# Welfare Analysis of Implementable Macroprudential Policy Rules: Heterogeneity and Trade-offs*

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August 2015

**Abstract**

We characterize social welfare maximizing capital requirement policies in a macroeconomic model with household, firm and bank defaults calibrated to Euro Area data. We find that the most important role of capital regulation is to ensure that banks are sufficiently capitalized so as to keep the risk of bank failure small. Getting the level and the risk weight parameters right is then of foremost importance. The counter-cyclical adjustment of capital requirements is also beneficial but its welfare impact is smaller.

When capital requirements are low, all agents benefit from increasing them. Beyond a certain level, a trade-off appears between the welfare of savers and borrowers. Savers benefit from tighter capital regulation due to lower social costs from bank failures and higher bank profits. Borrowers lose due to a reduced supply of bank loans.

Keywords: Macroprudential policy; Risk weights; Capital buffer; Financial frictions; Default risk.

JEL codes: E3, E44, G01, G21

*We thank Antonio Antunes, Isabel Correira, Philipp Hartmann, Patrik Kehoe, Jesper Lindé, Simone Manganelli, Pedro Teles and seminar participants at European Central Bank, Institute for International Economics and Development (Vienna), CREST, Swiss National Bank, Bank of Portugal Conference on Financial Stability and Macroprudential Policy, and Birkbeck workshop for applied macroeconomics for helpful comments.

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# 1. Introduction

The regulation of bank capital has become one of the most important policy issues of the post-financial crisis era. Since the Lehman crisis and the Great Recession that followed, a consensus has emerged on the need to look at financial regulation from a macroprudential perspective. The new focus is on systemic stability and on the consequences of banking instability for aggregate credit supply and real activity. In parallel, significant research effort has been devoted to develop general equilibrium models that help understand the links between financial intermediation and the macroeconomy and, eventually, the channels of transmission of macroprudential policies.

Our paper aims to provide welfare-based analysis of realistic macroprudential policy instruments. For this purpose we use a microfounded DSGE model with bank default and focus on two important dimensions that have been overlooked in the literature. First, we characterize implementable macroprudential policy rules that mimic closely the way practical policy is conducted and show how these rules map into the Basel III policy instruments. To the best of our knowledge, ours is the first paper to offer a tractable means of analysing the capital conservation and countercyclical buffers in Basel III and to produce quantitative model-based prescriptions for these buffers.[1]

Second, we examine the role of agent heterogeneity (borrowing vs. saving households) and discuss who the winners and losers from macroprudential policy measures might be. Most papers in the macroprudential policy literature abstract from heterogeneity (under incomplete markets) because it complicates welfare analysis as the welfare weights on different agents become arbitrary.[2] Nevertheless, we believe that the impact of policy on different agents is a crucial element in real world policy making. We derive macroprudential policy conclusions that are robust to a wide range of Pareto weights attached to the different agents.

Our paper is part of a growing literature which incorporates banking in otherwise standard DSGE models (see e.g. Curdia and Woodford, 2010; Gertler and Kiyotaki, 2010; Gerali et al.,

[1] Much of the literature on macroprudential policy relies on chacterizing social planner allocations in highly stylized models (e.g. Bianchi and Mendoza, 2011; Jeanne and Korinek, 2013; Brunnermeier and Sannikov, 2014). The cost of the simplicity required for such analysis is that the policy tools considered (usually Pigouvian taxes) are not the ones used in practice.

[2] Notable exceptions are Goodhart et al (2013) and Lambertini, Mendicino and Punzi (2013) who, in discussing instruments such as loan-to-value (LTV) limits, show that policy also affects heterogeneous agents differently. Angelini, Neri and Panetta (2014) also examine macroprudential policy rules in a model with different types of agents, however they restrict their analysis to stabilization policies, rather than fully exploring the welfare implications of capital regulation.

2010; Meh and Moran, 2010; Gertler, Kiyotaki and Queralto, 2012). We consider a framework in which banks intermediate funds between savers and corporate and household borrowers, and where all borrowers (including banks) may default on their lenders due to idiosyncratic and aggregate shocks. The distinguishing feature of our work is our strong emphasis on the social costs of bank default which banks fail to internalize due to safety net guarantees and depositors' inability to price in the risk associated with individual banks' leverage decisions.[3] Bank default remains a neglected aspect of model-based macroprudential policy analysis and our paper fills an important literature void in this respect.[4]

In order to provide quantitative results, our model is calibrated so as to match the first and second moments of a number of key aggregate macroeconomic and financial variables for the Euro Area economy. What sets us apart from other papers fit to Euro Area data (e.g. Christiano, Motto and Rostagno, 2008; Gerali et al, 2010) is our emphasis on matching the empirical properties of a number of banking variables such as bank capital ratios, loan write offs, bank lending spreads and quantities, etc. We believe that it is key for a macroprudential policy model to match the properties of the financial side of the economy and our success in doing so is an important contribution.

Our welfare analysis relies on a measure of social welfare based on the weighted welfare of borrowers and savers and on the analysis of the full range of weighting schemes. We focus our attention on capital regulatory policies that are Pareto improving relative to a certain status quo. The model is solved using second order perturbation methods in order to capture consistently the impact of aggregate uncertainty on macroeconomic aggregates and welfare.

Our analysis yields several important policy conclusions. Firstly, we find that, regardless of the Pareto weights given to each of the two classes of agents in the social welfare function (borrowers and savers), it is always optimal to impose an average capital requirement and a mortgage risk weight high enough to keep bank defaults low and to reduce the strength of bank-related amplification channels. We also find that some degree of countercyclical adjustment in the capital ratios is optimal because it helps to reduce fluctuations in credit and, consequently, consumption volatility. However, the welfare contribution of this adjustment is small relative to the other components of the optimal macroprudential rule since this one acts mainly on

[3] Other papers that emphasize safe-net-related distortions are Martinez-Miera and Suarez (2014), Clerc et al. (2015), and Aoki and Nikolov (2015).

[4] Notable exceptions are Angeloni and Faia (2013), Kashyap, Vardoulakis and Tsomocos (2014) and Martinez-Miera and Suarez (2014), where banks are fragile due to either bank runs or excessive asset side risk-taking.

volatility, whose welfare impact is of second order. The level of bank capital ratios and risk weights have a larger (first order) welfare impact because they help to eliminate the excessive deadweight losses that arise from the bank-driven amplification of aggregate shocks.[5]

Secondly, we find that increasing capital requirements is Pareto-improving up to a point and redistributive after that. In the model, both borrowers and savers benefit from the reduction in financial fragility when capital requirements are raised from low levels. However, beyond a certain level, a trade-off appears between the welfare of borrowers and savers. Further increases in capital requirements and mortgage risk-weights continue to benefit savers who face a lower tax burden coming from deposit insurance. Additionally, tighter requirements increase the scarcity of bank capital and raise lending spreads and banks' profits, further benefiting the savers, who receive dividends from banks.

Borrowing households also benefit from the lower cost of bank default, but lose from tighter capital standards to the extent that those translate into higher loan interest rates. We find that, once bank default is close to zero, the negative impact on the supply of loans dominates and borrowing households lose from a further tightening of the capital requirements. Hence, our results suggest that high but not excessive capital requirements are beneficial for social welfare, independently of the Pareto weights attached to the welfare of each class of agents.

The trade-off between the welfare of savers and borrowers is also present when it comes to the degree of countercyclical adjustment of the capital requirements. When negative shocks hit and credit is relatively scarce, a more aggressive countercyclical response of the capital requirement to the credit gap helps to partly offset the credit supply impact of bank losses, thus stabilising the supply of loans in the economy. This clearly benefits borrowers. The savers, however, dislike the marginal increase in the deposit insurance cost and the reduced dividends from banks and firms. Quantitatively, however, the welfare implications that we find for either type of agent are very small.

In the final part of the paper we explore the relative importance of different types of shocks in explaining the gains associated with the optimal policy rule and we conclude with some reflections about the implications of our results for the quantitatively largely unexplored issue of

[5] Our results confirm the findings in Forlati and Lambertini (2011) and Christiano, Motto and Rostagno (2014) that aggregate risk shocks are important drivers of economic fluctuations. In addition, we argue that risk shocks are the source of important welfare losses due to their impact on banking instability. The importance of financial shocks more generally has also been emphasized by Jermann and Quadrini (2012), Liu, Wang and Zha (2013), and Iacoviello (2015).

the interaction between the objectives of micro and macroprudential policies. Microprudential regulation is concerned with ensuring the solvency of individual banks while macroprudential policy is tasked with systemic stability and with smoothing the fluctuations in aggregate credit supply. In fact, our results point to the existence of a large complementarity between these objectives.

In the model, having solvent banks (the goal of micropru) ensures that the financial system does not amplify real and financial shocks in an excessive manner (the goal of macropru). Our model predicts the type of conflict anticipated by Hanson, Kashyap, and Stein (2011) at the bottom of the financial cycle, when microprudential regulators may wish to avoid an increase in bank failure risk while macroprudential regulators may wish to sustain credit supply. However, our findings suggest that the gains from an aggressive countercyclical adjustment in capital requirements are unwarranted and that macroprudential regulators will also wish to keep bank-related shock amplification contained, overall predicting a smaller conflict than commonly presumed.

The paper is structured as follows. Section 2 briefly describes the model. Section 3 explains in detail our calibration procedure and the data we use. Section 4 contains quantitative results and the policy analysis. Section 5 concludes. The appendices provide further details on equilibrium conditions and the data used in the calibration.

# 2. Model Economy

Following Clerc et al. (2015), we consider an economy populated by saving households (denoted by $s$) and borrowing households (denoted by $m$) that consume, supply labor to the production sector and invest in housing. Households belong to two dynasties of ex ante identical infinitely lived agents that differ in terms of the subjective discount factor ($\beta_m \leq \beta_s$). In equilibrium, patient households save and impatient households borrow. The total mass of households is normalized to one, of which an exogenous fraction $n_s$ are savers and the remaining fraction $n_m = 1 - n_s$ are borrowers.

Entrepreneurs (denoted by $e$) own the capital used in the production technology. Capital purchase is financed with entrepreneurial wealth and bank loans. Capital and housing production face adjustment costs.

Banks raise equity from bankers (denoted by $b$) and deposits from households, to finance their loans. The loans extended to households and the banks extending them are denoted by

$H$, while those extended to entrepreneurs and the banks extending them are denoted by $F$.[6] Deposits are formally insured by a deposit insurance agency (DIA) funded with lump sum taxes. Deposit insurance provides an implicit subsidy to lending made by risky banks.

Households' and entrepreneurs' FOCs and the market clearing conditions that characterize the equilibrium of the model are reported in Appendix A.

## 2.1 Notation

All borrowers are subject to idiosyncratic return shocks $\omega_{i,t+1}$ which are iid across borrowers of class $i = \{m, e, H, F\}$ and across borrower classes, and are assumed to follow a log-normal distribution with a mean of 1 and a distribution function $F_i(\omega_{i,t+1})$. We will denote by $\overline{\omega}_{i,t+1}$ the threshold realization of $\omega_{i,t+1}$ below which the borrower of class $i$ defaults, so that the probability of default of such a borrower is $F_i(\overline{\omega}_{i,t+1})$.

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

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

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

$$\Gamma_i(\overline{\omega}_{i,t+1}) = G_i\left(\overline{\omega}_{i,t+1}\right) + \overline{\omega}_{i,t+1}[1 - F_i\left(\overline{\omega}_{i,t+1}\right)] \tag{2}$$

where $f_i\left(\omega_{i,t+1}\right)$ denotes the density distribution of $\omega_{i,t+1}$ conditional on the information available when the loans are originated at time $t$. Thus, the net share of assets that goes to the lender is $\Gamma_i(\overline{\omega}_{i,t+1}) - \mu_i G_i\left(\overline{\omega}_{i,t+1}\right)$, where $\mu_i G_i\left(\overline{\omega}_{i,t+1}\right)$ is the expected total cost of default expressed as a fraction of the borrowers' assets. The share of assets accrued to the borrowers of class $i$ is $(1 - \Gamma_i(\overline{\omega}_{i,t+1}))$.

## 2.2 Households

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

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

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

with $\varkappa \in \{s, m\}$, where $c_{\varkappa,t}$ denotes the consumption of non-durable goods and $h_{\varkappa,t}$ denotes the total stock of housing held by the various members of the dynasty (which is assumed to provide a proportional amount of housing services also denoted by $h_{\varkappa,t}$), $l_{\varkappa,t}$ denotes hours worked in the consumption good producing sector, $\eta$ 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 dynasty of saving households is assumed to maximize its present value of utility subject to the budget constraint

$$c_{s,t} + q_{h,t}\left(h_{s,t} - (1-\delta_{h,t})h_{s,t-1}\right) + d_t \leq w_t l_{s,t} + \widetilde{R}_{d,t} d_{t-1} - \Omega_{s,t} + \Pi_{s,t} \tag{4}$$

where $q_{h,t}$ is the price of housing, $\delta_{h,t}$ is the rate at which housing units depreciate, $w_t$ is the wage rate, and the return on deposits is given by

$$\widetilde{R}_{d,t} \equiv (1 - \gamma \Psi_{b,t}) R_{d,t-1} \tag{5}$$

where $\gamma$ is a transaction cost incurred when banks default and $\Psi_{b,t}$ is the probability of bank failure, which motivates depositors' aversion to bank default and a risk premium. Finally, $\Omega_{s,t}$ is a lump-sum tax used by the deposit insurance agency (DIA) to ex-post balance its budget, and $\Pi_{s,t}$ are dividends received from the production sector as well as from entrepreneurs and bankers.

