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Bank Capital in the Short and in the Long Run

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Abstract

How far should capital requirements be raised in order to ensure a strong and resilient banking system without imposing undue costs on the real economy? Capital requirement increases make banks safer and are beneficial in the long run but carry transition costs because their imposition reduces aggregate demand on impact. Under accommodative monetary policy, increasing capital requirements addresses financial stability risks without imposing large transition costs on the economy. In contrast, when the policy rate hits the lower bound, monetary policy loses the ability to dampen the effects of the capital requirement increase on the real economy. The long-run benefits of higher capital requirements are larger and the transition costs are smaller when the risk that causes bank failure is high.

JEL Codes: E3, E44, G01, G21.

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"Lord, make me chaste - but not yet", Saint Augustine

1. Introduction

Ensuring bank resilience is a pressing policy issue for a number of European countries at present. Undercapitalized banks make the economy more vulnerable to default risk and threaten to impose large fiscal costs from bailing out failing financial institutions. This makes desirable to raise bank equity buffers. Set against this is the fear that a rapid tightening of capital requirements leads to a credit crunch and large output losses.

In this paper we discuss how the above trade-off should be resolved. In particular, we ask the question of how far capital requirements should be raised in order to ensure a strong and resilient banking system without imposing undue costs on the real economy during the transition to the higher level. We argue that the answer crucially depends on the degree of fragility in the banking sector and, in the presence of nominal rigidities, on the conduct of monetary policy.

In order to understand and assess the short- and long-run effects of changes in capital regulation, we build a quantitative macro-banking model featuring both financial and nominal frictions. Banks intermediate funds between savers and borrowers and all borrowers including banks enjoy limited liability and have the option to default. External financing takes the form of non-recourse uncontingent nominal debt subject to costly state verification (CSV) frictions like in Bernanke, Gertler and Gilchrist (1999). Borrowers default when the value of their assets falls below that of their debt obligations. In addition, the model also features nominal price rigidities à la Calvo (1983) and a monetary authority that follows a standard Taylor-type rule. The model is calibrated to mimic salient macroeconomic and financial features of the euro area (EA) economy.

Two are the key bank-related distortions. First, bank risk is not priced at the margin. Banks operate under limited liability. Some deposits are insured and pay the risk free rate regardless of bank risk. Uninsured deposits are exposed to losses but pay an interest rate which is based on aggregate economy-wide bank failure risk rather than the decisions of each individual bank.

As a result, banks have an incentive to take excessive risk and capital regulation is effective to limit this and to reduce banks' default risk and the associated bank (deposit) funding costs.

Second, the costs of capital regulation arise due to limited participation in the market for bank equity. In a key departure from Modigliani-Miller, the scarcity of the wealth of the subset of households that can hold bank equity creates a spread between the risk-adjusted return on bank equity and the risk-free rate. Thus, if capital requirements increase very quickly bank equity funding costs increase, reducing lending and real activity in the short-run.

We use our quantitative model as a laboratory to explore the real and welfare effects of capital requirement increases. We show that higher capital requirements are always successful in making banks less fragile and, thus, in reducing the social costs caused by their default. However, the transition to tighter capital requirements always carries short term output costs due to the reduction in credit and aggregate demand on impact. The net effect on economic activity and welfare depends of which of the two effects dominates. The conduct of monetary policy and the degree of bank riskiness are crucial in this respect.

A capital requirement increase is more desirable if implemented gradually or in conjunction with an accommodative monetary policy or when banks are more fragile. When monetary policy reacts to the changes in output and inflation implied by capital requirement increases, the transition costs remain small relative to the longer term financial stability benefits. In contrast, when monetary policy is less accommodative, or cannot respond at all due to a binding effective lower bound (ELB), tightening capital requirements causes a larger slowdown of lending and real activity on impact. A smaller and more gradual increase in capital requirements is thus vital to maintain aggregate demand over the transition to a world with better capitalized banks.

The size of the risk that capital regulation has to address is key for the overall balance between the transition costs and the long-run benefits of changes in capital requirements. In a scenario of heightened uncertainty about the returns on banks' loan portfolio, higher capital requirements are more beneficial in the long-run. Larger long-run benefits are factored in by forward looking agents and mitigate the drop in demand over the transition. Thus, higher bank risk not only increases the long run benefits of higher requirements but also reduces the transition costs.

In the normative part of the analysis, we characterize the level of the capital requirements that maximizes household welfare. We find that including transition costs is crucial as these costs can significantly reduce the optimal capital requirement increase. The optimal design of a capital increase crucially depends on the degree of accomodation in monetary policy, as measured by the policy interest rate fall in response to inflation undershoots. Pursuing the goal of full price stability, the monetary authority allows the macroprudential authority to optimally implement larger capital requirement increases. In contrast, in the proximity of the ELB, the optimal increase in the capital requirement is more moderate and the welfare gains associated with it are the also less sizable. When the degree of bank fragility is high, capital requirement increases are most beneficial, which is consistent with standard microprudential logic.

Our paper contributes to the growing literature on the impact of changing bank capital requirements (see e.g. Van Den Heuvel, 2008; Gertler, Kiyotaki and Queralto, 2012; Martinez-Miera and Suarez, 2014; Nguyen, 2014; Clerc et al., 2015; Begenau, 2016; Christiano and Ikeda, 2017; Mendicino et al., 2018). Most of these studies generally conclude that there are long-term gains from having capital requirements higher than before the crisis and even above the prescriptions of Basel III. Our work quantifies these conclusions by considering the effects over the transition from the initial levels and assessing the overall balance between the long-run benefits and the transition costs. In addition to the previous literature, we quantify the importance of the conduct of monetary policy for the optimal changes in capital regulation.

Our analysis differs from papers on the interaction between monetary and macroprudential policy (e.g. De Paoli and Paustian, 2013; Lambertini et al. 2013; Kiley and Sim, 2015; Leduc and Natal, 2016; Collard et al., 2017; Carrillo et al. 2017; Gersbach el al., 2018) in that our main focus is not on cyclical macroprudential policy. Differentially from most studies looking at this interaction, our model contains an explicit prudential rationale for capital requirements, which are the centerpiece of the micro and macroprudential regulation of banks under the Basel process. This enables us to quantify the effectiveness of changes in capital requirements policies in terms of their primary financial stability purpose rather than just limiting the analysis to their stabilization effects. In this respect, our framework also allows us to quantify the crucial role of the degree of bank riskiness in the assessment of the costs and benefits of capital requirements.

Our results are consistent with the literature on fiscal multipliers at the ELB. This literature concludes that fiscal policy has large expansionary effects when monetary policy does not offset its impact on aggregate demand (e.g. Christiano, Eichenbaum and Rebelo, 2011; Erceg and Linde, 2014; and Eggertson, Ferrero and Raffo, 2014). While the focus of our paper is on capital requirements rather than on fiscal policy, the intuition for the amplified negative short-term real effects of macroprudential policy at the ELB is the same. When monetary policy cannot or does not offset the impact of policy changes on aggregate demand, this should be taken into account, whether the policy changes are fiscal or macroprudential.

The paper is structured as follows. Section 2 outlines the model. Section 3 discusses the calibration to Euro Area data. Section 4 investigates the long-run effects of higher capital requirements, while Section 5 reports the transition effects and discusses how these are affected by the presence of a binding ELB on nominal interest rates and by bank riskness. Section 6 discusses the optimal increase in capital requirements in the presents of transitional costs. Section 7 concludes.

2. Model Economy

This section presents the macro-banking model that we use for the assessment of increases in capital requirements. Our model shares a number of features with Mendicino et al. (2018), which we extend to include monetary policy, nominal debt contracts and nominal price rigidities.

Main ingredients of the model. We consider an economy populated by a dynasty of saving households. The dynasty consists of three different classes of members: workers, entrepreneurs, and bankers, with measures given by x_j, $j = w, e, b$, respectively. Workers supply labor to the production sector and transfer their wage income to the household. Entrepreneurs and bankers manage entrepreneurial firms and banks, respectively, and can transfer their accumulated earnings back to the dynasty as dividends or once they retire. They use their scarce net worth to provide equity financing to entrepreneurial firms and banks, respectively. Entrepreneurs receive consumption insurance from their dynasty, while their firms and banks can individually default on the debt issued to finance their activities.[1]

Firms' debt financing takes the form of bank loans. The competitive banks finance their loans by raising equity from bankers and deposits from households.[2]. A fraction κ of deposits are insured by a deposit guarantee scheme (DGS) funded with lump sum taxes. The remaining fraction $1 - \kappa$ are risky deposits.[3]

Key frictions. First, entrepreneurial firms and banks operate under limited liability, finance their investments with debt, and default when the value of their assets falls below their debt obligations. Their external financing is subject to costly state verification (CVS) frictions as in Bernanke, Gertler and Gilchrist (1999) but debt, realistically, is non contingent.

Second, individual bank default risk is not priced at the margin but on the basis of depositors' expectations about the potential losses associated with the risk of failure of an average bank.[4] This friction provides banks with an incentive to take excessive risk and to lever up excessively, providing a prima facie case for regulatory capital requirements.[5] On the other hand, given the limied participation in the market for bank equity, increasing the capital requirements may reduce the supply of bank credit and affect the level of entrepreneurial activity.

Finally, the model also features nominal distortions: debt contracts are written in nominal terms and there are nominal price rigidities *à la* Calvo (1983). Nominal debt induces some redistribution of real wealth between borrowers and savers when inflation realizes above or

[1]Assuming that dynasties provide consumption risk-sharing to their members while individual members (or the firms and banks that they own) may default on their debts avoids having budget constraints with kinks and facilitates solving the model with perturbation methods.

[2]All the agents will be described as competitive because they are atomistic and take prices as given. However, the scarcity of entrepreneurs' and bankers' wealths will make them extract rents in equilibrium.

[3]One can alternatively interpret κ as the fraction of bank debt that benefits from a government bailout in case of default. This formulation allows us to consider liability structures other than 100% insured deposits ($\kappa = 1$) without complicating banks' capital structure decisions.

[4]This assumption can be motivated by banks' opacity which makes it difficult for outsiders to hold banks to account, as well as by the dispersion and lack of sophistication of their lenders, which makes them unwilling or unable to monitor the banks (Dewatripont and Tirole, 1994). The motivation is similar to that based on the unobservable risk-taking choice in Christiano and Ikeda (2017) which in our model is made through bank leverage and the riskness of the loans made to entrepreneurial firms. Regardless of the precise microfoundations, the end result is that market discipline is weak even in the absence of a financial safety net.

[5]Our framework is consistent with the views that posit the need for regulating bank leverage when bank debtholders are unsophisticated and/or dispersed (Dewatripont and Tirole, 1994) or receive governement guarantees (Kareken and Wallace, 1978), and then lack capability and/or incentives to monitor the banks.

below expectations, generating distortions in the allocation of resources.[6] On the other hand, nominal price rigidities generate inefficient wage and price dispersion.[7]

Policy authorities. We assume that, starting from a given initial level, the macroprudential authority sets the long-term level of the bank capital requirement and the speed of implementation of the change in the requirement from its initial level. The monetary authority sets the short term risk free rate according to a Taylor-type rule that responds smoothly to inflation and output growth.

2.1 Notation

Firms and banks are subject to idiosyncratic return shocks $\omega_{j,t+1}$ $(j \in \{b, f\})$ which are independently distributed and assumed to follow a log-normal distribution with a mean of one and standard deviation of σ_j, identical across borrowers of the same class. For each class of borrower, we denote by $F_j(\omega_{i,t+1})$ the distribution function of $\omega_{j,t+1}$ and by $\overline{\omega}_{j,t+1}$ the threshold realization below which a borrower of class j defaults, so that the probability of default of such borrower can be found as $F_j(\overline{\omega}_{i,t+1})$.

