Bank Capital in the Short and in the Long Run*

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VERY PRELIMINARY – PLEASE DO NOT CIRCULATE

Abstract

How far and how quickly should capital requirements be raised in order to ensure a strong and resilient banking system without imposing undue costs on the real economy? To address this question build a quantitative model with nominal rigidities and financial intermediation calibrated to match the salient features of the EA economy. Higher capital requirements are beneficial in making banks safer but carry short term output costs because their imposition can reduce aggregate demand on impact. Under accomodative monetary policy, higher capital requirements are successful in addressing financial stability risks (by bringing the bank default probability close to zero) without imposing large costs on the economy. In contrast, under a less accomodative monetary policy an increase in capital requirements imply a marked slowdown of lending and real activity. 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. Thus, a longer phase-in period is needed to dampen the real costs of an increase in capital requirements and ensure that this policy change is welfare improving.

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

1. Introduction

Ensuring bank resilience in economies suffering from the aftermath of banking crises is a pressing policy issue for a number of European countries at present. Undercapitalized banks make the economy more vulnerable to financial shocks and threaten to impose large fiscal costs from bailing out failing financial institutions. This makes it desirable to raise bank equity buffers. Set against this is the fear that a rapid tightening of capital requirements will lead to a credit crunch and a large output loss.

In this paper we ask the question of how far and how quickly capital requirements should be raised in order to ensure a strong and resilient banking system without imposing undue short term costs on the real economy. We argue that the answer crucially depends on the conduct of monetary policy. When monetary policy reacts aggressively to inflation undershoots, it offsets the negative aggregate demand effects from tighter capital requirements and the short term output costs from the capital increase do not cancel out its longer term financial stability benefits. As a result, a significant bank capital increase implemented over a relatively short time horizon is beneficial. In contrast, when monetary policy is less accommodative, tighter capital requirements cause a larger slowdown of lending and, thus, real activity. A smaller increase in capital requirements and a longer phase-in period are then more appropriate.

In order to understand the short- and long- run effects of changes in capital regulation and how these are affected by the conduct of monetary policy, we build a quantitative macro-banking model featuring both nominal and financial frictions. Banks intermediate funds between depositors and borrowers and all borrowers including banks can default and enjoy limited liability. External financing takes the form of non-recourse uncontingent debt subject to costly state verification (CSV) frictions like in Bernanke, Gertler and Gilchrist (1999). Default occurs when the return on the borrowers' assets falls below their debt obligations. In addition, the model also features a monetary authority that follows a standard Taylor-type rule, debt contracts written in nominal terms and nominal price rigidities a' la Calvo (1983).

The key bank-related distortion is that 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 bank debt is exposed to losses but pays an interest rate which is based on aggregate economy-wide bank failure risk rather than the decisions of the individual bank.[1] These distortions imply that banks have an incentive to take excessive risk and capital regulation is needed to limit this.

The costs of capital regulation arise due to limited participation in the market for bank equity. In a key departure from Modigliani-Miller, equity can be held only by a subset of households and the resulting scarcity creates a spread between the risk-adjusted return on bank equity and the risk free rate. Thus, large increases in capital requirements that are implemented quickly increase bank funding costs and reduce lending and real activity.

The model is calibrated to match real, nominal and banking moments of Euro Area micro and macro data.[2] Using our quantitative model, we show that higher capital requirements are successful in making banks less vulnerable and are, thus, beneficial in the long-run. However, tighter capital requirements also carry short term output costs because they reduce credit and aggregate demand on impact. The net effect on economic activity and welfare depends of which of the two effects dominates. A capital requirement increase may turn out to be desirable if implemented gradually or in conjunction with a monetary policy that leans against aggregate demand fluctuations through a strong response to inflation deviations from target.

If the Taylor rule is not strongly responsive or if the effective lower bound on nominal interest rates (ELB) binds, the interest rate does not fall sufficiently and the short-run costs of the capital requirement increase can be amplified very significantly. Moving more gradually with a capital requirement increase is therefore vital in order to maintain aggregate demand over the transition to a world with better capitalized banks.[3]

We also explore how a capital increase should be designed in order to maximize household welfare and achieve a Pareto improvement. We find that the optimal design of a capital increase crucially depends on the monetary policy response to inflation deviations from target. Pursuing the goal of full price stability, the monetary authority allows the macroprudential authority to

[1] This assumption is motivated by banks' opacity which makes it difficult for outsiders to hold them to account. Another motivation is moral hazard such as the unobservable risk-taking choice in Christiano and Ikeda (2017). Regardless of the precise microfoundations, the end result is that market discipline is weak even in the absence of a financial safety net.

[2] Differently from related attempts (e.g. Christiano, Motto and Rostagno, 2008; Gerali et al, 2010), in addition to key EA macroeconomic variables, we match the moments of banking variables such as capital ratios, write-offs, loan spreads, loan-to-GDP ratios, etc.

[3] A similar combination of long term benefits and short term ELB-driven costs are found in the case of structural reforms by Eggertson, Ferrero and Raffo (2014).

optimally implement a larger and faster increase in capital requirements. In close proximity to the ELB (when monetary policy cannot react as desired), the optimal increase in capital requirements should be more modest and should occur over a longer time period.

Our work lends support to the long implementation horizon in Basel III which gave banks a 5 year period to build up the new capital buffers. While our baseline results call for even slower implementation (over 10 years), robustness analysis shows that under a scenarios of heightened uncertainty about the return on banks' loan portfolio, higher capital requirements are more beneficial and, ceteris paribus, should be implemented faster.

Our paper contributes to the growing literature on the impact of changing bank capital requirements (see e.g. Gertler, Kiyotaki and Queralto (2012), Martinez-Miera and Suarez, 2014; Clerc et al., 2015; Nguyen 2014; Christiano and Ikeda, 2017).[4] These studies generally conclude that capital requirements should be increased from pre-crisis levels to levels above the prescriptions of Basel III. Our work significantly qualifies these conclusions by incorporating transitional costs and the impact of nominal rigidities. In addition to previous literature we also examine the case in which monetary policy is constrained by the zero floor on nominal interest rates. We show that the short run costs of higher capital requirements can be much higher once we incorporate these elements into the analysis.

Our analysis differs from papers on optimal monetary and macroprudential policy (e.g. De Paoli and Paustian, 2013; Kiley and Sim, 2015; Leduc and Natal, 2016; Collard et al., 2017) in that our main focus is not limited to cyclical macroprudential policy. We contribute to existing studies by providing a prudential rational for capital requirements. This enables us to appreciate the effectiveness of changes in capital requirements policies in terms of their financial stability implications and not only for their stabilization properties on credit supply.

Our results are also 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 (see e.g. Christiano, Eichenbaum and Rebelo, 2011 and Erceg and Linde, 2014 among others). While the focus of our paper is on capital requirements rather than on fiscal policy, the intuition for the amplified 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

[4]Our analysis differs from studies that incorporates banking in otherwise standard New Keynesian DSGE models, such as Curdia and Woodford (2010) Gertler and Kiyotaki (2010), Gerali et al. (2010), and Meh and Moran (2010) in that we provide a normative assessment of capital regulation.

changes are fiscal or macroprudential. In our case, this calls for a gradual implementation of capital increases in order to avoid excessive short term output costs at the ELB.

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 short-run effects and discusses how these are affected by the presence of a binding ELB on nominal interest rates. Section 6 discusses the optimal design of an increase in capital requirements in normal times and in an environment when the ELB is binding. Section 7 conducts robustness analysis and finally, Section 8 concludes.

2. Model Economy

This section presents the macro-banking model we use to analyze the effect of an increase in bank capital requirements. The model builds on Clerc et al. (2015) and Mendicino et al. (2016) and extends the latter framework to include monetary policy, nominal debt contracts and nominal price rigidities.

Key Distortions. The model features three key distortions related to the banking sector: i) absence of bank risk pricing at the margin that insulate banks from the effect of their risk taking on the cost of deposits; ii) limited participation in the market for bank equity that makes equity supply scarce and equities a more expensive source of bank funding. As a result of the first two types of distortions banks have an incentive to take as much risk as possible by leveraging up to the regulatory limit. The average probability of bank default is used as a proxy for financial instability.

All borrowers operate under limited liability and default when the return on their assets falls below their debt obligation. External financing is subject to costly state verification (CVS) frictions as in Bernanke, Gertler and Gilchrist (1999) but debt is non contingent.

Finally, the model also features two main sources of nominal distortions: debt contracts written in norminal terms and nominal price rigidities a-la Calvo (1983). Nominal assets induce private risk and unnecessary redistribution of wealth between borrowers and savers generated by the uncertain real returns. Thus, movements in the interest rate and unexpected changes in inflation, imply unexpected capital gains and losses on the real cost of the debt and generate distortions in the allocation of resources and affect aggregate demand.[5] On the other hand,

[5] For an analysis on the distortion related to the presence of assets in nominal terms, see Christiano, Motto and Rostagno (2004, 2010).

nominal prices rigidity generate inefficient wage and price dispersions.[6] Movements in the policy interest rate and unexpected changes in inflation, affect both the real value of debt and the cost of price dispersion.

Agents. We consider an economy populated by two dynasties: patient households (denoted by s) and impatient households (denoted by m). Households that belong to each dynasty differ in terms of their subjective discount factor, $\beta_m \leq \beta_s$. The total mass of households is normalized to one, of which an exogenous fraction x_s are patient and the remaining fraction $x_m = 1 - x_s$ are impatient. In equilibrium, impatient households borrow.[7]

The patient dynasty consists of three different classes of members, workers, entrepreneurs, and bankers, with measures given by x_ϱ for $\varrho = w, e, b$, 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 patient households as dividends or once they retire. They use their scarce net worth to provide equity financing to entrepreneurial firms and banks, respectively. Entrepreneurs and bankers receive consumption insurance from their dynasty, while the firms and banks that they own can individually default on their debts.

The impatient dynasty consists of workers only and its borrowing takes the form of non-recourse mortgage loans secured against an individual housing unit which is subject to an idiosyncratic return shock. Similarly to entrepreneurs and bankers, impatient workers receive consumption insurance from their dynasty and can individually default on their mortgages.[8]

We assume two types of competitive banks that finance their loans by raising equity from bankers and debt from patient households.[9] The loans extended to impatient households and the banks extending them are denoted by M, while those extended to firms (denoted by f) and

[6] See Woodford (1999), Erceg, Henderson and Levin (2000), Schmitt-Grohe and Uribe (2004, 2005, 2007a, 2007b) for further discussions on nominal price rigidities.

[7] As in other papers in the literature (e.g. Iacoviello, 2005), the distinction between patient and impatient households is a minimal deviation from the infinitely lived representative household paradigm that allows to simultaneously have saving and borrowing households. For interpretation purposes, one can think of impatient households as representing the decisions and welfare of net borrowers such as younger or poorer households.

[8] Assuming that dynasties provide consumption risk-sharing to their members while 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.

[9] 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.

the banks extending them are denoted by F.[10] A fraction κ of bank debt are deposits insured by a deposit insurance agency (DIA) funded with lump sum taxes. Banks are subject to capital requirements set by a prudential authority.

The macroprudential authority sets the bank capital requirement level and the speed of implementation of changes in the requirement. The monetary authority sets the short term risk free rate according to a rule that responds gradually to inflation and GDP growth.

2.1 Notation

All borrowers are subject to idiosyncratic return shocks $\omega_{i,t+1}$ which are iid across borrowers of class $i \in \{m, f, M, F\}$ and across borrower classes, and are assumed to follow a log-normal distribution with a mean of one and a stochastic standard deviation $\sigma_{i,t+1}$. We will denote by $F_{i,t+1}(\omega_{i,t+1})$ the distribution function of $\omega_{i,t+1}$ and by $\overline{\omega}_{i,t+1}$ the threshold realization below which a borrower of class i defaults, so that the probability of default of such borrower can be found as $F_{i,t+1}(\overline{\omega}_{i,t+1})$.[11]

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

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

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

$$\Gamma_{i,t+1}(\overline{\omega}_{i,t+1}) = G_{i,t+1}\left(\overline{\omega}_{i,t+1}\right) + \overline{\omega}_{i,t+1}[1 - F_{i,t+1}\left(\overline{\omega}_{i,t+1}\right)] \tag{2}$$

where $f_{i,t+1}\left(\omega_{i,t+1}\right)$ denotes the density function of $\omega_{i,t+1}$. In the presence of a proportional asset repossession cost μ_i, as we assume, the net share of assets that goes to the lender is $\Gamma_{i,t+1}(\overline{\omega}_{i,t+1}) - \mu_i G_{i,t+1}\left(\overline{\omega}_{i,t+1}\right)$. The share of assets eventually accrued to the borrowers of class i is $(1 - \Gamma_{i,t+1}(\overline{\omega}_{i,t+1}))$.

[10] Having banks specialized in each class of loans simplifies their pricing, avoiding cross-subsidization effects that would otherwise emerge due to banks' limited liability.

[11] The subscript $t+1$ in the distribution function and in the functions $G_{i,t+1}(\cdot)$ and $\Gamma_{i,t+1}(\cdot)$ defined below is a shorcut to reflect the time-varying standard deviation of $\omega_{i,t+1}$.

2.2 Households

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

$$E_t\left[\sum_{i=0}^{\infty}(\beta_{\varkappa})^{t+i}\left[\log\left(C_{\varkappa,t+i}-\kappa C_{\varkappa,t+i-1}\right)+v_{\varkappa,t+i}\log\left(H_{\varkappa,t+i}\right)-\frac{\varphi_{\varkappa}}{1+\eta}\left(L_{\varkappa,t+i}\right)^{1+\eta}\right]\right] \tag{3}$$

with $\varkappa = s, m$, where $C_{\varkappa,t}$ denotes the consumption of non-durable goods and $H_{\varkappa,t}$ denotes the total stock of housing held by members of the dynasty (this provides a proportional amount of housing services also denoted by $H_{\varkappa,t}$), $L_{\varkappa,t}$ denotes hours worked in the consumption good producing sector, η is the inverse of the Frisch elasticity of labor supply, $\varphi_{\varkappa}$ is a preference parameter and $v_{\varkappa,t}$ is a housing preference shock that follows an AR(1) process.

