate (i_t^L). The interaction between lending units and entrepreneurs is modeled by means of the financial contract as in Bernanke, Gertler, and Gilchrist (1999).

[8]In order to solve the model, we will make some assumptions about how the central bank conducts monetary policy, which will lead to the reserve supply to adjust endogenously.

A key feature of our model is that lending units obey the following balance sheet identity:

$$L_t = D_t^{IB} + K_t^b \tag{6}$$

stating that each lending unit can finance loans L_t using either fund from deposit units D_t^{IB} -at the cost of the interbank rate- or bank capital K_t^b. As in Gerali et al (2010), the two sources of finance are perfect substitutes from the point of view of the balance sheet. Lending units face costs related to the capital position of the bank. In particular, lending units pay a quadratic cost whenever the capital-to-assets ratio K_t^b/L_t moves away from a target value v^b, set by the financial regulator:

$$\Upsilon_t = \frac{\kappa}{2}\left(\frac{K_t^b}{L_t} - v^b\right)^2 K_t^b \tag{7}$$

with $\kappa > 0$. Bank capital is accumulated each period out of retained earnings according to

$$K_t^b = (1-\delta^b)K_{t-1}^b + \Pi_{t-1}^L \tag{8}$$

where Π_t^L are the profits made by the lending units, and δ^b measures resources used in managing bank capital. Given this law of motion, bank capital is not a choice variable for the bank. On the lending unit's side, there are two financial frictions present: the financial accelerator, and the capital costs and dynamics. Therefore, it is helpful to separate the maximization process of the bank in two steps, to capture the different interest rate spreads that arise from the frictions. First, assume that there is no financial accelerator mechanism, so the problem for the lending unit is just to choose loans and funds from deposit units so as to maximize profits:

$$\max_{\{L_t, D_t^{IB}\}} \Pi_t^L = i_t^F L_t - i_t^{IB} D_t^{IB} - \frac{\kappa}{2}\left(\frac{K_t^b}{L_t} - v^b\right)^2 K_t^b \tag{9}$$

subject to the balance sheet in equation 6, where i_t^F denote the lending rate in the absence of the financial accelerator, i.e. the risk-free lending rate. The first-order conditions deliver a condition linking the spread between friction-less rates on loans and on deposits to the degree of leverage, i.e.

$$i_t^F = i_t^{IB} - \kappa\left(\frac{K_t^b}{L_t} - v^b\right)\left(\frac{K_t^b}{L_t}\right)^2 \tag{10}$$

Equation 10 shows that the spread is inversely related to the overall capital-to-assets ratio of banks: in particular, when banks are scarcely capitalized and leverage increases, margins become wider. On the one hand, the higher the leverage, the wider (i.e. more positive) the spread between the risk-free loan rate and the interbank rate, the more the bank wants to lend, increasing profits per unit of capital (or return on equity). On the other hand, as leverage increases further, the deviation from v^b becomes more costly, reducing bank profits.

A.3. Equilibrium in the Financial Sector

Since all deposit units face the same interbank and reserve interest rates, as well as the same reserve requirement ratio, all of them will set the same deposit rate i_t^D and reserve rate ς_t. The same applies to the lending units. Based on these equilibrium conditions, the following consolidated financial sector balance sheet emerges:

$$L_t = (1 - \varsigma_t) D_t + K_t^b \tag{11}$$

Now, to understand how monetary policy works in the model, note that equation 4 can be written as follows:

$$\varsigma_t = \varsigma_t^{MP} - \left(\frac{i_t^R - i_t^{IB} - \psi_1}{\psi_2} \right) \tag{12}$$

Denote Δ_t as the spread between the interbank rate and the rate paid on reserve balances: $\Delta_t \equiv i_t^{IB} - i_t^R$. Following Glocker and Towbin (2012), we assume that the central bank maintains Δ_t equal to a constant $\Delta \geq 0$, which from equation 4 again, pins down the difference between effective reserves and required reserves to a constant

$$\varsigma_t - \varsigma_t^{MP} = - \left(\frac{\Delta - \psi_1}{\psi_2} \right) \equiv \Omega \geq 0 \tag{13}$$

Now, while the spread between the rate on reserves and the interbank rate is constant, the spread between the rate paid on deposits and the interbank rate is determined by the zero-profit condition for deposit-taking banks:

$$i_t^D = (1 - \varsigma_t) i_t^{IB} + \varsigma_t i_t^R - G^{\varsigma} = i_t^{IB} - \varsigma_t^{MP} - G^{\varsigma} \tag{14}$$

where G^{ς} is the cost of holding reserves from equation 2, that is now also constant given Δ and Ω. From 14, it is easy to see that changes in the reserve requirements will have a direct negative impact on the deposit interest rates.

To conclude this subsection, since households do not hold cash, aggregate nominal reserves $\varsigma_t P_t D_t$ correspond to the monetary base in our model. Taking into account reserve remuneration, real seignorage revenue T_t^S is

$$T_t^S = \varsigma_t D_t - \frac{i_{t-1}^R}{\pi_t} \varsigma_{t-1} D_{t-1}$$

All seignorage revenue is redistributed as a lump-sum transfer to households. The rest of the model follows the exact same structure as in Glocker and Towbin (2012), except for the Entrepeneurs and the Government sector.

B. The Household Sector

There is a continuum of households. In a given period households derive utility from consumption C_t and disutility from working (h_t). Their instant utility function is $u(C_t, h_t) = \ln C_t - \Psi \frac{h_t^{1+\phi}}{1+\phi}$. Consumption is a Cobb-Douglas bundle of home C_t^H and foreign C_t^F goods: $C_t \propto (C_t^H)^{\gamma} (C_t^F)^{1-\gamma}$. The resulting price index reads $(P_t^H)^{\gamma} (P_t^F)^{1-\gamma}$. Households can invest their savings in real deposits D_t and foreign nominal bonds B_t, evaluated at the nominal exchange rate S_t. Because of limited capital mobility, acquiring foreign bonds entails a small holding cost[9] $\frac{\psi_B}{2} \left(\frac{S_t}{P_t} B_t \right)^2$. By supplying labor, households receive labor income $W_t h_t$. In addition, they receive gross interest payments on their deposits $i_{t-1}^D D_{t-1}$, interest payments on foreign bonds $i_{t-1}^* S_t B_{t-1}$, dividends from deposit units Π_t^S and intermediate goods producers Π_t^R, and lump-sum transfers T_t from the government. The budget constraint reads

$$\begin{aligned} P_t C_t + P_t D_t + S_t B_t = i_{t-1}^D P_{t-1} D_{t-1} + i_{t-1}^* S_t B_{t-1} + P_t W_t h_t + \\ + P_t \sum_{j \in (S,R)} \Pi_t^j + P_t T_t + \frac{\psi_B}{2} P_t \left(\frac{S_t}{P_t} B_t \right)^2 \end{aligned} \tag{15}$$

[9]The assumption ensures stationarity in small open-economy models (Schmitt- Grohé and Uribe 2003).

Households discount instant utility with β. They maximize their expected lifetime utility function subject to the budget constraint, which leads to the familiar optimality conditions:

$$1 = E_t \Lambda_{t,t+1} \frac{i_t^D}{\pi_{t+1}} \tag{16}$$

$$1 - \psi_B \frac{S_t}{P_t} B_t = E_t \left[\Lambda_{t,t+1} \frac{i_t^*}{\pi_{t+1}} \frac{S_{t+1}}{S_t} \right] \tag{17}$$

$$W_t = \Psi h_t^{\phi} C_t \tag{18}$$

where the stochastic discount factor is given by $\Lambda_{t,t+1} = \beta^k \frac{C_t}{C_{t+k}}$ and $\pi_t = P_t/P_{t-1}$ is the gross inflation rate.

C. Capital Goods Producers

Capital goods producers build the capital stock, which is sold to entrepreneurs. They purchase the previously installed capital stock net of depreciation from enterpreneurs and combine it with investment goods to produce the capital stock for the next period. Investment goods have the same composition as final consumption goods. Capital is subject to quadratic adjustment costs according to $\frac{\chi}{2}\left(\frac{I_t}{K_{t-1}} - \delta\right)^2 K_{t-1}$, where δ is the depreciation rate of capital. The parameter χ captures the sensitivity of changes in the price of capital to fluctuations in the investment to capital ratio.

The market price of capital is denoted by Q_t. The optimization problem is to maximize the present discounted value of dividends by choosing the level of new investment I_t. Since the optimization problem is completely static, it reduces to

$$\max_{I_t} \left[(Q_t - 1) I_t - \frac{\chi}{2} \left(\frac{I_t}{K_{t-1}} - \delta \right)^2 K_{t-1} \right]. \tag{19}$$

The maximization problem yields the following capital supply curve: $Q_t = 1 + \chi\left(\frac{I_t}{K_{t-1}} - \delta\right)$. Finally, the aggregate capital stock evolves according to the following law of motion $K_t = (1-\delta)K_{t-1} + I_t$.