Following Bernanke, Gertler and Gilchrist (1999) (henceforth, BGG), the share of total assets owned by borrowers of class j which end up in default is defined as

$$G_j\left(\overline{\omega}_{i,t+1}\right) = \int_0^{\overline{\omega}_{j,t+1}} \omega_{j,t+1} f_j\left(\omega_{j,t+1}\right) d\omega_{j,t+1}, \tag{1}$$

and the expected share of asset value of such class of borrowers that goes to the lender as

$$\Gamma_j(\overline{\omega}_{j,t+1}) = G_j\left(\overline{\omega}_{j,t+1}\right) + \overline{\omega}_{j,t+1}[1 - F_j\left(\overline{\omega}_{j,t+1}\right)] \tag{2}$$

where $f_j\left(\omega_{j,t+1}\right)$ denotes the density function of $\omega_{j,t+1}$. In the presence of a proportional asset repossession cost μ_j, as we assume, the net share of assets that goes to the lender can be expressed as $\Gamma_j(\overline{\omega}_{j,t+1}) - \mu_j G_j\left(\overline{\omega}_{j,t+1}\right)$. The share of assets eventually accrued to the borrowers of class j is $(1 - \Gamma_j(\overline{\omega}_{j,t+1}))$.

[6]Distortions related to nominal assets are analyzed in Christiano, Motto and Rostagno (2004, 2014) and Jermann, Gomes and Schmid (2016)

[7]See Woodford (1999), Erceg, Henderson and Levin (2000), Schmitt-Grohe and Uribe (2006, 2007) for further discussions on nominal price rigidities. Monetary policy (that is, changes in the policy interest rate specified below) and unexpected changes in inflation, affect both the real value of debt and the cost of price dispersion, producing real effects.

2.2 Households

Dynasties provide consumption risk sharing to their members and are in charge of taking most household decisions

$$\max_{\{C_{t+\tau},L_{t+\tau},K_{s,t+\tau},D_{t+\tau},B_{t+\tau}\}_{\tau=0,1,2,\dots}} \mathbb{E}\left[\sum_{\tau=0}^{\infty}\beta^{t+\tau}\left[\log\left(C_{t+\tau}\right)-\frac{\varphi}{1+\eta}\left(L_{t+\tau}\right)^{1+\eta}\right]\right] \tag{3}$$

subject to:

$$\begin{aligned} & P_tC_t+\left(Q_t+P_ts_t\right)K_{s,t}+D_t+B_t \\ & \leq \left(P_tr_{k,t}+\left(1\text{–}\delta_t\right)Q_t\right)K_{s,t-1}+W_tL_t+\widetilde{R}_t^dD_{t-1}+R_{t-1}B_{t-1}+P_tT_{s,t}+P_t\Pi_t+P_t\Xi_t \end{aligned} \tag{4}$$

where C_t denotes consumption and L_t denotes hours worked in the consumption good producing sector. Parameter φ measures the disutility of labor, and η is the inverse of the Frisch elasticity of labor supply. P_t is the nominal price of the consumption good and W_t is the nominal wage rate. Households can hold physical capital $K_{s,t}$ with nominal price Q_t, depreciation rate δ_t, and rental rate $r_{k,t}$, subject to a management cost s_t which is taken as given by households.

The risk free asset (which is in zero net supply) bought at $t-1$, B_{t-1}, pays the (gross) short-term nominal interest rate R_{t-1} in period t. The portfolio of bank deposits held at $t-1$, D_{t-1}, contains a fraction κ of insured deposits that always pay back the promised gross interest rate R_{t-1}^d and another fraction $1-\kappa$ which pays back the promised rate R_{t-1}^d if the issuing bank is solvent but experiences some default losses if the bank fails. Thus we can write the (gross) return on the whole deposit portfolio as

$$\widetilde{R}_t^d = R_{t-1}^d - (1-\kappa)\Omega_t, \tag{5}$$

where Ω_t is the average loss rate per unit of bank debt realized at t due to bank defaults (see Appendix 1 for its expression in equilibrium). For $\kappa < 1$, making (the bundle of insured and uninsured) bank debt attractive to savers requires setting a contractual gross interest rate R_{t-1}^d higher than the free rate R_{t-1}.

Finally, $T_{s,t}$ is a lump-sum tax used by the DGS to ex-post balance its budget, Π_t are aggregate net transfers of earnings or wealth from entrepreneurs and bankers to the household at period t, and Ξ_t are profits from firms that manage the capital stock held by the households.

2.3 Entrepreneurs and Bankers

In each period some entrepreneurs and bankers become workers and some workers become either entrepreneurs or bankers.[8] Each period can be logically divided in three stages: payment stage, surviving stage, and investment stage. In the payment stage, previously active entrepreneurs ($\varrho = e$) and bankers ($\varrho = b$) get paid on their previous period investments. In the surviving stage, each agent of class ϱ stays active with probability θ_ϱ and retires with probability $1 - \theta_\varrho$, becoming a worker again and transferring any accumulated net worth to the patient dynasty. At the same time, a mass $(1 - \theta_\varrho)\, x_\varrho$ of workers become new agents of class ϱ, guaranteeing that the size of the population of such agents remains constant at x_ϱ. The cohort of new agents of class ϱ receives total net worth $\iota_{\varrho,t}$, from the patient dynasty. In the investment stage entrepreneurs and bankers provide equity financing to entrepreneurial firms and banks, respectively, and can send their net worth back to the household in the form of dividends.

2.3.1 Individual entrepreneurs

Entrepreneurs are agents that invest their net worth into entrepreneurial firms. Letting λ_t denote the Lagrange multiplier of the budget constraint of the representative household in period t, the problem of the representative entrepreneur can be written as

$$V_{e,t} = \max_{A_t, dv_{e,t}} \left\{ dv_{e,t} + \mathbb{E}\frac{\Lambda_{t+1}}{\pi_{t+1}} \left[(1 - \theta_e)\, N_{e,t+1} + \theta_e V_{e,t+1} \right] \right\} \tag{6}$$

subject to:

$$\begin{gathered} A_t + dv_{e,t} = N_{e,t} \\ N_{e,t} = \int_0^\infty \rho_{f,t}\,(\omega) dF_{f,t}\,(\omega)\, A_{t-1} \\ dv_{e,t} \geq 0 \end{gathered}$$

where $\Lambda_{t+1} = \beta\lambda_{t+1}/\lambda_t$ is the stochastic discount factor of the representative household, $\pi_{t+1} = P_{t+1}/P_t$ is the inflation rate, $N_{e,t}$ is the nominal value of the entrepreneur's net worth, A_t is the part of the net worth symmetrically invested in the continuum of entrepreneurial firms further

[8]This guarantees that entrepreneurs and bankers never accumulate enough net worth so as to stop investing all their net worth in the equity of firms and banks, respectively (see, e.g. Gertler and Kiyotaki, 2010). It allows us to capture the reluctance of firms and banks to cut dividends or rise new equity, especially in bad times.

described below, $dv_{e,t} \geq 0$ is the dividend that the entrepreneur pays to the household, and $\rho_{f,t}(\omega)$ is the rate of return on the entrepreneurial equity invested in a firm that experiences a return shock ω (whose expression in equilibrium is provided in Appendix A).

As in Gertler and Kiyotaki (2010), we guess that the value function is linear in net worth

$$V_{e,t} = \upsilon_{e,t} N_{e,t}, \tag{7}$$

where $\nu_{e,t}$ is the shadow value of one unit of entrepreneurial equity. Then we can write the Bellman equation in (6) as

$$\upsilon_{e,t} N_{e,t} = \max_{A_t, dv_{e,t}} \left\{ dv_{e,t} + \mathbb{E}\frac{\Lambda_{t+1}}{\pi_{t+1}} \left[1 - \theta_e + \theta_e \upsilon_{e,t+1}\right] N_{e,t+1} \right\}. \tag{8}$$

Insofar as $\upsilon_{e,t} > 1$ (which we verify to hold true under our parameterizations), entrepreneurs will find optimal not to pay dividends prior to retirement (that is, $dv_{e,t}$ is only positive and equal to $N_{e,t}$ when the entrepreneur retires). Finally, (8) allows us to define entrepreneurs' stochastic discount factor as

$$\Lambda_{e,t+1} = \Lambda_{t+1} \left[1 - \theta_e + \theta_e \upsilon_{e,t+1}\right].$$

2.3.2 Entrepreneurial firms

The representative entrepreneurial firm takes equity A_t from entrepreneurs and borrows $B_{f,t}$ from banks at nominal interest rate R_t^b to buy physical capital from capital producers at t. In the next period, the firm rents the available effective units of capital, $\omega_{f,t+1} K_{f,t}$, where $\omega_{f,t+1}$ is the firm-idiosyncratic return shock, to capital users and sells back the depreciated capital to capital producers. Entrepreneurial firms operate across two consecutive dates and pay out their terminal net worth to entrepreneurs. Assuming ex-ante symmetry across firms, the problem of the representative entrepreneurial firm is

$$\max_{K_{f,t}, B_{b,t}, R_t^b} \mathbb{E}\left[\Lambda_{e,t+1}(1 - \Gamma_{f,t+1}\left(\overline{\omega}_{f,t+1}\right))\left((1 - \delta_{t+1})\frac{Q_{t+1}}{P_{t+1}} + r_{k,t+1}\right)\pi_{t+1}\right] K_{f,t}$$

subject to the budget constraint,

$$Q_t K_{f,t} = B_{f,t} + A_t, \tag{9}$$

where $B_{f,t}$ is the loan taken from the bank, and

$$\mathbb{E}\left[\Lambda_{b,t+1}(1-\Gamma_{b,t+1}\left(\overline{\omega}_{b,t+1}\right))\widetilde{R}^b_{t+1}B_{b,t}\right] \geq v_{b,t}\phi_t B_{f,t}, \tag{10}$$

which is the participation constraint of the bank and reflects the competitive pricing of the loans that banks are willing to offer for different choices of leverage by the firm.

As further explained in subsection 2.3.5, (10) imposes that loan rate R^b_t must be such that the expected, properly discounted payoffs that the loans provide to bank owners (taking their limited liability into account) are large enough to compensate bankers for the opportunity cost of the equity financing contributed to such loans, $v_{b,t}\phi_t B_{f,t}$, where $v_{b,t}$ is the equilibrium shadow value of one unit of bankers' wealth and ϕ_t is the (binding) capital requirement faced by the bank when extending loans. The term $\Lambda_{b,t+1}$ is bankers' stochastic discount factor, $1-\Gamma_{b,t+1}(\overline{\omega}_{M,t+1})$ accounts for the fact that bankers obtain levered returns from the bank's loan portfolio, and $\overline{\omega}_{b,t+1}$ is the threshold of the idiosyncratic shock to bank asset returns below which the bank defaults.[9].