Patient Households. The patient households' budget constraint is as follows

$$\begin{aligned} & P_tC_{s,t}+Q_{h,t}\left[H_{s,t}-(1-\delta_{h,t})H_{s,t-1}\right]+\left(Q_{k,t}+P_ts_t\right)K_{s,t}+D_t+B_t \\ \leq\;& \left(P_tr_{k,t}+(1-\delta_{k,t})\,Q_{k,t}\right)K_{s,t-1}+W_tL_{s,t}+\widetilde{R}_t^dD_{t-1}+R_{t-1}B_{t-1}+P_tT_{s,t}+P_t\Pi_{s,t}+P_t\Xi_{s,t} \end{aligned} \tag{4}$$

where P_t is the nominal price of the consumption good, $Q_{h,t}$ is the nominal price of housing, $\delta_{h,t}$ is the rate at which housing units depreciate, and W_t is the nominal wage rate. Savers can hold physical capital $K_{s,t}$ with the nominal price $Q_{k,t}$, depreciation rate $\delta_{k,t}$, and rental rate $r_{k,t}$, subject to a management cost s_t which is taken as given by households.

Each individual saver s can also invest in a nominal risk free asset B_t (in zero net supply) and in a perfectly diversified portfolio of bank debt D_t. The return on such debt has two components. A fraction κ is interpreted as insured deposits that always pay back the promised gross deposit rate R^d_{t-1}. The remaining fraction $1-\kappa$ is interpreted as uninsured debt that pays back the promised rate R^d_{t-1} if the issuing bank is solvent and a proportion $1-\kappa$ of the net recovery value of bank assets in case of default.[12] Importantly, we assume banks' individual risk profiles to be unobservable to savers, so they must base their valuation of bank debt on

[12] One can alternatively interpret κ as the fraction of bank debt that will benefit from a government bailout in case of default. This formulation allows us to consider deviations from full bank debt insurance ($\kappa = 1$) without complicating banks' capital structure decisions.

the anticipated credit risk of an average unit of bank debt.[13] The return on bank debt is

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

where Ω_t is the average default loss per unit of bank debt as defined in Appendix (under construction). Hence, for $\kappa < 1$, bank debt is overall risky and, to make it attractive to savers, it will have to promise a contractual gross interest rate R_{t-1}^d higher than the free rate R_{t-1}^{rf}.

Finally, $T_{s,t}$ is a lump-sum tax used by the DIA to ex-post balance its budget, $\Pi_{s,t}$ are aggregate net transfers of earnings from entrepreneurs and bankers to the household at period t, and $\Xi_{s,t}$ are profits from firms that manage the capital stock held by the patient households.[14]

Impatient Households. The impatient households' budget constraint is different from (4) in that these households borrow, do not invest in capital, and do not receive transfers from entrepreneurs and bankers:

$$P_t C_{m,t} + Q_{h,t} H_{m,t} - B_{m,t} \leq W_t L_{m,t} + (1 - \Gamma_{m,t}(\overline{\omega}_{m,t}))\,(1 - \delta_{h,t})\,Q_{h,t} H_{m,t-1} - P_t T_{m,t}, \tag{6}$$

where $B_{m,t}$ is the overall amount of mortgage lending granted by banks, $T_{m,t}$ is the lump-sum tax through which borrowers contribute to the funding of the DIA, and $(1-\Gamma_{m,t+1}(\overline{\omega}_{m,t}))\,(1 - \delta_{h,t})\,Q_{h,t} H_{m,t-1}$ is net housing equity after accounting for the fraction of housing repossessed by the bank on the individual housing units that default on their mortgages.

This formulation posits that individual household members default on their mortgages in period t when the value of their housing units, $\omega_{m,t}\,(1 - \delta_{h,t})\,Q_{h,t} H_{m,t-1}$, is lower than the outstanding mortgage debt, $R_t^M B_{m,t}$, that is when $\omega_{m,t} \leq \bar{\omega}_{m,t}$, where

$$\bar{\omega}_{m,t} = \frac{R_{t-1}^M B_{m,t-1}}{Q_{h,t}\,(1 - \delta_{h,t})\,H_{m,t-1}} = \frac{R_{t-1}^M \frac{B_{m,t-1}}{P_{t-1}}}{\frac{Q_{h,t}}{P_t}\,(1 - \delta_{h,t})\,H_{m,t-1}} \frac{1}{\pi_t} \tag{7}$$

is a household's default threshold, $\pi_t = P_t / P_{t-1}$ is the inflation rate and R_t^M is the gross nominal rate on the corresponding loan.

Importantly, the problem of the borrowing households includes a second constraint, the participation constraint of the bank, which reflects the competitive pricing of the loans that

[13] This is consistent with the view (e.g. in Dewatripont and Tirole, 1994) that small unsophisticated savers lack the incentives and/or ability to monitor the banks and delegate such task into bank supervisors.

[14] As further specified in Appendix (under construction), the total costs of deposit insurance are shared by the patient and impatient households in proportion to their size in the population.

banks are willing to offer for different choices of leverage by the household:

$$E_t \{\Lambda_{b,t+1} [(1 - \Gamma_{M,t+1}(\overline{\omega}_{M,t+1}))(\Gamma_{m,t+1} (\overline{\omega}_{m,t+1}) - \mu_m G_{m,t+1} (\overline{\omega}_{m,t+1})) (1 - \delta_{h,t+1}) Q_{h,t+1}] H_{m,t}\}$$
$$\geq \quad \upsilon_{b,t}\phi_{M,t}B_{m,t} \tag{8}$$

As further explained in subsection 2.3.5, (8) imposes that the expected, properly discounted payoffs that the bank generates to its owners by granting mortgages are large enough to compensate bankers for the opportunity cost of the equity financing contributed to such loans, $\upsilon_{b,t}\phi_{M,t}B_{m,t}$, where $\upsilon_{b,t}$ is the equilibrium shadow value of one unit of bankers' wealth and $\phi_{M,t}$ is the (binding) capital requirement for this class of loans. The term $\Lambda_{b,t+1}$ is bankers' stochastic discount factor, $1 - \Gamma_{M,t+1}(\overline{\omega}_{M,t+1})$ accounts for the fact that bankers obtain levered returns from the bank's loan portfolio, and $\overline{\omega}_{M,t+1}$ is the threshold of the idiosyncratic shock to bank asset returns below which the bank defaults.[15] The term $(\Gamma_{m,t+1} (\overline{\omega}_{m,t+1}) - \mu_m G_{m,t+1} (\overline{\omega}_{m,t+1})) (1 - \delta_{h,t+1}) Q_{h,t+1}$ reflects the part of the returns on one unit of housing, net of repossession costs incurred when the borrower defaults, that is taken by the bank.

2.3 Entrepreneurs and Bankers

In each period some entrepreneurs and bankers become workers and some workers become either entrepreneurs or bankers.[16] Each period can be logically divided in three stages: payment stage, surviving stage, and investment stage. In the payments 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.

[15] When solving this problem, the borrowing households take $\overline{\omega}_{M,t+1}$ as given, since the impact of an infinitesimal marginal loan on bank solvency is negligible. Instead, the borrower internalizes the impact on his decisions on his own default threshold $\overline{\omega}_{m,t+1}$.

[16] This guarantees that entrepreneurs and bankers never accummulate enough net worth so as to stop investing their net worth in the equity of firms and banks, respectively (see, e.g. Gertler and Kiyotaki, 2010)

2.3.1 Individual entrepreneurs

Entrepreneurs are agents that invest their net worth into entrepreneurial firms. The problem of the representative entrepreneur can be written as

$$V_{e,t} = \max_{A_t, dv_{e,t}} \left\{ dv_{e,t} + E_t \frac{\Lambda_{t+1}}{\pi_{t+1}} \left[(1-\theta_e) N_{e,t+1} + \theta_e V_{e,t+1} \right] \right\} \tag{9}$$

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

where $\Lambda_{t+1} = \beta_s c_{s,t}/c_{s,t+1}$ is the stochastic discount factor of the patient dynasty, $N_{e,t}$ is 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 described below, $dv_{e,t} \geq 0$ are dividends that the entrepreneur pays to the saving dynasty at retirement, and $\rho_{f,t}(\omega)$ is the rate of return on the entrepreneurial equity invested in a firm that experiences a return shock ω.

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

$$V_{e,t} = v_{e,t} N_{e,t}, \tag{10}$$

where $\nu_{e,t}$ is the shadow value of one unit of entrepreneurial equity. Then we can write the Bellman equation in (9) as

$$v_{e,t} N_{e,t} = \max_{A_t, dv_{e,t}} \left\{ dv_{e,t} + E_t \frac{\Lambda_{t+1}}{\pi_{t+1}} \left[1 - \theta_e + \theta_e v_{e,t+1} \right] N_{e,t+1} \right\}. \tag{11}$$

Entrepreneurs find optimal not to pay dividends prior to retirement insofar as $\nu_{e,t} > 1$, which we verify to hold true under our parameterizations. Finally, (11) allows us to define entrepreneurs' stochastic discount factor as

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

2.3.2 Entrepreneurial firms

The representative entrepreneurial firm takes A_t equity from entrepreneurs and borrows $B_{f,t}$ from banks at nominal interest rate R_t^F 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. Firms live for a period and pay out their terminal net worth to entrepreneurs. Assuming symmetry across firms, the problem of the representative entrepreneurial firm is

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

subject to the participation constraint of its bank

$$E_t\Lambda_{b,t+1}(1-\Gamma_{b,t+1}(\overline{\omega}_{b,t+1}))\widetilde{R}_{t+1}^F B_{f,t} \geq \upsilon_{b,t}\phi_{F,t}B_{f,t} \tag{12}$$

where $B_{f,t} = Q_{k,t}K_{f,t} - A_t$ is the loan taken from the bank. As explained when presenting the problem of the borrowing households, the participation constraint of the bank can be interpreted as the equation capturing the competitive pricing of bank loans for different possible decisions on leverage by the firm. Further details on (12) appear in subsection 2.3.5.

The payoff that bank F receives from its portfolio of loans to entrepreneurial firms can be expressed as $\widetilde{R}_{t+1}^F B_{f,t} = (\Gamma_{f,t+1}(\overline{\omega}_{f,t+1}) - \mu_f G_{f,t+1}(\overline{\omega}_{f,t+1}))\left((1-\delta_{k,t+1})Q_{k,t+1} + P_{t+1}r_{k,t+1}\right)K_{f,t}$, which takes into account that a firm defaults on its loans when the gross return on its assets, $\omega_{f,t+1}R_{t+1}^K Q_{k,t}K_{f,t}$, is insufficient to repay $R_t^F B_{f,t}$, i.e. for $\omega_{f,t+1} < \overline{\omega}_{f,t+1}$,where

$$\overline{\omega}_{f,t} = \frac{R_{t-1}^F B_{f,t-1}}{\left((1-\delta_{k,t})Q_{k,t} + P_t r_{k,t}\right)K_{f,t-1}} = \frac{R_{t-1}^F \frac{B_{f,t-1}}{P_{t-1}}}{\left((1-\delta_{k,t})\frac{Q_{k,t}}{P_t} + r_{k,t}\right)K_{f,t-1}}\frac{1}{\pi_t} \tag{13}$$

is a firm's default threshold.

Upon default, the bank recovers returns $(1-\mu_f)\omega_{f,t+1}\left((1-\delta_{k,t+1})Q_{k,t+1} + P_{t+1}r_{k,t+1}\right)K_{f,t}$, where μ_f is a proportional asset repossession cost.

2.3.3 Law of motion of entrepreneurial net worth

Taking into account effects of retirement and the entry of new entrepreneurs, the evolution of active entrepreneurs' nominal net worth can be described as:[17]

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

[17] To save on notation, we also use $n_{e,t+1}$ to denote the aggregate counterpart of what in (9) was an individual entrepreneur's net worth.

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 exiting entrepreneurs:

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

2.3.4 Individual bankers

Bankers can invest their net worth $N_{b,t}$ into two classes j of competitive banks that extend loans $B_{j,t}$ to either impatient households ($j = M$) or firms ($j = F$). There is a continuum of banks of each class. The problem of the representative banker is

$$V_{b,t} = \max_{e_t^M, e_t^F, dv_{b,t}} \{dv_{b,t} + E_t\Lambda_{t+1}[(1-\theta_b) N_{b,t+1} + \theta_b V_{b,t+1}]\} \tag{14}$$

$$E_{M,t} + E_{F,t} + dv_{b,t} = N_{b,t}$$

$$N_{b,t} = \int_0^\infty \rho_{M,t}(\omega) dF_{M,t}(\omega) E_{M,t-1} + \int_0^\infty \rho_{F,t}(\omega) dF_{F,t}(\omega) E_{F,t-1}$$

$$dv_{b,t} \geq 0$$

where $E_{j,t}$ is the diversified equity investment in the measure-one continuum of banks of class j. $dv_{b,t}$ is a dividend that the banker pays to the saving dynasty at retirement, and $\rho_{j,t}(\omega)$ is the rate of return from investing equity in a bank of class j that experiences shock ω.

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

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

where $\nu_{b,t}$ is the shadow value of a unit of banker wealth. The Bellman equation in (14) becomes

$$v_{b,t}N_{b,t} = \max_{E_t^M, E_t^F, dv_{b,t}} \{dv_{b,t} + E_t\Lambda_{t+1}[1-\theta_b + \theta_b v_{b,t+1}] N_{b,t+1}\}, \tag{15}$$

and bankers will find it optimal not to pay dividends prior to retirement ($dv_{b,t} = 0$) insofar as $\nu_{b,t} > 1$. From (15), bankers' stochastic discount factor can be defined as

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

From (15), interior equilibria in which both classes of banks receive strictly positive equity from bankers ($E_{j,t} > 0$) require the properly discounted gross expected return on equity at each class of bank to be equal to $v_{b,t}$:

$$E_t[\Lambda_{b,t+1}\rho_{M,t+1}] = E_t[\Lambda_{b,t+1}\rho_{F,t+1}] = v_{b,t}, \tag{16}$$

where $\rho_{j,t+1} = \int_0^\infty \rho_{j,t+1}(\omega)\, dF_{j,t+1}(\omega)$ is the return of a well diversified unit-size portfolio of equity stakes in banks of class j.

