Sectoral Credit Allocation, Capital Requirements and Financial Stability

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July 2023

Abstract

Banking crises are often preceded by large expansions in residential real estate credit. However, banks' prudential regulation imposes typically lower minimum equity-capital funding requirements on residential real estate lending than on corporate lending. This paper quantifies the consequences of regulatory designs that fail to take into account the macroprudential dimension of the growth in real estate lending. I develop a DSGE model in which banks intermediate real estate loans to households and corporate loans to firms and where abnormally high defaults in either of these sectors can make banks fail. Calibrated for the Euro Area, results show that capital requirements based on the default risk of individual exposures amplify the reallocation of credit towards the real estate sector in the path to banking crises. Distortions to the allocation of credit in the path to crises, as well as the frequency and severity of banking crises, can be better mitigated by sector-specific macroprudential buffers than by generic buffers such as the Countercyclical Capital Buffer (CCyB) of Basel III.

Keywords: Banking Crises, Macroprudential Policy, Real Estate Credit

JEL codes: G01,G21,G28

*I am extremely grateful to my advisor, Javier Suarez, for invaluable guidance and support, as well as Rafael Repullo and Sebastián Fanelli. This paper also benefited from comments and discussions with Dante Amengual, Guillermo Caruana, David Martinez-Miera, Enrico Perotti, Josep Pijoan-Mas, Enrique Sentana, participants at seminars and reading groups at CEMFI and the Amsterdam Business School. All remaining errors are my own. I gratefully acknowledge financial support from the Spanish Ministry of Education, FPI grant PRE2019-089343.

1 Introduction

Capital regulation is the centerpiece of banks' prudential regulation. By requiring banks to finance at least a fraction of their assets with liabilities with loss absorption capacity such as common equity, they intend to primarily protect the wider economy against bank failures (Bhattacharya et al., 1998) and to contain the excessive leverage and risk taking incentives potentially implied by the presence of deposit insurance (Kareken and Wallace, 1978). International bank capital standards as set in Basel I (Basel Committee on Banking Supervision, 1988) and Basel II (Basel Committee on Banking Supervision, 2004) were established following a microprudential approach. Their focus was on preventing the failure of individual banks. When Basel II added greater risk-sensitivity to its predecessor, mainly through the so-called Internal-Ratings Based Approach (IRB), it did so by making capital requirements on each unit of lending a function of credit risk parameters of the individual exposures such as their probability of default (PD) and their loss given default (LGD).

Under this design, mortgage loans to households typically carry much lower capital requirements (or risk weights, in regulatory jargon) than corporate loans. As a result, for each given amount of equity, banks can lever up (and expand their asset investment) much more in the mortgage lending business than in the corporate lending business. This feature of bank regulation is in sharp contrast with recent evidence showing the role of the expansion in mortgage lending in sowing the seeds for systemic banking crises (Jordà et al., 2016; Müller and Verner, 2021). Awareness about the social costs of banking crises (Laeven and Valencia, 2013) and the role of general equilibrium and feedback effects in their propagation to the broader economy (especially in the form of damage to banks' capacity to lend in the aftermath of a crisis) pushed to the adoption of a macroprudential approach to the assessment and design of prudential regulation (Hanson et al., 2011). Under Basel III, minimum capital requirements are still calibrated following the microprudential approach but there are some regulatory macroprudential buffers that authorities can activate or release to deal with macroprudential concerns.

This paper assesses the contribution of the predominantly microprudential design of capital requirements to the distortion of bank lending decisions in the path to systemic banking crises and to the frequency and severity of those crises. It is shown that the differences in the typical capital requirements imposed on household mortgages relative to corporate loans favor a relative concentration in the former when vulnerabilities accumulate (as a result of shocks) in the path to crises, leaving banks and the economy excessively exposed to the materialization of risk in the real estate sector. In a counterfactual policy exercise, the analysis shows the macroprudential advantages of introducing sector-specific countercyclical capital buffers as a complement to existing microprudential requirements. They mitigate the cross-sectoral distortions in the path to crises and make crises less frequent and less severe. These results suggest that the macroprudential perspective adopted in Basel III (Basel Committee on Banking Supervision, 2010) after the Global Financial Crisis can be reinforced by adopting an explicit sectoral dimension in the operationalization of its novel macrorprudential buffers, most notably the Countercyclical Capital Buffer (CCyB) and the Systemic Risk Buffer (SRB).[1]

In spite of the close association between real estate specific credit booms and the occurrence of banking crises, there are few quantitative studies that assess the interaction of sectoral developments with capital regulation and the effectiveness of sector-specific capital buffers in preventing or mitigating the impact of such episodes. This paper fills this gap by building a macroeconomic model with leverage and bankruptcy related frictions in which credit is intermediated by banks. Borrowers from the household and the corporate sectors are exposed to shocks that can push them into default. Banks finance their lending with insured deposits and scarce equity funding from their owners. Correlated

[1] The guidelines in Basel III allow for national variation in the design of the macroprudential buffers. Some European countries have made active use of sectoral-specific buffers. In Spain, the corresponding regulation considers the possibility of a sectoral CCyB which has not been activated so far.

defaults produce fluctuations in the default rates experienced by banks on each category of loans and, when default rates are high enough, can produce bank failures and bank net worth losses that damage banks' capacity to lend in subsequent periods. Capital requirements replicating the features of the IRB approach of Basel II and III limit bank leverage and establish the "capital price" of investing in each class of loans. The model is calibrated to match data targets in the Euro Area, in the period between 2003 and 2013, roughly corresponding to the Basel II regulatory regime.[2]

In the model, distortions due to deposit insurance and limited liability encourage banks to prefer, other things equal, lending exposed to higher non-diversifiable risk (that is, more correlated defaults).[3] Intuitively, this happens because bank owners enjoy the upside gains from abnormally low default rates in good states but do not fully internalize the losses (to the deposit insurance agency and the rest of the economy) caused by abnormally high default rates when they fail in bad states.

In the calibrated model, non-diversifiable risk is a far more important determinant of defaults for real estate loans than for corporate loans. In the path to crises, rises in diversifiable risk hitting the corporate sector contribute to tilt bank portfolios further towards real estate loans, while increases in non-diversifiable risk act as triggers of banking crises, which have a devastating impact on production, investment and other real outcomes. The microprudential design of the risk-based capital requirements faced by banks under the IRB approach amplifies the distortions.

Although the combination of risk taking incentives by banks and rising non-diversifiable risk are the main drivers of banking crises in the model, there are strong amplification effects that operate through the balance sheet of intermediaries. As defaults materialize in

[2] Although the guiding principles for Basel III were adopted in 2010, the legal and practical implementation of the agreement was gradual over a long transition period.

[3] Following Mendicino et al. (2021), shocks pushing individual borrowers into default are modeled as in Bernanke et al. (1999) but with two components, one which is idiosyncratic and another with is non-diversifiable at bank level. Aggregate risk shocks as in Christiano et al. (2014) affect the variance of the idiosyncratic and non-diversifiable shocks causing aggregate fluctuations in default risk.

the real estate sector, large losses mount on the balance sheet of banks which hamper their ability to extend credit to both households and firms. The resulting fall in the demand for assets by firms and households triggers the dynamics of the financial accelerator as asset prices fall (Kiyotaki and Moore, 1997; Bernanke et al., 1999).

Consistently with the evidence, the model predicts that expansions in real estate credit are strongly associated to poorer economic outcomes in subsequent years (Mian and Sufi, 2009; Jordà et al., 2016). In the baseline calibration, the years preceding a crisis are characterized by a ratio of real estate loans to GDP which is on average close to one standard deviation above its mean, while banking crises imply cumulative falls in GDP of 13% in the three years following a crisis.[4] Unlike expansions in credit to the corporate sector, which tend to be driven by positive productivity shocks, the first order force driving banks to expand their balance sheet towards real estate is an increase in non-diversifiable risk in the economy. In the model, expansions in real estate credit predict lower future GDP growth because they reflect the prospect of higher future default rates on bank loans and a credit crunch following future bank net worth losses.

The analysis reveals that the reallocation of credit towards the real estate sector and the subsequent output losses are more severe under designs of bank capital requirements that are more responsive to the risk of individual loans. Macroprudential buffers such as the CCyB of Basel III, which is intended to build up resilience during periods of excessive credit expansion and reduce credit crunches during downturns, partially succeeds in smoothing the impact of banking crises but does not reduce the reallocation of credit in the path to crises. In contrast, sector-specific macroprudential buffers responding to credit growth within each class of lending effectively protect the economy against the sectoral reallocation that takes place when idiosyncratic credit risk grows in the corporate sector while non-diversifiable risk accumulates in real estate. In this way, sector-specific

[4] A similar computation for the Euro Area yields output losses of around 12% following the Global Financial Crises

macroprudential buffers further mitigate the frequency and severity of banking crises.