The payoff that the bank receives from its portfolio of loans to entrepreneurial firms can be expressed as $\widetilde{R}^b_{t+1}B_{f,t} = \left(\Gamma_{f,t+1}\left(\overline{\omega}_{f,t+1}\right)-\mu_f G_{f,t+1}\left(\overline{\omega}_{f,t+1}\right)\right)\left(\left(1-\delta_{t+1}\right)Q_{t+1}+P_{t+1}r_{k,t+1}\right)K_{f,t}$, which takes into account that a firm defaults on its loans when the terminal value of its assets, $\omega_{f,t+1}R^K_{t+1}Q_tK_{f,t}$, is insufficient to repay $R^b_tB_{f,t}$, in which case the bank incurs a proportional repossession cost μ_f and appropriates the physical capital of the defaulted firms. The default threshold for entrepreneurial firms is:

$$\overline{\omega}_{f,t} = \frac{R^b_{t-1}B_{f,t-1}}{\left(\left(1-\delta_t\right)Q_t+P_tr_{k,t}\right)K_{f,t-1}} = \frac{R^b_{t-1}\frac{B_{f,t-1}}{P_{t-1}}}{\left(\left(1-\delta_t\right)\frac{Q_t}{P_t}+r_{k,t}\right)K_{f,t-1}}\frac{1}{\pi_t} \tag{11}$$

[9]When solving this problem, the entrepreneurial firm takes $\overline{\omega}_{b,t+1}$as given, since the impact of an infinitesimal marginal loan on bank solvency is negligible. Instead, the firm internalizes the impact of its decision on its own default threshold $\overline{\omega}_{f,t+1}$.

2.3.3 Law of motion of entrepreneurial net worth

Taking into account the effects of retirement and the entry of new entrepreneurs, the evolution of active entrepreneurs' nominal net worth can be described as:[10]

$$N_{e,t} = \theta_e \rho_{f,t} A_{t-1} + \iota_{e,t},$$

where $\rho_{f,t} = \int_0^\infty \rho_{f,t}(\omega) dF_{f,t}(\omega)$ is the return on a well-diversified unit portfolio of equity investments in entrepreneurial firms and $\iota_{e,t}$ is new entrepreneurs' net worth endowment, which we assume to be a proportion χ_e of the net worth of the retiring entrepreneurs:

$$\iota_{e,t} = \chi_e (1 - \theta_e) \rho_{f,t} A_{t-1}.$$

2.3.4 Individual bankers

Bankers invest their net worth $N_{b,t}$ into competitive banking sector that extend loans $B_{f,t}$ to the entrepreneurial firms. There is a continuum of measure one of banks. The problem of the representative banker is

$$V_{b,t} = \max_{E_{b,t}, dv_{b,t}} \{dv_{b,t} + \mathbb{E}\Lambda_{t+1} [(1 - \theta_b) N_{b,t+1} + \theta_b V_{b,t+1}]\} \tag{12}$$

subject to:

$$E_t + dv_{b,t} = N_{b,t}$$
$$N_{b,t} = \int_0^\infty \rho_{b,t}(\omega) dF_b(\omega) E_{t-1}$$
$$dv_{b,t} \geq 0$$

where $E_{b,t}$ is the diversified equity investment in the continuum of banks, $dv_{b,t}$ is the dividend that the banker pays to the household dynasty, and $\rho_{b,t}(\omega)$ is the rate of return from investing equity in a bank that experiences an idiosyncratic shock ω (see Appendix A for its expression in equilibrium).

As in the case of entrepreneurs, we guess that bankers' value function is linear

$$V_{b,t} =_{b,t} N_{b,t},$$

[10] To save on notation, we also use $N_{e,t+1}$ to denote the aggregate counterpart of what in (6) was an individual entrepreneur's net worth.

where $v_{b,t}$ is the shadow value of a unit of banker wealth. The Bellman equation in (12) becomes

$$v_{b,t}N_{b,t} = \max_{E_{b,t},dv_{b,t}} \left\{ dv_{b,t} + \mathbb{E}\Lambda_{t+1} \left[1 - \theta_b + \theta_b v_{b,t+1}\right] N_{b,t+1} \right\}, \tag{13}$$

and, insofar as $v_{b,t} > 1$ (which we will verify to hold under our parameterizations), bankers will find it optimal not to pay dividends prior to retirement (so $dv_{b,t}$ will only be positive and equal to $N_{b,t}$ when the banker retires). From (13), bankers' stochastic discount factor can be defined as

$$\Lambda_{b,t+1} = \Lambda_{t+1} \left[1 - \theta_b + \theta_b v_{b,t+1}\right].$$

From (13), an interior equilibria in which banks receive a strictly positive amount of equity from bankers ($E_{b,t} > 0$) requires that properly discounted gross expected return on equity be equal to $v_{b,t}$:

$$\mathbb{E}[\Lambda_{b,t+1}\rho_{b,t+1}] = v_{b,t}, \tag{14}$$

where $\rho_{b,t+1} = \int_0^\infty \rho_{b,t+1}(\omega)\, dF_b(\omega)$ is the return of a well diversified unit-size portfolio of bank equity.

2.3.5 Banks

The representative bank issues equity $E_{b,t}$ among bankers and nominal deposits D_t that promise a gross interest rate R_t^d among households, and uses these funds to provide a continuum of identical loans of total size $B_{f,t}$. This loan portfolio has a terminal value of $\omega_{b,t+1}\widetilde{R}_{t+1}^b$, where $\omega_{b,t+1}$ is a log-normally distributed bank-idiosyncratic asset return shock and $\widetilde{R}_{t+1}^b$ denotes the realized gross return on a well diversified portfolio of loans.[11] Banks operate across two consecutive dates and give back their terminal net worth, if positive, to the bankers. If a bank's terminal net worth is negative, it defaults. The DGS then takes the returns $(1-\mu_b)\omega_{b,t+1}\widetilde{R}_{t+1}^b B_{f,t}$ where μ_b is a proportional repossession cost, pays the fraction κ of insured deposits in full, and pays a fraction $1-\kappa$ of the repossessed returns to holders of the bank's uninsured deposits.

[11] This layer of idiosyncratic uncertainty is an important driver of bank default and is intended to capture the effect of bank-idiosyncratic limits to diversification of borrowers' risk (e.g. regional or sectoral specialization or large exposures) or shocks stemming from (unmodeled) sources of cost (IT, labor, liquidity management) or revenue (advisory fees, investment banking, trading gains).

The objective function of the representative bank is to maximize the net present value of bankers' stake at the bank

$$NPV_{b,t} = \mathbb{E}\Lambda_{b,t+1} \max\left[\omega_{b,t+1}\widetilde{R}^b_{t+1}B_{f,t} - R^d_t D_t, 0\right] - v_{b,t}E_{b,t}, \tag{15}$$

where the equity investment $E_{b,t}$ is valued at its equilibrium opportunity cost $v_{b,t}$, and the max operator reflects shareholders' limited liability as explained above. The bank is subject to the balance sheet constraint, $B_{f,t} = E_{b,t} + D_t$, and the regulatory capital constraint

$$E_{b,t} \geq \phi_t B_{f,t}, \tag{16}$$

where ϕ_t is the capital requirement on entrepreneurial loans.

If the capital requirement is binding (as it turns out to be in equilibrium because partially insured deposits are always "cheaper" than equity financing), we can write the loans of the bank as $B_{f,t} = E_{b,t}/\phi_t$, its deposits as $D_t = (1-\phi_t)E_{b,t}/\phi_{,t}$. The threshold value of $\omega_{b,t+1}$ below which the bank fails is $\overline{\omega}_{b,t+1} = (1-\phi_t)\, R^d_t/\widetilde{R}^b_{t+1}$, since the bank fails when the realized return per unit of loans is lower than the associated debt repayment obligations, $(1-\phi_t)R_{d,t}$. Accordingly, the probability of failure of the bank is $\Psi_{b,t+1} = F_b(\overline{\omega}_{b,t+1})$, which will be driven by fluctuations in the aggregate return on loans, $\widetilde{R}^b_{t+1}$, as well as shocks to the distribution of the bank return shock $\omega_{b,t+1}$.

Using (2), the bank's objective function in (15) can be written as

$$NPV_{b,t} = \left\{\mathbb{E}\Lambda_{b,t+1}\left[1-\Gamma_b(\overline{\omega}_{b,t+1})\right]\frac{\widetilde{R}^b_{t+1}}{\phi_t} - v_{b,t}\right\}E_{b,t},$$

which is linear in the bank's scale as measured by $E_{b,t}$. So, banks' willingness to invest in loans with gross returns described by $\widetilde{R}^b_{t+1}$ and subject to a capital requirement ϕ_t requires having

$$\mathbb{E}\Lambda_{b,t+1}\left[1-\Gamma_b(\overline{\omega}_{b,t+1})\right]\widetilde{R}^b_{t+1} \geq \phi_t v_{b,t}, \tag{17}$$

which explains the expressions for the participation constraints (10) introduced in the entrepreneurial firms' problem. This constraint will hold with equality since it is not in the firms' interest to pay more for their loans than strictly needed.[12] Finally, we can write the banks' aggregate return on bank equity as $\rho_{b,t+1} = \left[1-\Gamma_b(\overline{\omega}_{j,t+1})\right]\widetilde{R}^b_{t+1}\phi_t$.

[12] In fact, any pricing of bank loans leading to $NPV_{b,t} > 0$ would make banks wish to expand $E_{b,t}$ unboundedly, which is incompatible with equilibrium. So, we could have directly written (10) with equality, as a sort of zero (rather than non-negative) profit condition.

2.3.6 Law of motion of bankers' net worth

Taking into account effects of retirement and the entry of new bankers, the evolution of active bankers' *aggregate* net worth can be described as:[13]

$$N_{b,t} = \theta_b \rho_{b,t} E_{b,t-1} + \iota_{b,t},$$

where $\iota_{b,t}$ is new bankers' net worth endowment (received from saving households), which we assume to be a proportion χ_b of the net worth of retiring bankers:

$$\iota_{b,t} = \chi_b (1-\theta_b) \rho_{b,t} E_{b,t-1}.$$

2.4 Consumption Goods Production Sector

We assume a continuum of monopolistically competitive firms that produce a differentiated intermediate good each. The output of each intermediate good producer $i \in [0,1]$ is then purchased by the perfectly competitive firms that produce the final consumption good.

Final good producers. Perfectly competitive final good producers combine the continuum of intermediate goods $y_t(i)$ into a single final good Y_t according to a CES technology

$$Y_t = \left(\int_0^1 y_t(i)^{\frac{1}{1+\theta}} di \right)^{1+\theta}$$

As a result of profit maximization and the zero profit condition, intermediate good firm i faces a downward-sloping demand curve given by

$$y_t(i) = \left(\frac{p_t(i)}{P_t} \right)^{-\frac{1+\theta}{\theta}} Y_t \tag{18}$$

The CES aggregate price index is defined as:

$$P_t = \left(\int_0^1 p_t(i)^{-\frac{1}{\theta}} di \right)^{-\theta} \tag{19}$$

where $p_t(i)$ is the price of each intermediate good. θ can simply be interpreted as the price elasticity of the demand for intermediate goods.

[13] To save on notation, we also use $N_{b,t+1}$ to denote the aggregate counterpart of what in (6) is an individual banker's net worth.

Intermediate good producers. Intermediate good producers combine labor $l_t(i)$ and capital $k_t(i)$ to produce $y_t(i)$ units of their intermediate good i using a constant-returns-to-scale technology:

$$y_t(i) = l_t(i)^{1-\alpha} k_{t-1}(i)^{\alpha}, \tag{20}$$

where α is the share of capital in production. Intermediate good firms are owned by the household dynasty and distribute profits or losses back to it.