**Impatient Households**. The dynasty of borrowing households also maximizes its present value of utility under the budget constraint

$$c_{m,t} + q_{h,t}h_{m,t} - b_{m,t} \leq w_t l_{m,t} + (1 - \Gamma_m(\overline{\omega}_{m,t}))R_{H,t}q_{h,t-1}h_{m,t-1} - \Omega_{m,t}, \tag{6}$$

and the participation constraint of the bank,

$$E_t\left[(1 - \Gamma_H(\overline{\omega}_{H,t+1}))(\Gamma^m(\overline{\omega}_{m,t+1}) - \mu_m G_m(\overline{\omega}_{m,t+1}))R_{H,t+1}\right] q_{h,t}h_{m,t} \geq \rho_t \phi_{H,t} b_{m,t}, \tag{7}$$

where $b_{m,t}$ is the size of the loan granted by the bank, $R_{H,t} = (1-\delta_{h,t})\, q_{h,t}/q_{h,t-1}$ is the return on housing, $(1-\Gamma_m(\overline{\omega}_{m,t}))R_{H,t}q_{h,t-1}h_{m,t-1}$ is net housing equity after accounting for the fraction of housing repossessed by the bank on the defaulting households, and $\Omega_{m,t}$ is the lump-sum tax through which borrowers possibly contribute to the funding of the DIA.[7] As explained by Clerc

[7]This modeling in which dynasties provide consumption risk-sharing to their members while members may default on their individual housing mortgages avoids kinks and facilitates solving the model with standard techniques.

el al. (2015), individual household members default in period $t$ when their idiosyncratic shock satisfies

$$\omega_{m,t} \leq \bar{\omega}_{m,t} = \frac{x_{m,t-1}}{R_{H,t}},$$

where

$$x_{m,t} = \frac{R_{m,t} b_{m,t}}{q_{h,t} h_{m,t}} \tag{8}$$

is a measure of household leverage and $R_{m,t}$ is the gross rate on the corresponding loan. In principle, this rate is part of the housing loan contract and, hence, would be part of the decision variables of the impatient dynasty in period $t$. However, treating the intermediate variable $x_{m,t}$ as part of the contract variables (together with $b_t^m$ and $h_t^m$ and in replacement of $R_{m,t}$) allows us to write the entire contract problem without explicit reference to $R_{m,t}$.

The participation constraint of the bank (7) is further explained in subsection 2.5. It reflects the need to compensate bankers for the *required expected rate of return* $\rho_t$ on the equity $e_{H,t} = \phi_{H,t} b_{m,t}$ involved in the funding of the loan, where $\phi_{H,t}$ is the (binding) capital requirement applied on this class of loans. The term $(1 - \Gamma_H(\overline{\omega}_{H,t+1})$ accounts for the fact that bank shareholders obtain levered returns from the loan portfolio of the bank that lends to households; $\overline{\omega}_{H,t+1}$ is the threshold of an idiosyncratic shock affecting the bank's gross loan returns below which the bank is unable to pay its deposits and defaults. The term $(\Gamma^m(\overline{\omega}_{m,t+1}) - \mu_m G_m(\overline{\omega}_{m,t+1}))R_{H,t+1}$ reflects the part of the returns, per unit of housing investment funded by the bank, that the bank appropriates after accounting for the cost of repossessing the housing of those households who default on their loans.

## 2.3 Entrepreneurs

Entrepreneurs are risk neutral agents who live two periods and whose measure in the population is normalized to one. An entrepreneur born at time $t$ values the transfers made to the patient dynasty at time $t+1$ ("dividends"), $c_{e,t+1}$, and the bequests left to the next cohort of entrepreneurs ("retained earnings"), $n_{e,t+1}$. Specifically, his optimization problem at $t+1$ is:

$$\max_{c_{e,t+1}, n_{e,t+1}} (c_{e,t+1})^{\chi_e} (n_{e,t+1})^{1-\chi_e} \tag{9}$$

subject to:

$$c_{e,t+1} + n_{e,t+1} \leq W_{e,t+1},$$

where $W_{e,t+1}$ is the wealth resulting from his activity in the previous period.[8] Optimization yields the "dividend" rule

$$c_{e,t+1} = \chi_e W_{e,t+1}, \tag{10}$$

the "earnings retention" rule

$$n_{e,t+1} = (1 - \chi_e) W_{e,t+1}, \tag{11}$$

and an expected utility of $E_t (W_{e,t+1})$ at $t$ that justifies that the entrepreneur will develop his activity at $t$ in the aim to maximize his expected wealth at $t+1$. To this end, the entrepreneur establishes a contract relationship with a perfectly competitive bank.

The contracting problem between the entrepreneur and the bank at $t$ can be written as one of maximizing the entrepreneur's expected wealth at $t+1$

$$\max_{x_{e,t}, k_t} E_t \left[ (1 - \Gamma_e (\overline{\omega}_{e,t+1})) R_{K,t+1} q_{k,t} k_t \right] \tag{12}$$

subject to the participation constraint of the bank:

$$E_t \left[ (1 - \Gamma_F (\overline{\omega}_{F,t+1})) (\Gamma_e (\overline{\omega}_{e,t+1}) - \mu_e G_e (\overline{\omega}_{e,t+1})) R_{K,t+1} \right] q_{k,t} k_t = \rho_t \phi_{F,t} b_{e,t}, \tag{13}$$

where $k_t$ is the capital purchased by the entrepreneur at a per unit price $q_{k,t}$ with his own initial net worth $n_{e,t}$ and a loan $b_{e,t} = (q_{k,t} k_t - n_{e,t})$, and $\overline{\omega}_{e,t+1}$ is the critical value of the idiosyncratic shock $\omega_{e,t+1}$ to the return on the entrepreneur's capital below which he defaults on his loan.

Specifically, the gross return at $t+1$ of the capital owned at $t$ is assumed to be

$$\omega_{e,t+1} R_{K,t+1} = \omega_{e,t+1} \left[ \frac{r_{K,t+1} + (1 - \delta_{k,t+1}) q_{k,t+1}}{q_{k,t}} \right],$$

where $r_{K,t+1}$ is the return obtained by renting one efficiency unit of capital to the productive sector at $t+1$ and $\delta_{k,t+1}$ is the rate at which capital depreciates. The shock $\omega_{e,t+1}$ is a simple way to rationalize the existence of idiosyncratic shocks to the entrepreneurs' performance and to generate a non-trivial default rate on entrepreneurial loans.

The shock realizes after the period $t$ loan with the bank is agreed and prior to renting the available capital to consumption good producers in that date. Default in period $t+1$ occurs for

$$\omega_{e,t+1} < \overline{\omega}_{e,t+1} \equiv \frac{x_{e,t}}{R_{K,t+1}} \tag{14}$$

[8] The transfer of $c_{e,t+1}$ to the savings households will allow us to focus the welfare analysis on households' lifetime utility without neglecting the consumption capacity associated with entrepreneurs' profits.

where

$$x_{e,t} = \frac{R_{F,t} b_{e,t}}{q_{k,t} k_t},$$

and $R_{F,t}$ is the gross loan rate agreed with the bank at $t$. The term $(1 - \Gamma_e(\overline{\omega}_{e,t+1}))$ in the objective function above accounts for the fraction of the return on capital that the levered entrepreneur appropriates under the prevailing loan. As in the case of borrowing households, treating the intermediate variable $x_{e,t}$ as one of the contract variables avoids having to directly solve for $R_{F,t}$ in the contract problem.

The participation constraint of the bank (13) is further explained in subsection 2.5. It reflects the need to compensate bankers for the required expected rate of return $\rho_t$ on the equity $e_{F,t} = \phi_{F,t} b_{e,t}$ that they contribute to the funding of the loan, where $\phi_{F,t}$ is the (binding) capital requirement applied on this class of loans. The term $(1 - \Gamma_F(\overline{\omega}_{F,t+1})$ accounts for the fact that bank shareholders obtain levered returns from the loan portfolio of the bank that lends to entrepreneurs; $\overline{\omega}_{F,t+1}$ is the threshold of an idiosyncratic shock affecting the bank's gross loan returns below which the bank is unable to pay its deposits and defaults.

The earnings retention rule (11) implied by our specification of entrepreneurs' preferences guarantee easy aggregation and generate the same type of net worth dynamics for the aggregate entrepreneurial sector as in BGG. Entrepreneurs' aggregate final wealth is determined as

$$W_{e,t} = (1 - \Gamma_{e,t}(\overline{\omega}_{e,t}))\, q_{k,t-1} R_{K,t} k_{t-1} - \Omega_{e,t}, \tag{15}$$

and (11) implies that entrepreneurial net worth evolves according to

$$n_{e,t} = (1 - \chi_e)\left[(1 - \Gamma_{e,t}(\overline{\omega}_{e,t}))\, q_{k,t-1} R_{K,t} k_{t-1} - \Omega_{e,t}\right], \tag{16}$$

where $\Omega_{e,t}$ is the lump-sum tax through which entrepreneurs possibly contribute to the funding of the DIA.

## 2.4 Bankers

Similarly to entrepreneurs, bankers are risk neutral agents who live for two periods and invest the net worth inherited from the previous generation of bankers as banks' inside equity capital. This OLG setup makes bankers' risk neutrality operate as in a one-period model but makes bank capital an important variable for aggregate dynamics (such as e.g. in Gertler and Kiyotaki, 2011).

A banker born at time $t$ values the transfers $c_{b,t+1}$ to the patient dynasty at $t$+1 ("dividends") and the bequests $n_{b,t+1}$ left to the next cohort of bankers ("retained earnings"). Specifically, at $t+1$ he solves

$$\max_{c_{b,t+1},n_{b,t+1}} (c_{b,t+1})^{\chi_b} (n_{b,t+1})^{1-\chi_b}$$

subject to:

$$c_{b,t+1} + n_{b,t+1} \leq W_{b,t+1},$$

where $W^e_{t+1}$ denotes final wealth.[9] Optimizing behavior yields the "dividend" rule

$$c_{b,t+1} = \chi_b W_{b,t+1},$$

the "earnings retention" rule

$$n_{b,t+1} = (1-\chi_b)W_{b,t+1}, \tag{17}$$

and an expected utility at $t$ of $E_t(W_{b,t+1})$, which makes the banker interested in maximizing at $t$ the expected value of his wealth at $t+1$.

Thus, the banker who starts up at period $t$ with a bequest $n_{b,t}$ decides how to allocate this wealth as inside capital across the two classes of existing banks $j = H, F$ by solving

$$\max_{e_{F,t},e_{M,t}} E_t(W_{b,t+1}) = E_t(\widetilde{\rho}_{F,t+1}e_{F,t} + \widetilde{\rho}_{H,t+1}e_{H,t}), \tag{18}$$

subject to

$$e_{F,t} + e_{H,t} \leq n_{b,t}, \tag{19}$$

where $\widetilde{\rho}_{j,t+1}$is the ex post gross return on the inside equity invested in a bank of class $j$. Interior equilibria in which both classes of banks receive strictly positive inside equity require

$$E_t\widetilde{\rho}_{F,t+1} = E_t\widetilde{\rho}_{H,t+1} = \rho_t, \tag{20}$$

where $\rho_t$ denotes bankers' required expected gross rate of return on equity investments undertaken at time $t$. This expected return is endogenously determined in equilibrium but individual banks take it as given in their decisions. Specifically, $\rho_t$ plays an essential role in the bank participation constraints that appear in the problems that determine the terms of the debt contracts established between each class of banks and their borrowers (see equations (7) and (13)).

[9] The transfer of $c_{b,t+1}$ to the savings households will allow us to focus the welfare analysis on households' lifetime utility without neglecting the consumption capacity associated with bank profits.

From (17), the aggregate evolution of bankers' initial net worth is determined by:

$$n_{b,t+1} = (1 - \chi_b) \left( \widetilde{\rho}_{H,t+1} e_{H,t} + \widetilde{\rho}_{F,t+1} e_{F,t} \right).$$

where $e_{H,t} + e_{F,t} = n_{b,t}$.

## 2.5 Banks

We assume two types of competitive banks ($j = H, F$) that operate for just one period each and raise equity, $e_{j,t}$, from bankers and deposits, $d_{j,t}$, from patient households, to extend loans, $b_{j,t}$ to either impatient households ($j = H$) or entrepreneurs ($j = F$). Each bank maximizes its expected equity payoff

$$E_t \max \left[ \omega_{j,t+1} \tilde{R}_{j,t+1} b_{j,t} - R_{d,t} d_{j,t}, 0 \right] \tag{21}$$

subject to the regulatory capital constraint

$$e_{j,t} \geq \phi_{j,t} b_{j,t},$$

where $R_{d,t}$ is the gross interest rate paid on the deposits taken at $t$ (which is the same for all banks given the presence of deposit insurance), $\phi_{j,t}$ is the regulatory capital requirement on loans of class $j$, and $\tilde{R}_{j,t+1}$ denotes the realized return on a well diversified portfolio of loans of class $j$. The max operator reflects the fact that the shareholders of the bank enjoy limited liability, so their payoffs cannot be negative.