To understand these results, notice that the generic CCyB increases proportionally the level of risk based capital requirements during periods when the ratio of total credit relative to GDP is increasing above its long term mean. However, because in the path to crises total credit increases at a slower rate than real estate credit, capital requirements increase too late to prevent the large losses associated to the real estate exposition to non-diversifiable risk. Moreover, by increasing the scarcity of bank equity, generic buffer rises can exacerbate the incentives to reallocate credit towards loans with lower risk weights during expansions. In contrast, sector specific macroprudential buffers can directly address excessive credit expansions in sectors where non-diversifiable risk is more important, achieving significant stabilization gains. In the model, these buffers can reduce output losses by roughly 3 percentage points in the three years following a banking crises, compared to the regime with the generic CCyB.

From a broader policy perspective, results in this paper suggest that while the reallocation of credit towards the real estate sector may look desirable from a microprudential point of view (insofar as real estate loans look individually safer than corporate loans) this should set off the alarms of "macroprudentially wary" regulators. The analysis therefore emphasizes the importance of the early adoption of well-targeted measures that prevent excessive credit reallocation towards sectors implying greater non-diversifiable risk.

Related Literature This paper is related to the macroeconomic literature studying the effectiveness of bank capital requirements in preventing financial crises and smoothing financial fluctuations (Begenau, 2020; Malherbe, 2020; Mendicino et al., 2021; Elenev et al., 2021; Begenau and Landvoigt, 2022). This paper contributes to this literature by studying the cross-sectoral implications of capital regulation in a setup with diversifiable and non-diversifiable risk. The results show how regulation based on microprudential criteria can amplify the role of the reallocation of credit towards the real estate sector in the path to banking crises. This paper is first at exploring how time-varying sectoral macroprudential buffers can help mitigate these distortions and reduce the frequency and severity of banking crises.[5]

Second, this paper is related to the work on drivers and effects of sector-biased credit growth. Part of the literature has emphasized the role of collateral and informational asymmetries regarding its quality or the solvency of borrowers (Gorton and Ordonez, 2020; Asriyan et al., 2022). In this tradition, booms are characterized by rising collateral values that lead to collateral-based lending at the cost of screening-based lending, sowing the seeds of large corrections during crises. A different strand of the literature emphasizes the role of external financing flows and occasionally binding financial constraints in causing crises dynamics (Bianchi and Mendoza, 2010; Mendoza and Quadrini, 2010), as well as the amplifying role of nominal frictions (Schmitt-Grohé and Uribe, 2016). This paper adds to this literature by investigating the role of bank risk taking distortions and capital regulation in exacerbating the reallocation towards real estate loans in the path to crises.

This paper is thus also related to the banking literature that has studied capital regulation in typically partial equilibrium setups (see Santos, 2001, for a survey). It is specially connected to contributions emphasizing the potential procyclical effects of risk-based capital requirements (Andersen, 2011; Repullo and Suarez, 2013).

The remainder of this paper is structured as follows. Section 2 presents the model. Section 3 discusses the solution method and calibration of the model. Section 4 analyzes the drivers of banking crises, under the baseline calibration. Section 5 assesses the effectiveness of different macroprudential buffers in preventing and mitigating the implications of banking crises. Section 6 concludes.

[5] Among the papers analyzing capital regulation in DSGE models, only a few have considered more than one borrowing sector (e.g. Mendicino et al., 2018). However, to my knowledge, this is the first paper discussing how the importance of non-diversifiable risk in real estate loans interacts with capital requirements to contribute to tilt bank portfolios towards real estate in the path to crises.

2 Model

The model presented in this section is a two-sector extension of the framework introduced by Mendicino et al. (2021), that introduces mortgage loans in the analysis. The economy is composed of a continuum of islands of measure one.[6] All agents in the economy are part of an infinitely lived dynasty, which makes labor supply, consumption and investment decisions on behalf of its members. Production factors and the final consumption good are perfectly mobile across islands. Time is discrete and the horizon is infinite.

The final good is produced in each island by a continuum of measure one of ex-ante identical firms, which combine labor and physical capital using a Cobb-Douglas technology. Firms finance the cost of their production inputs one period in advance. A fraction of these expenses are faced using equity funding provided by firm owners (entrepreneurs). To secure the remaining funds, firms subscribe one-period loan contracts with a firm-specialized bank subsidiary in their island. Firms choose their financial structure taking into account how loan rates increase with their leverage (due to, among other factors, rising bankruptcy costs).

In each island there is also a continuum of measure one of dwellings, inhabited by members of the dynasty called dwellers.[7] Each period, the dynasty endows each dweller with a given amount of funds, to be used as downpayment for housing units. The remainder of funds needed to purchase houses are financed through a one-period loan contract (mortgage loan) subscribed by each dweller with a real estate specialized bank subsidiary in their island. In a similar fashion as firms, the dynasty (or equivalently, each of the dwellers) decides the total housing units financed in this way, taking into account how loan rates increase with their leverage.

[6] The interpretation of islands does not need to be strictly geographical, but could be a metaphor for e.g. different industrial sectors.

[7] This formulation is isomorphic to a model with two continua of islands, one corresponding to firms and the other one to dwellings.

2.1 Household dynasty and dwellers

A long lived dynasty makes consumption, labor supply and investment decisions on behalf of its members. The lifetime discounted expected utility of the dynasty is

$$V_t = \mathbb{E}_t \sum_{s=t}^{\infty} \beta^{s-t} \left[\log(C_s) + \lambda_h \log(H_s) - \lambda_L \frac{l_s^{1+\varphi}}{1+\varphi} \right], \tag{2.1}$$

where β is the dynasty's discount factor, C_t denotes consumption of the final good (which is also the numeraire), H_t are housing units consumed by the dynasty and l_t is the household labor supply. Parameters λ_h and λ_L measure the relative preference of the household for housing units and labor, respectively. The Frisch elasticity of labor is denoted by φ.

Dynasty's resource constraint The resources available to the dynasty are derived from its labor income, the returns from financial and real investments it undertakes, the transfers it receives from bankers, entrepreneurs and dwellers and the profits from producers of physical capital and housing units. The dynasty devotes a fraction χ_h of its total wealth to the downpayments used to finance dwellings for its members, denoted by $EQ_t^h = \chi_h W_t$. The remainder fraction $1 - \chi_h$ is either consumed or invested in bank deposits and holdings of physical capital, so that

$$C_t + D_t + q_{k,t} K_{hh,t} \leq W_t - EQ_t^h, \tag{2.2}$$

where D_t are bank deposits, q_t is the price of physical capital and $K_{hh,t}$ are holdings of such capital by the dynasty, representing the non-bank-dependent part of productive investment in this economy. Total household wealth is is denoted by W_t and is given by

$$W_t = w_t l_t + R_{d,t-1} D_{t-1} + q_{k,t}(1-\delta_k) K_{hh,t-1} + K_{hh,t-1}^{\alpha_h} + \Pi_t^h + \Theta_t + \Upsilon_t, \tag{2.3}$$

where $R_{d,t-1}$ is the gross return on one unit of fully insured bank deposits, δ is the depreciation rate of physical capital and α_h captures the efficiency of the backyard technology operated by the dynasty. The term Π_t^h are the gross returns on housing equity that the dynasty receives from dwellers, while Θ_t collects net transfers from entrepreneurs and bankers. The profits generated by producers of physical capital and housing units, which operate a technology transforming the final consumption good into either productive capital or housing, is denoted by Υ_t.

Dwellers The dynasty endows island dwellers with $EQ_t^h = \chi_h W_t$ units of wealth to be used as downpayment for purchasing housing units (dwellings). The acquisition of such housing units, H_t at a price $q_{h,t}$, is subject to the financing constraint

$$q_{h,t} H_t \leq B_{h,t} + EQ_t^h, \tag{2.4}$$

where $B_{h,t}$ is the principal of the non-recourse mortgage loan that complements the funding coming from the downpayments $\chi_h W_t$.

The funds raised by dwellers are invested symmetrically across a continuum of ex-ante identical dwellings in each island. The value of each dwelling is subject to two independent shocks, with mean one and positive support.[8] Dwelling idiosyncratic shocks, denoted by ω_h, affect the value of each individual housing unit, while island-specific shocks ω_h^j affect the value of all housing units in an island. From the point of view of the specialized real estate bank in the island, only the former are diversifiable. The terminal net worth associated with each individual dwelling is given by

$$\Pi_{t+1}^h(\omega_h, \omega_h^j) = \omega_h \omega_h^j q_{h,t+1}(1-\delta_h) H_t - R_{h,t}^l B_{h,t}, \tag{2.5}$$

[8] In particular, I assume that shocks have mean one log normal distributions, with stochastic volatility: $\log(\omega_h) \sim \mathcal{N}\left(-\frac{\sigma_{h,t+1}^2}{2}, \sigma_{h,t+1}^2\right)$ and $\log(\omega_h^j) \sim \mathcal{N}\left(-\frac{\left(\sigma_{h,t+1}^j\right)^2}{2}, \left(\sigma_{h,t+1}^j\right)^2\right)$

where δ_h is the depreciation rate of housing units and $R^l_{h,t}$ is the promised gross rate on mortgage loans. Dwellers default on a mortgage when $\Pi^h_{t+1}(\omega_h, \omega^j_h) < 0$. The aggregate (adding across islands and dwellings) returns on housing equity $\chi_h W_t$ is given by

$$\Pi^h_{t+1} = \int_0^\infty \int_0^\infty \max\left[\Pi^h_{t+1}(\omega_h, \omega^j_h), 0\right] dF_{h,t+1}(\omega_h) dF^j_{h,t+1}(\omega^j_h), \tag{2.6}$$

which is rebated by dwellers to the dynasty at the end of each period.