2.3.5 Banks

The representative bank of class j issues equity $E_{j,t}$ among bankers and nominal debt $D_{j,t}$ that promises a gross interest rate R_t^d among patient households, and uses these funds to provide a continuum of identical loans of total size $B_{j,t}$. This loan portfolio has a return $\omega_{j,t+1}\widetilde{R}^j_{t+1}$, where $\omega_{j,t+1}$ is a log-normally distributed bank-idiosyncratic asset return shock and $\widetilde{R}^j_{t+1}$ denotes the realized return on a well diversified portfolio of loans of class j.[18] Banks live for a period and give back their terminal net worth, if positive, to the bankers next period. If a bank's terminal net worth is negative, it defaults. The DIA then takes the returns $(1-\mu_j)\omega_{j,t+1}\widetilde{R}^j_{t+1}B_{j,t}$ where μ_j is a proportional repossession cost, pays the fraction κ of insured deposits in full, and pays a fraction $1-\kappa$ of the repossesed returns to holders of the bank's uninsured debt.

The objective function of the representative bank of class j is to maximize the net present value of their shareholders' stake at the bank

$$NPV_{j,t} = E_t\Lambda_{b,t+1} \max\left[\omega_{j,t+1}\widetilde{R}^j_{t+1}B_{j,t} - R_t^d D_{j,t}, 0\right] - v_{b,t}E_{j,t}, \tag{17}$$

where the equity investment $E_{j,t}$ 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, $B_{j,t} = E_{j,t} + D_{j,t}$, and the regulatory capital constraint, $E_{j,t} \geq \phi_{j,t}B_{j,t}$,where $\phi_{j,t}$ is the capital requirement on loans of class j.

If the capital requirement is binding (as it turns out to be in equilibrium because partially insured debt financing is always "cheaper" than equity financing), we can write the loans of the bank as $B_{j,t} = E_{j,t}/\phi_{j,t}$, its deposits as $D_{j,t} = (1-\phi_{j,t})E_{j,t}/\phi_{j,t}$, and the threshold value of $\omega_{j,t+1}$

[18] 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).

below which the bank fails as $\overline{\omega}_{j,t+1} = (1-\phi_{j,t})\, R_t^d/\widetilde{R}_{t+1}^j$, since the bank fails when the realized return per unit of loans is lower than the associated debt repayment obligations, $(1-\phi_{j,t})R_{d,t}$. Accordingly, the probability of failure of a bank of class j is $\Psi_{j,t+1} = F_{j,t+1}(\overline{\omega}_{j,t+1})$, which will be driven by fluctuations in the aggregate return on loans of class j, $\widetilde{R}_{t+1}^j$, as well as shocks to the distribution of the bank return shock $\omega_{j,t+1}$.

Using (2), the bank's objective function in (17) can be written as

$$NPV_{j,t} = \left\{ E_t \Lambda_{b,t+1} \left[1 - \Gamma_{j,t+1}(\overline{\omega}_{j,t+1})\right] \frac{\widetilde{R}_{t+1}^j}{\phi_{j,t}} - v_{b,t} \right\} E_{j,t},$$

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

$$E_t \Lambda_{b,t+1} \left[1 - \Gamma_{j,t+1}(\overline{\omega}_{j,t+1})\right] \widetilde{R}_{t+1}^j \geq \phi_{j,t} v_{b,t}, \tag{18}$$

which explains the expressions for the participation constraints (8) and (12) introduced in borrowers' problems. These constraints will hold with equality since it is not in borrowers' interest to pay more for their loans than strictly needed.[19] Under the definition $\rho_{j,t+1} = \left[1 - \Gamma_{j,t+1}(\overline{\omega}_{j,t+1})\right] \frac{\widetilde{R}_{t+1}^j}{\phi_{j,t}}$, if (18) holds with equality for $j = M, F$, bankers' indifference between investing their wealth in equity of either class of banks, (16), is also trivially satisfied.

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:[20]

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

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 exiting bankers:

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

[19] In fact, any pricing of bank loans leading to $NPV_{j,t} > 0$ would make banks wish to expand $e_{j,t}$ unboundedly, which is incompatible with equilibrium. So, we could have directly written (8) and (12) with equality, as a sort of zero (rather than non-negative) profit condition.

[20] To save on notation, we also use $n_{b,t+1}$ to denote the aggregate counterpart of what in (9) was an individual banker's net worth.

2.4 Consumption Goods Production Sector

We assume a continuum of monopolistically competitive intermediate goods firms that produces a continuum of intermediate goods. The output of each intermediate good producer i is then purchased by a 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

$$y_t(i) = \left(\frac{p_t(i)}{P_t} \right)^{-\frac{1+\theta}{\theta}} Y_t \tag{19}$$

where P_t is the CES aggregate price index

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

and $p_t(i)$ is the price of each intermediate good.

Intermediate Good Producers. Each intermediate good firm $i \epsilon [0, 1]$ produces a single good, $y_t(i)$, combining $l_t(i)$ units of labor and $k_t(i)$ units of capital, according to the following constant-returns-to-scale technology

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

where z_t is an AR(1) productivity shock and α is the share of capital in production. Intermediate good firms are owned by the patient household and distribute profits and losses back to it.

Intermediate good producers set prices according to a typical Calvo setup. Prices are set for contracts of random duration. As a result, firms will not by able to maximize their profits period-by-period. Each contract expires each period with probability $1 - \xi$. When the contract expires, the intermediate producer i chooses the new price $\widetilde{p_t}(i)$ to maximize the present discounted value of future real profit over the validity of the contract:

$$E_t \left[\sum_{j=0}^{\infty} m_{t,t+j} \xi^j \left(\frac{\widetilde{p_{t,t+j}}(i)}{P_{t+j}} y_{t+j}(i) - mc_{t+j}(i) y_{t+j}(i) \right) \right]$$

subject to (**??**) and

$$\widetilde{p_{t,t+j}}(i) = X_{t,t+j}\widetilde{p}_t(i),$$

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

where $m_{t,t+j}$ is the patient household's stochastic discount factor between periods t and $t+j$, $mc_t(i)$ is the marginal cost for firm i at time t and $X_{t,t+j}$ is the indexation factor for prices that remain sticky between period t and $t+j$. The latter is defined as

$$X_{t,t+j} = \prod_{k=1}^{j} \pi_{ind,t+k},$$

where $\pi_{ind,t+k} = \overline{\pi}^{\chi}\pi_{t+k-1}^{1-\chi}$.So firms that cannot set a new price in a certain period, can still index their previous period price by the last period inflation rate ($\chi = 0$) or by the inflation target of the monetary authority ($\chi = 1$).

2.5 Capital and housing production

Producers of capital (X=k) and housing (X=h) combine investment $I_{X,t}$, with the previous stock of capital and housing, X_{t-1}, in order to produce new capital and housing which can be sold at nominal price $Q_{X,t}$.[21] The representative X-producing firm maximizes the expected discounted value to the saving dynasty of its profits:

$$\max_{\{I_{X,t+j}\}} E_t \sum_{j=0}^{\infty} \Lambda_{t,t+j} \left\{ \frac{Q_{X,t+j}}{P_{t+j}} \left[S_X\left(\frac{I_{X,t+j}}{X_{t+j-1}}\right) X_{t+j-1}\right] - I_{X,t+j} \right\} \tag{21}$$

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

$$S_X\left(\frac{I_{X,t}}{X_{t-1}}\right) = \frac{a_{X,1}}{1-\frac{1}{\psi_X}}\left(\frac{I_{X,t}}{X_{t-1}}\right)^{1-\frac{1}{\psi_X}} + a_{X,2}, \tag{22}$$

[21] We have examined a variation of the model with a fixed housing stock. The behaviour of the model as well as its policy implications were similar to the ones obtained in the current version.

where $a_{X,1}$ and $a_{X,2}$ are chosen to guarantee that, in the steady state, the investment-to-capital ratio is equal to the depreciation rate and $S'_X(I_X, t/X_t - 1)$ equals one (so that the implied adjustment costs are zero).

From profit maximization, it is possible to derive the supply of new capital or housing:

$$\frac{Q_{X,t+j}}{P_{t+j}} = \left[S'_X\left(\frac{I_{X,t}}{X_{t-1}}\right)\right]^{-1}, \tag{23}$$

Finally, the law of motion of the corresponding stock is given by

$$X_t = (1 - \delta_{X,t})\, X_{t-1} + S_X\left(\frac{I_{X,t}}{X_{t-1}}\right) X_{t-1}, \tag{24}$$

where $\delta_{X,t}$ is the time-varying depreciation rate, which follows an AR(1).

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 $\Xi_{s,t} = s_t K_{s,t} - z(K_{s,t})$ implies the first order condition

$$s_t = z'(K_{s,t}), \tag{25}$$

which determines the equilibrium fees for each $K_{s,t}$. We assume a quadratic cost function, $z(K_{s,t}) = \frac{\xi}{2} K_{s,t}^2$, with $\xi > 0$, so that (25) becomes

$$s_t = \xi K_{s,t}. \tag{26}$$

2.7 The Monetary Authority

The monetary authority sets the one-period continuously compounded nominal interest rate R_t according to a Taylor-type policy rule:

$$R_t = \rho_R R_{t-1} + (1 - \rho_R)\left[\bar{R}\left(\frac{\pi_t}{\bar{\pi}}\right)^{\phi_\pi}\left(\frac{GDP_t}{GDP_{t-1}}\right)^{\phi_{GDP}}\right] \tag{27}$$

where ρ_R is the interest rate smoothing parameter and ϕ_π and ϕ_{GDP} determine the responses to inflation and GDP growth deviations from steady state, respectively. The steady state levels of the monetary policy interest rate and inflation rate are denoted by $\bar{R}$ and $\bar{\pi}$. GDP_t is defined as the sum of aggregate consumption, housing investment and capital investment.[22]

2.8 Sources of Fluctuations and Other Details

The model economy features eight sources of aggregate uncertainty, namely shocks to productivity, z_t, housing preferences, v_t, the depreciation of housing, $\delta_{h,t}$, and capital, $\delta_{k,t}$, and the four *risk shocks.* The latter are the shocks to the standard deviation $\sigma_{j,t}$ of the idiosyncratic return shocks experienced by each of the four classes of borrowers $j = m, f, M, F$).[23] All aggregate shocks follow autoregressive processes of order one:

$$\ln \varkappa_t - \ln \bar{\varkappa} = \rho_{\varkappa} \left(\ln \varkappa_{t-1} - \ln \bar{\varkappa} \right) + u_{\varkappa,t},$$

where $\varkappa_t \in \{z_t, v_t, \delta_{h,t}, \delta_{k,t}, \sigma_{m,t}, \sigma_{f,t}, \sigma_{M,t}, \sigma_{F,t}\}$, $\rho_{\varkappa}$ is the corresponding (time invariant) persistence parameter, $\bar{\varkappa}$ is the unconditional mean of ϱ_t, and $u_{\varkappa,t}$ is the innovation to each shock, with mean zero and (time invariant) standard deviation $\sigma_{\varkappa}$.

To save on space, market clearing conditions and the equations describing the determination of variables such as $T_{s,t}$, $T_{m,t}$, $\Omega_{M,t}$, $\Omega_{F,t}$, and $\Psi_{b,t}$ appear in Appendix A.

3. Calibration

The model is calibrated using Euro Area macroeconomic, banking and financial data for the period 2001:1-2015:4. Time is in quarters.

The calibration proceeds in three steps. In the first stage we set a number of parameters to values commonly used in the literature. A second set of parameters are calibrated simultaneously so as to match key steady state targets. A third set of parameters is calibrated by matching simultaneously a number of second moments. Table 1 reports the calibration targets.[24] Both micro and macro data inform the model's calibration.

[22] To avoid the counterintuitive impact of the resource costs of default on the measurement of output, we define $GDP_t = C_t + I_{K,t} + I_{H,t}$. A more comprehensive definition of aggregate output Y_t is provided in Appendix A.

[23] We refer to the shocks$\{\sigma_{j,t}\}_{j=m,f,M,F}$ as "risk shocks" as in Christiano, Motto and Rostagno (2014).

[24] Appendix B describes the data series and sources. Series expressed in Euro amounts are deflated and their log value is linearly detrended before computing the targets for their standard deviations. Targets expressed as ratios, interest rates or rates of returns are found after linearly detrending the corresponding series in levels.

Pre-set parameters. Following convention, we set the Frisch elasticity of labor supply, η, equal to one, the parameter governing habits in consumption, κ, equal to 0.6, the capital-share parameter of the production function, α, equal to 0.30 and the depreciation rate of physical capital, δ_k, equal to 0.03.[25] The labor disutility parameter ν_L, which only affects the scale of the economy, is normalized to one. The average net markup of intermediate firms θ is 20%, which is in the middle of the range of values used in the literature. We choose a value of 0.9 for the Calvo parameter, ξ, which is consistent with recent EA evidence on price stickiness.[26] The bankruptcy cost parameters, μ, are set equal to a common value of 0.30 for all sectors.[27] 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, ϕ_y, of 0.125, and a reaction to inflation, ϕ_π, of 1.5.

Parameters set with steady state targets. Although the second stage parameters are set simultaneously, some parameters are linked to specific targets. The share of insured deposits in bank debt $\varkappa$ is set to 0.54 in line with the evidence by Demirgüç-Kunt, Kane, and Laeven (2014) for EA countries. The inflation target $\overline{\pi}$ is equal to 2%. The discount factor of savers, β_s, is set to 0.9975 implying a 1% real risk free rate. The capital requirement, ϕ, is 8% and the risk weights on corporate loans (ϕ_F) and mortgages (ϕ_M) are, respectively, 100% and 50%.