Banks are subject to an idiosyncratic portfolio return shock $\omega_{j,t+1}$ which is iid across the banks of class $j$ and is assumed to follow a log-normal distribution with a mean of one and a distribution function $F_j(\omega_{j,t+1})$. This shock can be interpreted as a shock to each individual bank's ability to extract payoffs from its loans. If the capital requirement is binding (as it turns out to be in equilibrium), the threshold value of $\omega_{j,t+1}$ below which the bank fails is

$$\overline{\omega}_{j,t+1} = (1 - \phi_{j,t}) \frac{R_{d,t}}{\tilde{R}_{j,t+1}}, \tag{22}$$

since the bank fails when the realized return on its loan portfolio is lower than its deposit repayment obligations, which are $(1 - \phi_{j,t})R_{d,t}$ per unit of lending. Accordingly, the default rate among banks of each class $j$, $\Psi_{j,t} = F_j(\overline{\omega}_{j,t+1})$, will be driven by fluctuations in the corresponding aggregate return on loans of class $j$, $\tilde{R}_{j,t+1}$ (itself driven by households' or firms' default rates). When a bank fails, its equity is written down to zero and its assets are taken over by the deposit insurance fund which pays out all deposits in full. The deposit insurance agency incurs resolution costs equal to a fraction $\mu_j$ of total bank assets.

Using the fact that the capital requirement is binding, we can write the loans of a bank of class $j$ as $b_{j,t} = e_{j,t}/\phi_{j,t}$ and its deposits as $d_{j,t} = (1 - \phi_{j,t})e_{j,t}/\phi_{j,t}$. Then, from (21), we can write the ex post gross rate of return on each unit of equity invested in the bank as

$$
\begin{aligned}
\widetilde{\rho}_{j,t+1} &= \max\left[\omega_{j,t+1} - \overline{\omega}_{j,t+1}, 0\right] \frac{\tilde{R}_{j,t+1}}{\phi_{j,t}} \\
&= \left[\int_{\overline{\omega}_{j,t+1}}^{\infty} \omega_{j,t+1} f_j\left(\omega_{j,t+1}\right) d\omega_{j,t+1} - \overline{\omega}_{j,t+1} \int_{\overline{\omega}_{j,t+1}}^{\infty} f_j\left(\omega_{j,t+1}\right) d\omega_{j,t+1}\right] \frac{\tilde{R}_{j,t+1}}{\phi_{j,t}} \qquad (23) \\
&= \left[1 - \Gamma_j(\overline{\omega}_{j,t+1})\right] \frac{\tilde{R}_{j,t+1}}{\phi_{j,t}}. \qquad (24)
\end{aligned}
$$

Note that limited liability and the fact that bank liabilities (deposits) are insured will allow banks to meet bankers' required expected return on equity with lower returns on lending than in a world of full-liability or no deposit insurance. This suggests that these distortions push in the direction of expanding credit availability to impatient households and entrepreneurs.

The average default rate of banks, weighted by liabilities is defined as

$$
\Psi_{b,t} = \frac{d_{H,t-1}\Psi_{H,t} + d_{F,t-1}\Psi_{F,t}}{d_{t-1}}. \qquad (25)
$$

where $d_t = d_{H,t} + d_{F,t}$ and $d_{j,t} = \frac{1-\phi_{j,t}}{\phi_{j,t}} e_{j,t}$ with $e_{H,t} = \left(n_{b,t} - e_{F,t}\right)$.

## 2.6 Production Sector

We assume a perfectly competitive production sector made up of firms owned by the patient agents. This sector is not directly affected by financial frictions.

### 2.6.1 Consumption Goods

The representative goods-producing firm produces a single good, $y_t$, using $l_t$ units of labor and $k_t$ units of capital, according to the following constant-returns-to-scale technology:

$$
y_t = z_t {l_t}^{1-\alpha} {k_t}^{\alpha} \qquad (26)
$$

where $z_t$ is an AR(1) productivity shock and $\alpha$ is the share of capital in production.

### 2.6.2 Capital Production

Capital producers combine a fraction of the final goods which they use as investment goods, $I_{K,t}$, with the previous stock of capital goods, $k_{t-1}$, in order to produce new capital goods which can be sold at price $q_{k,t}$. The representative capital producing firm maximizes the expected discounted value of profits, which is given by

$$\max_{\{I_{k,t+j}\}} E_t \sum_{j=0}^{\infty} \Lambda_{t,t+j} \left\{ q_{k,t+j} \left[ S_k \left( \frac{I_{k,t+j}}{k_{t+j-1}} \right) k_{t+j-1} \right] - I_{k,t+j} \right\} \tag{27}$$

where $\Lambda_{t,t+j \equiv} \beta_s \frac{U_{c_{s,t+j+1}}}{U_{c_{s,t}}}$ is the stochastic discount factor of the saving dynasty and $S_k \left( \frac{I_{k,t+j}}{k_{t+j-1}} \right) k_{t+j-1}$ gives the units of new capital produced by investing $I_{k,t+j}$.

The increasing and concave function $S_k(\cdot)$ captures the existence of adjustment costs, which we specify as in Jermann (1998):

$$S_k \left( \frac{I_{k,t}}{k_{t-1}} \right) = \frac{a_{k,1}}{1 - \frac{1}{\psi_k}} \left( \frac{I_{k,t}}{k_{t-1}} \right)^{1 - \frac{1}{\psi_k}} + a_{k,2}, \tag{28}$$

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

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

$$q_{k,t} = \left[ S_k' \left( \frac{I_{k,t}}{k_{t-1}} \right) \right]^{-1}, \tag{29}$$

which implies that in steady state $q_{k,t}$ is constant and equal to one.

Finally, the law of motion of physical capital is given by

$$k_t = (1 - \delta_{k,t}) k_{t-1} + S_k \left( \frac{I_{k,t}}{k_{t-1}} \right) k_{t-1}, \tag{30}$$

where $\delta_{k,t}$ is time-varying and follows an AR(1) process.

### 2.6.3 Housing Production

We assume that housing producers act in a way that is analogous to that of capital producers. That is, house producing firms purchase housing investment goods $I_{h,t}$ from the final good producers, combine them with the existing stock of housing, $h_{t-1}$, and transform them into new housing units, which are sold at a real price $q_{h,t}$. The production of new housing is subject to housing adjustment costs. The representative house producing firm maximizes the expected discounted value of profits,

$$\max_{\{I_{ht+j}\}} E_t \sum_{j=0}^{\infty} \Lambda_{t,t+j} \left[ q_{h,t+j} \left[ S_h \left( \frac{I_{h,t+j}}{h_{t+j-1}} \right) h_{t+j-1} \right] - I_{h,t+j} \right], \tag{31}$$

where the presence of adjustment costs is captured by

$$S_h \left( \frac{I_{h,t}}{h_{t-1}} \right) = \frac{a_{h,1}}{1 - \frac{1}{\psi_h}} \left( \frac{I_{h,t}}{h_{t-1}} \right)^{1-\frac{1}{\psi_h}} + a_{h,2}. \tag{32}$$

Introducing investment adjustment costs in the production of housing is equivalent to assuming that housing production requires a factor of production, say land, which is in fixed supply (see Davis and Heathcote, 2005; Iacoviello and Neri, 2010). As in the case of physical capital, the parameters $a_{h,1}$ and $a_{h,2}$ are chosen to guarantee that in the steady state the corresponding investment-to-capital ratio is equal to the depreciation rate and $S_h' \left( I_{h,t}/h_{t-1} \right)$ equals one (so that the implied adjustment costs are zero).

The first order condition for $I_{h,t}$ yields the following equation for house prices:

$$q_{h,t} = \left[ S_h' \left( \frac{I_{h,t}}{h_{t-1}} \right) \right]^{-1}. \tag{33}$$

And the evolution of the aggregate housing stock is

$$h_t = (1 - \delta_{h,t}) h_{t-1} + S_h \left( \frac{I_{h,t}}{h_{t-1}} \right) h_{t-1}, \tag{34}$$

where $\delta_{H,t}$ is time-varying and follows an AR(1) process.

## 2.7 Macroprudential Policy

The macroprudential authority sets the capital requirements applicable to bank lending in period $t$ according to the simple policy rule

$$\phi_t = \bar{\phi} + \phi_b \log \left( \frac{b_t}{b} \right), \tag{35}$$

where is $\bar{\phi}$ is the reference level of capital requirements (which determines their steady-state value) and $\phi_b$ captures the existence of some cyclical adjustments which are assumed be a function of deviations of total loans, $b_t = b_{e,t} + n_m b_{m,t}$, from its long-run mean.[10] The sector specific capital requirements are established as proportions of the general requirement $\phi_t$ as follows

$$\phi_{H,t} = \tau_\phi \phi_t, \qquad \phi_{F,t} = \phi_t, \tag{36}$$

implying a risk weight $\tau_\phi$ on mortgage loans and a full risk weight on entrepreneurial loans.

We view the above simple rule as a parsimonious way to capture three important aspects of the much more complex risk-based capital regulation observe in real-life: (i) the average capital requirement per unit of risk-weighted assets, (ii) the typical risk-weight on mortgages,[11] and (iii) the degree to which capital regulation responds to cyclical conditions (e.g. by imposing, on top of some minimal capital requirement, the build-up or release of additional capital buffers such as the capital conservation buffer and the countercyclical capital buffer of Basel III). We can interpret a capital requirement rule such as (35) as being constructed with the aim that the strength of the countercyclical response ($\phi_b$) almost never leads the capital ratio below some regulatory minimum. In the calibration, we will formally capture this by setting the countercyclical parameter to a value such that most fluctuations in $\phi_t$ (say, the two standard deviation bands around its mean) fall above such minimum. We further discuss this in Section 3.

## 2.8 Market clearing

The economy aggregate conditions are the following. The fraction of borrowers, $n_m$, is exogenous to the economy and the total mass of households has been normalized to one, so savers and borrowers have measures $n_s = (1 - n_m)$ and $n_m$, respectively. The aggregate housing stock equals the house holdings of the two dynasties:

$$h_t = n_s h_{s,t} + n_m h_{m,t};$$

[10] In practice these adjustments may not only reflect regulatory or supervisory practice (e.g. the regulatory countercyclical capital buffers of Basel III or the mere exercise of forbearance in bad times) but also fluctuations in banks' capital ratios due to market pressure or to banks' holding of voluntary capital buffers in excess of the regulatory minima.

[11] We assume that corporate exposures carry a risk weight of one, as it is actually the case for unrated corporate borrowers under Basel III (as well as under its predecessor, Basel II).

total demand for households' labor by the consumption good producing firms equals the labor supply of the two dynasties:

$$l_t = n_s l_{s,t} + n_m l_{m,t};$$

total households' consumption equals the consumption of the two dynasties:

$$c_t = n_s c_{s,t} + n_m c_{m,t}.$$

The deposits held by the patient households ($d_t$) must equal the sum of the demand for deposit funding from the banks making loans to households, $(1 - \phi_{H,t})n_m b_{m,t}$, and from the banks making loans to entrepreneurs, $(1 - \phi_{F,t})b_{e,t}$:

$$d_t = (1 - \phi_{F,t})b_{e,t} + (1 - \phi_{H,t})n_m b_{m,t}.$$

The total equity provided by bankers must equal the sum of the demand for bank equity from the banks making loans to households, $\phi_{H,t} n_m b_{m,t}$, and from the banks making loans to entrepreneurs, $\phi_{F,t} b_{e,t}$:

$$n_{b,t} = \phi_{F,t} b_{e,t} + \phi_{H,t} n_m b_{m,t}$$

Note that

$$b_{e,t} = [q_{k,t} k_t - (1 - \chi_e) W_{e,t}]$$

and

$$b_{m,t} = \frac{q_{h,t} h_{m,t} x_{m,t}}{R_t^m}.$$

Thus, total loans are

$$b_t = b_{e,t} + n_m b_{m,t}.$$

Total output $Y_t$ equals the households' consumption , plus the resources absorbed in the production of the new capital $I_{K,t}$ and the new housing $I_{H,t}$, plus the resources lost in the recovery by lenders of the proceeds associated with defaulted bank loans, in transaction costs by depositors at failed banks, or by the deposit insurance agency in the recovery of bank assets:

$$\begin{aligned}
Y_t &= c_t + I_{h,t} + I_{k,t} \\
&\quad + \mu_e G_e \left(\overline{\omega}_{e,t}\right) R_{K,t} q_{h,t-1} k_{t-1} + \mu_m G_m \left(\overline{\omega}_{m,t}\right) R_{H,t} q_{h,t-1} \left(n_m h_{m,t-1}\right) + \gamma \Psi_{b,t} R_{d,t-1} d_{t-1} \\
&\quad + \mu_b \left[ G_H \left(\overline{\omega}_{H,t}\right) \widetilde{R}_{H,t} \left(n_m b_{m,t}\right) + G_F \left(\overline{\omega}_{F,t}\right) \widetilde{R}_{F,t} b_{e,t} \right].
\end{aligned}$$

The total costs to the deposit insurance agency $\Omega_t$ due to losses caused by $H$ and $F$ banks, and hence the total lump sum tax imposed on agents in order to finance the agency on a balanced-budget basis, are given by

$$\Omega_{H,t} = \left[\overline{\omega}_{H,t} - \Gamma_H\left(\overline{\omega}_{H,t}\right) + \mu_H G_H\left(\overline{\omega}_{H,t}\right)\right] \widetilde{R}_{H,t}\left(n_m b_{m,t}\right),$$

$$\Omega_{F,t} = \widetilde{R}_{F,t}\left(\overline{\omega}_{F,t} - \Gamma_F\left(\overline{\omega}_{F,t}\right) + \mu_F G_F\left(\overline{\omega}_{F,t}\right)\right) b_{e,t},$$

and

$$\Omega_t = \Omega_{F,t} + \Omega_{H,t} = \Omega_{s,t} + \Omega_{m,t} + \Omega_{e,t}. \tag{37}$$

Finally, we define $GDP_t$ as

$$GDP_t = c_t + I_{h,t} + I_{k,t}.$$

## 2.9 Sources of Fluctuations

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 follow an autoregressive process of order one:

$$\ln \varrho_t = \rho_\varrho \ln \varrho_{t-1} + u_{\varrho,t},$$

where $\varrho_t = \{z_t, v_t, \delta_{h,t}, \delta_{k,t}\}$, $\rho_\varrho$ is the persistence parameter, and $u_{\varrho,t}$ is the innovation to each shock with mean zero and standard deviation $\sigma_\varrho$.