D. Entrepeneurs

Entrepreneurs are the critical link between intermediate goods producers and capital goods producers. They purchase capital from the capital goods producers at the beginning of the period and resell at the end of the period. They rent it to intermediate goods producers at rental rate z_t. The structure of this part of the model is the same as in Bernanke et al. (1998), so we will not go into details.

Entrepreneurs finance their capital purchases out of their net worth N_t and with bank loans from bank lending units. For this setting, we consider only the case where the loan from the lending unit is denominated in domestic currency $Q_t K_t = N_t + L_t$. The interaction between entrepreneurs and bank lending units is characterized by an agency problem: entrepreneurs' projects face idiosyncratic shocks that are not publicly observable and they have an incentive to underreport their earnings. Lenders can verify the idiosyncratic shock at a cost. The optimal financial contract delivers the following key equation that links the spread between the aggregate expected real return on capital $E_t r^K_{t+1}$ and the risk-free lending to the entrepeneurs' leverage:

$$Q_t K_t = f\left(\frac{E_t r^K_{t+1}}{i^F_t / E_t \pi_{t+1}}\right) N_t, \text{ with } f'(\cdot) > 0 \tag{20}$$

Contrary to the standard model in Glocker and Towbin (2012), the risk-free rate is not the interbank rate, but it is given by equation 10. Given this, equation 20 shows that the external finance premium is

$$\frac{E_t r^K_{t+1}}{\left(i^{IB}_t - \kappa\left(\frac{K^b_t}{L_t} - \upsilon^b\right)\left(\frac{K^b_t}{L_t}\right)^2\right) / E_t \pi_{t+1}}$$

and increases with the share of debt in total financing. The entrepeneur's real return on capital is given by

$$r^K_t = \frac{z_t + Q_t(1-\delta)}{Q_{t-1}} \tag{21}$$

where z_t is the real rental cost of capital.[10]

With probability $1 - \nu$, entrepreneurs leave the market and consume their net worth. They are replaced by new entrepreneurs who receive a small transfer $\bar{g}$ from the departing

[10]Equation 21 takes into account that in a model with investment adjustment costs and incomplete capital depreciation, one has to differentiate between the entrepreneur's return on capital (r^K_t) and the rental rate on capital (z_t). The return on capital depends on the rental rate as well as on the depreciation rate of capital, adjusted for asset price valuation effects (i.e., variations in Q_t/Q_{t-1}).

entrepeneurs. Aggregate net worth is given by the following expression:

$$N_t = \nu V_t + (1-\nu)\bar{g} \tag{22}$$

where V_t denotes the net worth of surviving entrepreneurs. Different from Bernanke, Gertler, and Gilchrist (1999), but in line with Gertler, Gilchrist, and Natalucci (2007), we assume that the lending rate is fixed in nominal terms in the respective currency. Since we are only considering deposits in domestic currency, the net worth of surviving entrepreneurs is

$$V_t = (1-\tilde{\mu}) r_t^K Q_{t-1} K_{t-1} - i_{t-1}^L \frac{P_{t-1}}{P_t} L_{t-1} \tag{23}$$

where the term $\tilde{\mu}$ reflects the deadweight cost associated with imperfect capital markets (see Bernanke, Gertler, and Gilchrist 1999 for further details) and i_t^L is the state-contingent nominal lending rate specified in the optimal financial contract (see appendix 1). Combining equations 22 and 23 yields a dynamic equation for aggregate net worth.

Movements in net worth stem from unanticipated changes in returns and borrowing costs. Changes in Q_t are likely to provide the main source of fluctuations in r_t^K, which stresses that changes in asset prices play a key role in the financial accelerator. On the liabilities side, unexpected movements in the price level affect ex-post borrowing costs. For instance, unexpected inflation increases entrepreneurs' net worth.

E. Intermediate Goods Producers

Intermediate goods producers buy labor input from households and rent capital from entrepreneurs. They produce differentiated intermediate goods and operate in competitive input and monopolistically competitive output markets. The production function of intermediate goods producer $i \in [0,1]$ is

$$y_t(i) = \xi_t^A K_{t-1}(i)^\alpha h_t(i)^{1-\alpha} \tag{24}$$

where ξ_t^A is an aggregate technology term and follows an AR(1) process. Cost minimization implies $\frac{h_t(i) W_t}{z_t K_{t-1}(i)} = \frac{1-\alpha}{\alpha}$ and marginal costs are given by

$$mc_t \propto \frac{W_t^{1-\alpha} z_t^\alpha}{\xi_t^A} \tag{25}$$

F. Final Goods Producers

Final goods producers buy differentiated intermediate domestic goods from intermediate goods producers and transform them into one unit of final domestic good. They resell these transformed goods to households as consumption goods and to capital goods producers as investment goods. The final good is produced using a constant elasticity of substitution (CES) production function with elasticity of substitution ϵ to aggregate a continuum of intermediate goods indexed by $Y_t = \left(\int_0^1 y_t(i)^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}}$. Final domestic goods producers operate in competitive output markets and maximize each period the following stream of profits $P_t^H Y_t - \int_0^1 p_t^H(i) y_t(i) di$, where $p_t^H(i)$ is the price of intermediate good i. The demand for each intermediate input good is $y_t(i) = (p_t(i)/Y_t)^{-\epsilon} Y_t$ and the aggregate price level satisfies $P_t^H = \left(\int_0^1 p_t^H(i)^{1-\epsilon} di\right)^{\frac{1}{1-\epsilon}}$.

We assume that Calvo-type price staggering (Calvo (1983)) applies to the price-setting behavior of intermediate goods producers. The probability that a firm cannot reoptimize its price for k periods is given by θ^k. Profit maximization by an intermediate goods producer who is allowed to reoptimize his price at time t chooses a target price p_t^* to maximize the following stream of future profits:

$$\max_{\{p_t^*\}_{t\in\mathbb{Z}}} E_t \left[\sum_{k=0}^{\infty} \theta^k \Lambda_{t,t+k} \Pi_{t+k|t}^R(i) \right] \tag{26}$$

where profits are given by $\Pi_t^R(i) = \frac{p_t^*}{P_t} y_t(i) - mc_{t+k|t}(i) y_{t+k|t}(i)$. The first-order condition is

$$E_t \left[\sum_{k=0}^{\infty} \theta^k \Lambda_{t,t+k} y_{t+k|t}(i) \left(\frac{p_t^*}{P_{t+k}} - \frac{\epsilon}{\epsilon-1} mc_{t+k|t}(i) \right) \right] = 0 \tag{27}$$

Final import goods are provided in competitive markets and the foreign currency price is normalized to one: $P_t^F = S_t$.

G. Equilibrium in the Goods Market

The economy-wide resource constraint is given by

$$Y_t = \gamma \frac{P_t}{P_t^H}(C_t + I_t + G_t) + \frac{S_t}{P_t^H} X_t + \gamma \frac{P_t}{P_t^H} \Psi_t$$

Foreigners buy an exogenous amount X_t (expressed in foreign currency) of domestic goods and $\Psi_t = K_{t-1}(\frac{\chi}{2}(\frac{I_t}{K_{t-1}} - \delta)^2 + \tilde{\mu} r_t^K Q_{t-1} + G_t^{\varsigma}(\cdot) + \frac{\psi_B}{2}(\frac{S_t}{P_t} B_t)^2$ captures adjustment costs.

The balance of payment identity is

$$S_tB_t = P_t^H Y_t - P_t(C_t + I_t + G_t)(1 + i_{t-1}^*)S_tB_{t-1} + P_t\Psi_t$$

H. Government

As in Glocker and Towbin (2012), the Central Bank has two dimensions: the central bank's objective and the implementation of the policy. In terms of objectives, we will consider two exogenously given loss functions. In the first case, the monetary authority's loss function includes only the traditional objectives of output and price stability. The price stability loss function L_t^{PS} reads

$$L^{PS} = E(\hat{\pi}_t^2 + \lambda_Y(\hat{Y}_t)^2) \tag{28}$$

where $\hat{Y}_t$ is the log-deviation of output from its steady-state value and λ_Y reflects the policymakers' subjective weight of output stability relative to price stability. Moreover, we also consider the case where the central bank cares about financial stability, measured as the deviations from the stock of loans, yielding a loss function as follows:

$$L^{FS} = E(\hat{\pi}_t^2 + \lambda_Y(\hat{Y}_t)^2 + \lambda_L(\hat{L}_t)^2) \tag{29}$$

where $\hat{L}_t$ is the log-deviation of loans from their steady-state value and λ_L reflects the policymakers' subjective weight of loan stability relative to price stability.