We parameterize the degree of heterogeneity between borrowers and lenders using moments from the 2010 ECB Household Finance and Consumption Survey (HFCS).[28] In particular, we calibrate the share of borrowers in the economy, x_m, to match the proportion of indebted households in the Euro Area of 44%. The weights on housing in the utility of savers and borrowers, v_s and v_m, respectively, are key to match the shares of housing wealth held by indebted and non-indebted households in the EA.[29]

The discount factor of borrowers, β_m, and the new entrepreneurs' endowment parameter,

[25] These values are in common the empirical DSGE literature.

[26] Recent DSGE estimated of the Calvo parameter point towards a rather flat domestic Phillips curve in the EA. See, among others, Christoffel, Coenen and Warne (2010)

[27] 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).

[28] https://www.ecb.europa.eu/pub/economic-research/research-networks/html/researcher_hfcn.en.html

[29] In terms of the 2010 HFCS, housing wealth is defined as the value of the household's main residence + other real estate – other real estate used for business activities.

χ_e, match the ratios of mortgages and bank loans to non-financial corporations (NFC) to GDP. The new bankers' endowment parameter, χ_b, is used to match the cost of equity of EA banks.[30] The housing depreciation rate, δ_h, is pinned down by the ratio of residential investment to GDP. The parameter of the capital management cost function, ξ, 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.[31] The shadow value of bank equity υ_b matches the price to book ratio of banks.

In addition, we use the four idiosyncratic shocks to match the average write-off rates and the spreads between the loan rate and the risk free rate for both types of loans and the average probability of bank default.[32]

Parameters set to match second moments. In the third step we use the housing and capital adjustment cost parameters and the variance of the seven aggregate shocks to match the volatility of GDP and the volatility of house prices, HH loans, NFC loans, and of the write-offs rates and spreads of each type of loans all relative to GDP. The autoregressive coefficients, ρ, in the AR(1) processes followed by all shock are set equal to a common value of 0.9.

Calibration Results. As shown in Table 1, we match very closely the first and second moments selected as targets. Table 2 reports all the parameter values resulting from our calibration. The preference and technology parameters are in line with the values used by other authors.[33] Regarding the idiosyncratic shocks, the volatility of the shock to housing and entrepreneurial asset returns needed to match the data happen to be much larger than the volatility of the shock to bank asset returns. In contrast, the standard deviation of the aggregate risk shocks is larger for the shock to banks' asset returns than for the shock to households' and entrepreneurs' assets. The standard deviations of the productivity shock and housing preference shocks are not too different from what is estimated in other papers.[34] Our estimates also imply similar standard deviations for the housing and capital depreciation shocks.

[30] For the estimates of the cost of equity of euro area banks see BOX 1: https://www.ecb.europa.eu/pub/pdf/other/eb201601_article01.en.pdf

[31] See Appendix B for details.

[32] The model is calibrated assuming that the two types of banks have the same probability of default.

[33] Borrowers' discount factor falls within the two standard deviation bands estimated by Carroll and Samwick (1997). That is, within the interval (0.91, 0.99). See Iacoviello (2005), Campbell and Hercowitz (2009), and Iacoviello and Neri (2010) for similar values.

[34] See, e.g. Iacoviello and Neri (2010) and Jermann and Quadrini (2012).

Table 1: Calibration Targets

Description	Definition	Data	Model
A) Means			
Fraction of borrowers	$x_m/(x_s+x_m)$	0.437	0.437
Share of insured deposits	γ	0.54	0.54
Housing investment to GDP	I_h/GDP	0.058	0.058
Borrowers housing wealth share	$n_m h_m/h$	0.525	0.525
NFC loans to GDP	b_f/GDP	1.759	1.759
HH loans to GDP	$n_m b_m/GDP$	2.087	2.087
Write-off HH loans	$\Psi_m * 400$	0.316	0.407
Write-off NFC loans	$\Psi_f * 400$	0.686	0.692
Spread NFC loans	$(R_e - R_d) * 400$	0.011	0.011
Spread HH loans	$(R_m - R_d) * 400$	0.0087	0.0062
Banks' default	$\Psi_b * 400$	0.824	0.822
Equity return of banks	$\rho * 400$	8.139	8.384
Capital Share of Savers	K_s/K	0.22	0.22
LTV	$n_m b_m/q_h h_m$	0.552	0.552
Price to book ratio (banks)	υ_b	1.577	1.577
Risk Free Real Rate	$(R^f - \overline{\pi}) * 400$		
Inflation Targeting	$\overline{\pi}$	2	2
Capital Requirement	ϕ	0.08	0.08
Risk Weight Corporate Loans	ϕ_F	1	1
Risk Weight Mortgage Loans	ϕ_M	0.5	0.5
B) Standard Deviations			
std(GDP)	$\sigma(GDP) * 100$	2.248	2.288
std(House prices)/std(GDP)	$\sigma(q_{ht})/\sigma(GDP)$	2.784	2.253
std(NFC loans)/std(GDP)	$\sigma(b_f)/\sigma(GDP)$	4.287	5.369
std(HH loans)/std(GDP)	$\sigma(n_m b_m)/\sigma(GDP)$	2.843	3.627
std(Spread NFC loans)/std(GDP)	$\sigma(R_f - R_d)/\sigma(GDP)$	0.044	0.061
std(Spread HH loans)/std(GDP)	$\sigma(R_m - R_d)/\sigma(GDP)$	0.056	0.030
std(Banks' default)	$\sigma(\Psi_b) * 100$	1.01	1.051
std(inflation)	$\sigma(\pi) * 100$	0.199	0.188
std(Write-offs NFC)/std(GDP)	$\sigma(\Psi_f)/\sigma(GDP)$	0.05	0.065
std(Write-offs HH)/std(GDP)	$\sigma(\Psi_m)/\sigma(GDP)$	0.013	0.013
std(Business Investment)/std(GDP)	$\sigma(I_k)/\sigma(GDP)$	2.445	2.165
std(Housing Investment)/std(GDP)	$\sigma(I_h)/\sigma(GDP)$	4.017	3.145

Table 2: Parameters Values

Description	Par.	Value	Description	Par.	Value
A) pre-set parameters					
Frisch elasticity of labor	η	1	HH bankruptcy cost	μ_m	0.3
Disutility of labor ($\varkappa = s, m$)	$\varphi_{\varkappa}$	1	NFC bankruptcy cost	μ_f	0.3
Habits formation	κ	0.6	Bank M bankruptcy cost	μ_M	0.3
Capital share in production	α	0.3	Bank F bankruptcy cost	μ_F	0.3
Survival rate of entrepreneurs	θ_e	0.975	GDP coeff. (taylor rule)	ϕ_y	0.1
Shocks Persistence (all ϱ)	ρ_{ϱ}	0.9	Inflation coeff. (taylor rule)	ϕ_{π}	1.5
Calvo probability	ξ	0.9	Smoothing parameter (taylor rule)	ρ_R	0.75
B) Calibrated parameters					
Fraction of borrowers	$\varkappa_m$	0.777	Capital requirement for banks	ϕ	0.08
Discount factor borrowers	β_m	0.9832	Corporate risk weight	ϕ_F	1
Shared of insured deposits	$\varkappa$	0.54	Mortgage risk weight	ϕ_M	0.50
Capital depreciation	δ_h	0.026	Capital managerial cost	ξ	0.001
Inflation Target	$\overline{\pi}$	2	Survival rate of bankers	θ_b	0.951
Discount factor savers	β_s	0.9975	Capital adjustment cost param.	ψ_k	6.02
Transfer from HH to entrepreneurs	χ_e	0.433	Housing adjustment cost param.	ψ_h	1.895
Housing weight in savers' utility	υ_s	0.181	STD NFC risk shock	$\sigma_{\epsilon}^{\sigma_f}$	0.059
Housing weight in borrowers' utility	υ_m	0.623	STD HH risk shock	$\sigma_{\epsilon}^{\sigma m}$	0.010
Housing depreciation	δ_k	0.008	STD bank risk shock ($\varkappa = M, F$)	$\sigma_{\epsilon}^{\sigma \varkappa}$	0.06
STD iid. risk for household borrower	σ_m	0.203	STD capital depreciation shock	$\sigma_{\epsilon}^{\delta_k}$	0.001
STD iid. risk for entrepreneurs	σ_f	0.391	STD housing depreciation shock	$\sigma_{\epsilon}^{\delta_h}$	0.001
STD iid. risk for mortgage lender	σ_M	0.014	STD TFP shock	σ_{ϵ}^{A}	0.009
STD iid. risk for corporate lender	σ_F	0.029	STD preference shock	σ_{ϵ}^{J}	0.137

The parameters in a) are set to standard values in the literature, whereas in b) are calibrated to match the data targets.

4. Long-run Effects of Higher Capital Requirements

We use our quantitative model as a laboratory to explore the real and welfare effects of an increase in capital requirements. We start our analysis by exploring the long-run implications of higher capital requirements. To help understand those effects, we first illustrate the partial-equilibrium effects of higher capital requirements on bank lending standards. Then, we explore the impact of capital requirement in general equilibrium.

4.1 Impact on Lending Standards

The banks' participation constraints (8) and (12) determine *lending standards* in the economy. This is the combination of loan interest rates and borrower leverage that guarantee that the returns on loans will deliver bankers the required rate of return on the equity funding they provide. In this section we take this to be exogenous although in equilibrium this will be determined by a market clearing condition for banker equity.[35]

Figure 1.a displays the lending standards for the two borrowers. In addition to the calibrated value of 8% (solid line) we also consider the Basel III level (dashed line).[36]

For a given capital requirement, loan rates are increasing and convex in borrower leverage. At very low levels of leverage, the loan rate is locally insensitive to leverage because the probability of default is zero. Once borrower leverage is sufficiently high, the probability of default is also higher and the resulting loan interest rate increases to compensate for the expected credit losses, which include the asset repossession costs incurred in the event of default.

Higher capital requirements force the bank to reduce its leverage and to rely more on more expensive equity funding. Bank default risk falls and, with it, the implicit safety net subsidy. The result is an increase in the bank's weighted average cost of funding which is passed on to borrowers in the form of a tightening in lending standards. This explains the outward shift in the loan pricing schedules.[37]

[35] We produce the lending standards curves in partial equilibrium: with debt funding rates, the shadow value of bankers wealth, and the aggregate determinants of bank and borrower default risk fixed at their steady state levels.

[36] Basel III imposes a minimum capital ratio of 8%, a capital conservation buffer of up to 2.5% and a countercyclical capital buffer (CCB) of up to 2.5%, meaning that, over the credit cycle, the implied capital requirement will typically range between 8% and 13%, and its steady state value (when the capital conservation buffer is fully covered but the CCB is zero) is likely to be 10.5%.

[37] We produce the lending standards curves in partial equilibrium: with debt funding rates, the shadow value

4.2 Real and Welfare Effects

We now explore the long-run effects of higher capital requirements on the welfare of the two types of households as well as on key macroeconomic aggregates. We do this now in general equilibrium with all prices and rates of return endogenous and jointly determined.

The welfare of the representative household of each type $\varkappa = s, m$ is defined below:

$$V_{\varkappa,t} \equiv \max E_t \sum_{t=0}^{\infty} (\beta_\varkappa)^t U\left(c_{\varkappa,t}, h_{\varkappa,t}, l_{\varkappa,t}\right), \tag{28}$$

and can be written in recursive form as follows:

$$V_{\varkappa,t} = U(c_{\varkappa,t}, h_{\varkappa,t}, l_{\varkappa,t}) + \beta_\varkappa E_t V_{\varkappa,t+1}, \tag{29}$$

Here V_{st} and V_{mt} will be equivalently referred to as the welfare of the saving and borrowing households, respectively. Figure 1.b documents that savers' welfare increases with the level of capital requirement, whereas borrowers' welfare first increases and then decreases.

In the long run, higher capital requirements affect bank funding costs in two off-setting ways. An increase in capital requirements lowers the cost of deposit funding (see Figure 1.c) but, at the same time, it increases the share of more expensive equity funding. The net impact on the cost of borrowing, and thus on economic activity, depends on which effect dominates.

The hump shape in borrowers' welfare in Figure 1.b reflects the changing nature of the above trade off as capital requirements rise. When the probability of bank default is high, the first force dominates and credit supply actually expands leading to higher investment and GDP (not shown in the figure). But once bank failure probabilities and the deposit spread become sufficiently close to zero, tighter capital requirements raise the cost of credit and borrowers no longer benefit from a larger capital requirement. Savers continue benefiting as higher capital requirements lead to higher bank profits and, subsequently, to higher dividends from retiring bankers who return to the household.

In addition to the calibrated value of 8% in the figures we also focus on two other levels. The first is the level that maximizes the welfare of borrowers, i.e. 9.52 %. This is an interesting

of bankers wealth, and the aggregate determinants of bank and borrower default risk fixed at their steady state levels. In general equilibrium, these effects get combined with the endogenous response in the interest rate on bank debt and on other relevant prices. In fact, if a bank's risk of failure is initially high enough e.g. because its capital requirement is too low, increasing the capital requirement may effectively reduce the cost of bank debt to the extend of expanding rather than contracting loan supply.

reference because it is the level that would be optimal if, starting from the calibrated level of 8%, the macroprudential authority decided to gradually increase capital requirements aiming at a Pareto optimal increase. In practise, the macroprudential authority would increase capital requirements until both borrowers and savers benefit and stop as soon as one group begins to see its welfare fall. Hence, the highest capital requirement that all can agree upon is the one that maximizes the welfare of borrowing households. The other level signaled in the figure is the Basel III benchmark level of 10.5%.