In addition, we allow the dispersion of these idiosyncratic shocks to fluctuate over time, so we will denote by $\tilde{\sigma}_t^{\omega_i}$ the standard deviation of the iid shock $\omega_{i,t}$, with $i = \{m, e, H, F\}$. We will refer to the shocks to such dispersion as "risk shocks" in the same spirit as in Christiano, Motto and Rostagno (2014). For simplicity the standard deviation of the risk shocks that hit each $\tilde{\sigma}_t^{\omega_i}$ will be denoted by $\sigma_i$, with $i = \{m, e, H, F\}$.

# 3. Calibration

The model is calibrated at the quarterly frequency using macroeconomic and financial data for the Euro Area over the period 2001:1-2013:4. Table 1 reports the targets used for the calibration. All series are in real terms and their log value is linearly detrended. See Appendix B for the description of the corresponding series and data sources.

In the model, households and entrepreneurs default due to both idiosyncratic reasons and aggregate fluctuations in asset prices. Thus, the stochastic average of financial and macroeconomic variables is affected by both idiosyncratic and aggregate shocks. Most of the parameters are calibrated to match the first and second unconditional moments of some key variables. Some parameters are so tightly linked to a specific target that can be directly set at a first stage. Other parameters are also set at a first stage following convention. The rest of the parameters are found simultaneously so as to minimize a loss function that weights equally the distance betwen the targeted empirical moments and the theoretical moments of the second-order approximation of the model.[12]

We notice a close relationship between some of the parameters found in the second stage and the stochastic mean of some variables. In particular, the discount factor of the savers, $\beta_s$, set to 0.995, helps to match the average 3-month EURIBOR rate over the period. The fraction of bankers' wealth distributed to savers, $\chi_b$, is used the match the 8% median return on average equity in the 100 largest Euro Area banks. The weights on housing in the utility of savers and borrowers, $v_s$ and $v_m$ respectively, are used to match the share of housing wealth of 52.5% held by the indebted households in the Euro Area as reported by the 2010 ECB Household Finance and Consumption Survey (HFCS) and the complementary share held by the non-indebted households.[13] The discount factor of the borrowers, $\beta_m$, and the dividend payout of the non-financial corporations (NFC), $\chi_e$, are set to match the ratios of household (HH) mortgages to GDP and NFC bank loans to GDP, which are 1.427 and 1.815, respectively. The depreciation of the housing stock, $\delta_h$, is calibrated to match a ratio of residential investment to GDP of about 6%. Further, the volatility of the productivity shock helps us to match the volatility of GDP.

The variance of the four idiosyncratic shocks, the housing and capital adjustment cost parameters and the variance of the eight aggregate shocks are mainly useful to match the remaining targets.[14] In particular, we match the average write-off rates and the spreads between

[12] Alternatively, the choice of these parameters could have been based on a simulated method of moments (as in e.g. Kim and Ruge-Murcia, 2009) or a maximum likelihood method. However, simulation based moment matching results to be too slow for the estimation of a medium-scale model solved with a second-order approximation. Likelihood-based methods are computationally even more demanding since they require the use of non-linear filters for the construction of the likelihood function (see e.g. An and Schorfheide, 2007).

[13] 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.

[14] The model is calibrated under the assumption of equal probability of default for the two types of banks.

the loan rate and the risk free rate for both types of loans.[15] According to bank accounting conventions, we define: (Write-offs/Loans) = (%defaulted loans) x (losses due to defaulted loans per unit of lending). Thus, for the case of NFC loans, the model counterpart to write-offs as a fraction of existing loans is:

$$\Psi_{e,t} = F_e\left(\overline{\omega}_{e,t}\right)\left[\frac{b_{e,t-1} - \frac{(1-\mu_e)}{F_e(\overline{\omega}_{e,t})}\left(\int_0^{\overline{\omega}_{e,t}} \omega_{e,t} f_e\left(\omega_{e,t}\right) d\omega_{e,t}\right) R_{K,t} q_{h,t-1} k_{t-1}}{b_{e,t-1}}\right]$$
$$= F_e\left(\overline{\omega}_{e,t}\right) - (1-\mu_e) G_e(\overline{\omega}_{e,t}) R_{K,t} \frac{q_{h,t-1} k_{t-1}}{b_{e,t-1}}. \tag{38}$$

A similar definition applies to mortgage loans. Our calibration matches average write-offs of 0.118% for mortgage loans and 0.627% for commercial loans. We also match the volatility relative to GDP of house prices, HH loans, NFC loans and of the write-offs and the spreads for both types of loans.

Regarding the capital regulation tools, we set the reference level parameter $\bar{\phi}$ and the countercyclical parameter $\phi_b$ so that the model-generated mean and standard deviation of the capital ratio, $\phi_t$, which happen to be 10% and 0.78%, respectively, roughly match the corresponding moments of the time series of the cross-sectional average of the capital ratio observed among the 100 largest Euro Area banks over the period 2001-2007, which equal 10.5% and 0.75%, respectively.[16] As for the risk weight for mortgages, $\tau_\phi$, we directly set it equal to 0.5 so as to match the standardized 50% risk weight on mortgages established in Basel II.[17] Importantly, the calibration of $\bar{\phi}$ and $\phi_b$ is such that the lower bound of the two standard deviation band of the model-generated capital requirement $\phi_t$, which equals 8.44% and we will interpret as the implied "minimum capital requirement", is just slightly above the regulatory minimum capital requirement of 8% imposed by Basel I, II and III.[18]

[15] See Appendix B for details on the computation of the spreads.

[16] A cyclical adjustment, $\phi_b$, of 0.1 implies that increasing total credit by one standard deviation induces an increase of about 0.56 percentage points in the capital requirement $\phi_t$.

[17] This risk weight has remained unaltered across the subsequent Basel accords on bank capital standards (Basel I, II, and III) prevalent in the period 2001-2013.

[18] An alternative calibration of the capital requirement rule in (35) could aim at matching the regulatory tools in Basel III. Specifically, the minimum capital requirement is 8% in terms of total capital (tier 1 + tier 2) but in practice under Basel III banks' capital ratio in steady state would also include the 2.5% capital conservation buffer. So we can interpret that Basel III corresponds to a reference level parameter $\bar{\phi}$ equal to 0.105. In addition, the Basel III countercyclical capital buffer of up to 2.5% means that the strength of the

Regarding the parameters set directly prior to finding out the remaining ones, we calibrate the share of borrowers in the economy, $n_m$, to match a proportion of indebted households in the Euro Area of about 44%, as documented in the 2010 HFCS. The labor disutility parameter $\nu_L$, which only affects the scale of the economy, is inconsequentially normalized to one. Following literature standards, the Frisch elasticity of labor supply, $\eta$, is also set equal to one, the capital-share parameter of the production function, $\alpha$, is set equal to 0.30, and the depreciation rate of physical capital, $\delta_k$, is set equal to 0.030. Similarly, the autoregressive coefficients in the AR(1) processes followed by all shock are set equal to a common value $\rho$=0.90 and the bankruptcy cost parameters are set equal to a common value $\mu$=0.30 for all sectors.[19] Finally, the transaction cost incurred by depositors when their banks default, $\gamma$, is assumed to be equal to 0.1.

Table 2 reports all the parameter values resulting from our calibration. As evidenced in Table 1, we match very closely the first and second moments established as targets. The preference and technology parameters we find are in line with the values used by other authors. Borrowers' discount factor falls within the two standard deviation bands estimated by Carroll and Samwick (1997).[20] 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.[21] Our estimates also imply similar standard deviations for the housing and capital depreciation shocks. The model implied yearly average bank default rate is 1.68%.[22]

counter-cyclical response ($\phi_b$) would need to be set to a value such that the implied capital requirement ranges typically between 8% and 13%.

[19] Similar values for $\mu$ are used, among others, by Carlstrom and Fuerst (1997). Djankov, Hart, McLiesh and Shleifer (2008) document that debt enforcement costs, conditional on default, represent an average value loss of around 48% worldwide and 25% in OECD countries.

[20] That is, within the interval (0.91, 0.99). See Iacoviello (2005), Campbell and Hercowitz (2009), and Iacoviello and Neri (2010) for similar values.

[21] See, e.g. Jermann and Quadrini (2012).

[22] We have not targeted this moment due to the difficulty to properly estimate an average bank failure probability using a rather short time series. The implied number, however, does not seem excessive for a period that includes a severe bank crisis.

Table 1: Calibration Targets

| Description | Definition | Data | Model |
|---|---|---|---|
| A) Stochastic means | | | |
| Fraction of borrowers | $n_m$ | 0.437 | 0.437 |
| Equity return of banks | $\rho * 400$ | 8.00 | 8.05 |
| Risk free rate | $(R_d - 1) * 400$ | 2.00 | 2.00 |
| Borrowers housing wealth share | $n_m q_h h_m$ | 0.525 | 0.539 |
| Housing investment to GDP | $I_h/GDP$ | 0.060 | 0.064 |
| HH loans to GDP | $n_m b_m/GDP$ | 1.427 | 1.387 |
| NFC loans to GDP | $b_e/GDP$ | 1.815 | 1.878 |
| Write-off HH loans | $\Psi_m * 400$ | 0.118 | 0.118 |
| Write-off NFC loans | $\Psi_e * 400$ | 0.627 | 0.621 |
| Spread HH loans | $(R_m - R_d) * 400$ | 0.770 | 0.870 |
| Spread NFC loans | $(R_e - R_d) * 400$ | 1.230 | 1.320 |
| B) Standard Deviations | | | |
| std(House prices)/std(GDP) | $\sigma(q_{h,t})/\sigma(GDP_t)$ | 2.601 | 2.867 |
| std(HH loans)/std(GDP) | $\sigma(n_m b_{m,t})/\sigma(GDP_t)$ | 2.139 | 2.337 |
| std(NFC loans)/std(GDP) | $\sigma(n_m b_{m,t})/\sigma(GDP_t)$ | 3.186 | 3.233 |
| std(Write-off HH)/std(GDP) | $\sigma(\Psi_{m,t})/\sigma(GDP_t)$ | 0.023 | 0.022 |
| std(Write-off NFC)/std(GDP) | $\sigma(\Psi_{e,t})/\sigma(GDP_t)$ | 0.208 | 0.198 |
| std(Spread HH loans)/std(GDP) | $\sigma(R_m - R_d)/\sigma(GDP_t)$ | 0.235 | 0.173 |
| std(Spread NFC loans)/std(GDP) | $\sigma(R_e - R_d)/\sigma(GDP_t)$ | 0.148 | 0.183 |
| std(GDP) | $\sigma(GDP_t) * 100$ | 2.3 | 2.304 |

Interest rates, equity returns, write-offs, and spreads are reported in annualized percentage points. The standard deviation of GDP is in quarterly percentage points.

Table 2: Parameters Values

| Description | Par. | Value | Description | Par. | Value |
|---|---|---|---|---|---|
| Fraction of borrowers | $n_m$ | 0.437 | Capital share in production | $\alpha$ | 0.3 |
| Discount factor savers | $\beta_s$ | 0.995 | Depositor cost of bank default | $\gamma$ | 0.1 |
| Discount factor borrowers | $\beta_m$ | 0.9827 | HH bankruptcy cost | $\mu_m$ | 0.3 |
| Housing weight in $s$ utility | $v_s$ | 0.1 | NFC bankruptcy cost | $\mu^e$ | 0.3 |
| Housing weight in $m$ utility | $v_m$ | 0.273 | Bank H bankruptcy cost | $\mu_H$ | 0.3 |
| Disutility of labor | $\varphi$ | 1 | Bank F bankruptcy cost | $\mu_F$ | 0.3 |
| Frisch elasticity of labor | $\eta$ | 1 | Dividend payout NFC | $\chi_e$ | 0.016 |
| Housing depreciation | $\delta_h$ | 0.010 | Dividend payout of bankers | $\chi_b$ | 0.02 |
| Capital depreciation | $\delta_k$ | 0.030 | Capital requirement - level | $\bar{\phi}$ | 0.1 |
| Housing adjustment cost | $\psi_h$ | 1.20 | Capital requirement - risk weight | $\tau_\phi$ | 0.5 |
| Capital adjustment cost | $\psi_k$ | 1.10 | Capital requirement - CCB | $\phi_b$ | 0.1 |
| Std. productivity shock | $\sigma_z$ | 0.0037 | Shocks Persistence | $\rho$ | 0.9 |
| Std. housing pref. shock | $\sigma_\nu$ | 0.0403 | Std. housing depr. shock | $\sigma_{\delta_h}$ | 0.00120 |
| iid shock to housing returns | $\tilde{\sigma}^{\omega_m}$ | 0.318 | Std. capital depr. shock | $\sigma_{\delta_k}$ | 0.00105 |
| iid shock to capital returns | $\tilde{\sigma}^{\omega_e}$ | 0.450 | Std. risk shock HH | $\sigma_m$ | 0.0118 |
| iid shock to HH loans returns | $\tilde{\sigma}^{\omega_H}$ | 0.0183 | Std. risk shock NFC | $\sigma_e$ | 0.049 |
| iid shock to NFC loans returns | $\tilde{\sigma}^{\omega_F}$ | 0.0363 | Std. risk shock Bank H and F | $\sigma_{H/F}$ | 0.0632 |

# 4. Capital Regulation and Welfare

In the following, we compute optimal capital regulation defined as the set of parameters governing the average level of the capital requirement, $\bar{\phi}^*$, the risk weight on mortgages, $\tau_\phi^*$, and the cyclical adjustment parameter, $\phi_b^*$, that maximize social welfare.