Problem of the dynasty The dynasty chooses sequences of consumption, bank deposits, holdings of physical capital, housing units and how to optimally finance the purchase of such units, in order to maximize its expected lifetime utility. More specifically,

$$\left\{C_s, D_s, l_s, K_{hh,s}, H_s, R^l_{h,s}, B_{h,s}\right\}_{s=t}^\infty = \text{argmax } V_t, \tag{2.7}$$

subject to (2.2), (2.4) and the participation constraint of the specialized real estate bank subsidiaries, given by

$$\mathbb{E}_t \Lambda^b_{t+1} \Pi^b_{h,t+1} \geq EQ^b_{h,t} v^b_{t+1}. \tag{2.8}$$

Restriction (2.8) requires that the loan terms agreed between the financing banks and the dwellers be such that the properly discounted (using the discount factor Λ^b_{t+1}) payoffs, denoted by $\Pi^b_{h,t+1}$, expected by banks compensate bankers for the shadow value of their net worth invested as equity in the specialized real estate subsidiaries, given by $EQ^b_{h,t+1} v^b_{t+1}$. This constraint can also be interpreted as a menu of mortgage contracts, which specify loan amounts, loan rates and housing units acquired by dwellers, offered by the banks to the dynasty. More details about this constraint are provided in section 2.3.

2.2 Entrepreneurs and Firms

Entrepreneurs are long-lived agents that own and manage one period ventures, called firms. Individual entrepreneurs start each period with a net worth denoted by $n_t^f(i)$, which they can use to pay out dividends, $\text{div}_t^f(i)$, to the dynasty or to invest in a well diversified (across firms and islands) portfolio of firm equity $EQ_t^f(i)$. One period later, they receive the payoffs on their portfolio of firm equity, which are added to their net worth.

Each period, a fraction $1-\theta_f$ of entrepreneurs retires, at a point in which they rebate their net worth to the dynasty and get replaced by an identical mass of entering entrepreneurs endowed with an amount of wealth provided by the dynasty.

Value function of entrepreneurs The value associated to an entrepreneur at the beginning of period t is

$$V_t^f\left(n_t^f(i)\right) = \max_{\text{div}_t^f(i), n_{t+1}^f(i), EQ_t^f(i)} \left\{\text{div}_t^f(i) + \mathbb{E}_t\Lambda_{t+1}\left[(1-\theta_f)n_{t+1}^f(i) + \theta_f V_{t+1}^f(n_{t+1}^f(i))\right]\right\} \tag{2.9}$$

$$\text{s.t. } \text{div}_t^f(i) + EQ_t^f(i) = n_t^f(i), \tag{2.10}$$

$$n_{t+1}^f(i) = \rho_{t+1}^f EQ_t^f(i), \tag{2.11}$$

$$\text{div}_t^f(i) \geq 0 \tag{2.12}$$

where Λ_{t+1} is the stochastic discount factor of the dynasty and ρ_{t+1}^f is the average return on a well diversified portfolio of firm equity. It can be guessed and verified, as in Gertler and Kiyotaki (2010), that this value function is linear in net worth, so that

$$v_t^f n_t^f(i) = \max_{\text{div}_t^f(i), n_{t+1}^f(i), EQ_t^f(i)} \left\{\text{div}_t^f(i) + \mathbb{E}_t\Lambda_{t+1}\left[(1-\theta_f)n_{t+1}^f(i) + \theta_f v_{t+1}^f n_{t+1}^f(i)\right]\right\} \tag{2.13}$$

subject to (2.10)-(2.12), where v_t^f can be interpreted as the shadow value of one unit of entrepreneurial net worth. If $v_t^f > 1$ it can be shown that entrepreneurs would choose $\text{div}_t^f(i) = 0$.[9] Intuitively entrepreneurs, who receive consumption insurance from the dynasty, prefer to wait and let net worth grow until they retire. Substituting back in (2.13) we find that

$$v_t^f = \mathbb{E}_t \Lambda_{t+1}^f \rho_{t+1}^f, \tag{2.14}$$

where $\Lambda_{t+1}^f \equiv \Lambda_{t+1}\left[(1-\theta_f) + \theta_f v_{t+1}^f\right]$ is the stochastic discount factor associated to entrepreneurs.

Entrepreneurial Firms Entrepreneurial firms produce the final consumption good using a technology which combines capital and labor according to

$$Y_{t+1} = A_{t+1} K_{f,t}^{\alpha} L_t^{1-\alpha}, \tag{2.15}$$

where A_{t+1} is an aggregate productivity shock and α measures the relative importance of capital in the production function of firms. Physical capital employed by firms in production is denoted by $K_{f,t}$.

Firms' financing constraint I assume that firms need to finance the cost of their production inputs upfront. In order to do so, they use equity funding EQ_t^f provided by entrepreneurs and loans B_t^f extended by a specialized bank subsidiary in the island where they operate. The financing constraint of a firm thus given by

$$w_t L_t + q_{k,t} K_{f,t} = B_{f,t} + EQ_t^f. \tag{2.16}$$

[9] I guess and verify that this is indeed the case in the deterministic steady state in the calibrated version of the model.

Terminal net worth of a firm The value of firms' assets is subject to performance shocks that determine their terminal net worth. Idiosyncratic shocks are denoted by ω_f and affect each firm individually. Island specific (non-diversifiable) shocks are denoted by ω_f^j and affect the value of assets of all firms in an island. Both shocks have mean one and their variance evolves over time following an autoregressive process. The terminal net worth of an entrepreneurial firm is given by

$$\Pi^f_{t+1}(\omega_f, \omega_f^j) = \omega_f \omega_f^j \left[Y_{t+1} + q_{k,t}(1-\delta_k)K_{f,t}\right] - R^l_{f,t}B_{f,t}, \tag{2.17}$$

where $R^l_{f,t}$ is the promised gross rate on corporate loans. Firms are protected by limited liability, so they default on their loans whenever $\Pi^f_{t+1}(\omega_f, \omega_f^j) < 0$.

Problem of firms Firms choose their input mix, as well as the combination of leverage and interest rate on loans agreed with their financing bank in order to maximize the properly discounted expected terminal net worth generated to entrepreneurs. In other words, firms' problem is such that

$$\left(K_{f,t}, L_t, B_{f,t}, R^l_{f,t}\right) = \operatorname{argmax} \mathbb{E}_t \Lambda^f_{t+1} \max\left[\Pi^f_{t+1}(\omega_f, \omega_f^j), 0\right] \tag{2.18}$$

subject to the financing constraint (2.16) and the participation constraint of the specialized corporate bank subsidiary in their island given by

$$\mathbb{E}_t \Lambda^b_{t+1} \Pi^b_{f,t+1} \geq EQ^b_{f,t} v^b_{t+1}, \tag{2.19}$$

where $\Pi^b_{f,t+1}$ denotes the average payoffs received by bankers on their specialized corporate lending subsidiaries and $EQ^b_{f,t}$ is bank equity allocated by bankers to subsidiaries in the corporate sector. In a similar fashion as the problem of choosing mortgage loans in the problem of the household dynasty, this constraint specifies a menu of loan contracts such that bankers are properly compensated for the value of their scarce net worth when they extend credit to the corporate sector.

Aggregate firms' payoffs The total payoffs received by entrepreneurs investing in a well diversified portfolio of firm equity are computed by aggregating the terminal net worth across islands and firms, taking into account the limited liability of firms. In other words, the total firm payoffs are given by

$$\Pi_{t+1}^{f} = \int_{0}^{\infty} \int_{0}^{\infty} \max \left[\Pi_{t+1}^{f}(\omega_f, \omega_f^j), 0 \right] dF_{f,t+1}(\omega_f) dF_{f,t+1}^{j}(\omega_f^j), \tag{2.20}$$

and the average return on a portfolio of firm equity diversified across islands and firms is simply given by $\rho_{t+1}^{f} = \Pi_{t+1}^{f} / EQ_t^f$.