Intermediate good producers set prices according to a typical Calvo setup. Prices are set for contractual periods of random length during which an indexation rule applies. As a result, firms do not maximize their profits period by period. Each contract expires with probability $1-\xi$ per period. When the contract expires, the intermediate producer i sets the new price $\widetilde{p}_t(i)$ to maximize the present discounted value of future real profits over the validity of the contract:

$$\mathbb{E}\left[\sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^{\tau} \left(\frac{\widetilde{p}_{t,t+\tau}(i)}{P_{t+\tau}} y_{t+\tau}(i) - mc_{t+\tau}(i) y_{t+\tau}(i) \right)\right]$$

subject to (19)

$$\widetilde{p}_{t,t+\tau}(i) = X_{t,t+\tau} \widetilde{p}_t(i),$$

and

$$y_{t+\tau}(i) = \left(\frac{X_{t,t+\tau} \widetilde{p}_t(i)}{P_{t+\tau}} \right)^{-\frac{1+\theta}{\theta}} Y_{t+\tau},$$

where $\Lambda_{t,t+\tau}$ is the patient household's stochastic discount factor between periods t and $t+\tau$, $mc_t(i)$ is the marginal cost for firm i at time t and $X_{t,t+\tau}$ is the indexation factor for prices that remain sticky between periods t and $t+\tau$. When the price remains sticky, the intermediate good producer is still able to index his price to the steady state inflation rate in the economy, which is the (gross) inflation rate targeted by the monetary authority, $\overline{\pi}$, so that:

$$X_{t,t+\tau} = \overline{\pi}^{\tau}.$$

2.5 Capital Production

Producers of capital combine investment, I_t, with the previous stock of capital, K_{t-1}, in order to produce new capital which can be sold at nominal price Q_t. The representative capital producing firm maximizes the expected discounted value to the household dynasty of its profits:

$$\max_{\{I_{t+j}\}} \mathbb{E} \sum_{j=0}^{\infty} \Lambda_{t,t+j} \left\{ \frac{Q_{t+j}}{P_{t+j}} \left[S\left(\frac{I_{t+j}}{K_{t+j-1}} \right) K_{t+j-1} \right] - I_{t+j} \right\} \tag{21}$$

where $S\left(\frac{I_{t+j}}{K_{t+j-1}}\right) K_{t+j-1}$ gives the units of new capital produced by investing I_{t+j}. The increasing and concave function $S(\cdot)$ captures adjustment costs, as in Jermann (1998):

$$S\left(\frac{I_t}{K_{t-1}}\right) = \frac{a_1}{1-\frac{1}{\psi_K}} \left(\frac{I_t}{K_{t-1}}\right)^{1-\frac{1}{\psi_K}} + a_2, \tag{22}$$

where a_1 and a_2 are chosen to guarantee that, in the steady state, the investment-to-capital ratio is equal to the depreciation rate and $S(I_t/K_{t-1})$ equals one (so that the implied adjustment costs are zero).

Finally, the law of motion of the capital stock can be written as

$$K_t = (1-\delta) K_{t-1} + S\left(\frac{I_t}{K_{t-1}}\right) K_{t-1}, \tag{23}$$

where δ is the depreciation rate of capital.

2.6 Capital Management Firms

The capital management cost s_t associated with households direct holdings of capital $K_{s,t}$ is a fee levied by a measure-one continuum of capital management firms operating with decreasing returns to scale. These firms have a convex cost function $z(K_{s,t})$ where $z(0) = 0$, $z'(K_{s,t}) > 0$ and $z''(K_{s,t}) > 0$. Under perfect competition, maximizing profits $\Xi_t = s_t K_{s,t} - z(K_{s,t})$ implies the first order condition

$$s_t = z'(K_{s,t}), \tag{24}$$

which determines the equilibrium fees for each $K_{s,t}$. We assume a quadratic cost function, $z(K_{s,t}) = \frac{\varsigma}{2} K_{s,t}^2$, with $\varsigma > 0$, so that (24) becomes

$$s_t = \varsigma K_{s,t}. \tag{25}$$

2.7 Policy Authorities

The monetary and macroprudential authorities set the one-period short-term nominal interest rate R_t and the capital requirement on loans, ϕ, respectively.

Monetary authority. The monetary authority sets the one-period short-term nominal interest rate R_t according to a Taylor-type policy rule:

$$R_t = R_{t-1}^{\rho_R} \left[\bar{R} \left(\frac{\pi_t}{\bar{\pi}} \right)^{\alpha_\pi} \left(\frac{GDP_t}{GDP_{t-1}} \right)^{\alpha_{GDP}} \right]^{(1-\rho_R)} \tag{26}$$

where ρ_R is the interest rate smoothing parameter, α_π and α_{GDP} determine the responses to deviations of inflation from its target level $\bar{\pi}$ and of GDP growth from its steady state, respectively. The steady state level of the nominal interest rate is denoted by $\bar{R}$. GDP_t is defined as the sum of aggregate consumption and capital investment.[14]

Macroprudential authority. The macroprudential authority sets the level of the capital requirement on loans, ϕ.

2.8 Other Details

To save on space, market clearing conditions and the equations describing the determination of the deposit loss rate due to bank default, Ω_t, the lump sum taxes needed to cover the cost of the DGS, T_t, banks' average default rate, $\Psi_{b,t}$, the rates of return on entrepreneurial and bank equity, $\rho_{f,t}(\omega)$ and $\rho_{b,t}(\omega)$, and the write-off rate on bank loans, $\Upsilon_{f,t}$, appear in Appendix A.

3. Mapping the Model to the Data

The model is calibrated using EA macroeconomic, banking and financial data for the period 2001:1-2016:4. Time is in quarters.

The calibration proceeds in two steps. First, we set a number of parameters to values commonly used in the literature. A second set of parameters are calibrated simultaneously so

[14]To avoid the counterintuitive impact of the resource costs of default on the measurement of output, we define $GDP_t = C_t + I_t$. A more comprehensive definition of aggregate output, Y_t, is provided in Appendix A.

as to match key steady state targets. Table 1 reports the calibration targets. [15] Both micro and macro data inform the calibration of the model.

[PLEASE INSERT TABLE 1 ABOUT HERE]

Pre-set parameters. Following convention, we set the Frisch elasticity of labor supply, η, equal to one, the capital-share parameter of the production function, α, equal to 0.30, and the depreciation rate of physical capital, δ, equal to 0.03. The labor disutility parameter, φ, which only affects the scale of the economy, is normalized to one. The average net markup of intermediate firms, θ, is 20% and the Calvo parameter, ξ, is 0.75 in line with values used in the literature. The bankruptcy cost parameters, μ_f and μ_b, are set equal to a common value of 0.30 for both banks and entrepreneurial firms.[16] Regarding the monetary policy rule, we choose a degree of interest rate inertia, ρ_R, of 0.75 , a moderate reaction to the output growth, α_{GDP}, of 0.1, and a reaction to inflation, α_π, of 1.5. Calibrating the parameter ψ_K in the adjustment cost function of capital producing firms would require the matching of second order moments, i.e. moments that require the specification of the stochastic structure of the model. Since the analysis in this paper abstract from aggregate shocks, we borrow from the calibration in Mendicino et al. (2018) a value for the parameter which is in the middle of the range of values used in the literature.

Parameters set with steady state targets. Although the second stage parameters are set jointly, some parameters can be linked to specific targets. The steady state inflation parameter, $\overline{\pi}$, and the discount factor, β, directly pin down the inflation target of 1.77% per annun and the yearly risk free rate of 2.32%. The bank capital requirement parameter, ϕ, is set to the

[15]Appendix B describes the data series and sources. Series expressed in euro amounts are deflated before computing the targets for their standard deviations. Targets expressed as ratios, interest rates or rates of returns are in levels.

[16]Similar values for μ are used, among others, in Carlstrom and Fuerst (1997), which refers to the evidence in Alderson and Betker (1995), where estimated liquidation costs are as high as 36% of asset value. Among non-listed bank-dependent firms these cost can be expected to be larger than among the highly levered publicly traded US corporations studied in Andrade and Kaplan (1998), where estimated financial distress costs fall in the range from 10% to 23%. Our choice of 30% is consistent with the large foreclosure, reorganization and liquidation costs found in some of the countries analyzed by Djankov et al. (2008).

reference capital requirement of 8% that characterized Basel I and II.[17] The share of insured deposits in bank debt κ is set to 0.54 in line with the evidence by Demirgüç-Kunt, Kane, and Laeven (2015) for EA countries.

The new entrepreneurs' endowment parameter, χ_e, helps to match the ratio of bank loans to non-financial corporations (NFC loans) over GDP. The new bankers' endowment parameter, χ_b, is used to make the steady state bank expected return on equity, ρ_b, equal to the average cost of equity of EA banks.[18] The parameter of the capital management cost function, ς, is set to match the share of physical capital directly held by savers in the model with an estimate, based on EA flow of funds data, of the proportion of assets of the NFC sector whose financing is not supported by banks.[19] In addition, the survival rate of bankers, θ_b, is used so that the shadow value of bank equity, υ_b, matches the average price-to-book ratio of banks over the calibration period.

We use the two idiosyncratic shocks, σ_f and σ_b, to match simultaneously the average probability of default of NFCs, the spread between the NFC loan rate and the risk free rate, and the average probability of bank default.

Table 2 reports all the parameter values resulting from our calibration. As shown in Table 1, we match very closely the eleven moments selected as targets for the calibration.

[PLEASE INSERT TABLE 2 ABOUT HERE]

4. Long-run Effects of Higher Capital Requirements

We use our quantitative model as a laboratory to explore the real and welfare effects of increases in capital requirements. To build some intuition, we start by assessing the long-run (steady state) effects of setting a time-invariant capital requirement, $\phi_t = \phi$, at levels above the 8% of the baseline calibration. Figure 1 and 2 report the long-run effects of alternative values of ϕ on

[17] Basel II featured a total regulatory capital requirement equal to 8% of "risk weighted assets". Thus calibrating PHI to 8% implies assuming that the loans in the model carry a full risk-weight, as it is the case for loans to unrated corporations under the standardized approach of Basel II and III.

[18] For estimates of the cost of equity faced by euro area banks, see Box 1 at: https://www.ecb.europa.eu/pub/pdf/other/eb201601_article01.en.pdf

[19] See Appendix B for details.

key macroeconomic aggregates and on household welfare, respectively.

[PLEASE INSERT FIGURES 1 AND 2 ABOUT HERE]

In the long run, higher capital requirements affect bank funding costs in two partially offsetting ways. On the one hand, an increase in capital requirements lowers bank defaults and, thus, the cost of bank debt funding. On the other, it increases the share of more expensive equity funding, producing a non-monotonic effect on the weighted average cost of bank funding. This explains the shape of the average real bank funding cost in Figure 1. Such cost gets transmitted to the cost of borrowing and, through it, to economic activity. When the probability of bank default is high, the first force dominates and credit supply actually expands (as shown in the credit to GDP panel of Figure 1) and, with it, investment and GDP (not shown). However, once the probability of bank failure and the deposit spread become sufficiently close to zero, tighter capital requirements raise the cost of credit and reduce investment and GDP. In contrast, the cost of deposit insurance to taxpayers falls monotonically with ϕ since the reduction in bank leverage unambiguously reduces the probability of bank failure and the costs to the DGS (see Figure 1).

Figure 1 also displays the long-run welfare implications of changes in capital requirements. Household welfare is defined in a recursive form as

$$V_t = U(C_t, L_t) + \beta E_t V_{t+1}. \tag{27}$$

Alternative capital requirement levels are compared in consumption-equivalent terms w.r.t. to the reference capital requirement of 8%.[20] The hump shape in the welfare gains reflects the changing nature of the above trade off as capital requirements rise. In addition to the calibrated value of 8% in the figures we also signal two other levels: (i) the level that maximizes household welfare in the calibrated model economy (9.54%); (ii) the Basel III benchmark capital requirement level (10.5%).[21] In the long-run, both levels of capital requirements significantly reduce the probability of bank default and, thus, the deposit spread and the social cost of bank

[20]The consumption equivalent measure is calculated as the percentage increase in steady-state consumption that would make welfare under a capital requirement of 8% equal to welfare under the alternative policy.