## 4.1 Heterogeneity and the Social Welfare Function

The representative household of each type maximizes the expected lifetime utility:

$$V_{\varkappa,t} \equiv \max E_t \sum_{t=0}^{\infty} (\beta_\varkappa)^t U(c_{\varkappa,t}, h_{\varkappa,t}, l_{\varkappa,t}), \ \varkappa = s, m \tag{39}$$

which can be written in a recursive form as follows:

$$V_{\varkappa,t} = U(c_{\varkappa,t}, h_{\varkappa,t}, l_{\varkappa,t}) + (\beta_\varkappa)^t E_t V_{\varkappa,t+1}, \tag{40}$$

where $V_{st}$ and $V_{mt}$ will be equivalently referred to as the welfare of the saving and borrowing households, respectively.

We state the problem leading to an optimal capital requirement policy rule as one of maximizing a social welfare function defined as a weighted average of the expected lifetime utility of each of the two classes of households:

$$\tilde{V}_t \equiv [\zeta V_{s,t} + (1-\zeta) V_{m,t}], \tag{41}$$

where $\zeta \epsilon [0,1]$ is the weight on savers' welfare. Since with heterogenous agents and incomplete markets there is no commonly accepted criterion for the choice of the weights assigned to each agent, we will analyze what happens under all possible values of $\zeta$. This is equivalent to exploring the whole Pareto frontier of expected lifetime utilities that can be reached by optimizing on the capital requirement policy rule.

For each weight on savers' welfare, we maximize the welfare function with respect to the three parameters of the policy rule. We search over a multidimensional grid of the following dimensions: $[0.08, 0.2]$ for the capital requirement level, $\bar{\phi}$, $[0.4, 1]$ for the mortgage risk weight parameter, $\tau_\phi$, and $[0.1, 3]$ for the cyclical adjustment parameter, $\phi_b$.[23] As we will see subsequently, changing policy parameters can increase the welfare of one of the two classes of

[23] The three-dimensional grid is based on a step of 0.0025 for $\bar{\phi}$ and $\tau_\phi$ and 0.1 for $\phi_b$.

agents while decreasing the welfare of the other. In some cases, maximizing the weighted sum of the welfare of the two groups of agents may generate outcomes that worsen the situation of one of the group relative to the initially calibrated policy rule. To avoid a situation involving such a redistributional impact, we will constrain the social welfare maximization problem so as to ensure that the solution constitutes a Pareto improvement relative to the calibrated policy rule (i.e. no agent is worse off).

In what follows we report the welfare effects of the various policies in terms of a consumption-equivalent measure calculated as the percentage increase in steady state consumption that would make each class of agents' welfare under the initially calibrated policy equal to their welfare under the optimized policy rule.

## 4.2 Optimized Regulatory Policy Rules

Figure 1 displays the coefficients on the optimal capital requirement rule for each value of $\zeta \epsilon [0, 1]$, whereas, in Figure 2, we summarize the policy rules by the average values of the implied capital requirement, $\phi_t$, and the interval obtained by adding and subtracting two standard deviations of $\phi_t$ from its average value. By looking at the average and the typical range of variation of the capital requirement we can infer what the rule would prescribe in terms of tools such as those seen in Basel III. Specifically, we will interpret that the lower limit of the two-standard deviation band of the capital requirement $\phi_t$ gives us the *minimum capital requirement* implied by the optimized policy rule, while the amplitude of such band gives us the maximum size of regulatory buffers such as the *capital conservation buffer* and the *countercyclical capital buffer* (which will tend to reach their maximal and minimal levels, respectively, at the peak and trough of the credit cycle). Figure 3 reports the associated welfare gains for savers and borrowers as we vary the Pareto weight on savers $\zeta$.

The results yield a very clear picture. A higher weight on savers leads to a much higher capital requirement and a much higher risk weight on housing loans. The countercyclical response is unaffected. Obviously, increasing $\zeta$ increases the welfare gains of the savers and diminishes those of the borrowers. In fact, the changes in the welfare gains and in the policy coefficients stop beyond $\zeta = 0.47$ because at that point the constraint imposing that both groups must be at least as well off as under the initially calibrated policy becomes binding. For values of $\zeta$ below 0.47, the optimized regulatory tools produce strictly positive welfare gains for both savers and borrowers. This includes the case with $\zeta = 0$, i.e. when the policymaker only maximizes the welfare of the borrowers and yet savers obtain gains equivalent to a non-negligible 0.6% permanent increase in their baseline consumption.

When $\zeta = 0.304$ the welfare gains (in consumption-equivalent terms) for the two groups are equalized. The existence of this case is an interesting property of our economy since nothing guarantees ex ante the existence of a policy reform that has an equal-size welfare impact on heterogenous agents. Without attaching any specific normative advantage to this solution, we are going to set it as our *benchmark optimized policy* and use it to illustrate the trade-offs involved in the choice of the various parameters of the policy rule.

Under our benchmark optimized policy, the average capital requirement is 13.5% - about 3.5 percentage points higher than under our calibrated policy. Moreover, the two standard deviations band has a width of 9 percentage points, implying that our optimized policy rule prescribes a value of 9% for the sum of the capital conservation buffer and the countercyclical capital buffer. This implies quite a large room for manoeuvre over the credit cycle: when credit exceeds steady state by two standard deviations, our macroprudential policy rule pushes capital requirements up to a level of about 18%, while when it falls short of the steady state value by minus two standard deviations, capital requirements fall to a "minimum level" of about 9%, slightly above the "minimum level" associated with our initially calibrated policy.

To compare the policy prescriptions under our benchmark optimized rule with those of Basel III, notice that Basel III imposes a minimum capital ratio of 8%, a capital conservation buffer of up to 2.5% and a countercyclical capital buffer 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 countercyclical capital buffer is zero) is likely to be 10.5%. This means that our benchmark optimized policy rule exhibits a minimum level slightly higher than that in Basel III, a 3 percentage points higher steady state level, and an almost twice as big countercyclical variation over the credit cycle.

In the following sections we analyze the welfare and real economy consequences of capital requirement policy in more detail. We focus the discussion on the effects of the various policy parameters on the welfare of each class of agents and on the degree to which capital requirement policies are able to stabilize the impact of aggregate shocks. Importantly, the second-order approximation method that we use allows us to take the effects of aggregate uncertainty into account.

## 4.3 The Impact of Capital Requirements on Savers and Borrowers

In this section we analyze the impact of the three policy parameters on the welfare of savers and borrowers. This is done with the help of Figures 4 and 5. Figure 4 describes the welfare effects of varying each of the parameters of the policy rule while keeping the other two fixed at their optimized baseline values. Figure 5 contains the responses of key equilibrium quantities and prices to the changes in these parameters.

### 4.3.1 Capital Requirement Level Parameter $\bar{\phi}$

Column A of Figure 4 shows the welfare impact of changing the reference level of the capital requirements, $\bar{\phi}$. Savers' welfare increases with $\bar{\phi}$, whereas borrowers' welfare first increases and then decreases with it. As shown in Row A of Figure 5, higher capital requirements, by reducing bank leverage, reduce bank defaults. Depositors perceive banks to be safer and the cost of deposit funding declines. Through these changes, higher bank capital requirements may benefit both savers and borrowers.

However, tightening capital requirements also forces banks to use a larger fraction of more expensive equity financing per unit of lending, which corrects the limited liability distortion and, other things equal, tightens the supply of loans. The hump shape in borrowers 'welfare reflects the net effects of two counteracting forces –lower deposit funding costs and the cost of imposing a larger use of scarce equity– on credit supply. When bank fragility is high, the first force dominates and credit supply actually expands, which increases investment and real wages (not shown in the figure). But once bank failure probabilities get sufficiently close to zero and the deposit spread becomes virtually zero, tighter capital requirements raise the cost of credit, reduce investment and wages, and borrowers no longer benefit from a larger $\bar{\phi}$. Meanwhile, savers continue benefiting from increases in $\bar{\phi}$ through the impact on bank profits and the subsequent dividends received from banks.

### 4.3.2 Mortgage Risk Weight $\tau_{\phi}$

The welfare impact of a higher risk weight on mortgages is qualitatively similar to that of higher capital requirements (as seen in Column B of Figure 4 and Row B of Figure 5). When the risk weight is increased from a low level, both groups gain and then, beyond a certain point, changes in risk weights lead to a trade-off between the welfare of the two groups of agents. Quantitatively the impact is somewhat less pronounced, especially for lenders, partly because the impact of the mortgage risk weight on residual bank failure risk is smaller.

#### 4.3.3 Cyclical Response Parameter $\phi_b$

Examining the welfare impact of the cyclical response parameter, $\phi_b$, two key results emerge. First, borrowers gain from a stronger countercyclical response to credit while savers lose (see Column C of Figure 4). At the benchmark optimized capital level, bank failure risk is very low and such a move mitigates the reduction in the supply of credit in response to negative shocks while not significantly increasing banks' fragility (see Row C of Figure 5). This is good for borrowers. Savers, however, keep paying the increasing residual deposit insurance cost and receive lower dividends from banks and firms, which explains the decline in their consumption as $\phi_b$ increases.

Second, the welfare impact of changing $\phi_b$ once the other policy parameters are set at their optimized values, is rather limited. Importantly, the cyclical response parameter does not affect the steady state of the model and, hence, its impact on welfare is directly connected to its impact on the volatility of aggregate variables. Under the optimized values of $\bar{\phi}$ and $\tau_\phi$, bank fragility is not a large source of additional instability anymore (the credit cycle is already dampened) and shifts in $\phi_b$ only have marginal effects on the cyclicality of credit supply.

Interestingly, these key results do not follow under the initially calibrated policy rule. Under such rule, a stronger countercyclical adjustment is detrimental for both borrowers and savers. At a lower level of the capital requirements a stronger reduction in the requirements significantly increases banks' fragility, which makes depositors require a higher premium in compensation for the costs incurred when banks default and causes a negative impact on credit supply. The simultaneous reduction in credit supply and increase in the social cost of bank failure explains why both agents become worse off.

#### 4.3.4 Wrapping up

As a summary of what is told by the various panels of Figure 4, Table 3 focuses on the benchmark optimized policy, $(\bar{\phi}, \tau_\phi, \phi_b) = (0.142, 0.54, 0.1)$, and reports how much the welfare of savers and borrowers would change if each of the parameters were set back to their value under the calibrated policy. The parameter value modified on each row is written in bold. Clearly, the largest variations (in absolute value) are associated with the level parameter $\bar{\phi}$, meaning that this is the main contributor to the welfare gains implied by the optimal policy rule for both classes of agents. The effects of the mortgage risk weight $\tau_\phi$ and the countercyclical adjustment parameter $\phi_b$ are of much smaller magnitude. The effects of these two parameters on each class of agents are sort of mirror image of each other: $\tau_\phi$ slightly contributes to the welfare gains of the savers (in slight detriment of borrowers) and $\phi_b$ contributes to the welfare of the borrowers (in slight detriment of the savers). Yet, it should the noticed that the calibrated value of $\tau_\phi$ was already very close to its optimized value, while $\phi_b$ is five folds bigger under the optimal policy than under the calibrated policy. So, on an absolute basis, the mortgage risk weight seems indeed a more important ingredient of the optimal capital requirement rule than the countercyclical adjustment component.

Table 3: Welfare Gains

| Policy Parameters | | | Welfare Gains | |
|---|---|---|---|---|
| $\bar{\phi}$ | $\tau_\phi$ | $\phi_b$ | Savers | Borrowers |
| **0.10** | 0.54 | 0.5 | $-1.524$ | $-2.140$ |
| 0.142 | **0.50** | 0.5 | $-0.028$ | 0.033 |
| 0.142 | 0.54 | **0.1** | 0.028 | $-0.070$ |

Second-order approximation. Individual welfare differences (in consumption equivalent terms) w.r.t. the benchmark optimized policy.

## 4.4 Sources of the Welfare Gains

This paper explores the role of capital regulation policy in the presence of a rich stochastic structure. The policy is not ex ante targeted to smooth any particular source of fluctuations. However, in order to understand the sources of the welfare gains observed in prior sections, we are going to reassess the welfare gains under the benchmark optimized policy when one or several of the aggregate shocks are shut down. This will give us a measure of which are the shocks whose accommodation, using the optimal capital requirement policy, matter the most for the welfare gains associated with such policy.