2.3 Bankers and Banks

Bankers are long lived members of the dynasty, who own and manage bank subsidiaries in each island. They start each period with a given net worth $n_t^b(i)$. Bankers choose how to allocate their net worth in diversified portfolios of specialized real estate and corporate bank subsidiaries, or to pay out dividends $\mathrm{div}_t^b(i)$ to the dynasty. In a similar fashion as entrepreneurs, each period an exogenous fraction $1 - \theta_b$ of bankers retire, rebating their net worth to the dynasty. At this point, they get replaced by an identical mass of new bankers, endowed with an amount of net worth provided by the dynasty.

Value function of bankers The value function of a banker starting period t with net worth $n_t^b(i)$ satisfies the Bellman equation

$$V_{t+1}^b(n_t^b(i)) = \max_{\substack{\text{div}_t^b(i), EQ_{h,t}^b(i), \\ EQ_{f,t}^b(i), n_{t+1}^b(i)}} \left\{ \text{div}_t^b(i) + \mathbb{E}_t \Lambda_{t+1} \left[(1-\theta_b) n_{t+1}^b(i) + \theta_b V_{t+1}^b(n_{t+1}^b(i)) \right] \right\}, \tag{2.21}$$

$$\text{s.t. } \text{div}_t^b(i) + EQ_{h,t}^b(i) + EQ_{f,t}^b(i) = n_t^b(i), \tag{2.22}$$

$$n_{t+1}^b(i) = \rho_{h,t+1}^b EQ_{h,t}^b(i) + \rho_{f,t+1}^b EQ_{f,t}^b(i), \tag{2.23}$$

$$\text{div}_t^b(i) \geq 0, \tag{2.24}$$

where $EQ_{f,t}^b(i)$ and $EQ_{h,t}^b(i)$ denote investment in a well diversified (across islands) portfolio of bank equity in subsidiaries specialized in extending either corporate or real estate loans, respectively. The gross return on equity invested in each class of well-diversified portfolios is denoted by $\rho_{f,t+1}^b$ and $\rho_{h,t+1}^b$.

In a similar fashion as in the problem of entrepreneurs, it can be guessed and verified that the value function of bankers is linear in net worth, so that the Bellman equation in (2.21) can be written as

$$v_{t+1}^b n_t^b(i) = \max_{\substack{\text{div}_t^b(i), EQ_{h,t}^b(i), \\ EQ_{f,t}^b(i), n_{t+1}^b(i)}} \left\{ \text{div}_t^b(i) + \mathbb{E}_t \Lambda_{t+1} \left[(1-\theta_b) n_{t+1}^b(i) + \theta_b v_{t+1}^b n_{t+1}^b(i) \right] \right\}, \tag{2.25}$$

subject to (2.22) - (2.24). Following a similar argument as in the problem of entrepreneurs, as long as $v_t^b > 1$, bankers, who receive consumption insurance from the dynasty, would prefer to accumulate net worth until they retire, choosing $\text{div}_t^b(i) = 0$. Moreover, by a no arbitrage type of argument, a solution to the bankers' problem requires that the properly discounted returns on bank equity be equalized across the two types of bank subsidiaries.

In other words, the solution to the Bellman equation in (2.25) requires that

$$v_t^b = \mathbb{E}_t \Lambda_{t+1}^b \rho_{h,t+1}^b = \mathbb{E}_t \Lambda_{t+1}^b \rho_{f,t+1}^b, \tag{2.26}$$

where $\Lambda_{t+1}^b \equiv \Lambda_{t+1}(1 - \theta_b + \theta_b v_{t+1}^b)$ denotes the stochastic discount factor of bankers.

Banks Credit in each island is intermediated by bank subsidiaries, specialized in lending to either the real estate or the corporate sector. Banks are one period ventures owned and managed by bankers, which extend risky loans in the island where they are located. Loans are funded with a mix of equity funding, provided by bankers, and insured deposits, held by the dynasty. Bank leverage is limited by capital requirements.

The balance sheet of a bank extending loans to borrowers sector $s = f, h$ is given by

$$B_{s,t} = D_{s,t} + EQ_{s,t}^b, \tag{2.27}$$

where $D_{s,t}$ are deposits issued by banks in sector s and $EQ_{s,t}^b$ is equity allocated by bankers in subsidiaries specialized in sector s. Bank capital requirements impose a restriction on bank leverage, or equivalently, a minimum amount of equity funding of the form

$$\phi_{s,t} B_{s,t} \leq EQ_{s,t}^b, \tag{2.28}$$

where $\phi_{s,t}$ denotes the capital charges on loans of class s.

Banks' returns Banks invest in a portfolio of risky loans, diversified across borrowers in their island. Borrowers experience shocks that lead a fraction of them to default on their loans, at a point in which the bank repossesses borrowers' assets, facing proportional recovery costs in the process. Gross realized returns on one unit of loans extended in the real estate sector are given by

$$\tilde{R}^l_{h,t+1}(\omega^j_h) \equiv$$
$$R^l_{h,t}\left[1 - F_{h,+1}(\bar{\omega}_{h,t+1}(\omega^j_h))\right] + (1-\mu_h) q_{h,t+1}(1-\delta_h)\frac{H_t}{B_{h,t}}\int_0^{\bar{\omega}_{h,t+1}(\omega^j_h)} \omega_h dF_{h,t+1}(\omega_h), \tag{2.29}$$

where $\bar{\omega}_{h,t+1}(\omega^j_h)$ denotes the default threshold on mortgage loans in island j and is given by

$$\bar{\omega}_{h,t+1}(\omega^j_h) \equiv \frac{R^l_{h,t} B_{h,t}}{\omega^j_h q_{h,t+1}(1-\delta_h) H_t}, \tag{2.30}$$

and μ_h are the proportional repossession costs associated with mortgage loans.

Similarly, realized gross returns on each unit of corporate loans are defined as

$$\tilde{R}^l_{f,t+1}(\omega^j_f) \equiv R^l_{f,t}\left[1 - F_{f,+1}(\bar{\omega}_{f,t+1}(\omega^j_f))\right] +$$
$$(1-\mu_f)\omega^j_f \frac{q_{k,t+1}(1-\delta_k)K_{f,t} + Y_{t+1}}{B_{f,t}} \int_0^{\bar{\omega}_{f,t+1}(\omega^j_f)} \omega_f dF_{f,t+1}(\omega_f), \tag{2.31}$$

where $\bar{\omega}_{f,t+1}(\omega^j_f)$ is the default threshold for corporate loans in island j, defined as

$$\bar{\omega}_{f,t+1}(\omega^j_f) \equiv \frac{R^l_{f,t} B_{f,t}}{\omega^j_f \left[q_{k,t+1}(1-\delta_k)K_{f,t} + Y_{t+1}\right]}, \tag{2.32}$$

and μ_f is the fraction of firm assets lost in the repossession process of bankrupt firms.

Banks' payoffs The terminal net worth of a bank subsidiary in island j specialized in lending in sector s is given by

$$\Pi^b_{s,t+1}(\omega^j_s) \equiv B_{s,t}\tilde{R}^l_{s,t+1}(\omega^j_s) - R_{d,t}D_{s,t}. \tag{2.33}$$

Bank owners are protected by limited liability and therefore bank subsidiaries default on deposits when their loan portfolios report losses that exhaust the loss absorption capacity provided by bank equity. The total payoffs on a diversified (across islands) portfolio of bank equity in sector s is given by

$$\Pi^b_{s,t+1} \equiv \int_0^{\infty} \max\left[\Pi^b_{s,t+1}(\omega^j_s), 0\right] dF^j_{s,t+1}(\omega^j_s), \tag{2.34}$$

and the returns on one unit of bank equity are simply defined as $\rho^b_{s,t+1} \equiv \frac{\Pi^b_{s,t+1}}{EQ^b_{s,t}}$.

Banks' participation constraint Due to the scarcity of bankers' net worth, reflected in its shadow value v^b_t, the terms agreed between banks and borrowers in each sector must be such that bankers are compensated for the value of their net worth invested as bank equity. This restriction is expressed as

$$E_t \Lambda^b_{t+1} \Pi^b_{s,t+1} \geq EQ^b_{s,t} v^b_t, \tag{2.35}$$

which explains the so called bank participation constraints in (2.8) and (2.19).

Competitive pricing of loans I assume that each bank subsidiary is representative of a competitive banking sector. Hence, the pricing of loans in equilibrium is such that the participation constraints of banks, (2.8) and (2.19), are binding in equilibrium.[10]

2.4 Producers of capital and housing units

Capital and housing units are produced by competitive agents. Such producers transform the final consumption good into units of the corresponding stock using a technology that

[10] An alternative, isomorphic description of the banking sector in each island, consists of a continuum of identical bank subsidiaries of each class. In this description, bank subsidiaries undercut each other competing for loans. Hence, in equilibrium, loan terms are such that the participation constraints of banks bind in equilibrium.

captures the adjustment costs in each of the stocks. Producers of stock $X_t = K_t, H_t$ choose investment $I_{x,t}$ in order to solve

$$\max_{I_{x,t}} q_{x,t} X_t - I_{x,t}, \tag{2.36}$$

$$\text{s.t.} X_t = S\left(\frac{I_{x,t}}{X_{t-1}}\right) X_{t-1} + (1-\delta_x) X_{t-1}, \tag{2.37}$$

where $S\left(\frac{I_{x,t}}{X_{t-1}}\right)$ captures adjustment costs as in Jermann (1998).[11] Equation (2.37) describes the law of motion of the aggregate capital and housing stocks.