[21]Basel III imposes a minimum capital ratio of 8%, a capital conservation buffer (CCB) of up to 2.5% and a countercyclical capital buffer (CCyB) of up to 2.5%, meaning that, over the credit cycle, the implied

default. As a result, increasing capital requirements from the calibrated 8% to higher levels generates positive long-run welfare effects. However, while the level that maximizes household welfare implies a slightly higher credit level, under Basel III the long-run level of credit is slightly below the initial one.

5. The Transition to Higher Capital Requirements

The results presented above show that higher capital requirements are very effective in reducing the probability of bank failure, and the real costs associated with it, but at the cost of potentially reducing, beyond some point, the availability of bank credit in the long run. In this section, we examine the transition to higher capital requirements. The experiment is conducted as follows:

- In period $t = 1$, we start the economy at the deterministic steady state associated with the initial capital requirement, ϕ_1.
- For periods $t = 2, 3, 4, ...$ we compute the response of the economy (transition) to an anticipated gradual increase in ϕ_t up to the new time-invariant long-run level $\bar{\phi}$, with

$$\phi_t = \lambda\bar{\phi} + (1 - \lambda)\phi_{t-1}. \tag{28}$$

  where λ is a partial adjustment parameter that shapes the speed of implementation of the increase in the long-run requirement.[22]

- The speed of implementation is known to all agents at the beginning of period $t = 2$ and, during the transition, the economy is not subject to aggregate shocks.[23] In the description of the results below, we will refer to T as the implementation horizon.[24]

capital requirement will typically range between 8% and 13%. Attributing a 10.5% in steady state is consistent with assuming a fully-loaded CCB and a neutral or non-activated CCyB. The analysis presented in this paper abstracts from unsustainable credit developments against which the CCyB is intended to fight as suggested by the CCyB guidelines.

[22] The adjustment parameter λ lies between 0 and 1. The closer it is to 1 the faster the speed of adjustment.

[23] Thus we compute the model implications for changes in ϕ by solving the system of non-linear equations given by the set of first order conditions and market clearing conditions for the perfect foresight path using the Newton-Raphson algorithm.

[24] T is the period at which the 99th percent of the adjustment is completed.

5.1 The Baseline Experiment

Our baseline experiment assumes an increase in the capital requirement of 2.5 pp (up to the Basel III level) and an implementation horizon of 8 quarters ($T = 8$). In addition, the monetary authority follows the calibrated Taylor rule as in (26). The solid line in Figure 2 displays the results of the baseline transition.

[PLEASE INSERT FIGURE 2 ABOUT HERE]

Higher capital requirements make the financial system more solid and reduce the social costs associated with bank default. Aggregate consumption increases, mainly due to lower fiscal costs of bank default. However, at the same time, the capital increase causes a tightening of bank loan supply on impact. Lending spreads rise and lending volumes decline, which reduces investment demand from firms. Business investment falls substantially.

The nominal interest rate (determined by the Taylor-rule) is reduced gradually in response to the fall in inflation and real activity. The short real interest rate first increases, reflecting the slow reaction of monetary policy, before falling in a persistent manner. The fall in business investment is therefore moderated by the monetary policy driven reduction in real interest rates but overall the contractionary effects of the rise in lending spreads dominate. Aggregate economic activity contracts and inflation undershoots the target. The increase in capital requirements affects the economy very much as a demand shock would. Figure 2 also compares a 2.5pp (solid line) with a 1 pp increase (dashed line). The larger increase in capital leads to larger long-run financial stability gains, however it also implies more substantial transition costs.

5.2 Implementation Horizon and Monetary Policy Responsiveness

A crucial determinant of the size of those costs is the horizon over which the increase in capital requirements comes into force. So far we assumed a 8-quarter horizon (2 years). In Figure 3 we consider an implementation horizon of 20 quarters (5 years), resembling that envisaged under Basel III. A slower phase-in period mitigates the transition costs. It gives banks time to raise capital through retained profits thus allowing them to better maintain lending over the transition period. This is particularly important for large capital requirement increases such as the ones required by Basel III.

[PLEASE INSERT FIGURE 3 ABOUT HERE]

The short term costs from the imposition of higher bank capital requirements may be sizable, especially under a short implementation horizon. Some of these costs arise through a standard aggregate demand channel and, hence, may be affected by the response of monetary policy to the implied real and nominal developments. In particular, the extent to which the monetary authority responds to deviations of inflation from the target is key in determining how much output and inflation can fluctuate in the face of demand shocks. In Figure 4, we examine the capital requirement increase under different assumptions regarding the responsiveness of monetary policy to inflation: baseline Taylor-type rule ($\alpha_\pi = 1.5$, solid line) and a more aggressive rule ($\alpha_\pi = 10$, dashed line). The key message is that while the net long term benefits of higher capital are the same in the two scenarios, the short term costs differ significantly. However, the prospect that monetary policy would respond more aggressively to inflation deviations from the target leads to lower deflation along the transition path and thus lower output losses, eventually requiring a policy that, if anything, involves a lower decline in the policy interest rate.

[PLEASE INSERT FIGURE 4 ABOUT HERE]

5.3 Impact of the Effective Lower Bound

We now explore what happens when the policy rate is unable to respond as much as desired due to a binding ELB.[25] In Figure 5 we compare the effects of a 2.5 pp increase in capital requirements implemented over an 8-quarter period in the case in which the ELB is imposed (bashed line) with the baseline case in which the ELB does not bind (solid line).

[PLEASE INSERT FIGURE 5 ABOUT HERE]

[25]For the purposes of this analysis, the ELB is assumed to be 15 bps below the baseline short term interest rate. This is consistent with the average EONIA rate of 15.9 bps observed during the initial period of implementation of Basel III (2012Q1-2013Q4)

The transition costs are particularly large when monetary policy cannot be accommodative. Once the policy rate hits the ELB, monetary policy cannot reduce the interest rate in response to the fall in inflation and GDP. Inflation declines by more and this increases short-term real interest rates further. Consumption no longer supports overall demand as much as in the baseline. All demand components as well as GDP show a greater decline. In particular, higher real interest rates at the ELB leads to a fall in consumption. When monetary policy is constrained by the ELB, the negative effects on real activity are very sizable.

5.4 Importance of Bank Risk

Making banks safer is a key reason for increasing capital requirements. Bank risk determines the size of the benefits from higher capital requirements so varying it modifies both the long run gains and the welfare trade-offs associated with the transition to higher capital requirements.

As discussed when analyzing the long-run effects in Section 4, higher capital requirements have two opposing effects on banks' cost of funding. Other things equal, a higher share of expensive equity increases banks' weighted average cost of funds. However, making banks safer lowers the cost of bank debt funding, producing the opposite effect on the weighted average cost of funds. When the risk of bank failure is high, the reduction coming from the lower cost of deposit funding dominates and the benefits of higher capital requirements are larger. These trade-offs are also visible during the transition.

Figure 6 reports the transition to a 2.5 pp higher capital requirement in the baseline model (black lines) and in a version of the model that features higher banks' idiosyncratic default risk (red lines), i.e. larger dispersion of the idiosyncratic shocks to banks' loan portfolio returns, σ_b. We assume that before the increase in capital requirements takes place the expected average probability bank default is about 3.5%.[26] The figure confirms that not only the long-run benefits are larger, but also the short-run costs are smaller in economies with a more risky banking sector. Expectations of larger long-run benefits reduce the short run costs in economies with a

[26] At the beginning of the implementation of Basel III, Moody's expected default frequencies (EDF) for European financial institutions was between 3% and 4%. We mimic this in the model by increasing σ_b by 20% relative to the baseline calibration.

more risky banking sector.

[PLEASE INSERT FIGURE 6 ABOUT HERE]

6. Optimal Capital Requirement Increase

Section 4 investigates the net long-run benefits of higher capital requirements. We now assess the optimality of capital requirement increases taking into account the long run effects as well as the cost and benefits realized along the transition to the higher level. As shown in previous sections increases in capital requirements can lead to long run benefits but also to transition costs and the latter can be quite substantial in some circumstances. Thus, the net effects of capital requirements increases depend on which of the two effects dominate.

Alternative capital requirement levels are compared in consumption-equivalent terms, taking the calibrated capital requirement of 8% as the baseline.[27] The results crucially depend on the extent to which monetary policy is able to offset the negative aggregate demand consequences of the capital increase, on the riskness of the banking sector, and on the length of the implementation horizon. Table 3 reports the results for a rich variety of scenarios regarding these three dimensions.

[PLEASE INSERT TABLE 3 ABOUT HERE]

Baseline case. We start by exploring the welfare implications of higher levels of capital requirements in the no ELB regime. Figure 7 reports the welfare gains of higher capital requirements with (black line) and without (red line) the welfare effects over the transition. We assume an implementation horizon of 8 quarters. Once we include the effects over the transition, the welfare curve shifts downward, suggesting that neglecting the transition overestimates the welfare effects of changes in capital requirements. Panel I of Table 3 (column A) shows that a slower implementation horizon delivers a higher optimal increase in capital requirements and somewhat larger welfare gains.

[PLEASE INSERT FIGURE 7 ABOUT HERE]

[27]We search over a grid that allows capital requirements to increase from 0pp to 3pp with a step 0.005.

When monetary policy responds more aggressively to inflation, the optimal long run capital increases are more sizable. Column B considers the case of a strict inflation targeting central bank. This is an especially important regime since monetary policy completely offsets the distortions due to nominal rigidities by keeping prices stable at all times. A monetary authority which pursues the goal of full price stability and strongly reacts to any change in inflation, allows the macroprudential authority to optimally implement a larger increase in capital requirements. As a results, the net welfare benefits from the increase in capital requirements are the largest.

Effective lower bound. Next, we consider the case of an increase in capital requirements implemented in the proximity of the ELB. Figure 8 also considers the case of the policy rate to being either 5, 10 or 15 bp away from the ELB. In a proximity of the ELB, the ability of monetary policy to mitigate the transitional effects of the capital increase is limited. The dashed curves in Figure 8 highlight that the closer is the ELB the larger are the welfare losses of increasing capital requirements by too much.

As reported in panel I of Table 3 (column C and D), being closer to the ELB reduces both the optimal capital level and the welfare gains implied by such policy change. Whenever, the ELB becomes an effective constraint, the speed of implementation becomes a more crucial factor compared to the case in which the policy rate can fall into negative territory. A slow implementation horizon reduces the probability of hitting the ELB and allows for relatively larger capital requirements increases.

Higher banking risk. In the previous section, we have shown that the long-run benefits of higher capital requirements are larger and the costs are smaller when bank risk is higher. By comparing Figure 7 and 8, we can argue that the optimal capital level and the welfare gains associated to it are sizably higher in an economy with higher bank risk. Panel II of Table 3 (column A) reports that in the absence of an ELB, the optimal capital level is close to the Basel III prescriptions of a 2.5 pp increase. This result holds even in the case of a strict inflation targeting central bank (column B). As in the baseline case, a stronger monetary policy response to deviations of inflation from the target, mitigates the transition costs and allows the macroprudential authority to reach higher welfare gains by implementing a larger capital requirement increase.

Considering what happens when the policy interest rate is close to the ELB (column C and D) in an economy with more fragile banks is an interesting case as it resembles the EA economy during the recent financial crisis. The optimal capital requirement is reduced by the proximity of the ELB but it remains much higher than under the baseline bank riskness.

[PLEASE INSERT FIGURE 8 ABOUT HERE]

7. Conclusions

This paper assesses the macroeconomic implications of increasing capital requirements. We argue that the conduct of monetary policy is key in assessing the net benefits of capital requirement increases. In the presence of accommodative monetary policy, the transition costs are moderate because monetary policy reacts to offset the contractionary impact of higher capital requirements. In contrast, when the policy rate hits the lower bound, monetary policy loses the ability to maintain aggregate demand leading to larger short term costs.