As mentioned in the Introduction, it is reasonable to think that Central Banks may want to avoid abrupt fluctuations in credit, mainly because of the risk of a financial crisis. Studies from the Bank for International Settlements have pointed out that deviation of credit from its trend can predict financial crisis (Borio and Drehmann (2009), Borio et al. (2002)). Note, however, that we do not include a role for countercyclical capital buffers, for example, as there is no risk of a financial crisis.

In terms of instruments, we consider three: the interbank interest rate (i_t^{IB}), capital requirements (v_t^b), and reserve requirements (ς_t^{MP}). In practice, these instruments are used in many different ways by central banks and financial regulators. For example countries that use both reserve requirements and interest rates as policy tools include Brazil, Colombia, Peru, Turkey, and others. On the other hand, there are many different anchor variables for setting the level of the countercyclical regulatory capital requirements for banks. Drehmann et al. (2010) conclude that the best leading indicator is credit-to-GDP gap, whereas the best coincident indicator is banking spread. Still, the Basel Committee suggests the use of credit-to-GDP gap as an anchor variable for both periods. However, Repullo and Saurina Salas (2011) argue that the use of such variable may exacerbate procyclicality inherent in the financial system and recommend the use of output growth.

Having said that, we will consider several policy rules based on combinations of these instruments, that minimize the two loss functions proposed before. In particular, the general setting we consider is the following:

$$\hat{i}_t^{IB} = \phi_{\pi,i}\hat{\pi}_t + \phi_{Y,i}\hat{Y}_t + \phi_{L,i}\hat{L}_t$$
$$\hat{\varsigma}_t^{MP} = \phi_{\pi,\varsigma}\hat{\pi}_t + \phi_{Y,\varsigma}\hat{Y}_t + \phi_{L,\varsigma}\hat{L}_t$$
$$\hat{v}_t^{b} = \phi_{\pi,v}\hat{\pi}_t + \phi_{Y,v}\hat{Y}_t + \phi_{L,v}\hat{L}_t$$

In this paper we are interested in the interaction between the macroprudential instruments, using monetary policy as a complement. There is a consensus in the literature about the effectiveness of macroprudential policy to amplify the effect of monetary policy (under certain conditions), but little has been said about the sustainability of different macroprudential instruments. For this reason, we will consider a simple Taylor-rule for the interest rate, meaning $\phi_{L,i} = 0$, so that credit deviations are mitigated directly by capital or reserve requirements, leaving monetary policy focus on inflation and output. In another specification, we will also consider the case of an even simpler rule, where the interest rate only reacts to changes in inflation, to test the extend of the effectiveness of macroprudential instruments. As for capital requirements, we will only consider output and loans as potential anchor variables, as it is not usual to target inflation with this instrument. Moreover, we will set $\phi_{\pi,\varsigma} = 0$ in all our specifications, as our main focus is the effectiveness of reserve requirements as a macroprudential tool, and not as an unconventional monetary policy instrument.

I. Shocks and Calibration

The economy's dynamics is driven by five shocks: a cost-push shock (ξ_t^{CP}), a technology (or productivity) shock (ξ_t^{A}), a government spending shock (G_t), a foreign interest rate shock (i_t^*), and a foreign export demand shock (X_t). As usual, all shocks follow AR(1) processes, and the persistence and variances for each of them are shown in the annex (Table 4). The values therein are taken from an estimated DSGE model as described in Christoffel et al. (2008). Most of the rest of the parameters are standard (see Table 3 in the annex).

Several parameters are not calibrated directly but specified such that they match model-specific variables to their empirical counterparts in a standard small-open-economy as in Glocker and Towbin (2012). We use the case of Peru to set the steady-state value of ς_t^{MP} to 0.09 (average of the last 8 years, in local currency), and the effective reserve ratio (ς_t) to 0.1. This is in line with banks wanting to comply with the requirement, as reputational and operational costs would be severe. The other coefficients are calibrated such that they imply an interest rate differential between the interbank rate (i_t^{IB}) and the interest rate on reserves (i_t^R) in the steady state of 150 basis points on quarterly basis, as in Glocker and Towbin (2012). The steady-state leverage ratio of entrepreneurs is two. We choose the other parameters of the financial contract to generate a steady-state external finance premium of 50 basis points and an elasticity to leverage of $\eta = 0.05$ as in Christensen and Dib (2008) (standard in the literature).

Regarding the parameters on the lending units, we follow Gerali et al. (2010) for parameters such as the sensitivity to bank capital cost (κ), the debt-to-loans ratio, bank capital depreciation, and the target capital-to-loans ratio (v^b). Based on this, we set the steady-state capital ratio to be 0.11, above the requirement. This is a commonly observed fact in banking: they usually maintain more capital than the minimum that is required by regulation (see Allen and Rai (1996), Peura and Jokivuolle (2004), or Barth et al. (2013)).

III. Discretionary changes to macroprudential instruments

This section provides a set of simulation exercises two shed light on the transmission mechanism and potential effects of reserve and capital requirements to the financial system and the economy. Following Glocker and Towbin (2012) we assume that both variables follow an exogenous AR(1) process with autocorrelation 0.7 and we abstract from a systematic component in requirements' policy.

For this analysis we will keep monetary policy as simple as possible[11], and will particularly pay attention to the role of the financial accelerator in amplifying (or dampening) the macroprudential shocks. In the case of a change in reserve requirements, there are two

[11] In particular, we will assume a simple Taylor rule where the coefficient associated to the deviations of inflation, $\phi_{\pi,IB}$, is 1.5, and the other coefficients are zero.

perhaps opposite effects interacting: first, for a given monetary base, higher reserve requirements imply smaller broad money aggregates and we expect an economic contraction. On the other hand, if the rate of reserve remuneration lies below the market interest rate, then requirements also act as a tax on the banking sector, driving a wedge between deposit and lending rates.

In the case of capital requirements, an increase leads to an immediate contraction in credit, for a given spread between wholesale loan and interbank rate. Since banking capital accumulates only through previous period's profits, the only possible action for the bank is to cut lending, and thus interbank deposits. This will lead, eventually, to an increase in consumption (decrease in deposits), and a decrease in investment. In addition, given the lower level of leverage, margins for the lending units become tighter and even negative, leading to a reduction in profits and banking capital in the next period.

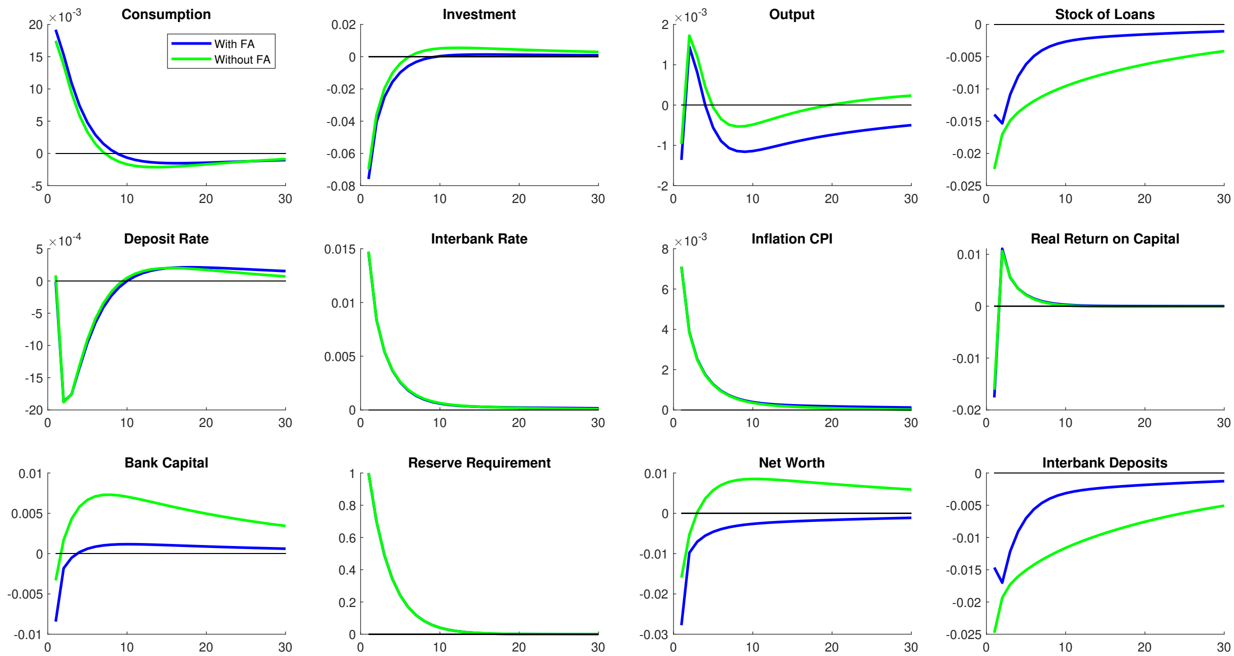
The effects discussed above might depend both on financial and nominal frictions. Therefore, while analyzing the effects of the macroprudential measures, we will consider scenarios with and without the financial accelerator mechanism, and with various degrees of price stickiness[12]. Figure 1 shows the effects of a one standard deviation discretionary change of reserve requirements. As discussed before, the negative effect on the deposit rate (tax effect) implies a decrease in consumption, which combined with an increase in the interbank rate, leads to a decrease in the stock of loans and investment. Additionally, we have that, contrary to a contractionary monetary policy shock, an increase in reserve requirements tightens credit conditions and depreciates the exchange rate at the same time. Because of the uncovered interest parity, the decline in the deposit rate also leads to an exchange rate depreciation and a rise in exports. Given this, the effect on output is ambiguous: for our particular parametrization, the effect seems to be initially positive, while later becomes contractionary.