### 4.4.1 Gains from the Accommodation of Aggregate Uncertainty

The results of this exercise are summarized in Table 4. It reports the welfare gains when all the shocks are present (part (i)) and when all or each of the three risk shocks (shock to the standard deviation of the idiosyncratic shocks that affect the returns of the assets of each of the borrowing classes of agents in our economy) are shut down (part (ii)). It also shows the welfare gains that remain when aggregate shocks other than the risk shocks are shut down (part (iii)) and when all sources of aggregate uncertainty are shut down (part (iv)). Note that in all cases, agents are still subject to the idiosyncratic shocks to their assets' returns.

Table 4: Welfare Gains

| | Savers | Borrowers |
|---|---|---|
| (i) All shocks | 0.66 | 0.66 |
| (ii) No risk shocks | 0.41 | 0.03 |
| - No *bank risk* shocks | 0.45 | 0.26 |
| - No *entrepreneurial risk* shocks | 0.62 | 0.43 |
| - No *housing risk* shocks | 0.66 | 0.65 |
| (iii) No other shocks | 0.65 | 0.65 |
| (iv) No aggregate uncertainty | 0.40 | 0.02 |

Second-order approximation to the welfare gains associated with the benchmark optimized policy vs. the calibrated policy.

The most striking finding from this table is that borrowers' welfare gains essentially vanish in the absence of risk shocks, of which the shocks affecting the dispersion of the returns of bank assets (*bank risk* shocks) and entrepreneurial assets (*entrepreneurial risk* shocks) are, in this order, the most important ones (explaining about 61% and 35% of borrowers' welfare gains, respectively). In the case of savers, better accommodating the risk shocks and, in particular, the bank risk shocks is also an important source of welfare gains (38% and 32%, respectively). Entrepreneurial risk shocks are important for borrowers and less so for savers. In contrast, risk shocks to housing returns (*housing risk* shocks) do not seem to explain the welfare gains of any of the two classes of agents. Differently from entrepreneurial risk shocks (which affect physical capital and get transmitted to the whole economy via wages), the housing risk shock only affects the borrowers, who, faced with larger default risk, reduce their leverage and put downward pressure on house prices. Saving households, however, respond in an offsetting manner, increasing their demand for housing and their consumption. Eventually, the aggregate effects turn out to be tiny.

To complete this discussion, Figures 6 and 7 show the way the economy reacts to bank and entrepreneurial risk shocks, which are the shocks that contribute the most to bank default under the calibrated capital requirement policy and, as just seen, to the welfare gains associated with the benchmark optimized capital requirement policy. The common message is that higher capital requirements (and, secondarily, larger countercyclicality attached to them) make the economy more resilient to these shocks.

As the solid lines in Figure 6 show, under the calibrated policy the bank risk shock causes a rise in bank default risk and produces a loss of bankers' net worth. Higher deposit funding costs and the reduced availability of bank capital lead to a decline in both housing and entrepreneurial loans, which get transmitted to the real economy in the form of lower investment, depressed wages, and eventually lower consumption and lower GDP. The dashed lines in Figure 6 show that the optimized policy almost completely offsets these effects: the high level of capital requirements, by keeping bank defaults and bankers' net worth losses close to zero, avoids the contractionary impact of the rise in bank funding costs and the fall in credit supply that would have otherwise occurred.

Figure 7 shows that the capacity of capital requirement policy to dampen the impact of the entrepreneurial risk shocks is more limited. This is because these shocks affect in first instance the default risk of the entrepreneurs, who react by deleveraging and, thus, by reducing their demand for bank loans and their investment. Banks get eventually hit through channels such as the default rate on entrepreneurial loans and the general depression in economic activity that follows the fall in investment. Notice that, as a result, the impact of the shock on bankers' net worth is protracted, reaching its maximum about ten quarters after the initial shock. As shown by the difference between the solid and dashed lines in Figure 7, capital requirements help by protecting banks from solvency risk when a entrepreneurial risk shock hits. Well capitalized banks can withstand losses without failing in large numbers, so preventing a loss of confidence in the banking system, the increase in banks' funding costs, and a larger contraction in credit. In fact, the countercyclical relaxation of capital standards can further lean against this but the net effect on the equilibrium amount of entrepreneurial loans and investment is still negative because the demand-side effect dominates.

### 4.4.2 Gains from the Accommodation of Idiosyncratic Uncertainty

Part (iv) in Table 4 also shows that a large fraction of savers' welfare gains (61%) remains even after all sources of aggregate uncertainty are shut down. This means that the benchmark optimized policy benefits the savers largely through steady state gains. The root of such gains is at the way capital requirements deal with the idiosyncratic uncertainty associated with the shocks that hit the asset returns of the various classes of borrowing agents, most notably the banks. Protected by limited liability and deposit insurance, the bankers fail to internalize part of the bankruptcy costs caused by high leverage and capital requirements can contribute to reduce the implied deadweight losses. Savers appropriate part of the saved resources through the reduction in the taxes needed to cover deposit insurance costs and through the higher dividend payouts received from entrepreneurial firms and banks, which are in turn the result of a more restricted supply of credit.

In the case of borrowers, the net welfare gains appropriated in the absence of aggregate uncertainty are virtually zero (see part (iv) in Table 4), because their welfare gains coming from the reduction in bank default risk (e.g. the lower taxes needed to cover deposit insurance costs) are offset by the higher cost of bank loans and more restricted access to credit.

On net terms, the borrowers benefit almost exclusively from the stabilization of aggregate risk, whereas savers turn out to be beneficiaries of the stabilization of both aggregate and idiosyncratic risk.

## 4.5 The Interaction of Micro and Macroprudential Policy Goals

Traditionally, microprudential regulation has been concerned with ensuring that individual banks do not go bankrupt. In contrast, the macroprudential perspective to financial regulation is focused on system-wide rather than individual bank level financial stability. In fact, there has been a recognition in academic and policy circles that an exclusive focus on making an individual bank safe (the objective of microprudential regulation) can lead to too much procyclicality in credit supply (one of the features that macroprudential policy seeks to avoid).[24] This is how the micro and macroprudential regulatory perspectives may come into conflict even though clear complementarities between the two objectives do also exist.

The quantitative importance of the interaction between micro and macroprudential goals has been so far been left unexplored in the literature. In our model, the objectives of keeping

[24] See e.g. Hanson, Kashyap and Stein (2011).

banks safe and preventing the financial system from creating procyclicality are complementary to a large extent. Safe individual banks (the goal of microprudential regulation) ensure that the bank net worth and bank funding shock amplification mechanisms do not operate in a powerful manner. When banks are safe, the financial system does not amplify real and financial shocks (satisfying the goal of macroprudential regulation). In fact, as we show in Figure 6, bank risk shocks have almost no effect when capital requirements are high and the probability of bank default is low.

Nevertheless, our welfare analysis of the countercyclical response coefficient in the policy rule $\phi_b$ (see Panel C of Figure 4) shows that conflicts between the micro and macroprudential objectives may arise at the bottom of the financial cycle. Savers lose from a stronger countercyclical response largely because they want to avoid the tax costs of supporting the marginal banks that are likely to fail as a result of a relaxation of capital standards. Microprudential regulators are likely to have exactly the same perspective. They wish to keep capital requirements high in order to avoid an increase in bank failure risk.

In contrast, as we saw in Panel C of Figure 4, borrowers (who care also about the stability of credit supply) would wish to see a reduction in capital requirements in order to support lending and reduce the power of the bank capital channel to amplify credit reductions following negative shocks. Macroprudential policymakers share this objective and hence may seek to relax capital standards at the bottom of the financial cycle.

However, the small welfare implications of the countercyclical response of capital requirements that we find suggests that conflicts between micro and macroprudential regulators are unlikely to be severe. Moreover, having fragile banks (in the sense of a high failure risk) adds to the procyclicality of the financial system and macroprudential authorities will also wish to keep bank failure risk low (though not zero). So there are complementarities between the micro and macroprudential policy goals which suggest that the potential conflicts between the two perspectives may be less severe than commonly believed.

# 5. Conclusions

This paper explores the quantitative policy implications of the model developed in Clerc et al. (2015), which we calibrate to Euro Area data. The differential contributions of this paper can be summarized as follows. First, we set the model parameters so as to match a number of important first and second moments referring to key Euro Area macroeconomic and financial aggregates during the 1999-2013 period. Second, we solve the model with second order perturbation techniques and compute the welfare of lenders and borrowers taking into account both idiosyncratic and aggregate risk. And we then find the values of the parameters of a simple capital regulation policy rule that maximize social welfare under all possible Pareto weights on the welfare of the borrowing and lending households who populate the model economy. Third, we provide an interpretation of the resulting policy rules in terms of the elements with which capital requirements are described in recent Basel-based capital regulation, namely a minimum capital ratio, the risk-weight assigned to mortgage exposures, and some potentially time-varying capital buffers. Fourth, we analyze the differential welfare impact of capital regulation on borrowers and savers, and quantify the contribution of the various shocks in the model to the welfare gains that they obtain from the optimal capital requirements policy rule.

Constraining optimal policy rules to be such that none of the two classes of agents lose welfare relative to the initially calibrated policy rule, we find that, as the weight of lenders in the social welfare function varies between 0 and 1, the implied minimum capital requirement varies between 8% and 11%, the risk weight on mortgages varies between 50% and 86%, and the sum of the capital conservation buffer and the countercyclical capital buffer varies between 8.5% and 9.5%.

A close look at the optimized policy rules uncovers that the most important aspect of capital requirement policy is to ensure that bank default is close to zero. This minimizes the deadweight costs of bank defaults and shuts down bank-related amplification channels, thus stabilizing the reaction of the economy to aggregate shocks. Thus, policy parameters determining the average level of the capital requirements (which is the sum of the minimum capital requirement and the average value of any other regulatory buffer) and the mortgage risk weight are key to neutralize the potential damage caused by financial instability. The cyclical adjustments coming from the presence of a countercyclical capital buffer (which turns out to be rather large under the optimized policy rules) have a less sizeable impact on social welfare.

The distortions from having undercapitalized banks are so large that all agents in society benefit when the level of the capital requirement and the mortgage risk weight are first increased from their low initial calibrated levels. But once the risk of bank default is small enough, further increases in capital requirements have opposite effects on the welfare of savers and borrowers. Savers gain because tight capital requirements reduce the tax cost of deposit insurance and boost the dividends that they receive out of the enlarged profits of the banks. Borrowers lose out because of lower mortgage credit supply and also because the squeeze on corporate lending reduces capital intensity and hits labor income.

In contrast, the pursuit of an active countercyclical policy via capital regulation tends to marginally benefit borrowers at the expense of savers. Essentially such policy stabilizes the aggregate fluctuations in credit supply which is welfare enhancing for the risk-averse borrowers. Savers lose out mainly because a more active countercyclical policy implies an effective reduction in the minimum capital ratio (and an increase in the size of the buffers added on top of it). This increases slightly the risk of bank default in downturns, which implies higher expected deposit insurance cost for tax payers. In any case, the welfare impact of the countercyclical adjustment of capital requirements is small in the aggregate and for both classes of agents. All in all, our results suggest the existence of a less severe conflict between the goals of micro and macroprudential policies than commonly thought.

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# Technical Appendix

## A Data

- 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.[25]

- 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.

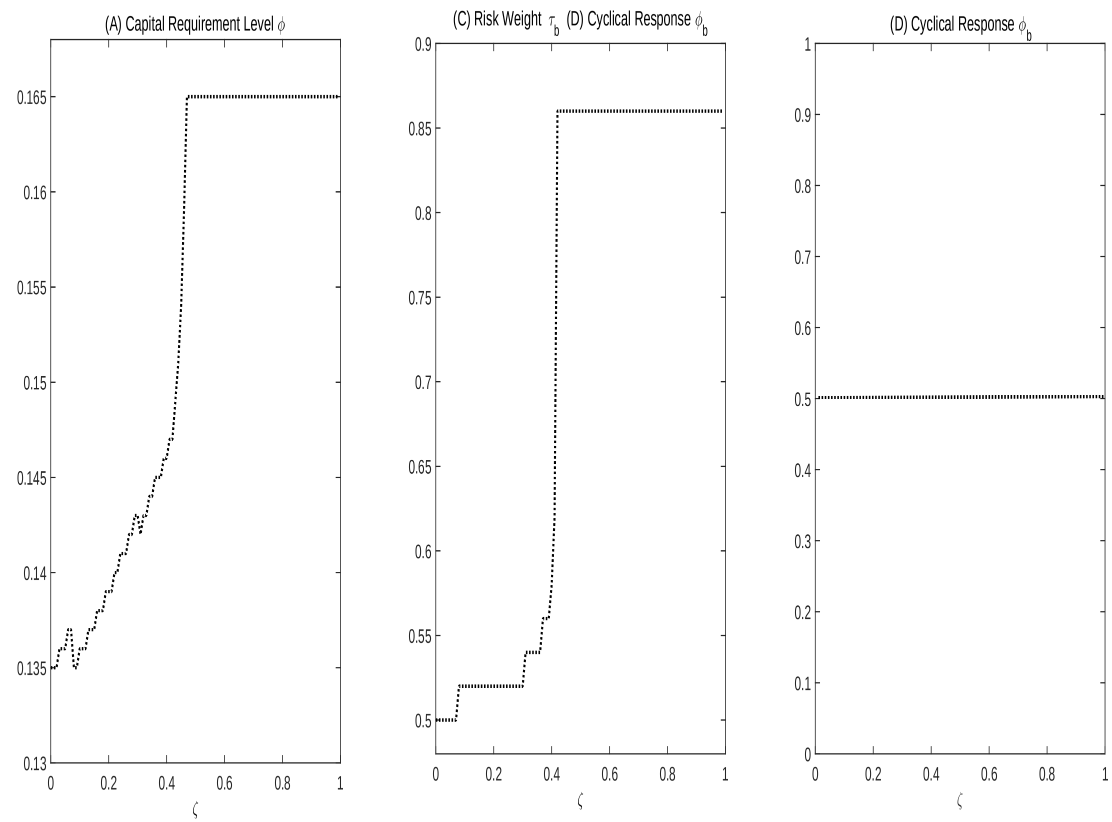
- Housing Investment: Gross fixed capital formation: housing, Current prices - Euro, divided by the Gross domestic product at market price, Deflator. Source: ESA - ESA95 National Accounts, Macroeconomic Statistics (S/MAC), European Central Bank.