Short-run real and welfare effects of higher capital requirements also depend on the fragility of the banking system. Consistently with standard microprudential goals, with more fragile banks an increase in capital requirements generate larger benefits while reducing the costs, thus, a larger increase in capital requirements is optimal.

References

[1] Alderson, M. J., Betker, B. L., 1995. Liquidation costs and capital structure. *Journal of Financial Economics* 39, 45-69.

[2] Andrade, G., Kaplan, S. N., 1998. How costly is financial (not economic) distress? Evidence from highly leveraged transactions that became distressed. *Journal of Finance* 53, 1443-1493.

[3] Begenau, J., 2016. Capital Requirements, Risk Choice, and Liquidity Provision in a Business Cycle Model, Harvard Business School, mimeo.

[4] Bernanke, B., Gertler, M., Gilchrist, S., 1999. The Financial Accelerator in a Quantitative Business Cycle Framework. *Handbook of Macroeconomics* 1, 1341-1393.

[5] Bianchi, J., Mendoza, E., 2011. Overborrowing, Financial Crises and 'Macro-Prudential' Policy. IMF Working Paper No. 11/24.

[6] Brunnermeier, M., Sannikov, Y., 2014. A Macroeconomic Model with a Financial Sector. *American Economic Review* 104, 379-421.

[7] Calvo, G. A., 1983. Staggered Prices in a Utility-Maximizing Framework. *Journal of Monetary Economics* 12, 383-398.

[8] Carlstrom, C., Fuerst, T., 1997. Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis. *American Economic Review* 87, 893-910.

[9] Carrillo, J., Mendoza, E., Nuguer, V., Roldan, J., 2017. Tight Money-Tight Credit: Coordination Failure in the Conduct of Monetary and Financial Policies. NBER Working paper 23151.

[10] Christiano, L., Eichenbaum, M. and Rebelo, S., 2011. When Is the Government Spending Multiplier Large? *Journal of Political Economy* 116, 78-121.

[11] Christiano, L., Motto R., Rostagno M., 2008. Shocks, Structures or Monetary Policies? The Euro Area and US after 2001. *Journal of Economic Dynamics & Control* 32, 2476-2506.

[12] Christiano, L., Motto R., Rostagno M., 2014. Risk Shocks. *American Economic Review* 104, 27-65.

[13] Christiano, L., Ikeda D., 2017. Bank Leverage and Social Welfare. *American Economic Review Papers and Proceedings*, forthcoming.

[14] Clerc, L., Derviz, A., Mendicino, C., Moyen, S., Nikolov, K., Stracca, L., Suarez, J., Vardoulakis, A., 2015. Capital Regulation in a Macroeconomic Model with Three Layers of Default. *International Journal of Central Banking* 11, 9-63.

[15] Collard, F., Dellas, H., Diba, B., Loisel, O., 2017. Optimal Monetary and Prudential Policies. *American Economic Journal: Macroeconomics* 9, 40-87.

[16] De Paoli, B. and Paustian, M., 2013. Coordinating Monetary and Macroprudential policies. *FRB of New York Staff Report* 653.

[17] Demirgüç-Kunt, A., Kane, E., Laeven, L., 2015. Deposit Insurance around the World: A Comprehensive Analysis and Database. *Journal of financial stability* 20, 155-183.

[18] Dewatripont, M., Tirole, J., 1994. A Theory of Debt and Equity: Diversity of Securities and Manager-Shareholder Congruence. *Quarterly Journal of Economics* 109(4), 1027-1054.

[19] Djankov, S., Hart, O., McLiesh, C., Shleifer, A., 2008. Debt Enforcement around the World. *Journal of Political Economy* 116, 1105-1149.

[20] Erceg, C., Linde, J., 2014. Is There a Free Fiscal Lunch in a Liquidity Trap? *Journal of the European Economic Association* 12, 73-107

[21] Eggertson, G., Ferrero, A., Raffo, A., 2014. Can Structural Reform Help Europe? *Journal of Monetary Economics* 61, 2-22.

[22] Gerali, A., Neri, S., Sessa, L., Signoretti, F., 2010. Credit and Banking in a DSGE Model of the Euro Area. *Journal of Money, Credit and Banking* 42, 107-141.

[23] Gersbach, H., Hahn, V., Liu, Y., 2018. Macroprudential Policy in the New Keynesian World. ETH Zurich, mimeo.

[24] Gertler, M., Kiyotaki, N., 2010. Financial Intermediation and Credit Policy in Business Cycle Analysis. *Handbook of Monetary Economics* 3, 547-599.

[25] Gertler, M., Kiyotaki, N., Queralto, A., 2012. Financial Crises, Bank Risk Exposure and Government Financial Policy. *Journal of Monetary Economics* 59, 517-534.

[26] Jeanne, O., Korinek, A., 2013. Macroprudential Regulation Versus Mopping Up After the Crash. NBER Working Paper No. 18675.

[27] Jermann, U., Gomes, G. and Schmid, L., 2016. Stocky Leverage. *American Economic Review* Volume 106 No 12, December, 3800-3828.

[28] Kareken, J.H., Wallace, N., 1978. Deposit Insurance and Bank Regulation: A partial-equilibrium exposition. *Journal of Business*, 413-438.

[29] Kashyap, A.K., Stein, J.C., 2004. Cyclical Implications of the Basel II Capital Standards. *Economic Perspectives* 28(1), 18-33.

[30] Kiley, M. T., Sim, J., 2017. Optimal Monetary and Macroprudential Policies: Gains and Pitfalls in a Model of Financial Intermediation. *Journal of Macroeconomics* 54, 232-259.

[31] Lambertini, L., Mendicino, C., Punzi, M., 2013. Leaning against Boom-Bust Cycles in Credit and Housing Prices. *Journal of Economic Dynamics and Control* 37, 1500-1522.

[32] Leduc, S., Natal, J.M., 2016. Monetary and Macroprudential Policies in a Leveraged Economy. *Economic Journal.*

[33] Martinez-Miera, D., Suarez, J., 2014. Banks' Endogenous Systemic Risk Taking. CEMFI, mimeo.

[34] Mendicino, C., Nikolov, K., Suarez, J., Supera, D., 2018. Optimal Dynamic Capital Requirement. *Journal of Money Credit and Banking*, forthcoming.

[35] Nguyen, T. T., 2014. Bank Capital Requirements: A Quantitative Analysis. Fisher College of Business Working Paper.

[36] Repullo, R., Suarez, J., 2013. The Procyclical Effects of Bank Capital regulation. *Review of Financial Studies* 26, 452-490.

[37] Schmitt-Grohe, S., Uribe, M., 2005. Optimal Fiscal and Monetary Policy in a Medium-Scale Macroeconomic Model, in Gertler, Mark and Kenneth Rogoff, eds., NBER Macroeconomics Annual 2005, MIT Press: Cambridge MA, 383-425

[38] Schmitt-Grohe, S., Uribe, M., 2007. Optimal Simple and Implementable Monetary and Fiscal Rules. *Journal of Monetary Economics* 54, 1702-1725.

[39] Van Den Heuvel, S.J., 2008. The Welfare Cost of Bank Capital Requirements. *Journal of Monetary Economics* 55, 298-220.

[40] Woodford, M., 2000. Pitfalls of forward-looking monetary policy. *American Economic Review* 90, 100-104.

Table 1: Model fit

Targets	Definition	Data	Model
Real risk-free rate	$(\beta^{-1}-1)\times 400$	2.32	2.32
Inflation	$(\overline{\pi}-1)\times 400$	1.77	1.77
Capital requirements	ϕ	0.08	0.08
Share of insured deposits	κ	0.54	0.54
NFCs' default	$F_f(\overline{\omega}_f)\times 400$	2.646	2.556
NFC loans to GDP	b_f/GDP	1.897	1.893
Spread NFC loans	$(R^f-R)\times 400$	1.244	1.295
Banks' default	$F_b(\overline{\omega}_b)\times 400$	0.665	0.665
Real equity return of banks	$(\rho_b-1)\times 400$	7.066	6.937
Banks price to book ratio	v_b	1.148	1.148
Capital share of households	K_s/K	0.22	0.219

Table 2: Model parameters

Preset parameters					
Disutility of labor	φ	1	Banks bankruptcy cost	μ_b	0.3
Frisch elasticity of labor	η	1	Capital adjustment cost parameter	ψ_k	4.567
Capital share in production	α	0.3	Price elasticity of demand	θ	0.2
Depreciation rate of capital	δ	0.03	Calvo probability	ξ	0.75
Population of entrepreneurs	n_e	1	Smoothing parameter (Taylor rule)	ρ_R	0.75
NFC bankruptcy cost	μ_f	0.3	Inflation response (Taylor rule)	α_π	1.5
Survival rate of entrepreneurs	θ_e	0.975	Output growth response (Taylor rule)	α_{GDP}	0.1
Population of bankers	n_b	1			
Calibrated parameters					
Discount factor of consumers	β	0.994	STD iid risk for banks	σ_b	0.029
Capital requirement for banks	ϕ	0.08	Survival rate of bankers	θ_b	0.873
Share of insured deposits	κ	0.54	Transfer from HH to entrepreneurs	χ_e	0.001
Steady-state inflation	$\overline{\pi}$	1.004	Transfer from HH to bankers	χ_b	0.859
STD iid risk for entrepreneurs	σ_f	0.298	Capital management cost	ς	0.006

Table 3: Optimal capital requirement increase when the speed of implementation is held fixed

		No ELB		ELB	
		A. Taylor rule	**B. Strict IT**	**C. -10 bp**	**D. -5 bp**
I. Baseline bank risk					
	Optimal increase	**1.19**	**1.22**	**1.16**	**0.85**
8Q	ELB	-	-	1Q	4Q
	Welfare gains	0.0588%	0.0604%	0.0588%	0.0528%
	Optimal increase	**1.26**	**1.29**	**1.26**	**0.87**
40Q	ELB	-	-	0Q	3Q
	Welfare gains	0.0601%	0.0615%	0.0601%	0.0561%
II. High bank risk					
	Optimal increase	**1.96**	**1.98**	**1.69**	**1.26**
8Q	ELB	-	-	3Q	5Q
	Welfare gains	0.1932%	0.1941%	0.1882%	0.1700%
	Optimal increase	**2.08**	**2.10**	**1.95**	**1.33**
40Q	ELB	-	-	2Q	5Q
	Welfare gains	0.1953%	0.1956%	0.1950%	0.1776%

Capital ratio increases are in percentage points. ELB refers to the number of quarters during which the policy rate is at the ELB following the implementation of the capital ratio increase. Welfare gains are computed as the percentage point increase in steady-state consumption. The optimal capital ratio increase without transitional cost is of 1.38 pp for the baseline case and of 2.19 pp in the high bank risk case. Welfare gains without transitional costs are of 0.0777619 % for the baseline case and of 0.238216 % for the high bank risk case.