The financial accelerator appears to be relevant to the transmission mechanism of reserve requirements. In particular, it strengthens the effect on investment; because of movements in the external finance premium, net worth of entrepreneurs and investment become more sensitive to fluctuations in the interbank rate. As a final result, the impact on output is more severe than in the baseline case, with a sharper and more persistent decline in the economic activity.

Regarding the effects of capital requirements, most of the are in line with the ones from the reserve requirements, both in direction and magnitude (see Figure 2). An increase in the

[12]For the analysis with different degress of price stickiness (see Figure 4 and 5 in the annex)

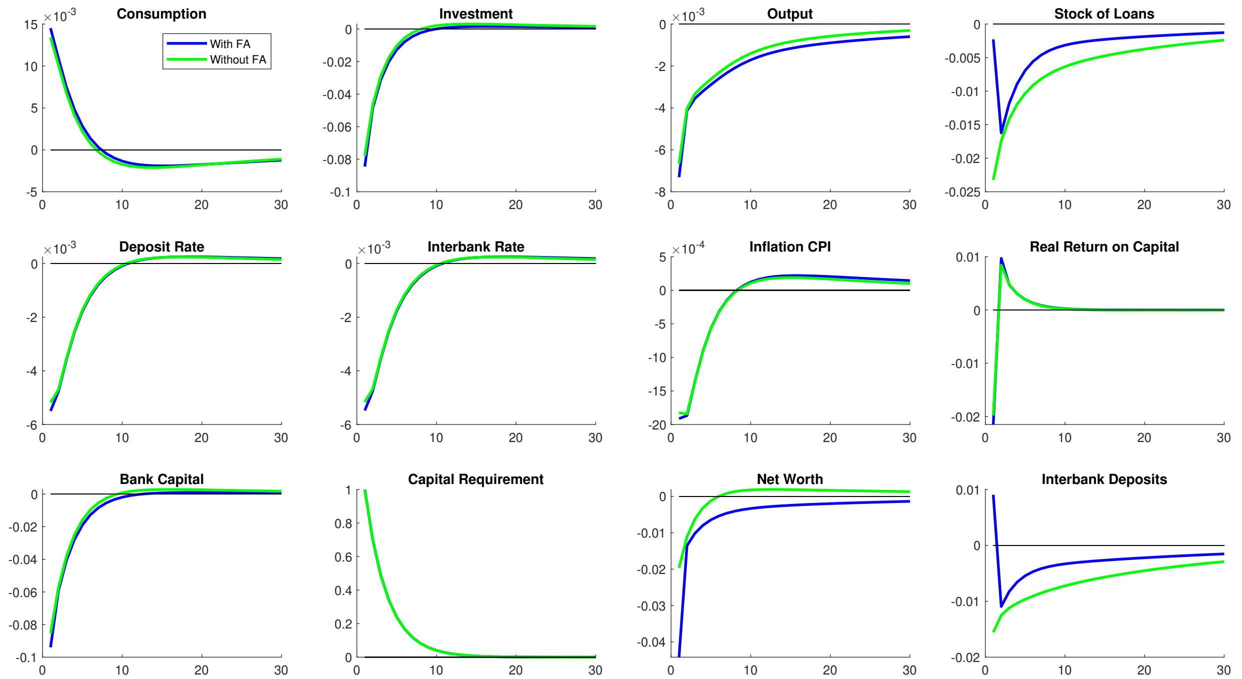
Figure 1: Reserve Requirement Shock and the Financial Accelerator



Note: The figure reports quarterly impulse responses to a 1-std deviation increase in reserve requirements, considering scenarios with and without the financial accelerator mechanism. Monetary policy is specified by an interest rate rule for the interbank interest rate as defined in section 2.8 with $\phi_{\pi,i} = 1.5$ and the other coefficients equal 0. The y-axis denotes the deviation in percent from the steady state.

capital requirements leads to a decrease in the stock of loans, which leads to a decrease in investment. The return on capital initially drops, but tends to stabilize almost immediately. Although consumption and investment react in opposite ways as in the reserve requirement case, the effect on output is undoubtedly negative. On the other hand, as me discussed previously, and increase in capital requirements needs to be matched by the banks by reducing lending instead of increasing -paradoxically- banking capital. Thus, bank capital tends to decrease, contrary to what we see after an increase in reserve requirements without the financial accelerator mechanism. Finally, the main difference between the aggregate effect of both macroprudential measures can be seen in the impact on inflation. In the case of capital requirements, inflation tends to decrease, in line with a decrease in output. However, for our calibration, an increase in reserve requirements leads to an increase in inflation, contrary to the popular notion that reserve requirements can be increased to contain inflation. The increase in the tax on banks increases overall production costs, which puts upward pressures on the overall price level. The financial accelerator does not seem to influence significantly the transmission mechanism of capital requirements, aside from the magnitude of the decrease in lending and interbank borrowing.

Figure 2: Capital Requirement Shock and the Financial Accelerator



Note: The figure reports quarterly impulse responses to a 1-std deviation increase in capital requirements, considering scenarios with and without the financial accelerator mechanism. Monetary policy is specified by an interest rate rule for the interbank interest rate as defined in section 2.8 with $\phi_{\pi,i} = 1.5$ and the other coefficients equal 0. The y-axis denotes the deviation in percent from the steady state.

IV. Optimal Policy rules and applications

In this section we analyze the optimal macroprudential policy rules considering two different objectives and plausible sensitivities in the different instruments. In particular, what we do is to find the optimal parameters for the different policy rules described in section H based on the loss functions provided there. The approach we follow is a grid-search-type optimizing process, with reasonable boundaries for the parameters to be plausible in a policy-making context.

Regarding the parameters of the Taylor-rule, we use the following search intervals. For $\phi_{Y,IB}$ we set it to $[0, 3]$ following[13] Schmitt-Grohé and Uribe (2007). On the other hand, the coefficient associated to inflation, $\phi_{\pi,IB}$, is set to be between $[1.1, 3]$ since values between 0 and 1 are not compatible with a rational expectations equilibrium. Note that we will not consider the case where the monetary policy rate reacts directly to loans, since our

[13] Although the authors apply this criteria to a welfare-based analysis, the same mechanism applies.

interest relies on the interaction between the two macroprudential instruments in addressing financial volatility.

For the parameters associated with the reserve requirements, we will follow the results[14] from Glocker and Towbin (2012) and set the search interval to $[0, 3.5]$. This is also plausible from a policy-making perspective, since in countries such as Peru, reserve requirements have more than tripled in the aftermath of the global financial crisis. For the case of the parameters associated to capital requirements, we follow Quiroz (2017) who studies the impact of Basel III requirements on a small-open economy such as Chile, and sets a maximum of 2.8 for $\phi_{Y,v}$. However, given that we want to compare our two measures of macroprudential policy, we set the search interval for the capital requirement parameters to $[0, 3.5]$ so that we do not rule out the possibility of both requirements reacting in the same magnitude.

A. Price Stability Objective

First we will consider a traditional central bank that only monitors fluctuations in output and inflation and does not respond to volatility in loans. The optimized coefficients in the policy rule and the value of the resulting loss function (in absolute value) are reported in Table 1, and we denote it as policy AI. The optimal coefficients we get are in line with Glocker and Towbin (2012) and Benes and Kumhof (2015), despite some differences.

Now, consider the case where the central bank is still only focused on the price stability objective, but uses another instrument that reacts to the deviations of the stock of loans. Note that here the central bank responds to loans because they contain information about the state of the economy, not because the containment of loan fluctuations is an end in itself. We denote as AII to the policy where the reserve requirement ratio (ς_t^{MP}) is the instrument that reacts to loans. The estimated coefficient $\phi_{L,\varsigma}$ obtained is 3.5, the upper bound of the search interval set. This is not surprising, since we have seen that reserve requirements have a direct impact on variables such as investment, output and the stock of loans (which eventually lead to effects on the economic activity). Moreover, in the previous section we showed that although an increase in reserve requirements seems to cause an increase in inflation, it is not significant in magnitude and thus the usual trade-off between price and output stability should not be an issue. Policy AII represents an reduction in the

[14] In their study, the authors consider the difference in levels of the reserve requirements as the policy instrument, thus the coefficients in the policy rules can only be compared when multiplying them by the steady state of the reserve requirements in our calibration (9%).