- 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.

[25] 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).

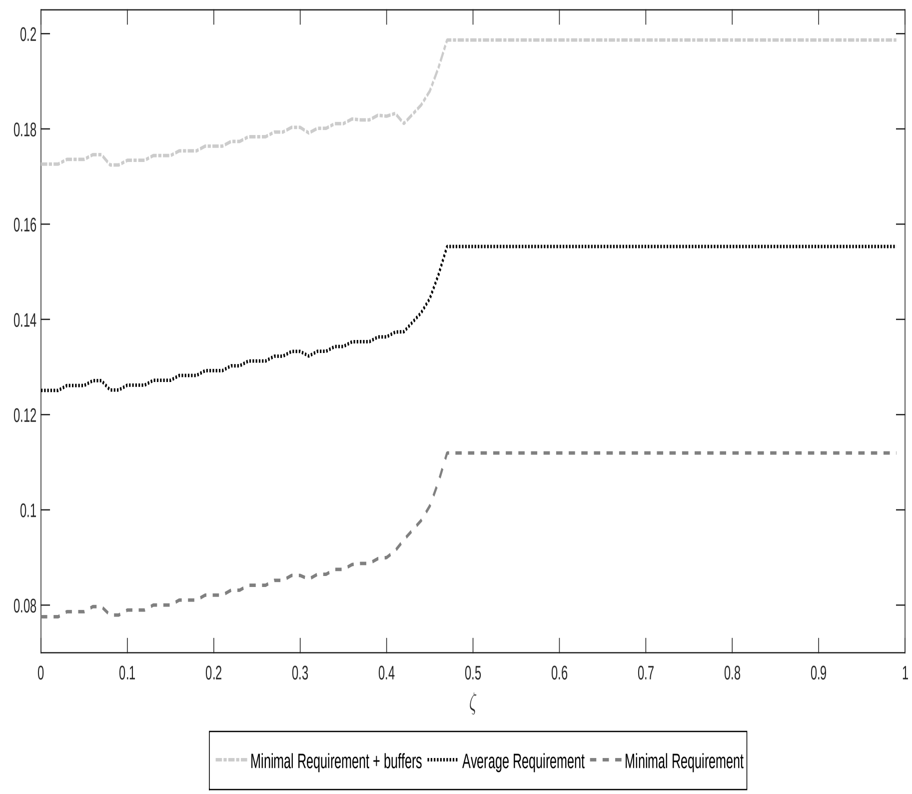
- Bank Equity Return: Median Return on Average Equity (ROAE), 100 Largest Banks, Euro Area. Source: Bankscope.
- Cross sectional mean and standard deviation of total capital ratio: Total Capital Ratio, 100 largest banks, Euro Area, period: 2001-2007, source: Bankscope.
- Spreads between the composite interest rate on loans and the composite risk free rate is computed in two steps. Firstly, we compute the composite loan interest rate as the weighted average of interest rates at each maturity range (for housing loans: up to 1 year, 1-5 years, 5-10 years, over 10 years; for commercial loans: up to 1 year, 1-5 years, over 5 years). Secondly, we compute corresponding composite risk free rates that take into account the maturity breakdown of loans. The maturity-adjusted risk-free rate is the weighted average (with the same weights as in case of composite loan interest rate) of the following risk-free rates chosen for maturity ranges:
  - 3 month EURIBOR (up to 1 year)
  - German Bund 3 year yield (1-5 years)
  - German Bund 10 year yield (over 5 years for commercial loans)
  - German Bund 7 year yield (5-10 years for housing loans)
  - German Bund 20 year yield (over 10 years for housing loans).
- Borrowers Fraction: Share of households being indebted, as of total households. Source: Household Finance and Consumption Survey (HFCS), 2010.
- Borrowers Housing Wealth: value household's main residence + other real estate - other real estate used for business activities (da1110 + da1120 - da1121), Share of indebted households, as of total households. Source: HFCS, 2010.

Figure 1: ***Optimized Capital Regulatory Tools***



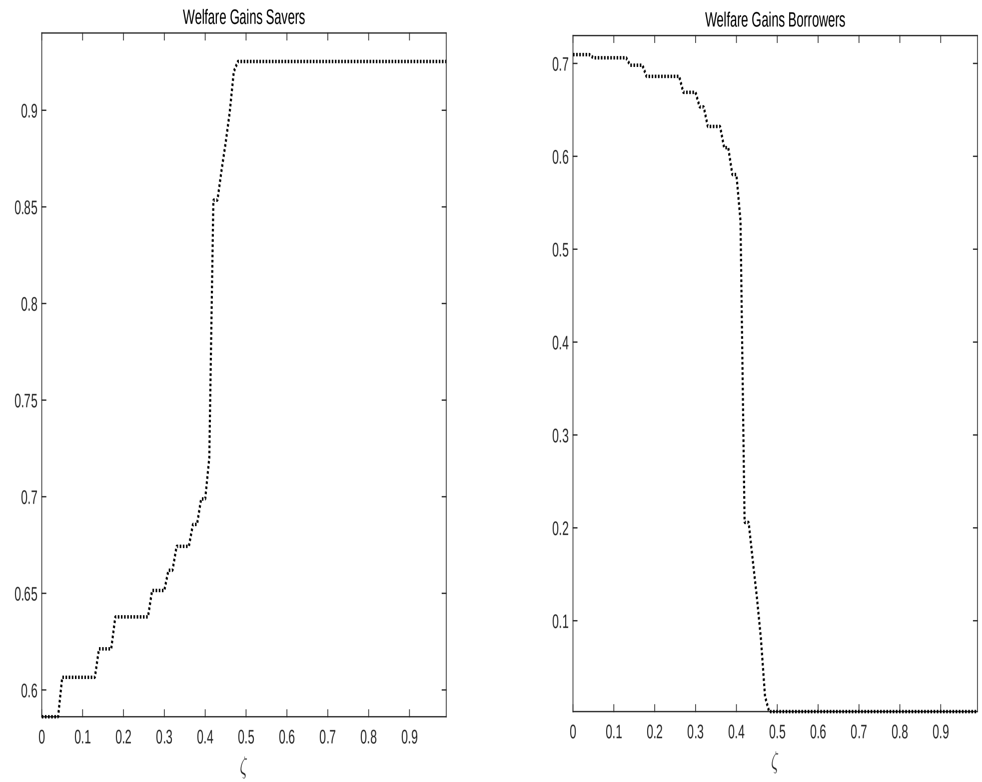

Note: Social welfare maximizing capital regulation policy rule w.r.t. savers' Pareto weight $\zeta$: capital requirement level $\bar{\phi}$ (panel A), optimal risk weight $\tau_\phi$ (panel B), optimal counter-cyclical response of bank capital to the credit gap $\phi_b$ (panel C). Capital regulation policy rule: $\phi_t = \bar{\phi} + \phi_b \log\left(b_t/b\right)$, $\phi_{H,t} = \tau_\phi \phi_t$, $\phi_{F,t} = \phi_t$.

Figure 2: ***Bank Capital Requirements under Alternative Optimized Policies***



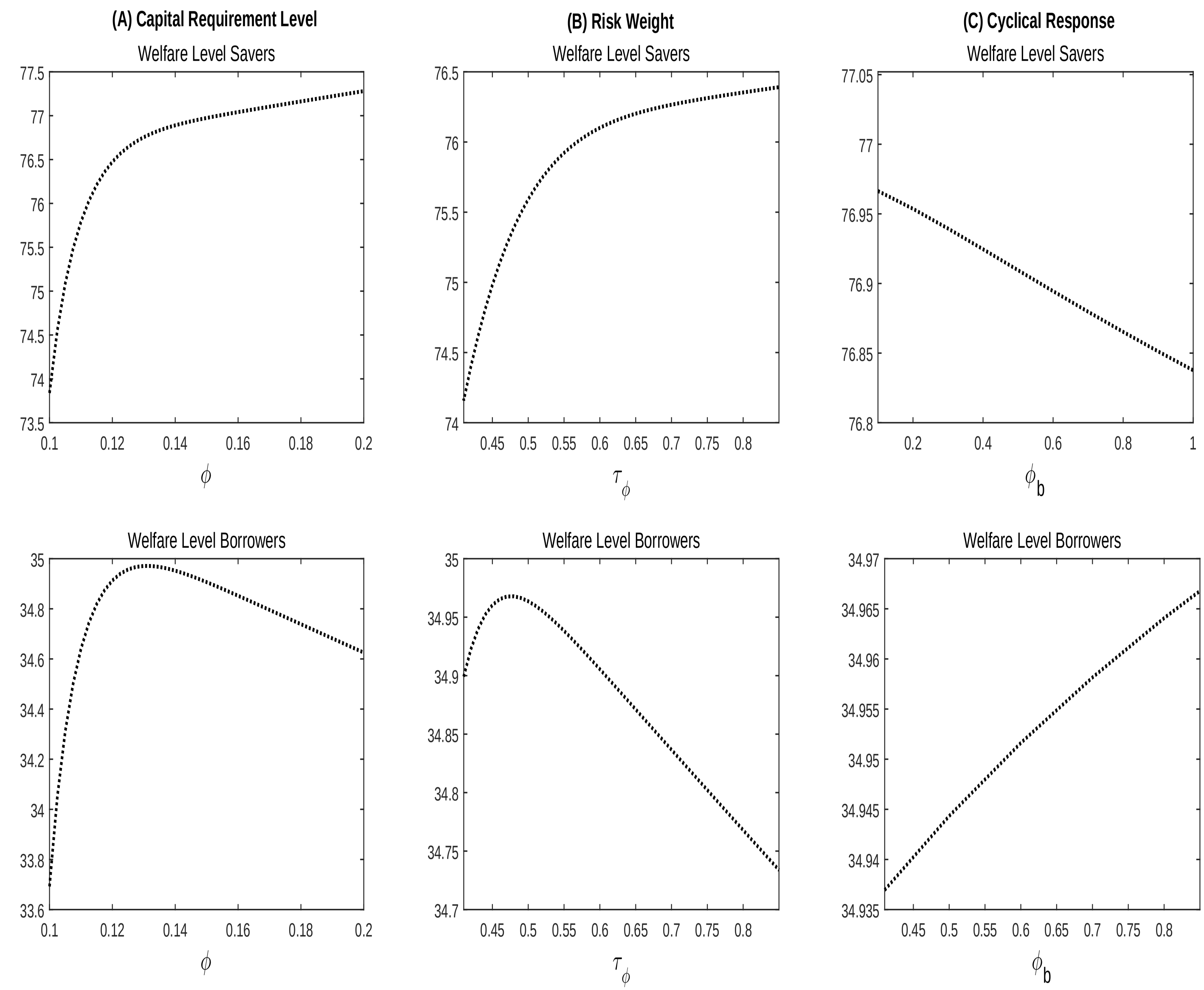

Note: Average capital requirement $\bar{\phi}$ (dotted line), minimal requirement (dashed line) and minimal requirement + buffers (dashed-dotted line) implied by the optimized $\bar{\phi}$, $\tau_{\phi}$ and $\phi_b$ corresponding to each value of the savers' Pareto weight $\zeta$. Capital regulation policy rule: $\phi_t = \bar{\phi} + \phi_b \log(b_t/b)$, $\phi_{H,t} = \tau_{\phi}\phi_t$, $\phi_{F,t} = \phi_t$.