Next we turn to the long term welfare effects of the policy. Table 3 (panel A) reports the change in the welfare of the two groups (measured in consumption equivalent units) from increasing capital requirements to the level that maximizes borrowers' welfare (row I) as well as to the steady-state level under Basel III (row II).

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 default. As a result, increasing capital requirements from the calibrated 8% to any of the two higher levels generates positive long-run welfare effects for both types of households. However, while the level that maximized Borrowers' welfare implies a slightly higher credit level, under Basel III the long-run level of credit is slightly below the initial one. For this reason, the Borrowers benefit somewhat less from the Basel III increase. In contrast, the long-run benefits of a Basel III-type policy change are more sizable for the Savers.

5. The Transition to Higher Capital Requirements

The results presented above show that higher capital requirements make the financial system less vulnerable in the long run by dampening the probability of bank default and by reducing the costs associated with bank failures. Overall, starting from the calibrated level of 8%, a moderate increase in capital requirements has a positive long-run welfare effect and also a positive (albeit very small) impact on economic activity.

In this section, we examine the transition to higher capital requirements. The experiment is conducted as follows:

- In period 1, we start the economy at the deterministic steady state;
- We compute the response of the economy (transition) to a permanent change in the parameter ϕ, i.e. a capital requirement increase, that is implemented gradually over a 8Q

period (from period 2 to period 9); The implementation path is known to all agents at the beginning of period 2;[38]

Our baseline experiment assumes an increase in capital requirement of 2.5 pp, i.e. the increase required by Basel III, that occurs in 8Q. In addition, the monetary authority follows the calibrated Taylor rule as in (27) and the ELB is not a contraint.

In other experiments, we also examine how the short run macroeconomic and welfare impact depends on the speed of implementation, the conduct of monetary policy and on the presence of an ELB constraint on nominal interest rates. The aim is to lay out the transmission mechanism of higher capital to the macroeconomy before examining in Section 6. how much and how fast capital requirements should be increased once we take transitional effects into account.

5.1 The Baseline Case

The dashed line in Figure 2.a displays the transition to a 2.5 pp higher capital requirements, assuming that it occurs gradually over 8 quarters. On impact, the capital increase causes a tightening of bank loan supply. Lending spreads rise and lending volumes decline which reduces investment demand from firms and leveraged mortgage borrowers. The rise in spreads is particularly pronounced for corporate borrowers whose loans carry a higher risk weight in the Basel regime. Thus, corporate lending suffers more from the credit supply reduction compared to household lending (not reported in the figure). Business investment falls substantially.

The nominal interest rate (determined by the Taylor-rule) is reduced gradually in line with the weakening prospects for inflation and real activity. Short real rates first increase, reflecting the slow reaction of monetary policy before falling in a persistent manner as the economy weakens. The fall in business investment is therefore moderated by the monetary policy driven reduction in real interest rates but overall the rise in lending spreads dominates with contractionary effects.

Aggregate consumption increases, mainly driven by higher consumption of savers who benefit from low real interest rates and from lower fiscal costs of bank default. In contrast, the consumption of leveraged households declines due to the higher costs of bank lending following the increase in capital requirements. Higher demand from savers fails to fully offset the decline

[38] 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 (non-linear perfect foresight path) using the Newton-Raphson algorithm.

in borrowers' demand. Aggregate economic activity contracts and inflation undershoots the target by a small amount. Overall, the increase in capital requirements affects the economy much as a demand shock would.

Table 3 reports the welfare implications of the policy changes analyzed above in two cases: when we only take into account the long-run effects (panel A) and when we also include the effects during the transition period (panel B.1). In the long-run the welfare effects are positive for both agents. Including the transition, however, implies large short-run costs that translate into net welfare costs for borrowers rather than benefits. See row (II) of Table 3.

A smaller increase in capital could lead to a positive welfare change for borrowres such as for example, a 1.52 pp increase in capital requirements (i.e. to the level that maximized long-run borrowers' welfare). Despite similar financial stability implications in the long-run, a smaller increase in capital requirements implies smaller short-run costs (see solid black line in Figure 3). Hence the 1.52 pp increase is beneficial for both classes of agents.

5.2 The Importance of the Phase-in Period

One crucial aspect of the capital requirement increase is the time horizon over which it comes into force. So far we considered an 8 quarter (2 year) horizon. In figure 2.b we assume a longer implementation horizon of 20 quarters (5 years) that resembles that envisaged under Basel III.

A slower phase-in period mitigates the short-run costs of an increase in capital requirements. It gives banks time to raise capital through retained profits thus allowing them to maintain lending over the transition period to higher capital requirements. This is particularly important for large capital requirement increases such as the ones required by Basel III.

The phase-in period is especially beneficial for borrowers. Panel (B.1) of Table 3 compares the welfare effects under a 8 quarter and 20 quarter implementation period. We can see that borrowers like a slower phase-in of capital requirement changes while savers prefer a quicker implementation since this boosts bank profit margins. As savers are the recipients of the profits from banks, this benefits them and their welfare increases by more.

5.3 The Importance of the Taylor Rule Inflation Response

We have seen that short term costs from the imposition of higher bank capital requirements may be sizeable, especially over a shorter implementation horizon. Since these costs arise through a standard aggregate demand channel, we now explore how they are affected by the size of the inflation response coefficient in the Taylor rule.

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 such as the one brought about by the increase in capital requirements. In Figure 3.a below, we examine the effect of a 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 long term benefits of higher capital are the same under the two alternative scenarios, the short term output costs differ significantly.

The increase in capital requirements reduces investment demand from firms and leveraged borrowers. Under a very reactive Taylor rule ($\alpha_\pi = 10$), policy is loosened aggressively, the real interest rate declines and, as a result, both borrowers and savers increase consumption. The short term decline in output and lending is therefore smaller compared to the baseline case ($\alpha_\pi = 1.5$).

Table 3 reports the welfare implications of the capital increase under the two monetary policy rules. Panel B.1 reports the results under the baseline Taylor-type rule ($\alpha_\pi = 1.5$) whereas panel C.1 displays the welfare effects for the $\alpha_\pi = 10$ case. The results indicate that while savers are only marginally affected by the conduct of monetary policy during the increase in capital requirements, borrowers are better off under the aggressive inflation response as this avoids a significant downturn. When $\alpha_\pi = 10$ even a large 2.5 pp increase in capital requirements is Pareto improving.

5.4 The Importance of the ELB

We now explore what happens when the policy rate is unable to respond as much as desired due to a binding ELB. We show that the short run costs of a capital increase are magnified and discuss how a slower implementation period and a more aggressive Taylor rule inflation response can mitigate the greater short term costs at the ELB.

Baseline case. In Figure 3.b we explore a 2.5 pp increase in capital requirements implemented over an 8-quarter period. The dashed black line displays the case in which the interest rate can go into negative territory and the ELB does not bind. The solid black line displays the case in which the ELB is imposed. The main message from the graphs is that a binding

ELB changes the impact of the capital increase significantly.

Once the policy rate hits the ELB, monetary policy cannot reduce the interest rate in response to a 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 greater declines. When monetary policy is constrained by the ELB, the negative effects on real activity are at their most sizable.

Borrowers' consumption is more sensitive to adverse movements in real income and real interest rates. As a result, higher real interest rates at the ELB leads to a decline in borrowers's consumption and welfare (see Table 3 row (III)). Hence borrowers would oppose a tightening of capital standards when the ELB binds. Such concerns would be even stronger when the increase in capital requirements occurs over a relatively short period (8 quarters).

The phase-in period. We have already argued that a more gradual implementation of the capital increase can help to mitigate its short term negative impact on aggregate demand. We now show that the speed of implementation is even more important when the ELB is binding.

The red solid line in Figure 3.b displays the case of a 20-quarter implementation horizon. The more gradual phase-in tightens credit supply less and, as a result, aggregate demand falls by a smaller amount compared to the case of faster implementation. Hence the ELB binds for a shorter period and the short term output costs are reduced. Borrower households gain from this as is shown by the smaller decline in their consumption.[39]

Interestingly, as a comparison between Figures 2.b and 3.b shows, the effect of a longer phase-in period is larger when the ELB is binding. Shocks to aggregate demand have an amplified effect when monetary policy is unable to accomodate them which is already suggestive that a slower implementation horizon will be optimal when the ELB binds.

The interest rate response to inflation. In the previous sections we showed that the conduct of monetary policy is key in determining the short-run costs of an increase in capital requirements. Here we show that, even when the ELB can bind, the conduct of monetary policy is crucial due to its effect on private sector expectations.

The dashed red line in Figure 3.b displays the case in which the monetary authority responds

[39] Nevertheless, contrary to the results presented above, in the presence of the ELB a longer phase-in period cannot guarantee that the capital requirement increase results into a Pareto improving policy (see Table 3 (B.1)). As we will see in Section 6., the presence of the ELB implies that the optimal increase in capital is smaller than 2.5pp.

more aggressively to inflation ($\alpha_\pi = 10$) and the capital requirement is increased over 8 quarters. We find that a more aggressive interest-rate response to inflation reduces the degree to which the ELB constrains the desired path of policy rates. This happens due to the *expectations channel*. A more aggressive response of monetary policy to inflation deviations from the target leads to higher expected inflation and output and hence requires a less accommodative policy. Inflation falls by less, the policy interest rate remains away from the ELB and the real interest rate declines helping to maintain real activity.[40]

Table 3 row (III) shows that a stronger response of monetary policy to inflation ensures that the short-term costs of a capital requirement increase do not cancel out the long-run benefits. This is particularly valuable for the borrowers who now also benefit from the capital requirements increase (see panel (C.1)).

6. Designing a Capital Requirement Increase

In the previous section we saw that higher capital requirements led to substantial short term costs which could be additionally amplified by the presence of the ELB. However, an aggressive Taylor rule inflation response as well as a long phase-in period could help mitigate these costs and increase the welfare of both borrowers and savers.

In this section, we explore the model's implication for the design of optimal capital regulation in a more formal manner. We maximize a measure of social welfare with respect to two policy parameters: the size of the long run capital requirement increase and the speed with which this increase is implementated. Thus, the desired policy is characterized by the combination of parameters that delivers the highest welfare.[41] Alternative rules are compared in consumption-equivalent terms, taking the calibrated capital requirement of 8% as the baseline.[42]

As we saw in the previous sections, increasing capital requirements beyond a certain level increases the welfare of savers (who benefit from higher bank profits) while decreasing the welfare of borrowers (who are hurt by higher borrowing costs). To avoid such a redistribution,

[40] **A limitation of our analysis is the absence of unconventional monetary policy (UMP) from the model. This would exaggerate the importance of the ELB but since it is a major extention, it is left for future work.**

[41] We search over a multidimensional grid that allows capital requirements to increase from 0pp to 3pp,with a step 0.005 over a period between 0 to 40 quarters.

[42] The consumption equivalent measure is calculated as the percentage increase in steady-state consumption that would make welfare under the calibrated policy equal to welfare under the optimized policy.

we focus on policies that generate incremental Pareto improvements. More specifically, we assume that the macroprudential authority increases capital requirements gradually until both borrowers and savers benefit and stop as soon as one group begins to see its welfare fall.[43]

The results are shown in Panel A of Table 4. Once again, we will show that the results crucially depend on the extent to which monetary policy is able to offset the negative aggregate demand consequences of the capital increase.

6.1 No ELB

Starting with the no ELB case, our quantitative model predicts an optimal increase in capital requirements which is lower than the 1.52pp that is optimal when we consider the long-run effects only. Under the baseline monetary policy response to inflation ($\alpha_\pi = 1.5$), the optimal long-run capital requirement increase is 1.045pp and is implemented over a very long horizon (40Q).[44]

As the monetary policy reaction function responds more aggressively to inflation, the optimal long run capital increase becomes larger while the optimal implementation horizon shortens. For a strict inflation targeting central bank, it is optimal to implement the capital requirement increase without delay.[45] 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 the largest and fastest increase in capital requirements. As a result, the net welfare benefits from the increase in capital requirements are the largest.

6.2 ELB

We now assume that the optimal increase in capital requirements is implemented in the proximity of the ELB. More specifically, we assume that the policy rate is 5 bp away. Table 4, Panel B reports the results. Close to the ELB, the ability of monetary policy to offset the negative impact of the capital increase is limited and, as a result, the optimal increase in capital

[43] If we maximised the weighted welfare of the two groups instead, we would find that higher capital ratios are optimal.

[44] 40Q is the upper bound for the implementation horizon. Removing this upper bound implies a longer optimal phase-in period but only marginal changes in the welfare of the two groups.

[45] The strict inflation targeting regime is especially important since monetary policy completely offsets the distortions due to nominal rigidities by keeping prices stable at all times.

requirements is smaller.[46] In addition, the change in capital requirements occurs over a much more extended period of time. This result holds even in the case of a strict inflation targeting central bank.[47]

7. Sensitivity to Key Model Features

We have assessed the extent to which capital requirements can be increased without imposing undue short term costs on the real economy. In this section, we examine how our results depend on key features of the model as well as aspects of the conduct of monetary policy other than the Taylor rule inflation response.

In particular, we illustrate the role of the degree of price stickiness and of debt contracts in nominal terms. In addition, we also explore the importance of model parameters specific to the modelling of the banking sector: the fraction of insured bank debt, κ, and the steady state degree of riskiness of the loan portfolio of banks, $\sigma_{\epsilon}^{\sigma\varkappa}$.[48]

We perform the sensitivity analysis assuming a stronger inflation response in the Taylor rule ($\alpha_{\pi} = 3$) than the calibrated one in order to explore also the impact of different model features on the the speed of implementation.[49]

7.1 Nominal Features

Nominal Debt Contracts. We start by comparing the transmission mechanism of an increase in capital requirement in our baseline model and in one with real debt contracts. Fig 4.a

[46] It is possible to show that under the optimal capital requirement policies displayed in Panel A, the policy rate would violate the lower bound.