Table 1: Optimal Policy Rules under a Price Stability Objective

Policy	Instrument	Coefficient			L^{PS}
		ϕ_L	ϕ_Y	ϕ_π	
	i^{IB}	-	0.7	2.37	
AI	ς^{MP}	-	-	-	**7.32**
	v^b	-	-	-	
	i^{IB}	-	0.7	2.35	
AII	ς^{MP}	3.5	-	-	**6.83**
	v^b	-	-	-	
	i^{IB}	-	0.7	2.39	
AIII	ς^{MP}	-	-	-	**6.92**
	v^b	3.5	-	-	

lost function of almost 7% with respect to the benchmark case. This is not surprising, as the central bank has three instruments for only two objectives.

Finally, we turn to the case where the central bank uses the capital requirements to respond to deviations in the stock of loans. The estimated coefficient $\phi_{L,v}$ obtained is 3.5, following the same logic as in the reserve requirements' case. We obtain very similar results in terms of minimizing the loss function focused only on output and inflation. These findings suggest that the two macroprudential instruments analyzed are useful even for a central bank that does not have financial stability as an objective. Moreover, they have the same effect when it comes to contribute to price and output stability by reacting to changes in the stock of loans.

B. Financial Stability Objective

In this section we consider a case where the central bank explicitly wants to stabilize the fluctuations in loans, as reflected in the loss function L_t^{FS} in section H. The results are displayed in Table 2. The block of specifications denoted by B are similar to the previous setting, but with the only difference of an additional objective in the central bank's loss function. As it was expected, including financial stability into the equation, without having an instrument specifically to target that variable, ends up being costly, as shown with Policy BI. Note that the coefficients related to inflation and output in the original Taylor-rule change with respect to the benchmark with only a price stability objective. This

Table 2: Optimal Policy Rules under a Financial Stability Objective

Policy	Instrument	Coefficient			L^{FS}
		ϕ_L	ϕ_Y	ϕ_π	
	i^{IB}	-	0.32	1.57	
BI	ς^{MP}	-	-	-	**12.14**
	v^b	-	-	-	
	i^{IB}	-	0.7	2.32	
BII	ς^{MP}	3.5	-	-	**9.81**
	v^b	-	-	-	
	i^{IB}	-	0.7	2.39	
BIII	ς^{MP}	-	-	-	**10.04**
	v^b	3.5	-	-	
	i^{IB}	-	-	1.63	
CI	ς^{MP}	3.5	3.5	-	**8.92**
	v^b	3.5	3.5	-	
	i^{IB}	-	-	1.36	
CII	ς^{MP}	3.5	-	-	**9.94**
	v^b	-	3.5	-	
	i^{IB}	-	-	1.64	
CIII	ς^{MP}	-	3.5	-	**10.58**
	v^b	3.5	-	-	

is explained by a potential trade-off between credit and the rest of the variables, and a lack of instruments.

Including any of the macroprudential instruments to target credit directly provides significant gains in terms of minimizing the loss function. In the case of reserve requirements, ς^{MP}, the loss function is reduced by 19%. Similarly, adding capital requirements, v^b, that depend positively on the deviations of credit provides a 17% decrease in the central bank's loss function. These results are in line with Glocker and Towbin (2012), who find that the use of reserve requirements as a policy tool leads to substantially lower loss function values in the presence of financial frictions.

To conclude, we also analyze the case with a strict separation of tasks, where interest rates react solely to inflation fluctuations, while the macroprudential instruments respond to output and loans. Policy CI shows that using reserve and capital requirements as instruments that depend both on loans and output has a significant impact on the loss function. Nevertheless, such a policy could be difficult and confusing to implement, and besides could lead to excessive volatility in the instruments. More plausible setting are shown as Policy CII and CIII, which exhibit a higher loss function (around 12% higher) than the one from the overcrowded specification. However, if we compare them to the case with no separation of tasks (BII and BIII), we see that the gains are very similar. Given that CII and CIII are more feasible options, they could be preferred from a policy-making perspective.

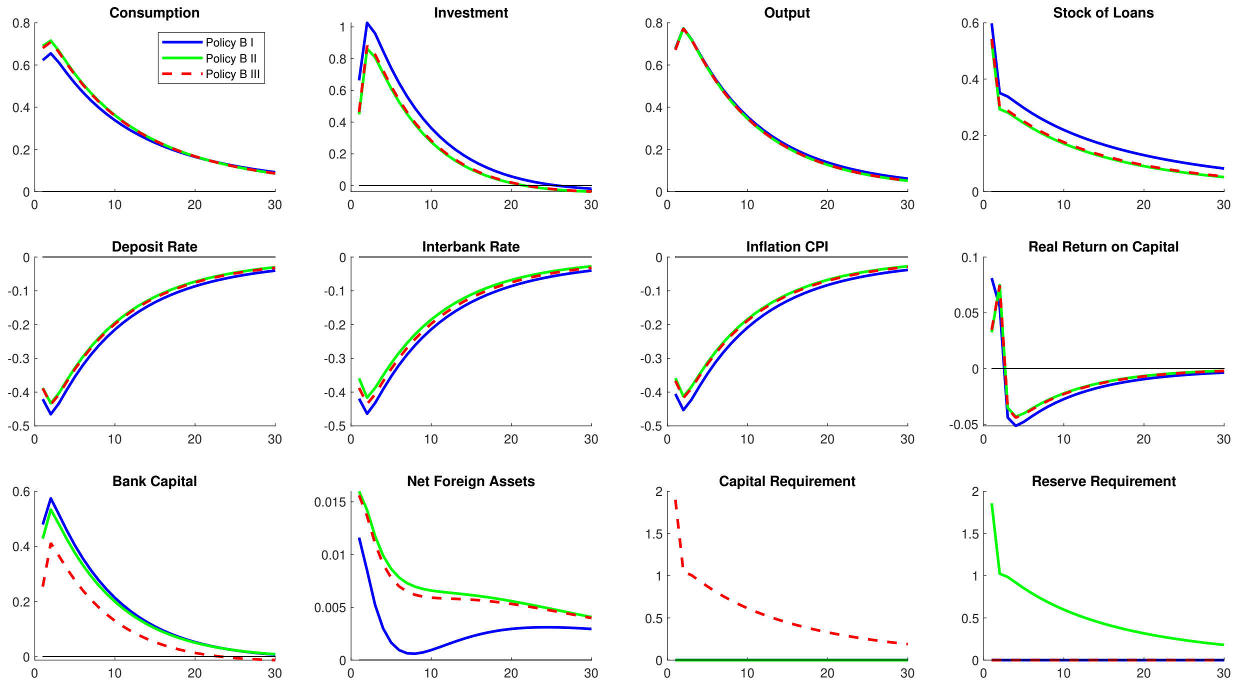
Based on the evidence presented in this section, we can draw some conclusions about the optimal macroprudential rules. First, even under a price stability objective framework, reserve and capital requirements can be beneficial if they are incorporated to a traditional Taylor-rule. Second, if financial stability is included as an objective of the central bank, the effects of macroprudential policies become more important, reducing the target loss function up to 19%. Additionally, they seem to be useful to target output fluctuations, not only credit. Finally, in the scenario of a financial stability objective and strict separation of tasks, reserve requirements provide a slightly better response to the exogenous shocks in the economy than capital requirements.

C. Application: technology shock

To illustrate the differences in the optimal policy rules described in the previous subsections, we show here how the economy reacts to a technology shock under these rules, as depicted in Figure 3. The natural transmission channel tells us that the expansionary shock triggers a decline in inflation and an increase in loans. A policy aiming to stabilize inflation would favor a decline in the interbank interest rate in order to keep real rates low. At the same time, with the objective of stabilizing output, interbank interest rates should increase. Hence, even if the central bank does not monitor credit growth, two goals should be implemented with one policy instrument: the interbank rate should increase and decrease at the same time. This becomes more dramatic if we include a financial stability objective such as in policy type B.

Macroprudential instruments, under such a scenario, proved to be helpful in stabilizing credit and some aggregate components of output. Due to the calibration of the optimal rules, the interbank rate reacts almost one-to-one to the decline in inflation. On the other hand, the positive effect on investment is reduced by around 33% if any of the macroprudential instruments is active (policies BII and BIII). The natural increase in

Figure 3: Technology shock under different Policy Rules and a Financial Stability Objective



Note: The figure reports quarterly impulse responses to a 1-std deviation positive technology shock, considering a scenario with a financial accelerator mechanism and different policy rules, as described in the legend. The y-axis denotes the deviation in percent from the steady state.

loans is also dampened by and increase in capital or reserve requirements, which induce tighter conditions in the credit market. Moreover, an important difference between the two macroprudential instruments, in their effect on bank capital after a technology shock. While reserve requirements do not seem to have a significant effect on this variable compared to the standard Taylor-rule, additional capital requirements trigger a decrease in banking capital. As mentioned before, this is due to the fact that the only source of bank capital is their own profits, which are affected by the increase in requirements.