3 Model Solution and Calibration

This section presents the stochastic processes for the aggregate shocks in the economy and the calibration of bank capital requirements. It then discusses the calibration of the model parameters, the solution method used and how the model fits the data.

3.1 Shock processes

There are four aggregate shocks in the economy which drive aggregate productivity, the variance of borrower (firms and households) idiosyncratic shocks and the variance of island shocks. The productivity shock follows an AR(1) process of the type

$$\log(A_{t+1}) = \varrho_A \log(A_t) + \varsigma_A \varepsilon_{A,t+1}, \tag{3.1}$$

where $\varrho_A \in (0,1)$ determines the persistence of the productivity shock, ς_A controls the variance and $\varepsilon_{A,t+1}$ is a standard normal innovation.

[11] Adjustment costs take the functional form $S\left(\frac{I_{x,t}}{X_{t-1}}\right) \equiv a_{1,x}\left(\frac{I_{x,t}}{X_{t-1}}\right)^{1+\frac{1}{\psi}} + a_{2,x}$, where $a_{1,x}$ and $a_{2,x}$ are chosen in such a way that the stock of capital and housing are stationary. Parameter ψ captures the intensity of adjustment costs.

Next I describe the risk shocks, that is, the shocks to the variance of island and borrower specific shocks. The variance of borrower specific shocks is given by

$$\log\left(\frac{\sigma_{s,t+1}}{\bar{\sigma}_s}\right) = \varrho_s \log\left(\frac{\sigma_{s,t}}{\bar{\sigma}_s}\right) + \varsigma_s \varepsilon_{s,t+1}, \tag{3.2}$$

where $\bar{\sigma}_s$ is associated to the steady state level of the cross sectional dispersion of borrower specific shocks, ϱ_s controls the persistence and ς_s controls the variance of these shocks.

The process for the variance of island specific shocks is determined by

$$\log\left(\frac{\sigma^j_{s,t+1}}{\bar{\sigma}^j_s}\right) = \varrho^j_s \log\left(\frac{\sigma^j_{s,t}}{\bar{\sigma}^j_s}\right) + \varsigma^j_s \varepsilon^j_{t+1}, \tag{3.3}$$

where, importantly, it is assumed that the innovations to the dispersion of island returns are common across sectors. These innovations determine the importance of the driver of borrowers' default that is not diversifiable at bank level. Thus, a higher realization of ε^j_{t+1} can be interpreted as a rise in the importance of systematic risk, which will tend to make individual borrower defaults more positively correlated. However, to capture sector asymmetries in the importance of systematic drivers of credit risk, the parameters $\bar{\sigma}^j_s$, ϱ^j_s and ς^j_s are calibrated separately for each sector. In other words, financial distress across islands is common to both sectors, but the effect of aggregate shocks on each sector may be different.

In the tradition of Christiano et al. (2014), I call innovations to the dispersion of idiosyncratic borrower returns either firm or household risk shocks and innovations to the dispersion of the island-wide component of returns, as island risk shocks.

3.2 Capital Requirements

Regulatory capital requirements are set following the internal ratings based approach in the Basel framework. Capital charges in each sector are computed as

$$\phi_{s,t} = \eta\phi_{s,t-1} + (1-\eta)\phi^*_{s,t}, \tag{3.4}$$

where $\phi^*_{s,t}$ is a function of the PDs and loss given default of each class of loans. Parameter η allows for the possibility of partial adjustment of capital charges. In this way, the model captures the fact that, some banks compute the probabilities of default using a point in time approach while others use a so-called through the cycle approach.

Capital charges $\phi^*_{s,t}$ are computed according to

$$\phi^*_{s,t} = M_{s,t} IRB_{s,t}(PD_{s,t}), \tag{3.5}$$

where $M_{s,t}$ captures the effect of additional buffers on risk weighted assets (RWA) on effective capital charges and is set to one in the baseline calibration. The regulatory probabilities of default (PDs) are computed as the conditional expectation of the annualized default frequencies in each class of loans, that is,

$$PD_{s,t} = 4E_t\left[\int_0^\infty \int_0^{\bar{\omega}_{s,t+1}(\omega_s^j)} dF_{s,t+1}(\omega_s) dF^j_{s,t+1}(\omega^j_s)\right]. \tag{3.6}$$

The function $IRB_{s,t}(.)$ is defined in regulatory guidelines and it is detailed in Appendix A, alongside further details on the computation of the buffers.

3.3 Model Solution and Parameter Choice

The model is solved with a third order approximation around its deterministic steady state, using a pruned state space system as suggested in Andreasen et al. (2018). Since the realized return on loans is a non linear function of the island specific shocks ω_f^j and ω_h^j, bank returns are not log normally distributed. In order to be able to use perturbation techniques to solve the model, I follow the procedure in Mendicino et al. (2021) to approximate realized returns on loan portfolios.[12]

The model is then calibrated following a two step procedure. In the first step, a subset of parameters are fixed to values previously used in the literature. In the second step, I use the simulated method of moments in order to match targets on real and financial variables at a quarterly frequency for the Euro Area, between 2003 and 2013, which corresponds to a period without significant changes in bank capital regulation.

Pre-set parameters In the first step I set the discount factor of households, β, to 0.995, the Frisch elasticity of labor, φ to 1, the depreciation rate of physical capital, δ_k to 0.025, the capital share in firm output, α to 0.3. These are all standard values in the macroeconomic literature. The relative dis-utility of labor, λ_L is normalized to 1. The depreciation rate on housing units, δ_h is set to 0.01, following Iacoviello and Neri (2010). Bankruptcy costs associated to firm, household and bank defaults, μ_ϑ, $\vartheta = h, f, b$ are set to 0.3 (see e.g. Djankov et al. (2008) and Granja et al. (2017)). Finally, the probability that bankers and entrepreneurs remain active (θ_b, θ_f) is set to 0.975, following Mendicino et al. (2021).

[12] The procedure consists in splitting the integral in (2.34) in sub-segments and approximate the returns on loan portfolios using a second order Taylor approximation around the middle point of each interval. See Mendicino et al. (2021) for further details.

Table 1: Internally calibrated parameters

Parameter	Symbol	Value	Parameter	Symbol	Value
New bankers' endowment	χ_b	0.682	Std. Island risk (Firms)	ς_f^j	0.055
New entrepreneurs' endowment	χ_f	0.584	Std. Island risk (HH)	ς_h^j	0.035
Housing equity	χ_h	0.388	Std. Firm risk	ς_f	0.075
Mean Island risk shock (Firms)	$\bar{\sigma}_f^j$	0.263	Std. HH risk	ς_h	0.025
Mean Island risk shock (HH)	$\bar{\sigma}_h^j$	0.216	Std. productivity shocks	ς_A	0.003
Mean Firm risk shocks	$\bar{\sigma}_f$	0.304	Pers. Island risk (Firms)	ϱ_f^j	0.705
Mean HH risk shocks	$\bar{\sigma}_h$	0.047	Pers. Island risk (HH)	ϱ_h^j	0.705
Relative housing preference	λ_h	0.109	Pers. Firm risk	ϱ_f	0.906
HH backyard technology	α_{hh}	0.1	Pers. HH risk	ϱ_h	0.926
Investment adjustment costs	ψ	1.99	Pers. Productivity	ϱ_A	0.98
			CR partial adjustment coefficient	η	0.9

Estimated Parameters The rest of the parameters of the model are estimated using the simulated method of moments. Although all parameters are estimated simultaneously, most of them are closely associated to a data target. The endowment of entering entrepreneurs, χ_f, the housing preference parameter, λ_h, and the parameter controlling the share of housing equity in total wealth,χ_h are associated to the credit to GDP ratios of each class of loans and the share of housing in total household wealth. Mean borrower idiosyncratic and island-sector specific risk shocks $\bar{\sigma}_i$ and $\bar{\sigma}_i^j$, with $i = f, h$ help target average spreads and write off rates for each class of loans. Bankers endowment χ_b helps match banks' average return on equity.

Similarly, the standard deviations of risk shocks and their persistence help match the standard deviations of credit to GDP ratios, spreads and write-offs in each sector, as well as the standard deviation of housing prices. Persistence and standard deviation of productivity help match productivity growth and the standard deviation of firms return on equity, while capital and housing adjustment costs ψ help match the volatility of the investment to GDP ratio. Finally, the smoothing parameter in capital requirements η affects the standard deviation of the return on equity of banks.