[47] In results that are available upon request, we have also examined the implications of the ELB by assuming that the distance between the effective lower bound and the initial policy rate is 7.5 bp and 10 bp, respectively. The further away is the ELB, the less relevant for the conduct of monetary policy. Nevertheless, whenever the ELB becomes an effective constraint, the optimal increase in capital requirement is more moderate and the speed of implementation substantially reduced compared to the case in which the policy rate can fall into negative territory.

[48] Interest-rate smoothing, ρ_R, and of the response to GDP growth, ϕ_y, in the monetary policy rule were also considered but did not significantly affect the results.

[49] When we performed the analysis under the baseline ($\alpha_{\pi} = 1.5$) we found that, while the long run capital increase was different between the different scenarios, the optimal implementation speed what often hitting the upper bound. Thus, a very slow implementation (40Q) was almost always appropriate.

compares the effect of a 2.5 pp capital requirement increase in our baseline model with nominal debt contracts (black lines) and in a version with real debt contacts (red lines). We also investigate the differences in the absence of the ELB (dashed lines) and when the ELB is a binding constraint (solid lines).

In the absence of the ELB, the model does not display any sizable difference between the two alternative assumptions. In contrast, if the ELB is a binding constraint, the model with nominal debt contracts exhibits larger short-run costs and more sizeable welfare costs for borrowers. This result is due to the well-known *debt-deflation channel*. A surprise fall in inflation increases the real interest rate payoff to savers at the expense of borrowers, implying a reallocation of resources across households. This effect is particularly sizeable due to the presence of the ELB.

Price Stickiness. The degree of price stickiness determines the slope of the Phillips curve and plays an important role in our analysis. We assume a very high degree of price rigidity in line with recent estimates that point to a very flat Phillips curve in the EA. This implies that aggregate demand has a large impact on real activity and relatively small impact on inflation. Here we explore the implications of assuming a much lower degree of price rigidity.

In Figure 4.b, we explore the transition to a 2.5 pp higher capital requirement in the benchmark model (black lines) and compare it to an economy with a lower degree of price rigidity (red lines). The figure also displays the response of the flexible price version of the same economy (dashed blu line). The key message is that a lower degree of price stickiness implies considerably smaller short-run output costs from a capital increase.

Table 5 panel C confirms that when the ELB is not binding, the optimal increase in capital requirements is larger and it is implemented at a faster pace in the economy with more flexible prices. However, under the Taylor-rule, the larger responsiveness of inflation translates into a much more volatile interest rate that is far more likely to violate the ELB. Thus, when the ELB becomes an effective constraint for the conduct of monetary policy, the lower degree of price rigidities requires a smaller increase in capital requirements and a longer phase-in period compared to the baseline.

7.2 Banking Features

Degree of banking distress. Making banks safer is a key reason for increasing capital requirements. Our model implies that, in the long-run, bank risk determines the size of the benefits from higher capital requirements. Hence, varying the degree of risk faced by the banking is an interesting sensitivity exercise to assess the extent to which economies with riskier banks should worry about the short run costs of increasing capital requirements.

Figure 4.c 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). 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.

As discussed in Section 4., in the long run, the capital requirements has two opposing effects on banks' cost of funding. A higher share of expensive equity increases banks' weighted average cost of capital but making banks safer lowers the cost of uninsured deposit funding and this reduces their weighted average cost of capital. When the risk of bank failure is high, the lower cost of deposit funding dominates and the benefits of higher capital are at their highest.

Even in this example, short run costs exist as evidenced by the initial decline in output and lending. However, they are smaller and, as can be seen from Table 5, the 2.5 pp increase in capital requirement brings larger net benefits. When banks are subject to greater uncertainty regarding the return on the loan portfolio (panel D), the optimal increase in capital requirement is twice as big as in the baseline model and the welfare gains are much larger for both borrowers and savers. The ELB requires slower implementation, but it does not alter the main message. Overall, our results lend support to the approach of gradually raising capital buffers to much higher levels in the context of a riskier banking sector even when nominal interest rates are close to the ELB.

Insured Bank Debt. We now explore the role of the insured fraction of bank debt (κ), which measures the importance of the safety net subsidies enjoyed by banks. To this purpose, we re-run the optimal policy assuming: i) no insured bank debt, ii) full deposit insurance. See Table 5, panel E and F, respectively.

In the interesting polar case where all bank debt is uninsured ($\kappa = 0$), bank failures do not impose any tax cost on households. As already discussed, we assume that individual banks are too opaque and therefore pay an interest rate on their debts which depend on the average risk of the banking system. This is beyond the control of any individual atomistics bank and hence it provides incentives for individual banks to take on risk in the form of as much leverage as permitted by capital regulation. Thus, the safety net subsidies disappear but the limited liability distortion remains and market discipline is ineffective in ensuring good behaviour by banks.

In such an environment, removing deposit insurance makes banks' debt funding more expensive and more responsive to shocks, reducing banks' resilience and increasing their potential contribution to the propagation of shocks. As a result, the absence of deposit insurance requires a larger optimal increase in capital requirements and a slower phase-in period compared to the baseline. In contrast, full deposit insurance requires a smaller increase and a slightly faster implementation.

The fraction of insured deposits (κ) also has implications for the welfare effects higher capital. Borrowers gain more when there is no deposit insurance, owing to the fact that higher capital requirements reduce bank funding costs and relax lending standards. Savers are not strongly affected.

8. Conclusions

To assess the macroeconomic implications of increasing capital requirements we build a macro-banking model that includes monetary policy, nominal debt and price rigidities. The model is calibrated to match the salient features of the EA economy.

We argue that the conduct of monetary policy is key in assessing the net benefits of capital requirement increases. In the absence of a lower bound on the monetary policy rate, these short term 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 as capital is increased, leading to larger short term costs. In the proximity of the ELB, a more moderate increase in capital requirement and a longer phase-in period are needed in order to prevent the short term costs from offsetting the long-term benefits. This ensures that the policy change is welfare improving for all households.

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Bank Capital in the Short and in the Long Run

Technical Appendix

A Model Details

Market Clearing Conditions:

Internal market clearing condition for banks' assets and liabilities

$$E_t + D_t = B_t \tag{30}$$

where $E_t = E_{M,t} + E_{F,t}$, $D_t = D_{M,t} + D_{F,t}$ and $B_t = x_m B_{m,t} + B_{f,t}$

Capital market equilibrium

$$K_t = x_s K_{s,t} + K_{f,t} \tag{31}$$

Housing market equilibrium

$$H_t = x_s H_{s,t} + x_m H_{m,t} \tag{32}$$

Labor market equilibrium

$$L_t = x_s L_{s,t} + x_m L_{m,t} \tag{33}$$

Aggregate supply

$$Y_t = \frac{z_t L_t^{1-\alpha} K_{t-1}^{\alpha}}{\Delta_t} \tag{34}$$

where $\Delta_t = \int_0^1 \left(\frac{p_t(i)}{P_t}\right)^{-\frac{1+\theta}{\theta}} di$.

Definitions:

and here the equations describing the determination of variables such as $T_{s,t}$, $T_{m,t}$, Ω_t, and $\Psi_{b,t}$

Deficit of the Deposit Insurance Agency:

$$T_t = \left[\omega_{F,t} - \Gamma_{F,t}(\overline{\omega}_{F,t}) + \mu_F G_{F,t}(\overline{\omega}_{F,t})\right] \widetilde{R}_{F,t} B_{f,t} + \left[\omega_{M,t} - \Gamma_{M,t}(\overline{\omega}_{M,t}) + \mu_M G_{M,t}(\overline{\omega}_{M,t})\right] \widetilde{R}_{M,t} B_{m,t} x_m \tag{35}$$

The deficit of the DIA that accrues to insured deposits is financed by a lump-sum tax on savers and borrowers.

$$T_{s,t} = \kappa_{ins} \frac{a_s T_t}{x_s} \tag{36}$$

$$T_{m,t} = \kappa_{ins} \frac{a_m T_t}{x_m} \tag{37}$$

where $a_m = 1 - a_s$.

The rest of the deficit is financed by the savers directly (insured deposits), so that we get the following expression for the nominal effective return on deposits, $\widetilde{R}_t^d$, in (5):

$$\widetilde{R}_t^d D_{t-1} = R_{t-1}^d D_{t-1} - (1-\kappa_{ins})\frac{T_t}{x_s} = \left[R_{t-1}^d - (1-\kappa_{ins})\Omega_t\right] D_{t-1} \tag{38}$$

where $\Omega_t = \frac{T_t}{x_s D_{t-1}}$.

The bank default rate is given by:

$$\Psi_{b,t} = \frac{\frac{\left(1-\phi_{M,t-1}\right)}{\phi_{M,t-1}} F_{M,t}(\overline{\omega}_{M,t}) E_{M,t-1} + \frac{\left(1-\phi_{F,t-1}\right)}{\phi_{F,t-1}} F_{F,t}(\overline{\omega}_{F,t}) E_{F,t-1}}{x_s D_t} \tag{39}$$

According to bank accounting conventions, we can find the write-off rate (write-offs/loans) for loans of type j that the model generates, $\Upsilon_{j,t}$, as the product of the fraction of defaulted loans of that type, $F_j\left(\overline{\omega}_{j,t}\right)$, and the average losses per unit of lending experienced in the defaulted loans, which can be found from our prior derivations. For example, in the case of NFC loans, this decomposition produces:

$$\begin{aligned}\Upsilon_{f,t} &= F_{f,t}\left(\overline{\omega}_{f,t}\right)\left[\frac{b_{f,t-1} - \frac{(1-\mu_f)}{F_{f,t}\left(\overline{\omega}_{f,t}\right)}\left(\int_0^{\overline{\omega}_{f,t}} \omega_{f,t} f_{f,t}\left(\omega\right) d\omega\right) R_t^K q_{k,t-1} k_{f,t-1}}{b_{f,t-1}}\right] \\ &= F_{f,t}\left(\overline{\omega}_{f,t}\right) - (1-\mu_f) G_{f,t}(\overline{\omega}_{f,t}) R_t^K \frac{q_{k,t-1} k_{f,t-1}}{b_{f,t-1}}.\end{aligned} \tag{40}$$

An expression for the writte-off rate of mortgage loans, $\Upsilon_{m,t}$, can be similarly obtained.

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.[50]

- 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)

[50] All monetary financial institutions in the Euro Area 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).

  - 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 Euro Area 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

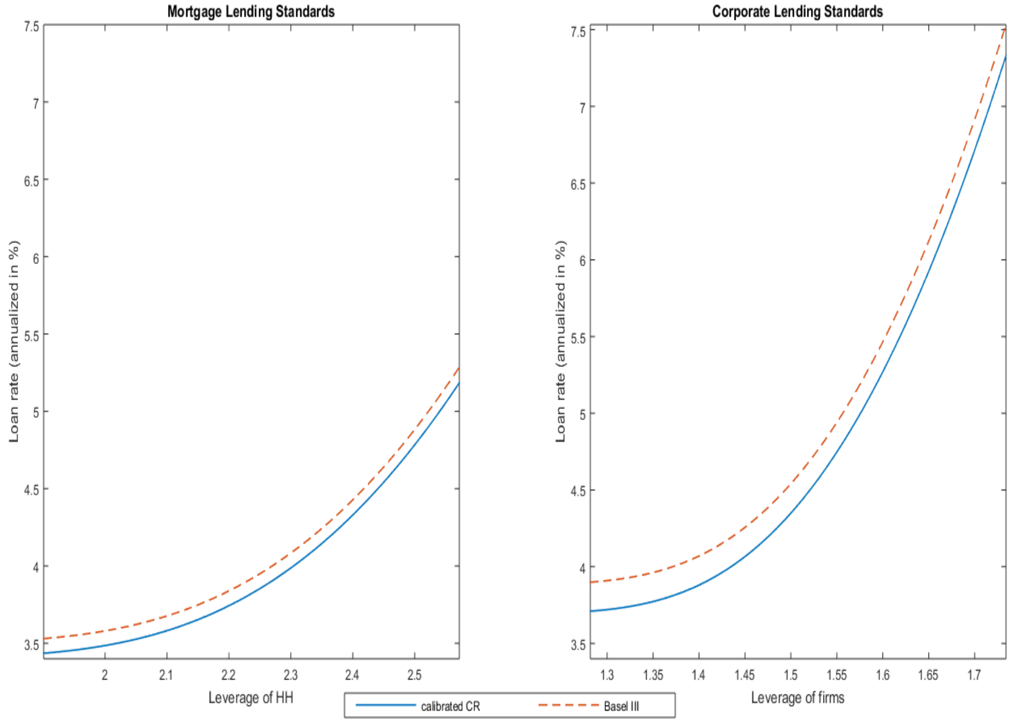

Figure 1.a. Lending Standards for borrowing households (LHS) and firms (RHS). Loan rate and leverage combinations for different levels of the capital requirement: calibrated (solid line) and Basel III (dashed line). All other parameters set to their calibrated values