V. Conclusion

This paper analyzes the interaction and effectiveness of two macroprudential instruments under different anchor variables and central bank's objectives. We build on a small open-economy model with nominal rigidities, financial frictions, a banking sector that is subject to reserve requirements, and include banking capital and capital requirements.

Under a price stability objective, the gains from adapting reserve and capital requirements to economic conditions are substantial when the economy faces nominal and financial frictions. The more traditional financial accelerator mechanism is complemented with the inherent procyclicality of banking capital accumulation, leaving scope for macroprudential measures.

On the other hand, if financial stability is included as an objective of the central bank, the effects of macroprudential policies become more relevant. In such a scenario, they seem to be useful to target output fluctuations, not only credit. Regarding the differences between the two instruments, the most important is that an increase in reserve requirements is associated with higher inflation, while tighter capital requirements lead to a drop in inflation. The overall impact on output is similar in magnitude, but more ambiguous in the case of reserve requirements, as it depends on the degree of price stickiness in the economy. Nevertheless, in terms of achieving the central bank's objectives, both instrument seem to perform similarly, and the benefits of complementing each other are not significant.

Finally, in the scenario of a financial stability objective and strict separation of tasks, reserve requirements provide a slightly better response to the exogenous shocks in the economy than capital requirements. Nevertheless, it is important to notice that the role of capital requirements is not necessarily to stabilize credit growth, but to force banks to build buffers that can be used in recessions. This dimension is not captured by the model, as there is no risk of financial crisis, but should be taken into consideration for future work.

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Annex

Annex 1: The log-linearized equations

Households

- Consumption-saving decision:

$$E_t\hat{C}_{t+1} - \hat{C}_t = \hat{i}_t^D - E_t\hat{\pi}_{t+1}$$

- Uncovered interest parity condition:

$$\hat{i}_t^D + \psi_B\hat{B}_t = \hat{i}_t^* + E_t\Delta\hat{s}_{t+1}$$

- Labor supply:

$$\hat{w}_t = \phi\hat{h}_t + \hat{C}_t$$

Deposit Units

- Reserve requirements:

$$\hat{i}_t^{IB} = \frac{i^R}{i^{IB}}\hat{i}_t^R - \psi_2(\tilde{\varsigma}_t - \tilde{\varsigma}_t^{MP})$$

- Deposit rate:

$$\hat{i}_t^D = \left((1-\varsigma)\frac{i^{IB}}{i^D} + \varsigma\frac{i^R}{i^D}\right)\hat{i}_t^{IB} - \frac{i^{IB} - i^R}{i^D}\hat{\varsigma}_t^{MP}$$

Lending Units

- Balance Sheet:

$$\hat{L}_t = \frac{D^{IB}}{L}\hat{D}_t^{IB} + \frac{K^b}{L}\hat{K}_t^b$$

- Bank capital dynamics

$$\hat{K}_{t+1}^b = (1-\delta^b)\hat{K}_t^b + \delta^b\hat{\Pi}_t^L$$

- Risk-free interest rate

$$\hat{i}_t^F = \frac{i^{IB}}{i^P}\hat{i}_t^{IB} - \kappa\frac{(K^b/L)^2}{i^F}\left((\frac{3K^b}{L} - 2v^b)(\hat{K}_t^b - \hat{L}_t) - v^b\hat{v}_t^b\right)$$

- Profits

$$\hat{\Pi}_t^L = \frac{i^F}{\delta^b}\frac{L}{K^b}(\hat{i}_t^F + \hat{L}_t) - \frac{i^{IB}}{\delta^b}\frac{D^{IB}}{K^b}(\hat{i}_t^{IB} + \hat{D}_t^{IB})$$
$$- \frac{\kappa}{2}\left(\frac{K^b}{L} - v^b\right)\left(\hat{K}_t^b\left(\frac{3K^b}{L} - v^b\right) - 2\frac{K^b}{L}\hat{L}_t - v^b\hat{v}_t^b\right)$$

Financial contract

- Leverage and external finance premium:

$$E_t\hat{r}_{t+1}^K - \hat{i}_t^F + E_t\hat{\pi}_{t+1} = \eta(\hat{Q}_t + \hat{K}_t - \hat{N}_t)$$

- Loan rate (nominal and real):

$$\hat{r}_t^L = \hat{Q}_t + \hat{K}_t + E_t\hat{r}_{t+1}^K - \hat{L}_t$$

$$\hat{i}_t^L = \hat{r}_t^L + E_t\hat{\pi}_{t+1}$$

Entrepeneurs

- Balance Sheet:

$$\hat{Q}_t + \hat{K}_t = \epsilon_L\hat{L}_t + (1-\epsilon_L)\hat{N}_t$$

- Net Worth:

$$\hat{N}_t = \nu\hat{N}_{t-1} + (1-\nu)(\hat{Q}_{t-1} + \hat{K}_{t-1}) + \hat{r}_t^K + \nu\frac{\epsilon_L}{1-\epsilon_L}(\hat{r}_t^K - (\hat{i}_{t-1}^L - \pi_t))$$

Intermediate Goods Producers

- Production function:

$$\hat{y}_t = \hat{\xi}_t^A + \alpha\hat{K}_{t-1} + (1-\alpha)\hat{h}_t$$

- Marginal costs:

$$\hat{mc}_t = \alpha\hat{z}_t + (1-\alpha)\hat{W}_t - \hat{\xi}_t^A$$

- Cost minimization:

$$\hat{h}_t + \hat{W}_t = \hat{z}_t + \hat{K}_{t-1}$$

- Price setting:

$$\hat{\pi}_t^d = \beta E_t \hat{\pi}_{t+1}^d + \frac{(1-\theta)(1-\theta\beta)}{\theta} \hat{mc}_t + \hat{\xi}_t^{CP}$$

Capital Goods Producers

- Investment Demand:

$$\hat{Q}_t = \chi(\hat{I}_t - \hat{K}_{t-1})$$

- Price of capital:

$$\hat{r}_t^K + \hat{Q}_{t-1} = \frac{MPK}{r^K} \hat{z}_t + \frac{1-\delta}{r^K} \hat{Q}_t$$

  where MPK is the marginal product of capital.

- Capital dynamics:

$$\hat{K}_t = (1-\delta)\hat{K}_{t-1} + \delta \hat{I}_t$$

Monetary and Macroprudential Policy

- Taylor-rule:

$$\hat{i}_t^{IB} = \phi_{\pi,i}\hat{\pi}_t + \phi_{Y,i}\hat{Y}_t + \phi_{L,i}\hat{L}_t$$

- Reserve requirements:

$$\hat{\varsigma}_t^{MP} = \phi_{\pi,\varsigma}\hat{\pi}_t + \phi_{Y,\varsigma}\hat{Y}_t + \phi_{L,\varsigma}\hat{L}_t$$

- Capital requirements:

$$\hat{v}_t^b = \phi_{\pi,v}\hat{\pi}_t + \phi_{Y,v}\hat{Y}_t + \phi_{L,v}\hat{L}_t$$

Market Clearing

- Goods market:

$$\hat{Y}_t = \gamma(c_y\hat{C}_t + i_y\hat{I}_t + g_y\hat{G}_t + (1-\gamma)\hat{\epsilon}_t) + (1-\gamma)(\hat{\epsilon}_t + \hat{X}_t)$$

- Balance of payments

$$\hat{B}_t = \hat{Y}_t - (c_y\hat{C}_t + i_y\hat{I}_t + g_y\hat{G}_t + (1-\gamma)\hat{\epsilon}_t) + i^*\hat{B}_{t-1}$$