In order to match data targets, as presented in Table 2, the model assigns an overall lower level of risk to the real estate sector. However, the relative importance non diversifiable

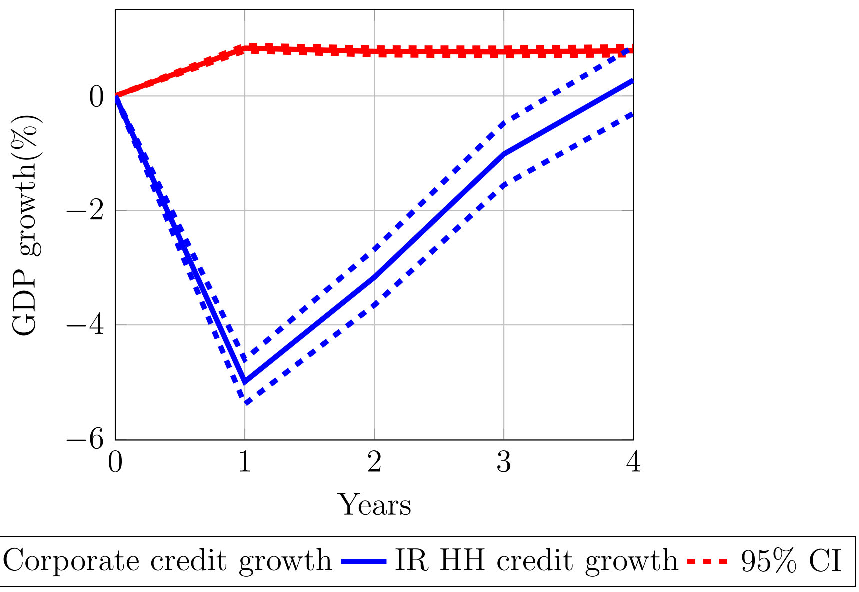
Table 2: Targeted Moments

Moment	Data	Model	Moment	Data	Model
Mean NFC Loans/GDP	1.785	2.046	Std. NFC Loans/GDP	0.128	0.237
Mean HH Loans/GDP	2.014	2.638	Std. HH Loans/GDP	0.053	0.059
Mean Spread NFC Loans	2.279	1.494	Std. Spread NFC Loans	0.493	0.907
Mean Spread HH Loans	1.331	0.5457	Std. Spread HH Loans	0.376	0.344
Mean write-off rate NFC Loans	0.543	0.584	Std. write-off NFC Loans	0.334	0.455
Mean write-off rate HH Loans	0.126	0.277	Std. write-off HH Loans	0.057	0.162
Mean Housing Wealth/ Total Non Financial wealth	0.947	0.633	Std. GDP	0.023	0.022
Mean ROE NFCs	4.706	4.223	Std. ROE NFCs	8.148	3.238
Mean ROE Banks	4.619	11.21	Std. ROE Banks	12.201	11.017
Mean Capital held by Households	0.185	0.153	Std. Investment/GDP	0.008	0.004
			Std. Housing prices	0.054	0.033

Notes: This table displays the targeted moments in the calibration and their model counterparts. Spreads, write-off rates and returns on equity are reported in annualized percentage points. The standard deviation of GDP corresponds to the standard deviation of the log of GDP, in quarterly terms. All variables are linearly detrended before computing standard deviations.

shocks is estimated to be greater for real estate loans. This result will be a crucial driver of the reallocation of loans during periods of increased volatility. Although untargeted by the calibration, the model predicts that expansions in real estate credit are predictive of lower future GDP growth, as shown in Figure 1. In contrast, the model predicts that expansions in corporate credit are associated to credit expansions.

Figure 1: Responses of GDP growth to innovations in Credit to GDP ratios



Notes: Impulse responses of GDP growth over a horizon k years ahead, to innovations in credit to GDP ratios (in levels, not percent) in each sector, computed using local projections estimates of $\Delta_k GDP_{t+k} = \Sigma_{j=0}^{J}\beta_{k,j}^{h}\Delta b_{h,t-j} + \Sigma_{j=0}^{J}\beta_{k,j}^{f}\Delta b_{f,t-j} + \Sigma_{j=0}^{J}\gamma_{k,j}\Delta GDP_{t-j} + \nu_{t+k}$.

These findings are consistent with the evidence in Müller and Verner (2021), who document in a long historical database that credit expansions in real estate are predictive of both lower future GDP growth and a higher probability of financial distress episodes. Although the model predicts that the effects of credit expansions in real estate materialize relatively early compared to their work, the connection between real estate expansions and future GDP growth is still captured by this framework.

4 Reallocation and Banking Crises

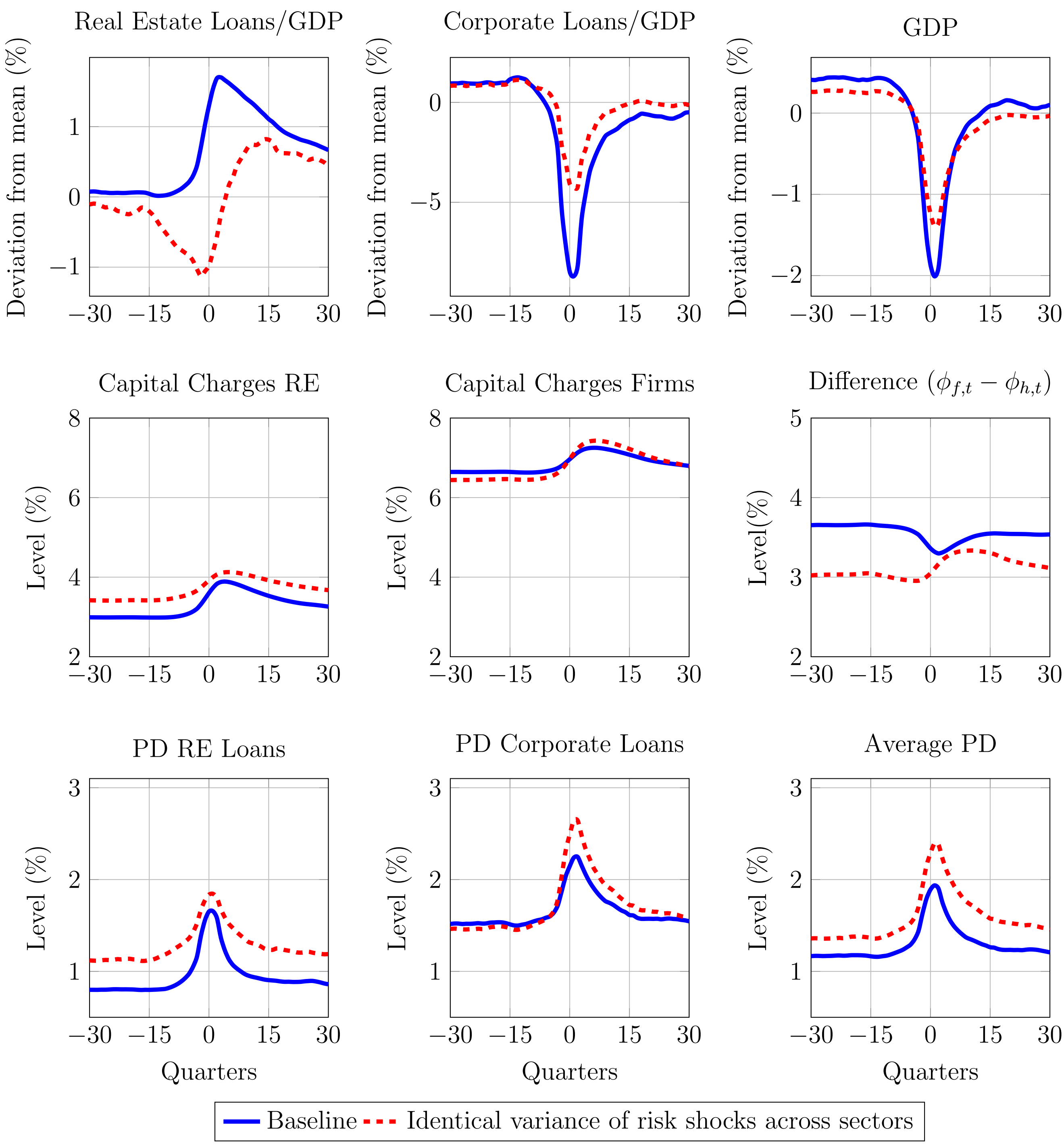
This section explains the main mechanisms that contribute to the buildup of risk during the path that leads to a banking crisis in the baseline model. Banking crises are defined, following Laeven and Valencia (2013), as events in which the gross outlays faced by the deposit insurance agency to repay deposits of failed banks are on average above 3% of GDP for a year. In order to do so, I perform two illustrative exercises. First, I compare the baseline model to an economy in which both real estate and corporate loans have the same exposure to non diversifiable risk. Then, I compare the baseline model with a setting where capital charges on loans extended in both sectors are identical and do not depend on the PDs of individual loans.