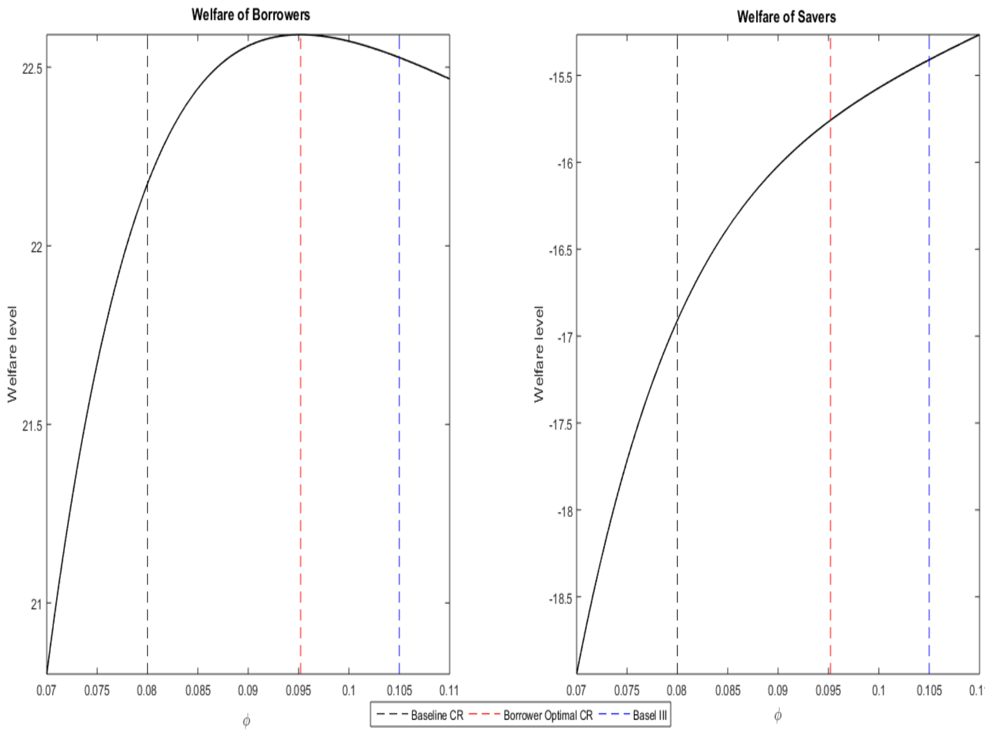

Figure 1.b. Long-run Effect of Capital Requirement Levels on Welfare. Steady state level of individual welfare w.r.t. the capital requirement parameter ϕ. All other parameters set to their calibrated values

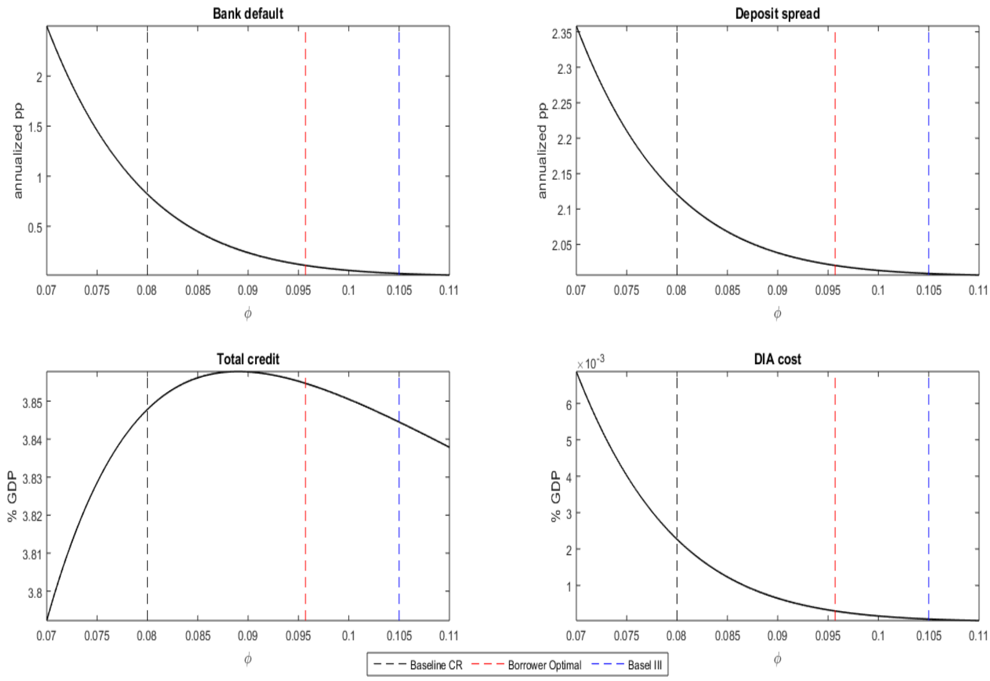

Figure 1.c. Long-run Effect of Capital Requirement Levels on Key Variables. Steady state figures of key variables w.r.t. the capital requirement parameter ϕ. All other parameters set to their calibrated values. The probability of bank default and the bank debt spread are in annualized percentage terms, the deposit insurance cost is measured as percentage of GDP.

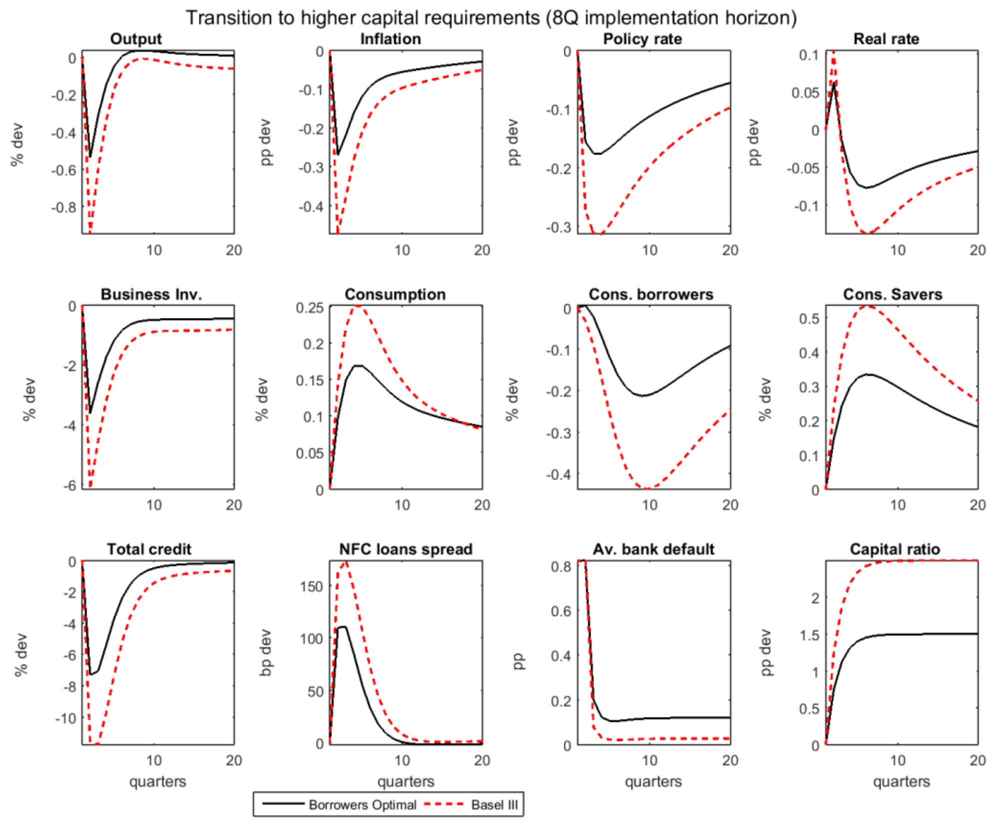

Figure 2.a Transition to higher Capital Requirements. Short-run effect on key variables of a permanent increase in the capital requirement parameter ϕ of 1.52 pp (black solid line) and a 2.5 pp (red dashed line) implemented over a 8-quarter period. All other parameters set to their calibrated values. The probability of bank default and the bank debt spread are in annualized percentage terms, the deposit insurance cost is measured as percentage of GDP.

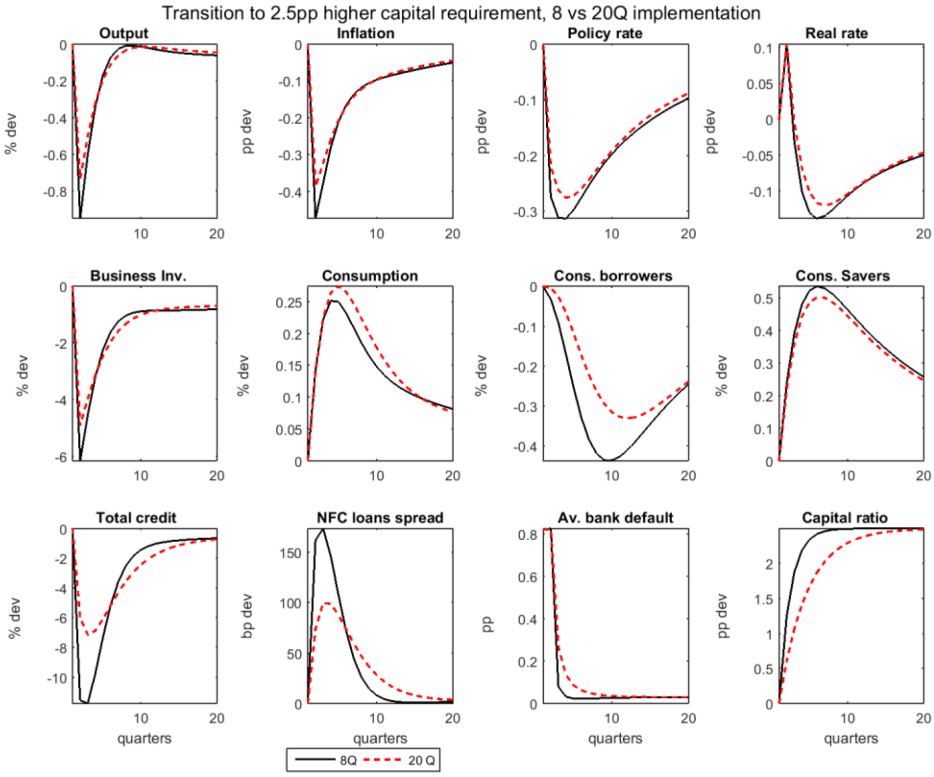

Figure 2.b Transition to higher Capital Requirements and the phase-in period. Short-run effects on key variables of a permanent increase in the capital requirement parameter ϕ by 2.5 pp over a 8-quarter (black solid line) and a 20-quarter period (black dashed line). All other parameters set to their calibrated values. The probability of bank default and the bank debt spread are in annualized percentage terms, the deposit insurance cost is measured as percentage of GDP.

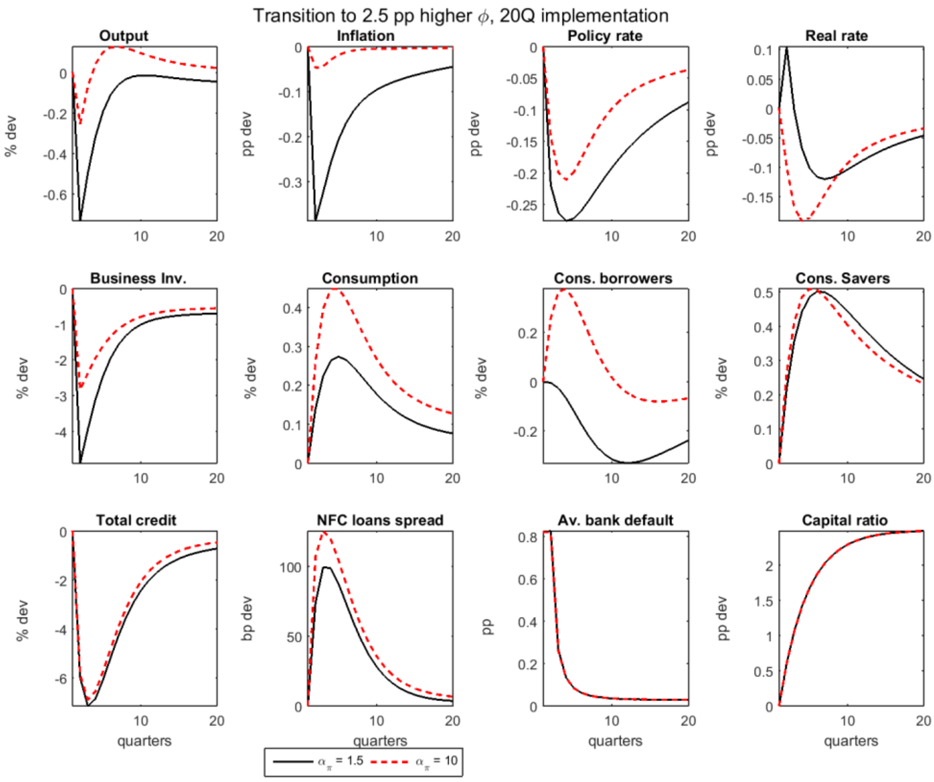

Figure 3.a Transition to higher Capital Requirements and the interest rate response to inflation. Short-run effect on key variables of a permanent increase in the capital requirement parameter ϕ by 2.5 pp over 20-quarter periods under different interest-rate rule responses to inflation. All other parameters set to their calibrated values. The probability of bank default and the bank debt spread are in annualized percentage terms, the deposit insurance cost is measured as percentage of GDP.