- Real exchange rate:

$$\hat{\epsilon}_t - \hat{\epsilon}_{t-1} = \Delta\hat{s}_t - \hat{\pi}_t^d$$

- CPI inflation rate:

$$\hat{\pi}_t = \gamma \hat{\pi}_t^d + (1 - \gamma) \Delta \hat{s}_t$$

Annex 2: Calibration

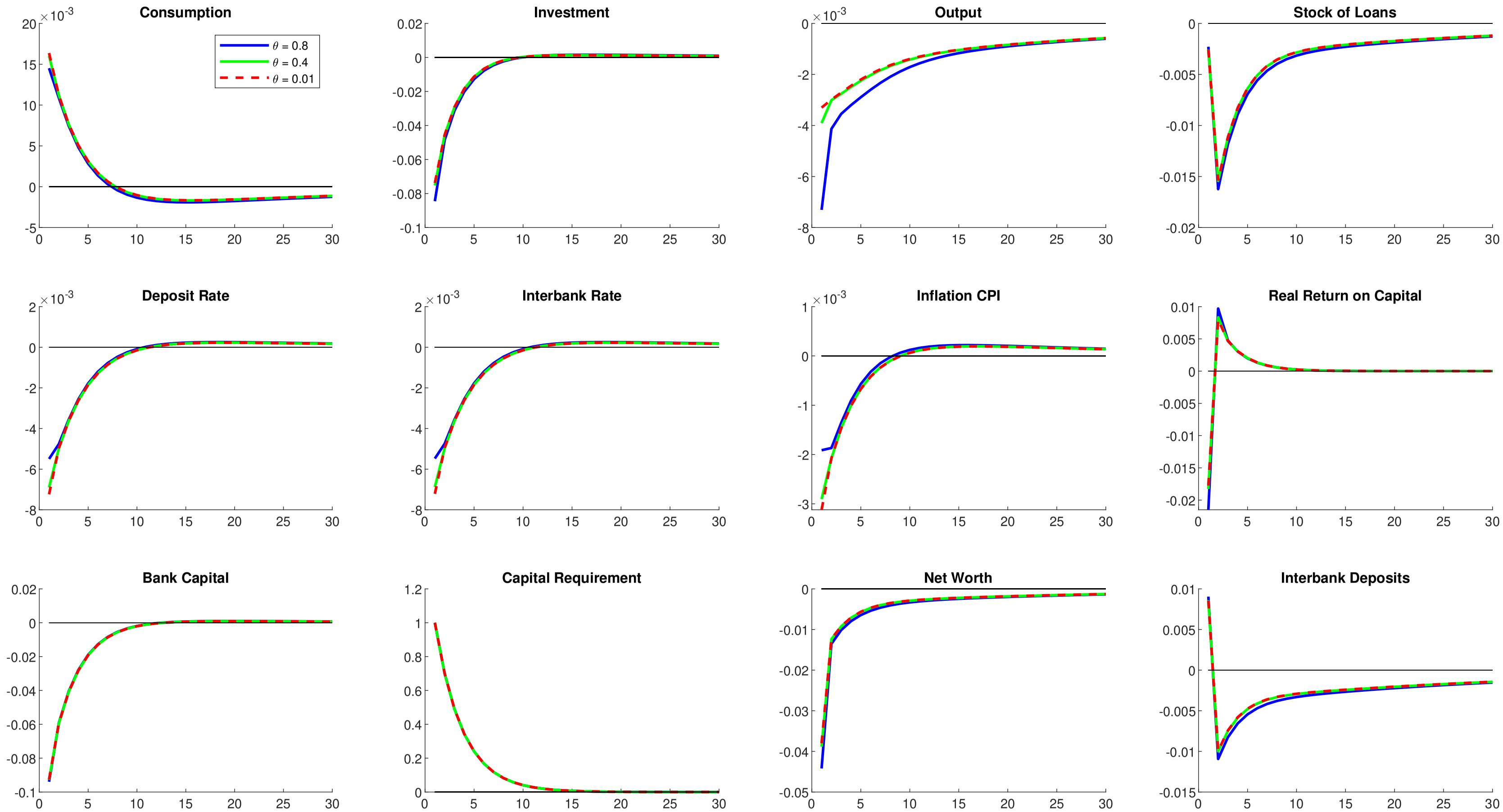
Table 3: Calibration

Param.	Value	Description
δ	0.025	Depreciation Rate of Capital
β	0.985	Discount Factor
α	0.33	Capital Share in Production
ϕ	3.00	Inverse of Frish Labor Supply Elasticity
θ	0.75	Degree of Price Stickiness
ν	0.97	Survival Rate of Entrepreneurs
χ	0.25	Capital Adjustment Costs
η	0.05	Elasticity of External Finance Premium
ψ_B	0.02	Adjustment Costs for Net Foreign Assets
γ	0.75	Share of Domestically Produced Goods
c_y	0.55	Share of consumption on output
i_y	0.22	Share of investment on output
g_y	0.23	Share of gov. spending on output
δ^b	0.1049	Bank capital depreciation
v^b	0.09	Target capital-to-loans ratio
K^b/L	0.11	Actual capital-to-loans ratio
κ	10	Sensitivity to bank capital cost

Table 4: Calibration of the Shocks

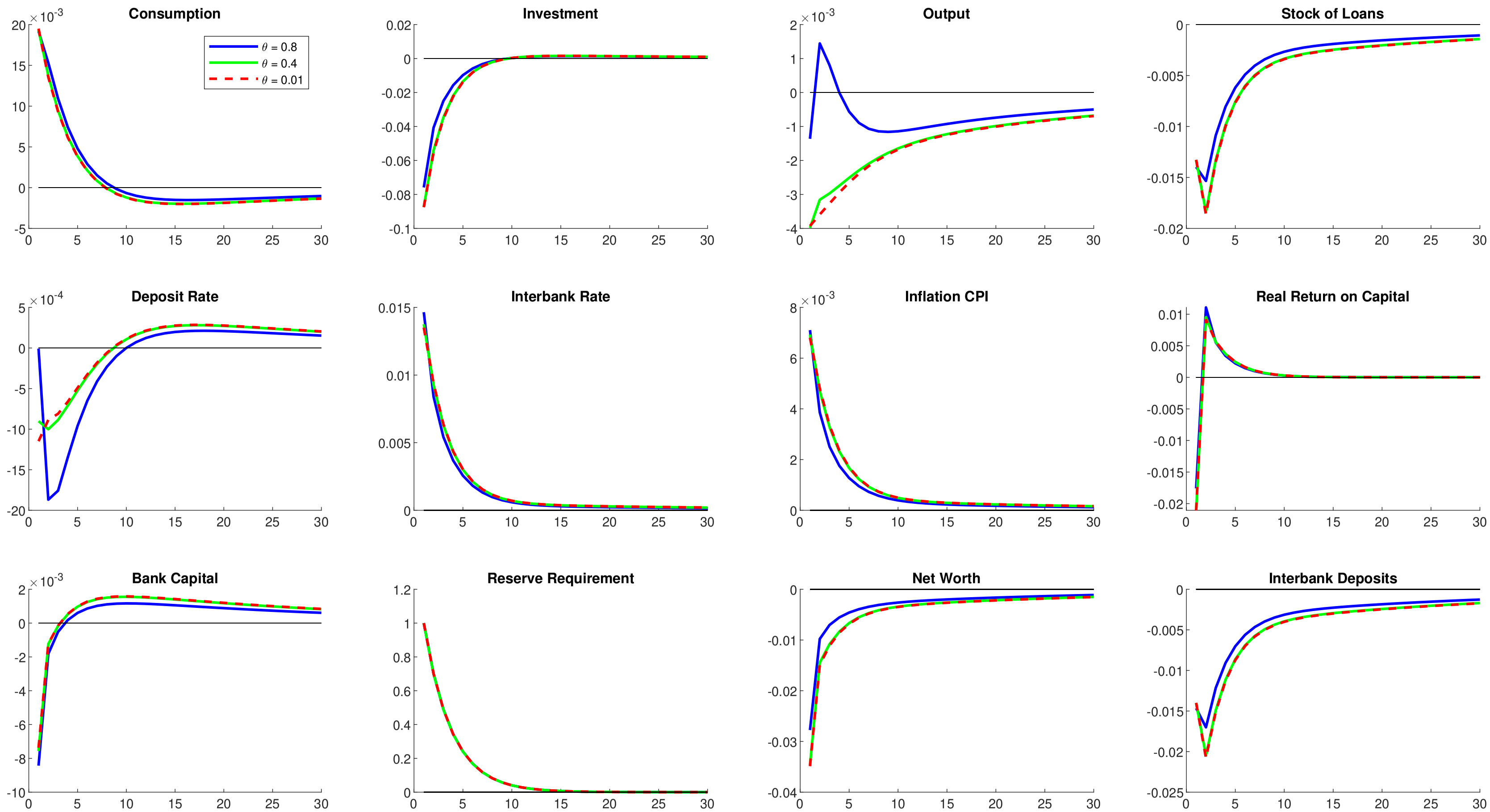
ρ	σ^2	Description
0.89	1.13	Technology Shock
0.40	0.14	Cost-Push Shock
0.86	4.63	Government Expenditures Shock
0.88	0.43	Foreign Interest Rate Shock
0.80	5.01	Export Demand Shock