4.1 Contribution to crises of the greater non-diversifiable risk of real estate loans

I begin by comparing the baseline economy to a counterfactual one in which the risk parameters have been chosen to remove any asymmetries between sectors, in terms of their exposure to non-diversifiable risk.[13] Figure 2 displays the path of variables for shocks that lead to a banking crises episode in the baseline model.

[13] Parameters are chosen to keep the average exposure of the economy to non-diversifiable risk constant, compared to the baseline case.

Figure 2: Role of non-diversifiable risk



Notes: Solid lines correspond to the baseline model. Dashed lines correspond to a version of the model where real estate and corporate lending have identical parameters for the variance and persistence of risk shocks (borrower idiosyncratic and island specific). Sample paths correspond to shock realizations that generate banking crises in the baseline model.

In this counterfactual experiment the relationship between real estate lending and banking crises breaks down. Intuitively, since the exposures of both sectors to non-diversifiable risk is the same, banks no longer have strong incentives to pursue one type of portfolio in which they can benefit from the increase in the volatility of loan portfolios.

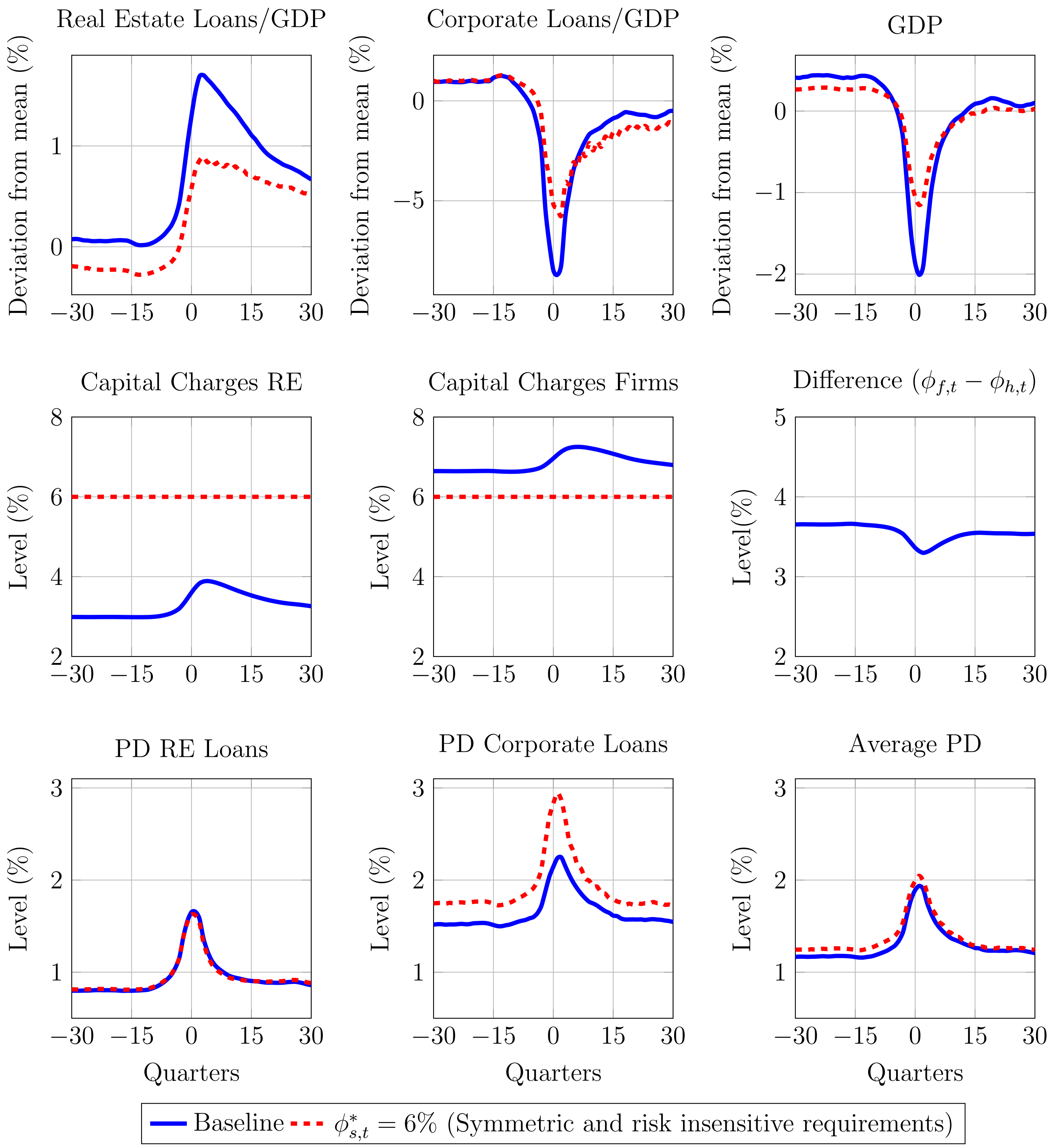
Moreover, the same shocks that lead to a banking crises in the baseline model, are associated to far more moderate downturns in the economy in which there are no incentives for reallocation towards the real estate sector. The rationale behind this result is that the impact of bank level distortions is smaller in the absence of underlying asymmetries in the risk profile of different economic sectors. In other words, when island risk materializes, bank assets are spread across sectors in such a way that the financial system suffers losses which are proportional to the overall level of non-diversifiable risk in the economy.

In contrast, in the baseline model bank level distortions disproportionately increase the exposure of the financial system to non diversifiable risk. This happens as banks' limited liability and deposit insurance guarantees makes them prefer exposures more sensitive to island risk. Intuitively, limited liability and deposit insurance guarantees imply that banks can profit from low default rates in the good states of the world but disregard the downside risk of states in which the realization of borrower default is abnormally high.

4.2 Role of capital requirements

Next, I explore a counterfactual economy in which capital regulation is flat across sectors, while keeping the average capital charges constant. Figure 3 shows the potentially distortionary effect of risk based capital regulation in the path to a banking crisis.

Figure 3: Role of Capital Requirements



Notes: Solid lines correspond to the baseline model. Dashed lines correspond to a version of the model where capital charges are set to 6% and are equal across sectors. Sample paths correspond to shock realizations that generate banking crises in the baseline model.

In this case, there are still incentives for banks to reallocate their portfolios towards real estate lending, but such incentives are tempered by the fact that they cannot disproportionately expand their balance sheets towards the sector with lower capital requirements (real estate). As a result, the recession that follows after the same sequence of shocks that induce a banking crises in the baseline model is also smaller.

This experiment highlights an important macroprudential dimension of capital requirements. Insofar as banks have incentives to invest in activities with high non-diversifiable risk, the design of capital requirements can amplify this distortion as banks expand their leverage by reallocating their portfolios towards exposures with lower risk weights.

The comparison between average PDs in the two economies further highlights the effects of microprudential regulation. Average PDs are actually lower in the baseline economy, compared to the model with flat capital requirements. That is, from a microprudential perspective, bank portfolios would actually look safer in the baseline case. However, from a macroprudential perspective, it is the exposure to non-diversifiable risk that matters.

This intuition also applies to the results on countercyclical buffers that are presented in the next section.

5 Assessment of Macroprudential Buffers

This section presents a series of counterfactual experiments to produce a policy evaluation of the buffers introduced in Basel III and their effect on the probability and severity of banking crises. The first buffer introduced is the capital conservation buffer of Basel III (CCB), which I interpret as an increase of 2.5 percentage points in the level of capital requirements on risk weighted assets. This buffer is constant across time and it is applied uniformly across sectors.

The second buffer introduced is the countercyclical capital buffer (CCyB) of Basel III. Following the guidelines in Basel III, I calibrate this buffer to be active in periods when the total credit to GDP ratio increases above its long term mean.[14] This buffer adds up to an additional 2.5 percentage points of risk weighted assets to the regulatory minimums.

Finally, I introduce a sectoral macroprudential buffer, which follows a rule identical to the one in the Basel CCyB, but adapted to respond to deviations in the credit to GDP ratio of each sector, and being applicable only to exposures such sector.