Figure 3: ***Welfare Gains***



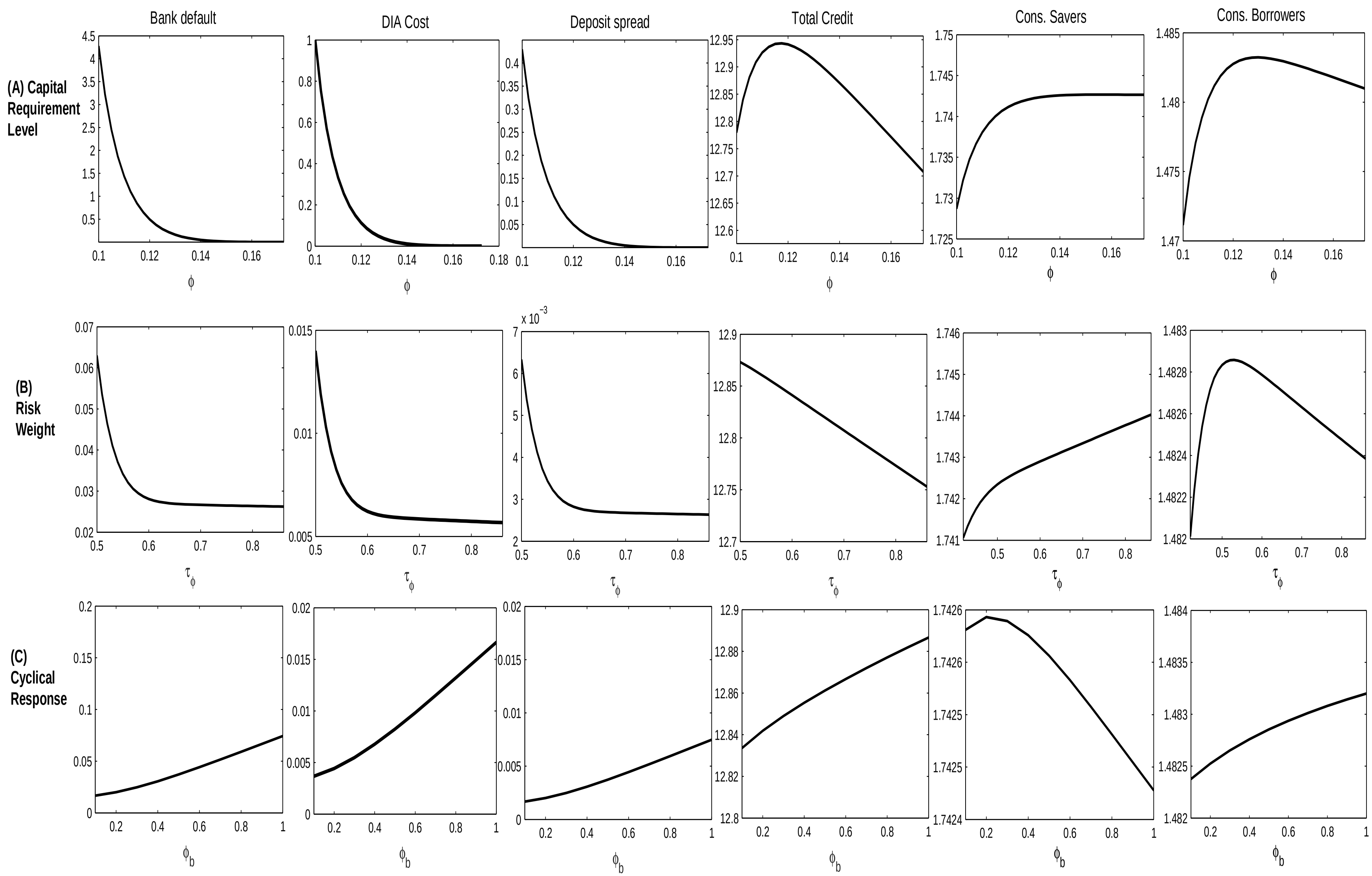

Note: Individual welfare gains implied by the optimal policy corresponding to each value of the savers' Pareto weight $\zeta$. The gains are measured in consumption-equivalent terms, as the percentage increase in the consumption of agents that would make their welfare under the initially calibrated policy rule equal to their welfare under each optimized policy rule.

Figure 4: ***Ceteris Paribus Changes in Regulatory Tools: Welfare***



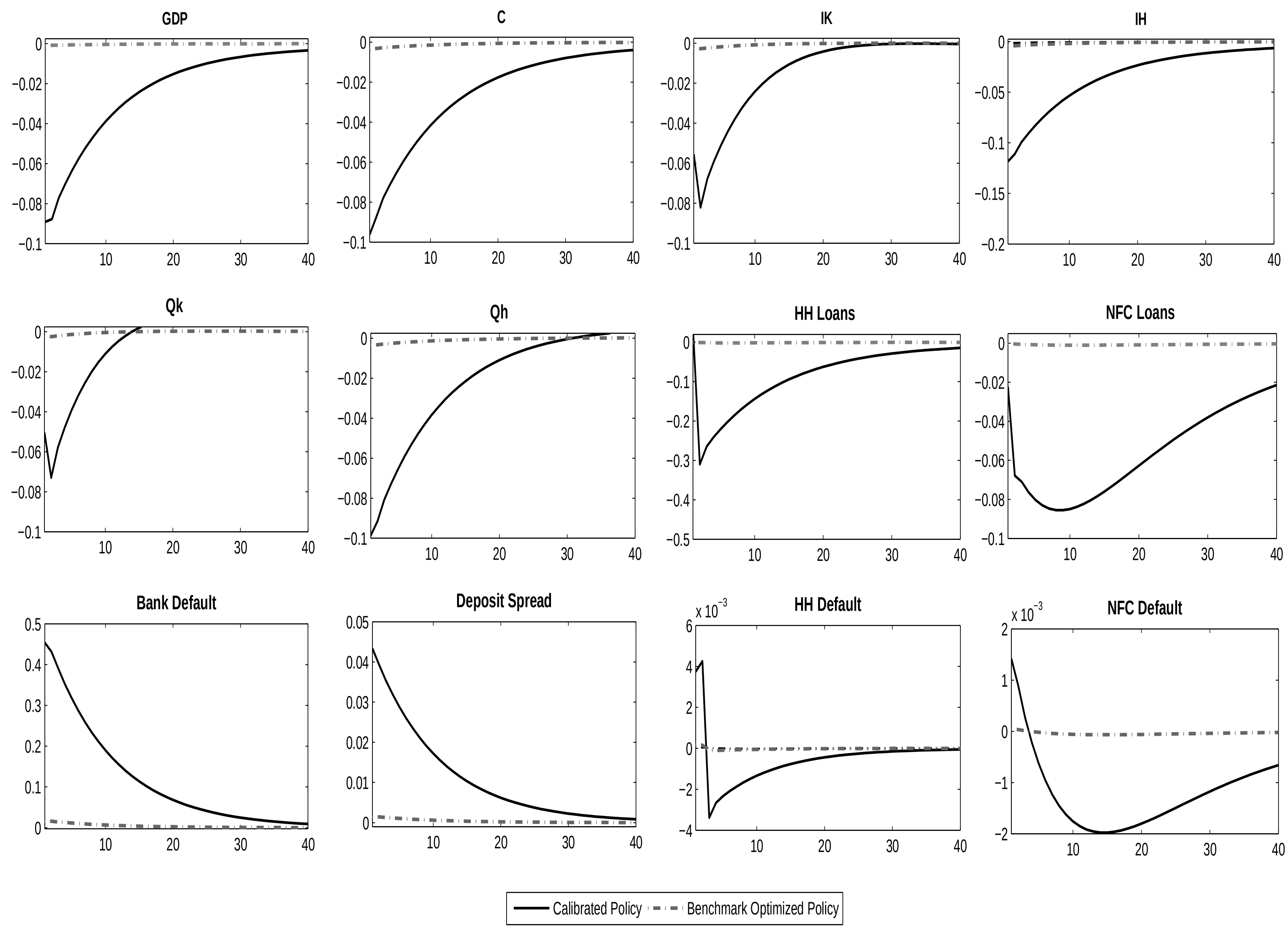

Note:Individual welfare w.r.t. ceteris paribus changes in the capital requirement level $\bar{\phi}$ (panel A), the mortgage risk weight $\tau_\phi$ (panel B), and the counter-cyclical response of banks' capital ratios to the credit gap $\phi_b$ (panel C). While changing one parameter, we keep the other parameters equal to their optimized values under $\zeta = 0.304$ (dashed line). Capital regulation policy rule: $\phi_t = \bar{\phi} + \phi_b \log(b_t/b)$, $\phi_{H,t} = \tau_\phi \phi_t$, $\phi_{F,t} = \phi_t$.

Figure 5: ***Ceteris Paribus Changes in Regulatory Tools: Stochastic Mean***



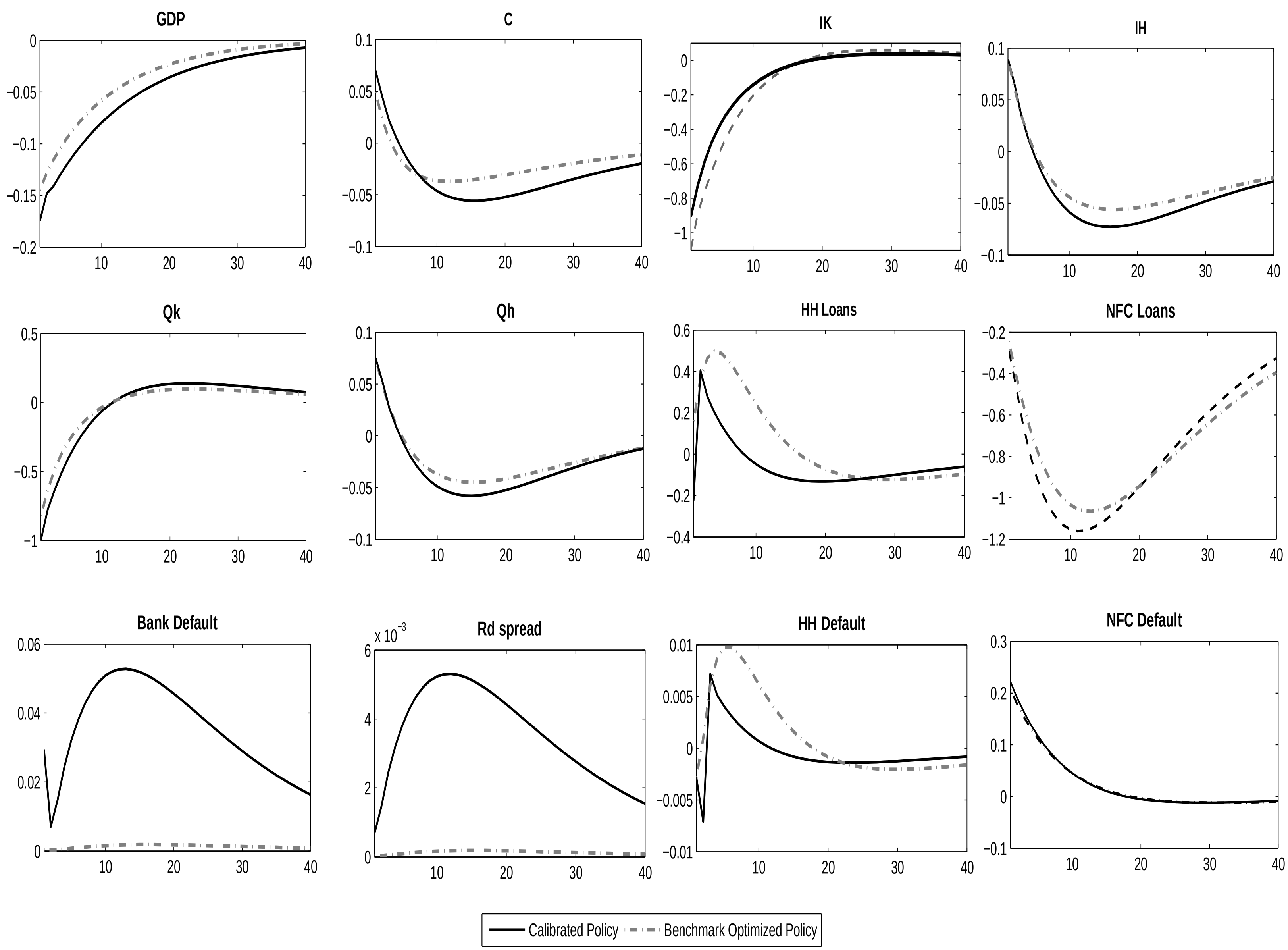

Note: Stochastic mean of key variables w.r.t. ceteris paribus changes in the capital requirement level$\bar{\phi}$ (A), the mortgage risk weight $\tau_\phi$ (B), and the counter-cyclical response of banks' capital ratios to the credit gap $\phi_b$ (C). While changing one parameter, we keep the other parameters equal to the optimized values(Pareto Weight $\zeta$=0.304). Capital regulation policy rule:$\phi_t = \bar{\phi} + \phi_b \log(b_t/b)$ , $\phi_{H,t} = \tau_\phi \phi_t$, $\phi_{F,t} = \phi_t$. Bank default and deposit spread are in annualized percentage terms, whereas the DIA cost is measured as percentage of GDP.

Figure 6: ***Increased Risk in Bank Asset Returns***




Note: Impulse-response function to a one-standard deviation negative bank risk shock under two alternative capital regulation policies: calibrated (solid line) and benchmark optimized ($\zeta$=0.304) (dashed line) policy. Capital regulation policy rule: $\phi_t = \bar{\phi} + \phi_b \log(b_t/b)$, $\phi_{H,t} = \tau_\phi \phi_t$, $\phi_{F,t} = \phi_t$. The response of Bank default, Deposit spread, HH default and NFC default are reported in annualized percentage points deviations from the steady state. All other variables are in percentage deviations from the steady state.

Figure 7: ***Increased Risk in Entrepreneurial Asset Returns***




Note: Impulse-response function to a one-standard deviation negative entrepreneurial risk shock under two alternative capital regulation policies: calibrated (solid line) and benchmakrk optimized ($\zeta$=0.304) (dashed line) policy. Capital regulation policy rule: $\phi_t = \bar{\phi} + \phi_b \log(b_t/b)$, $\phi_{H,t} = \tau_\phi \phi_t$, $\phi_{F,t} = \phi_t$. The response of Bank default, Deposit spread, HH default and NFC default are reported in annualized percentage points deviations from the steady state. All other variables are in percentage deviations from the steady state.