Figure 4: Capital Requirement Shock and the degree of Price Stickiness



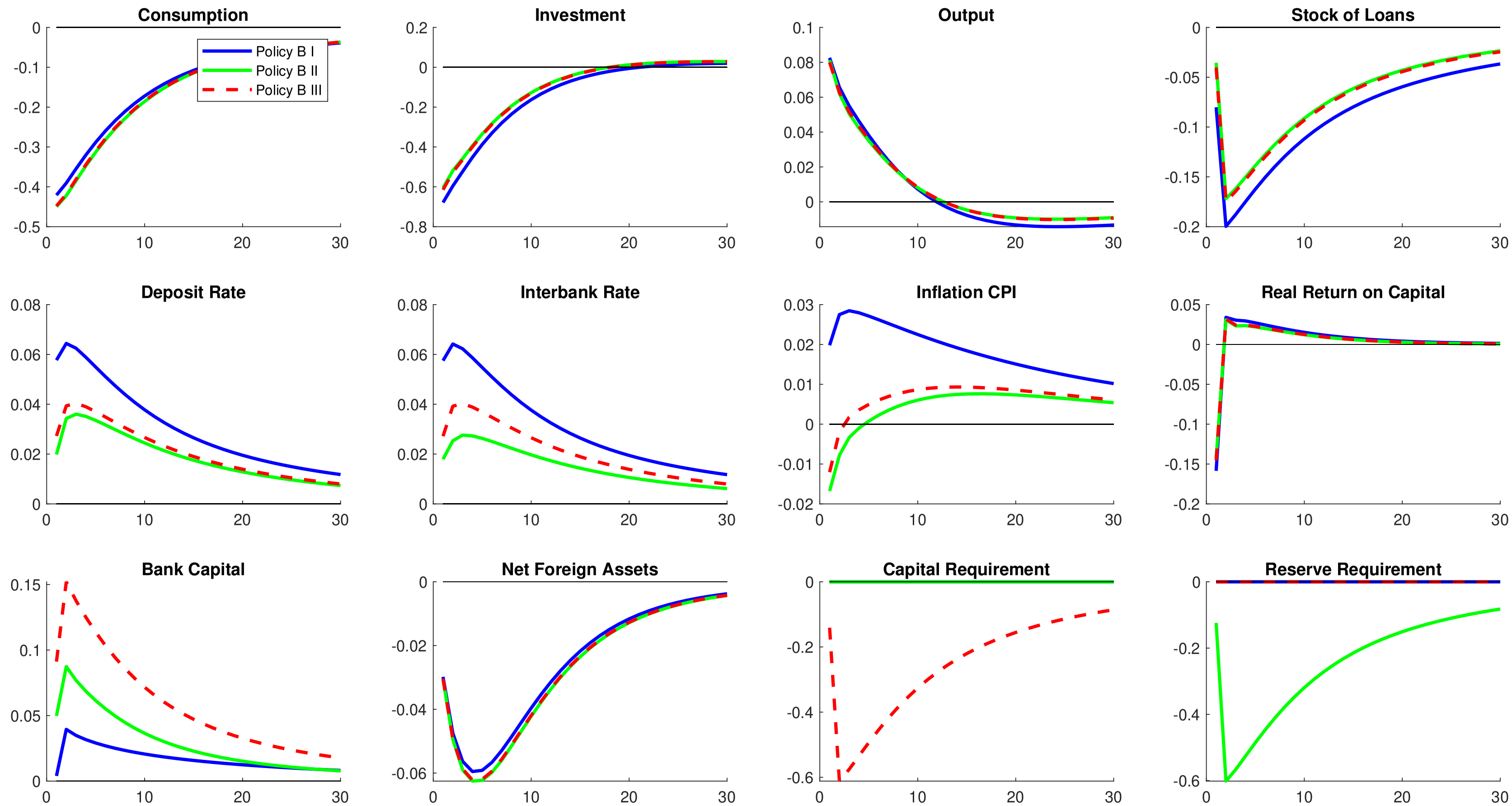
Note: The figure reports quarterly impulse responses to a 1-std deviation increase in capital requirements, considering a scenario with a financial accelerator mechanism and different values of θ. Monetary policy is specified by an interest rate rule for the interbank interest rate as defined in section 2.8 with $\phi_{\pi,i} = 1.5$ and the other coefficients equal 0. The y-axis denotes the deviation in percent from the steady state.

Figure 5: Reserve Requirement Shock and the degree of Price Stickiness



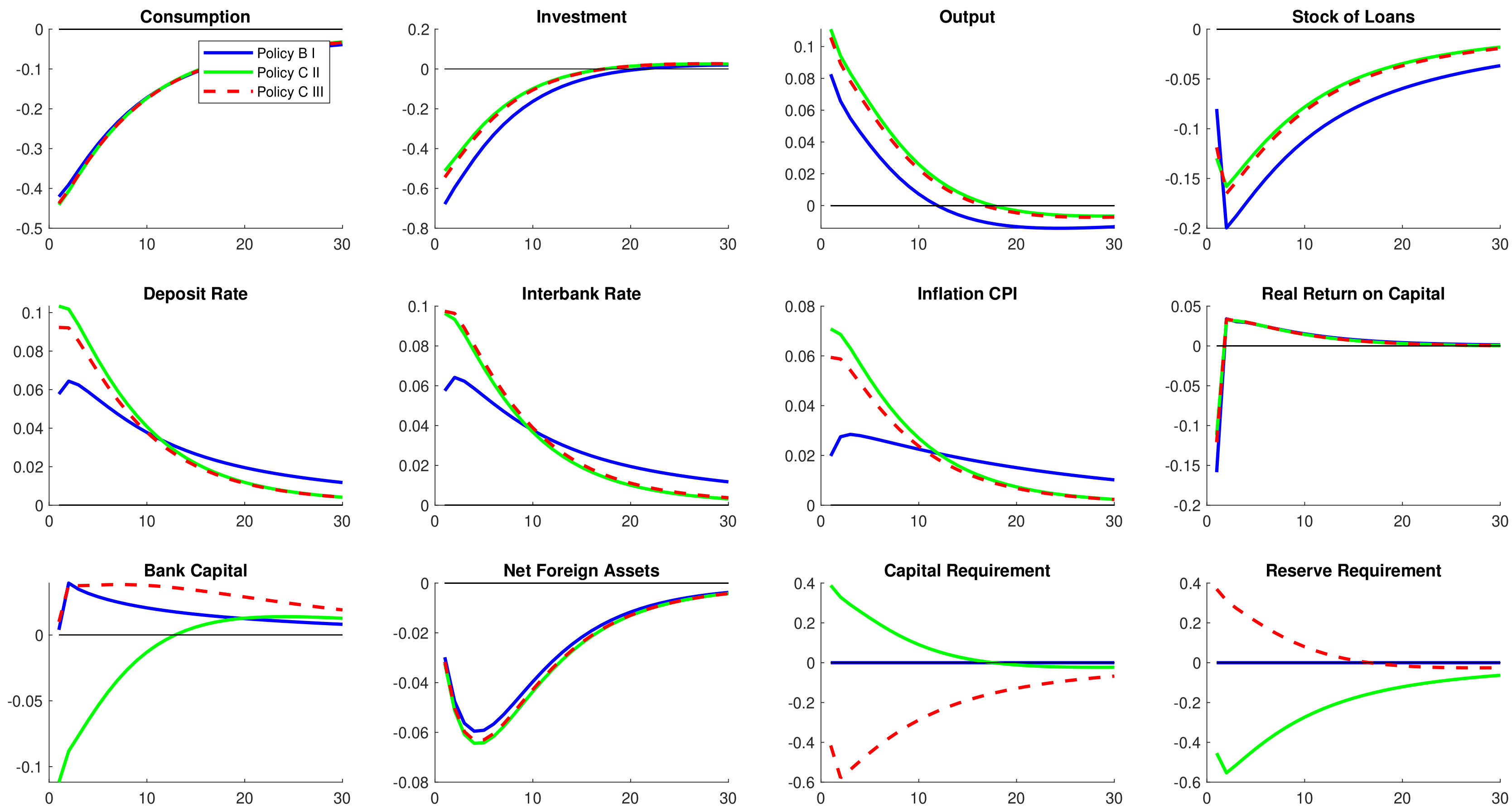
Note: The figure reports quarterly impulse responses to a 1-std deviation increase in reserve requirements, considering a scenario with a financial accelerator mechanism and different values of θ. Monetary policy is specified by an interest rate rule for the interbank interest rate as defined in section 2.8 with $\phi_{\pi,i} = 1.5$ and the other coefficients equal 0. The y-axis denotes the deviation in percent from the steady state.

Figure 6: Government shock under different Policy Rules and a Financial Stability Objective



Note: The figure reports quarterly impulse responses to a 1-std deviation increase in government expenditure, considering a scenario with a financial accelerator mechanism and different policy rules, as described in the legend. The y-axis denotes the deviation in percent from the steady state.

Figure 7: Government shock under different Policy Rules and a Financial Stability Objective



Note: The figure reports quarterly impulse responses to a 1-std deviation increase in government expenditure, considering a scenario with a financial accelerator mechanism and different policy rules, as described in the legend. The y-axis denotes the deviation in percent from the steady state.