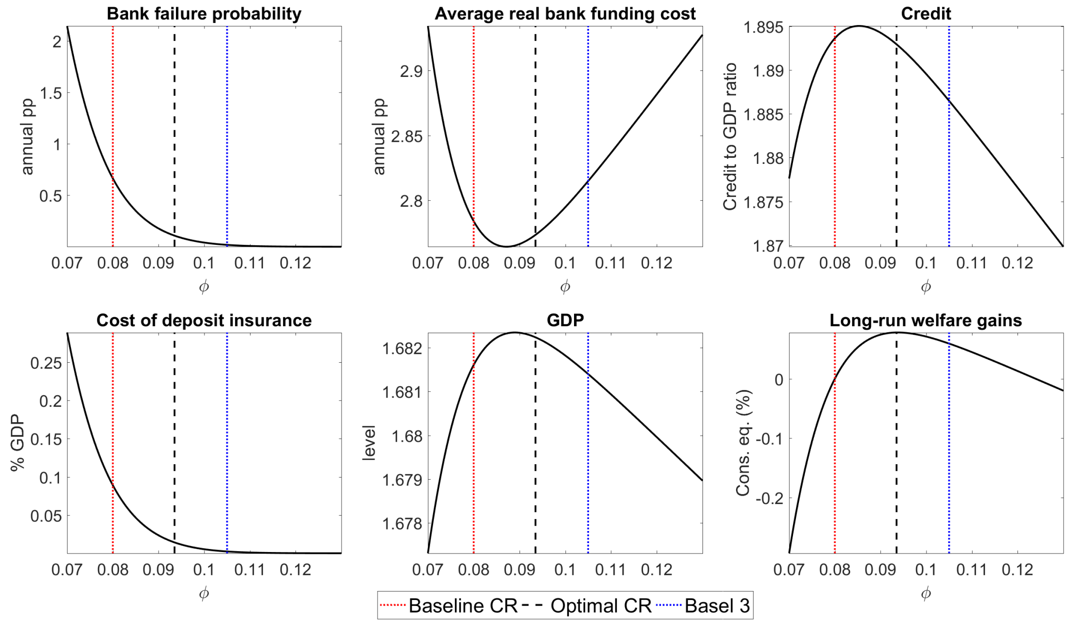

Figure 1: Impact of the capital requirement (CR) on key variables

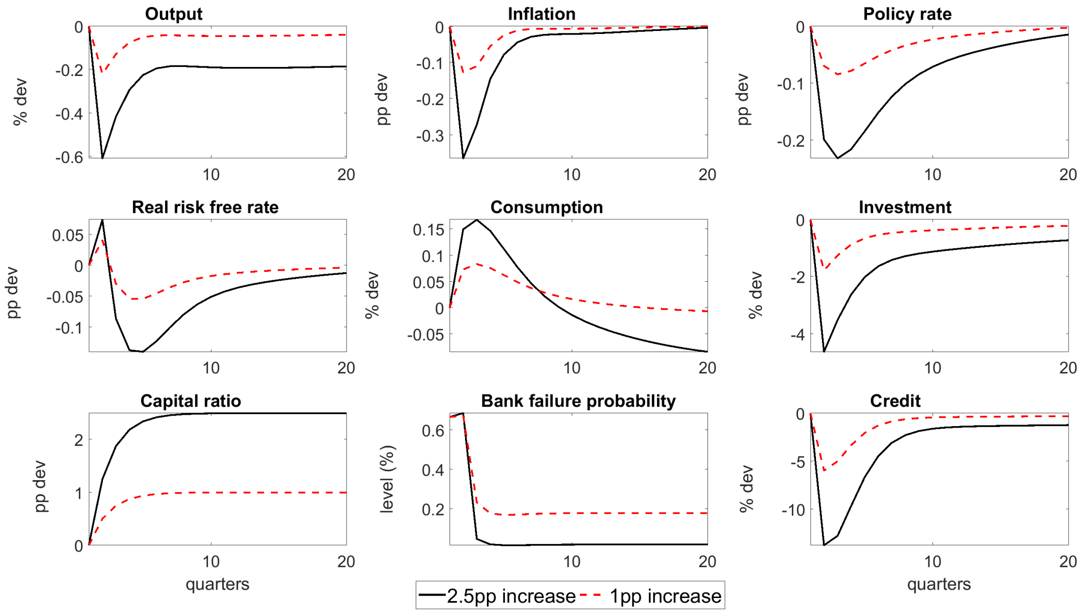

Figure 2: Transitional effects under different increases in the long-run capital requirement

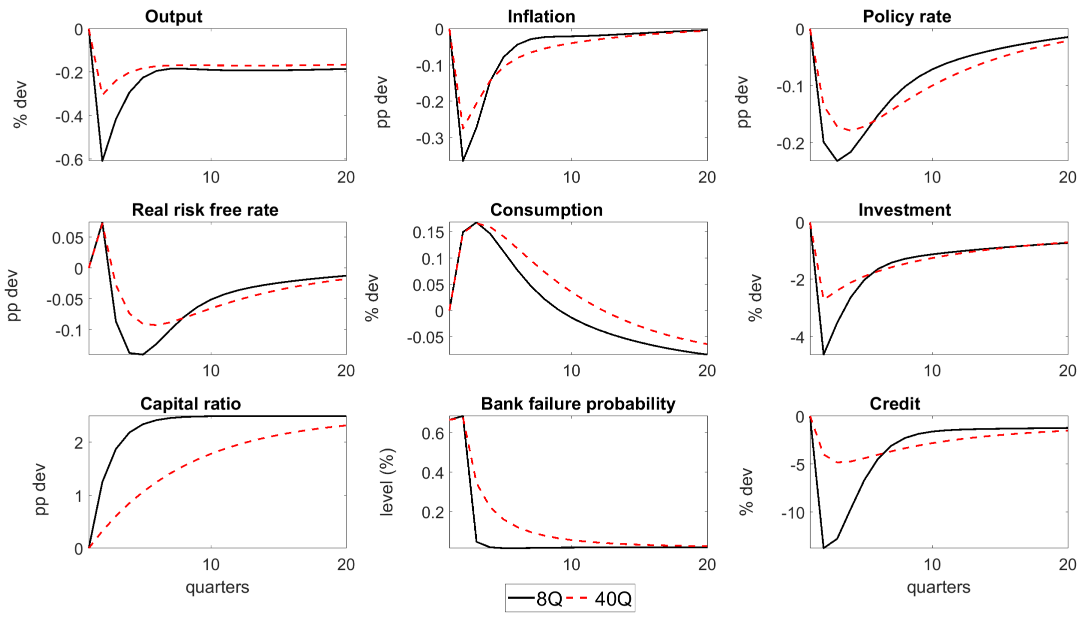

Figure 3: Transitional effects under different speeds of implementation of the increase in the capital requirements

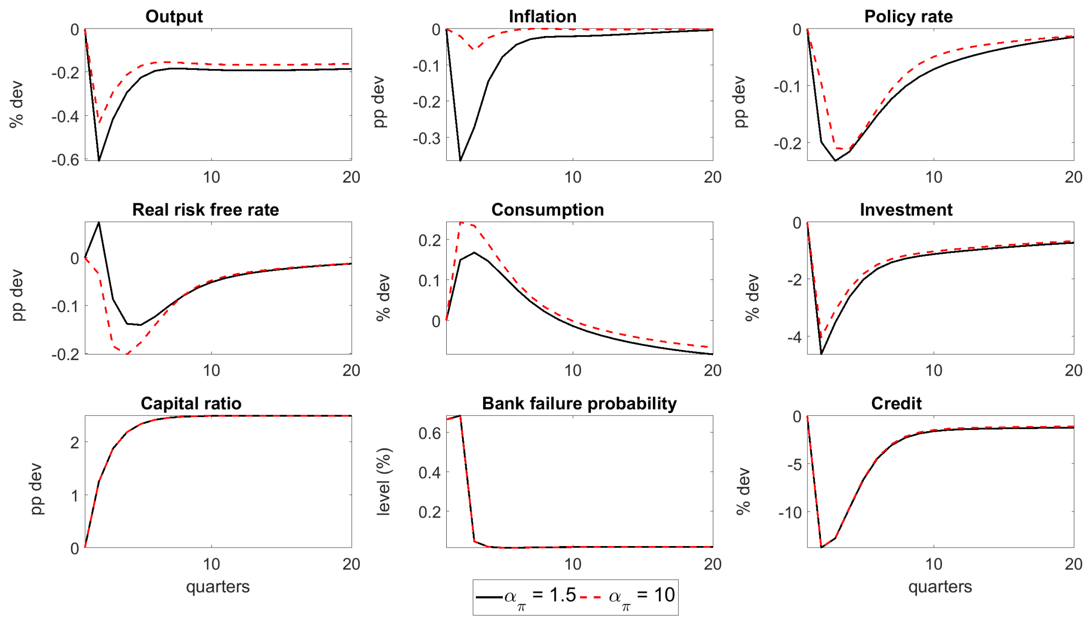

Figure 4: Transitional effects under different responses to inflation in the Taylor rule

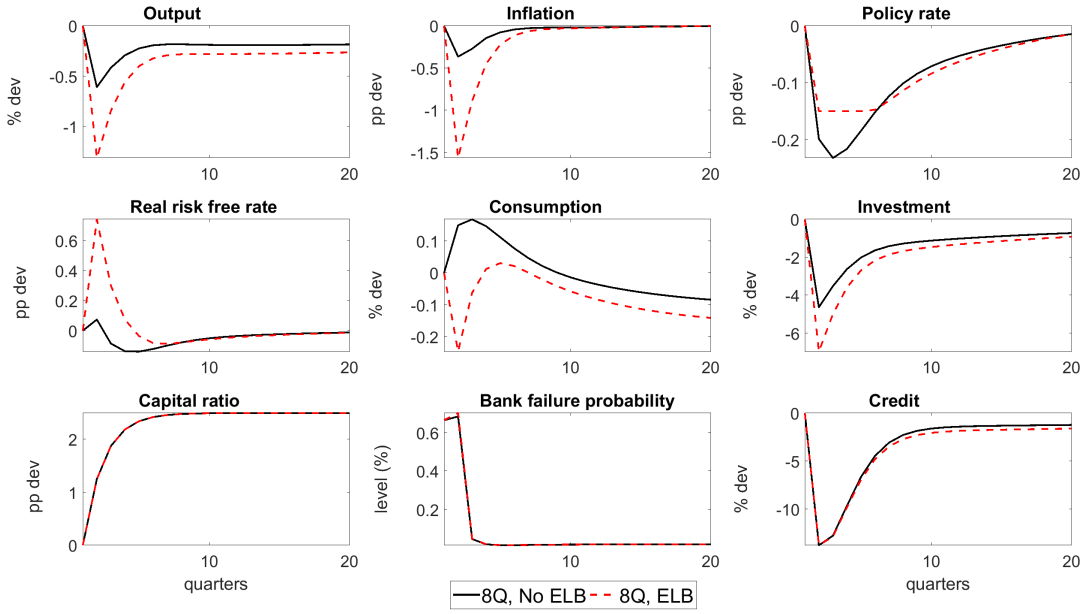

Figure 5: Transitional effects with and without an effective lower bound (ELB)