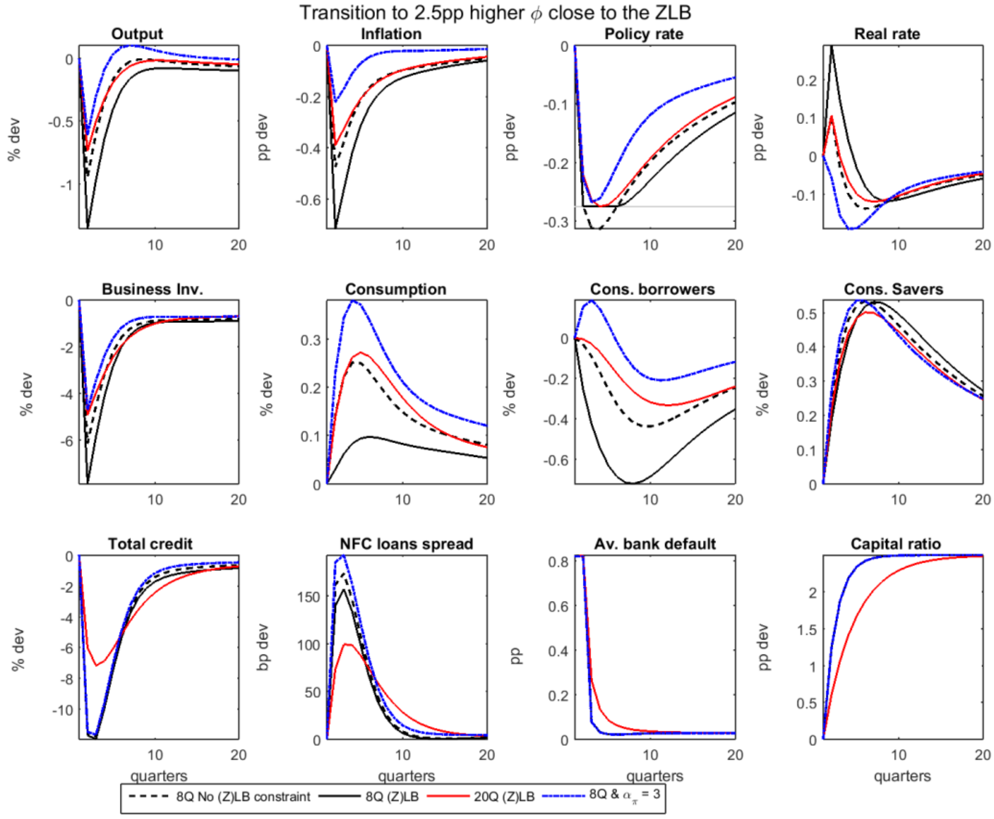

Figure 3.b Transition to higher Capital Requirements in proximity of the ZLB. Short-run effect on key variables of a permanent increase in the capital requirement parameter ϕ by 2.5 pp over 20-quarter periods under different interest-rate rule responses to inflation. All other parameters set to their calibrated values. The probability of bank default and the bank debt spread are in annualized percentage terms, the deposit insurance cost is measured as percentage of GDP.

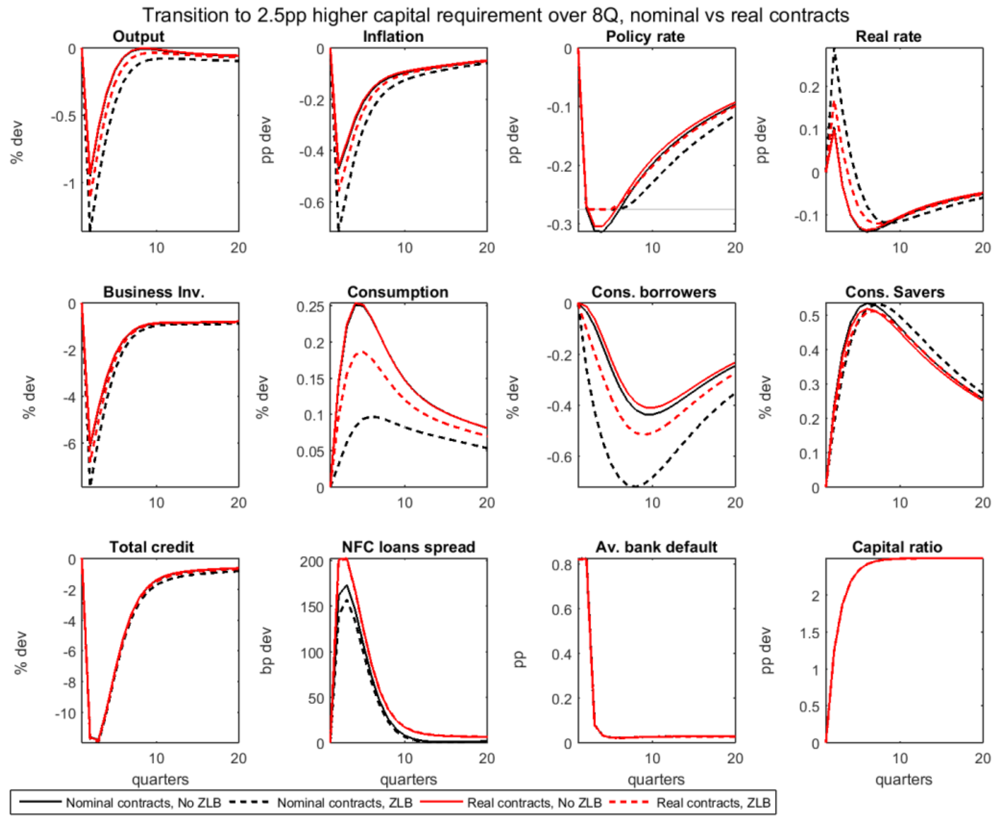

Figure 4.a Transition to higher Capital Requirements: Nominal vs Real Debt Contract

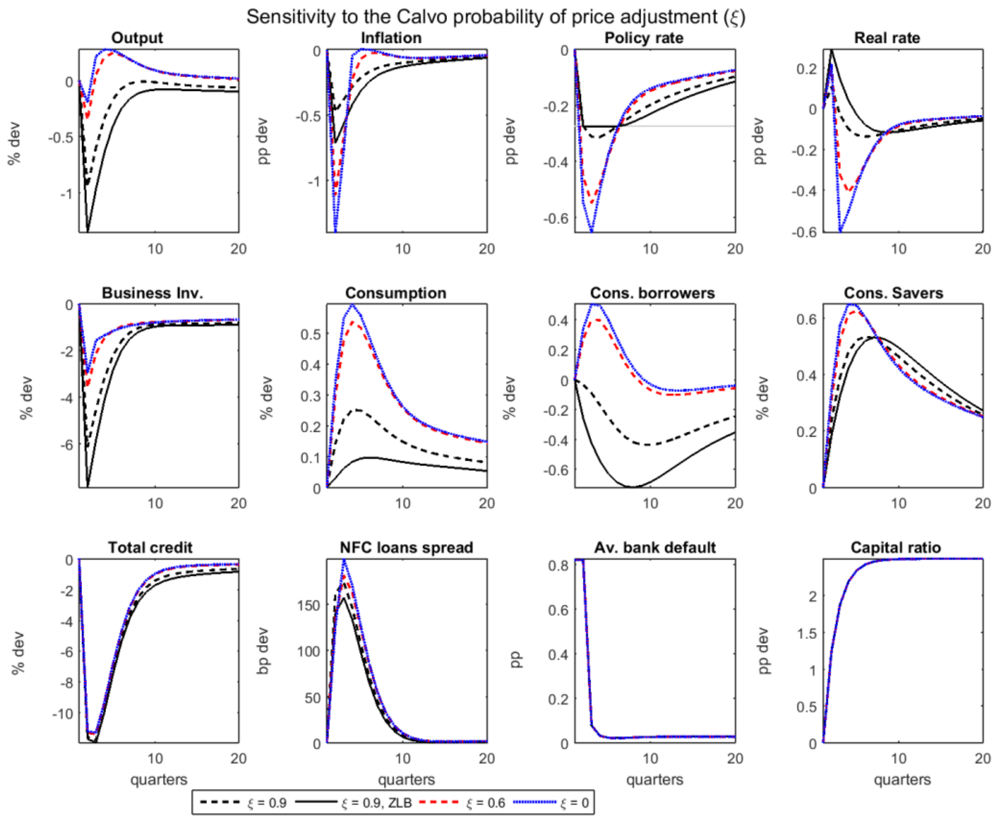

Figure 4.b Transition to higher Capital Requirements: Lower degree of price stickiness.

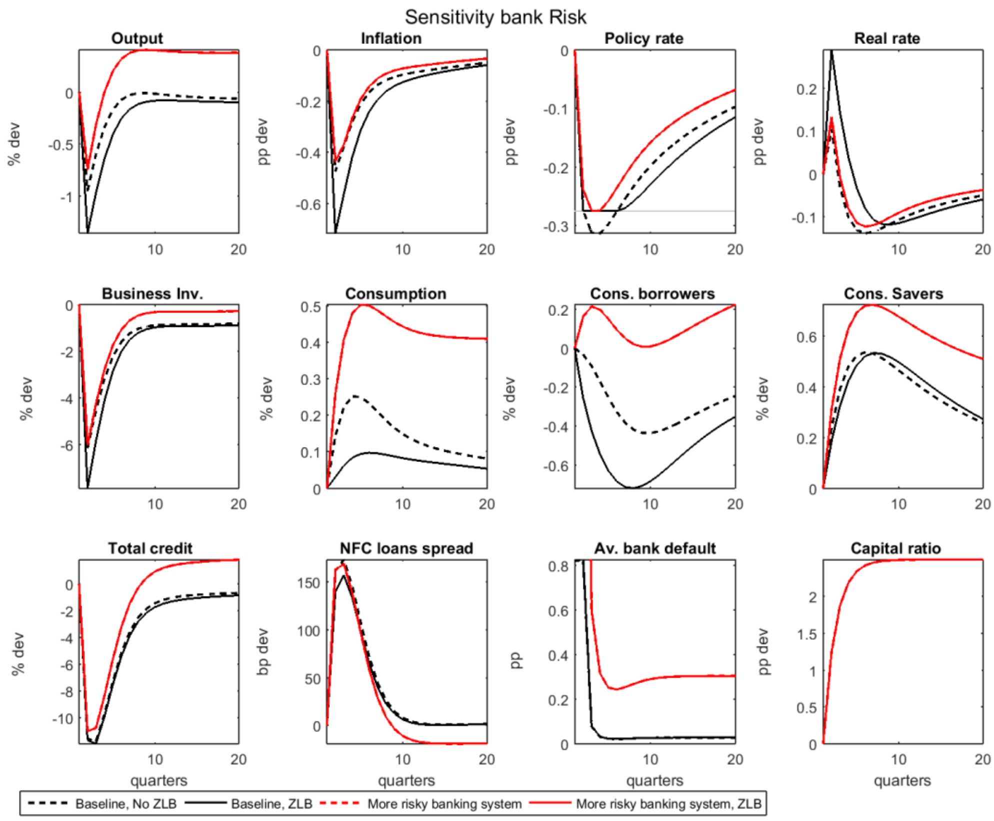

Figure 4.c Transition to higher Capital Requirements: higher degree of bank risk

	(A) Long-run Welfare Effects		(B) Welfare Effects including transition							
			(B.1) Baseline Model				(B.2) Taylor Coeff. = 10			
			8Q		20Q		8Q		20Q	
CR increase	**BORROWERS**	**SAVERS**	**BORROWERS**	**SAVERS**	**BORROWERS**	**SAVERS**	**BORROWERS**	**SAVERS**	**BORROWERS**	**SAVERS**
(I) Optimal: 1.52%	0.7046%	0.2862%	0.2202%	0.3229%	0.2501%	0.3168%	0.3870%	0.3028%	0.3893%	0.2997%
(II) Basel 3: 2.5%	0.5962%	0.3728%	-0.0935%	0.4524%	-0.0238%	0.4422%	0.1934%	0.4183%	0.2187%	0.4127%
(III) Basel 3: 2.5% (Z)LB*	0.5962%	0.3728%	-0.2775%	0.4730%	-0.0256%	0.4424%	0.1664%	0.4214%	-	-

Table 3. Welfare effects (consumption equivalent terms) in the long-run (A) and including transition (B) of an increase in capital requirement by 1.52 pp (row I), 2.5pp (row II) in normal times and in proximity of the (Z)LB (row III), where the lower bound is assumed to be **xx bp** below steady state.

	A. NO (Z)LB Contraint				B. (Z)LB Constraint			
	Taylor rule (inflation parameter)			Strict inflation targeting	Taylor rule (inflation parameter)			Strict inflation targeting
	1,5	3	10		1,5	3	10	
Optimal CR increase	1,045%	1,140%	1,185%	1,270%	0,775%	1,130%	1,145%	1,150%
Optimal speed	40 Q	25 Q	11 Q	0 Q	40 Q	39 Q	34 Q	32 Q
BORROWERS Welfare	0,315%	0,366%	0,405%	0,449%	0,299%	0,362%	0,386%	0,395%
SAVERS Welfare	0,237%	0,248%	0,255%	0,264%	0,185%	0,239%	0,246%	0,246%
Quarters of ZLB binding	NA	NA	NA	NA	3 Q	5 Q	4 Q	5 Q

Table 4. Optimal increase in capital requirement as summarized by the optimal change and speed of implementation in normal times (Panel A) and in proximity of the (Z)LB (Panel B), where the lower bound is assumed to be 5 bp below baseline. The welfare gains are measured as a percentage increase in long-term consumption (consumption equivalent).

	A. Baseline	B. Real Debt	C. Calvo Prob 0.6	D. Higher bank risk shock	E. No deposit insurance	F. Full deposit insurance	G. Taylor rule No Smoothing	H. Taylor rule No Output
I. NO (Z)LB								
Optimal CR increase	1,140%	1,200%	1,190%	2,720%	1,305%	0,970%	1,175%	1,140%
Optimal speed	25 Q	2 Q	6 Q	21 Q	26 Q	24 Q	20 Q	24 Q
BORROWERS Welfare	0,366%	0,426%	0,417%	2,786%	0,526%	0,241%	0,386%	0,368%
SAVERS Welfare	0,248%	0,252%	0,255%	0,960%	0,210%	0,269%	0,254%	0,250%
Volatility Policy rate	2,030%	11,052%	7,620%	5,317%	2,063%	1,919%	5,025%	2,045%
II. (Z)LB								
Optimal CR increase	1,130%	1,135%	0,950%	2,160%	1,310%	0,965%	1,050%	1,100%
Optimal speed	39 Q	39 Q	40 Q	40 Q	37 Q	39 Q	40 Q	37 Q
BORROWERS Welfare	0,362%	0,365%	0,368%	2,667%	0,523%	0,238%	0,362%	0,364%
SAVERS Welfare	0,239%	0,242%	0,214%	0,853%	0,205%	0,262%	0,218%	0,242%
Q of ZLB binding	2 Q	2 Q	2 Q	6 Q	2 Q	3 Q	4 Q	2 Q

Table 5. Optimal increase in capital requirement as summarized by the optimal change and speed of implementation in normal times (Panel I) and in proximity of the (Z)LB (Panel II), under alternative modelling assumption. The welfare gains are measured as a percentage increase in long-term consumption (consumption equivalent).