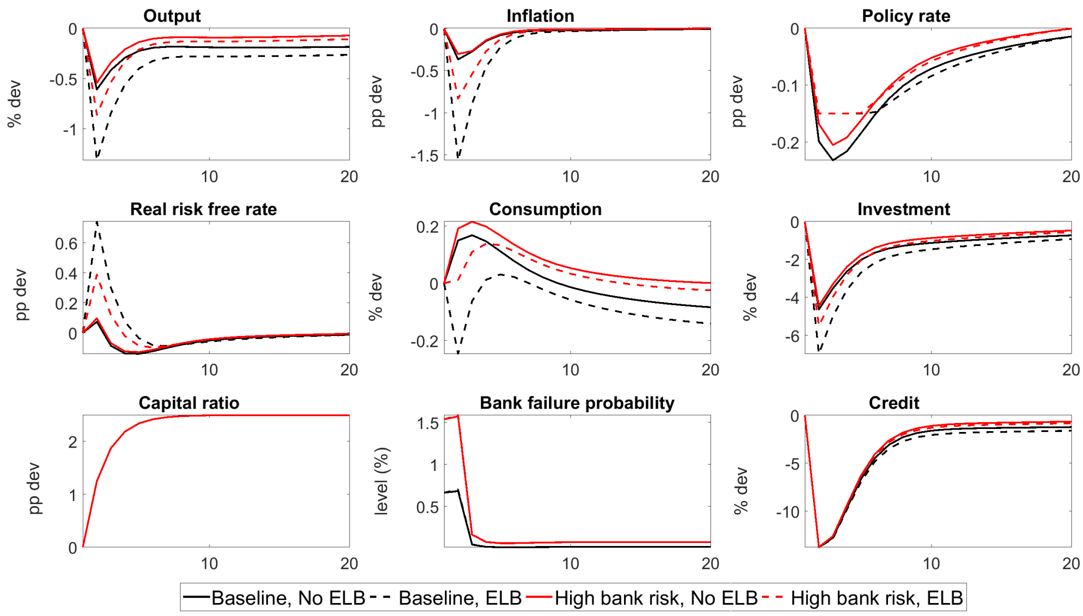

Figure 6: Transitional effects with variation in bank risk, with and without an ELB

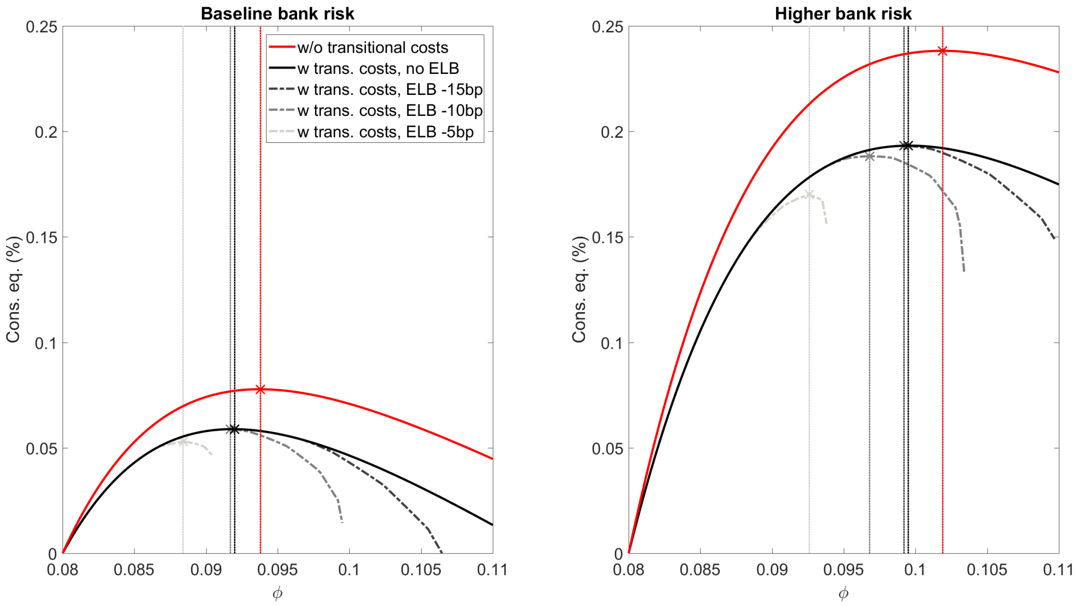

Figure 7: Optimal long-run capital requirement with and without consideration of transitional costs

Technical Appendices

A Model Details

Market Clearing Conditions
Aggregate supply:

$$Y_t = \frac{z_t L_t^{1-\alpha} K_{t-1}^{\alpha}}{\Delta_t}, \tag{29}$$

where $\Delta_t = \int_0^1 \left(\frac{p_t(i)}{P_t}\right)^{-\frac{1+\theta}{\theta}} di.$
Equilibrium in the market for physical capital:

$$K_t = K_{s,t} + K_{f,t}. \tag{30}$$

Summary of balance sheet constraints and market clearing condition for banks:

$$B_{f,t} = E_{b,t} + D_t. \tag{31}$$

Equilibrium in the market for entreprenurial equity:

$$A_t = N_{e,t}.$$

Equilibrium in the market for bank equity:

$$E_{b,t} = N_{b,t}.$$

Definitions
The expected loss rate on bank deposits due to bank default is

$$\Omega_t = \frac{\left[\omega_{b,t} - \Gamma_b(\overline{\omega}_{b,t}) + \mu_b G_b(\overline{\omega}_{b,t})\right] \widetilde{R}_{t+1}^b B_{f,t}}{D_{t-1}}.$$

The losses covered by the DGS following bank default are $\kappa\Omega_t D_{t-1}$, so the lump-sum taxes changed on households to finance the DGS are:

$$T_t = \kappa\Omega_t D_{t-1}. \tag{32}$$

The rest of the losses due to bank default are directly assumed by the depositors (as a lower than promised return on the uninsured fraction of their deposit portfolio), so the nominal effective return on deposits is $\widetilde{R}_t^d$ as written in (5).

The rate of return on entrepreneurial equity can be written as

Similarly the rate of return on bank equity can be expressed as

The bank default rate (and ex ante probability of bank failure) is given by:

$$\Psi_{b,t} = F_b(\overline{\omega}_{b,t}). \tag{33}$$

We define the write-off rate (write-offs/loans) on loans to entrepreneurs that the model generates, $\Upsilon_{f,t}$, as the product of the fraction of defaulted entrepreneurial loans, $F_f\left(\overline{\omega}_{f,t}\right)$, and the average losses per unit of lending, which can be found from our prior derivations:

$$\begin{aligned} \Upsilon_{f,t} &= F_f\left(\overline{\omega}_{f,t}\right)\left[\frac{B_{f,t-1} - \frac{(1-\mu_f)}{F_f\left(\overline{\omega}_{f,t}\right)}\left(\int_0^{\overline{\omega}_{f,t}} \omega f_f\left(\omega\right) d\omega\right) R_t^K Q_{t-1} K_{f,t-1}}{B_{f,t-1}}\right] \\ &= F_f\left(\overline{\omega}_{f,t}\right) - (1-\mu_f) G_f(\overline{\omega}_{f,t}) R_t^K \frac{Q_{t-1} K_{f,t-1}}{B_{f,t-1}}. \end{aligned} \tag{34}$$

B Data used in the calibration

- Gross Domestic Product: Gross domestic product at market price, Chain linked volumes, reference year 2005, Euro. Source: ESA - ESA95 National Accounts, Macroeconomic Statistics (S/MAC), European Central Bank.

- GDP Deflator: Gross domestic product at market price, Deflator, National currency, Working day and seasonally adjusted, Index. Source: ESA - ESA95 National Accounts, Macroeconomic Statistics (S/MAC), European Central Bank.

- Business Loans: Outstanding amounts at the end of the period (stocks), MFIs excluding ESCB reporting sector - Loans, Total maturity, All currencies combined - Euro area (changing composition) counterpart, Non-Financial corporations (S.11) sector, denominated in Euro. Source: MFI Balance Sheet Items Statistics (BSI Statistics), Monetary and Financial Statistics (S/MFS), European Central Bank.[28]

[28] All monetary financial institutions in the EA are legally obliged to report data from their business and accounting systems to the National Central Banks of the member states where they reside. These in turn report national aggregates to the ECB. The census of MFIs in the euro area (list of MFIs) is published by the ECB (see http://www.ecb.int/stats/money/mfi/list/html/index.en.html).

- Households Loans: Outstanding amounts at the end of the period (stocks), MFIs excluding ESCB reporting sector - Loans, Total maturity, All currencies combined - Euro area (changing composition) counterpart, Households and non-profit institutions serving households (S.14 & S.15) sector, denominated in Euro. Source: MFI Balance Sheet Items Statistics (BSI Statistics), Monetary and Financial Statistics (S/MFS), European Central Bank.

- Write-offs: Other adjustments, MFIs excluding ESCB reporting sector - Loans, Total maturity, All currencies combined - Euro area (changing composition) counterpart, denominated in Euro, as percentage of total outstanding loans for the same sector. Source: MFI Balance Sheet Items Statistics (BSI Statistics), Monetary and Financial Statistics (S/MFS), European Central Bank.

- Housing Investment: Gross fixed capital formation: housing, Current prices - Euro, divided by the Gross domestic product at market price, Deflator. Source: ESA - ESA95 National Accounts, Macroeconomic Statistics (S/MAC), European Central Bank.

- Housing Wealth: Household housing wealth (net) - Reporting institutional sector Households, non-profit institutions serving households - Closing balance sheet - counterpart area World (all entities), counterpart institutional sector Total economy including Rest of the World (all sectors) - Debit (uses/assets) - Unspecified consolidation status, Current prices - Euro. Source: IEAQ - Quarterly Euro Area Accounts, Euro Area Accounts and Economics (S/EAE), ECB and Eurostat.

- Bank Equity Return: Median Return on Average Equity (ROAE), 100 Largest Banks, Euro Area. Source: Bankscope.

- Spreads between the composite interest rate on loans and the composite risk free rate is computed in two steps. Firstly, we compute the composite loan interest rate as the weighted average of interest rates at each maturity range (for housing loans: up to 1 year, 1-5 years, 5-10 years, over 10 years; for commercial loans: up to 1 year, 1-5 years, over 5 years). Secondly, we compute corresponding composite risk free rates that take into account the maturity breakdown of loans. The maturity-adjusted risk-free rate is the weighted average (with the same weights as in case of composite loan interest rate) of the following risk-free rates chosen for maturity ranges:

  - 3 month EURIBOR (up to 1 year)

  - German Bund 3 year yield (1-5 years)
  - German Bund 10 year yield (over 5 years for commercial loans)
  - German Bund 7 year yield (5-10 years for housing loans)
  - German Bund 20 year yield (over 10 years for housing loans).

- Borrowers Fraction: Share of households being indebted, as of total households. Source: Household Finance and Consumption Survey (HFCS), 2010.

- Borrowers Housing Wealth: value household's main residence + other real estate - other real estate used for business activities (da1110 + da1120 - da1121), Share of indebted households, as of total households. Source: HFCS, 2010.

- Fraction of capital held by households: We set our calibration target for this variable by identifying it with the proportion of assets of the NFC sector whose financing is not supported by banks. To compute this proportion we use data from the EA sectoral financial accounts, which include balance sheet information for the NFC sector (Table 3.2) and a breakdown of bank loans by counterparty sector (Tables 4.1.2 and 4.1.3). From the raw NFC balance sheet data, we first produce a "net" balance sheet in which, in order to remove the effects of the cross-holdings of corporate liabilities, different types of corporate liabilities that appear as assets of the NFC sector get subtracted from the corresponding "gross" liabilities of the corporate sector. Next we construct a measure of leverage of the NFC sector
$$LR = \frac{\text{NFC Net Debt Securities} + \text{NFC Net Loans} + \text{NFC Net Insurance Guarantees}}{\text{NFC Net Assets}}$$
and a measure of the bank funding received by the NFC sector
$$BF = \frac{\text{MFI Loans to NFCs}}{\text{NFC Net Assets}}.$$
From these definitions, the fraction of debt funding to the NFC sector not coming from banks can be found as $(LR - BF)/LR$. Finally, to estimate the fraction of NFC assets whose financing is not supported by banks, we simply assume that the financing of NFC assets not supported by banks follows the same split of equity and debt funding as the financing of NFC assets supported by banks, in which case the proportion of physical capital in the model not funded by banks, K_s/K, should just be equal to $(LR-BF)/LR$. This explains the target value of K_s/K in Table 1.

- Price to book ratio of banks. Source: Datastream