5.1 Assessment of Basel III levels of Capital Requirements

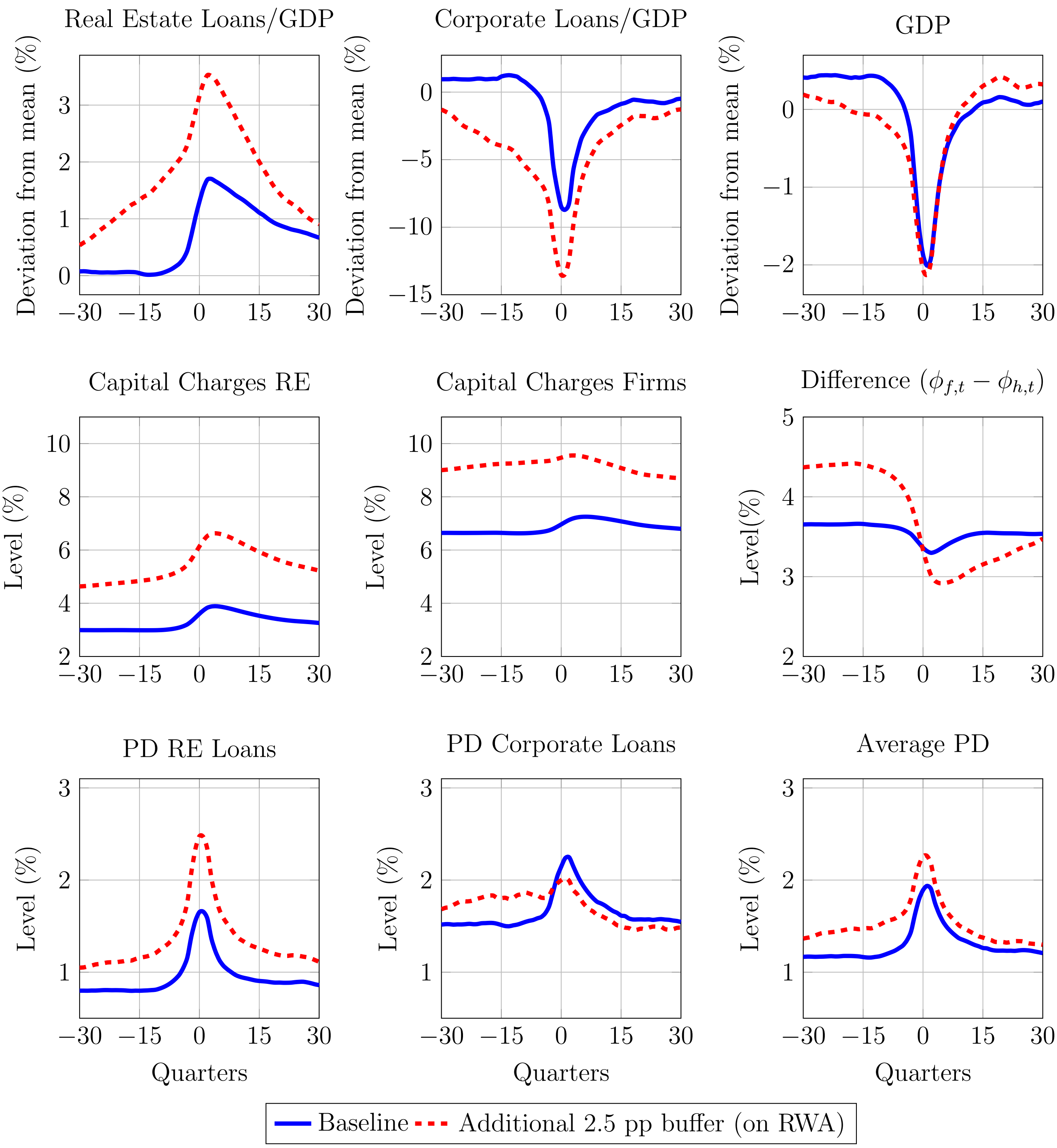
I begin by assessing the effectiveness of increasing the levels of capital as a fraction of risk weighted assets uniformly by 2.5 percentage points.[15]. Increasing the average level of capital in the financial system has dramatic effects in terms of reducing the probability of a banking crises, as described in Table 3. Intuitively, the larger loss absorption capacity of banks allows them to fail less often, in a way the classical microprudential view would suggest. Moreover, when they do fail, the cost to the deposit insurance agency is smaller, as bank leverage is lower in this case.

Perhaps more interestingly, if a banking crisis materializes in this regime, output losses are significantly larger than under the baseline calibration of capital requirements. By looking at the path to crises in Figure 4, the role of the reallocation towards real estate loans remains crucial. There are two forces behind the greater (conditional) severity of crises under the levels of capital requirements in Basel III.

[14] I use a smooth function to approximate the non linear design of the Basel III buffer in order to be able to solve the model using a third order approximation.

[15] That is, to 10.5% of risk weighted assets

Figure 4: Assessment of Uniform Increase in Capital Requirements



Notes: Solid lines correspond to the baseline model. Dashed lines correspond to capital requirements equal to 10.5% of risk weighted assets (introducing a 2.5% buffer as in the Capital Conservation Buffer of Basel III). Sample paths correspond to shock realizations that generate banking crises in each model

First, the rise in non-diversifiable risk, which in itself drives banks to reallocate loans towards real estate portfolios (due to distortions discussed in previous sections) is amplified in this case by an increase in *diversifiable* firm risk. As banks appropriately price the diversifiable risk in their corporate portfolios, they have stronger incentives to reallocate loans towards the real estate sector.

Second, uniformly increasing the levels of capital requirements by introducing the capital conservation buffer of Basel III induces greater differences in the level of capital charges of each class of loans. The consequence is that the distortions stemming from risk based capital regulation are amplified, leading to sharper incentives to reallocate loans towards the real estate sector when non-diversifiable risk increases.

These distortions can be partially addressed by the introduction of countercyclical buffers that are introduced next.

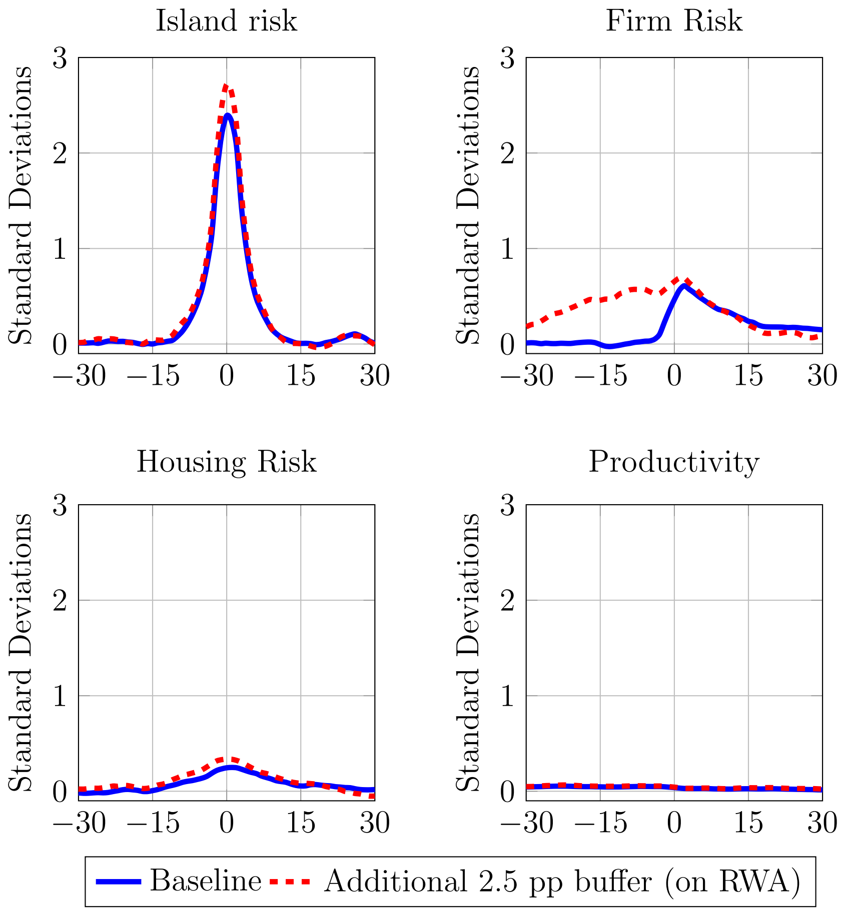
5.2 Assessment of Countercyclical Buffers

Finally, this paper explores the effectiveness of introducing a generic countercyclical buffer and sector specific countercyclical buffers.[16]

The generic CCyB is activated in periods where total credit is increasing above its mean and relaxed during downturns, as proposed by the Basel guidelines. Results show that a generic design of the CCyB provides only moderate smoothing of fluctuations around banking crises, as depicted in Figure 6. While a release of the buffer during downturns partially alleviates the problem of reallocation towards real estate, as corporate exposures benefit more from such a release (in equilibrium capital charges fall in spite of rising corporate PDs), this does not lead to significant stabilization gains. Table 3 shows that output losses during banking crises with a CCyB are similar to those achieved under the Basel III regime without countercyclical buffers.

[16]See the Appendix for details on the functional form adopted for the CCyB

Figure 5: Shocks leading to a crisis in baseline vs higher levels of capital requirements



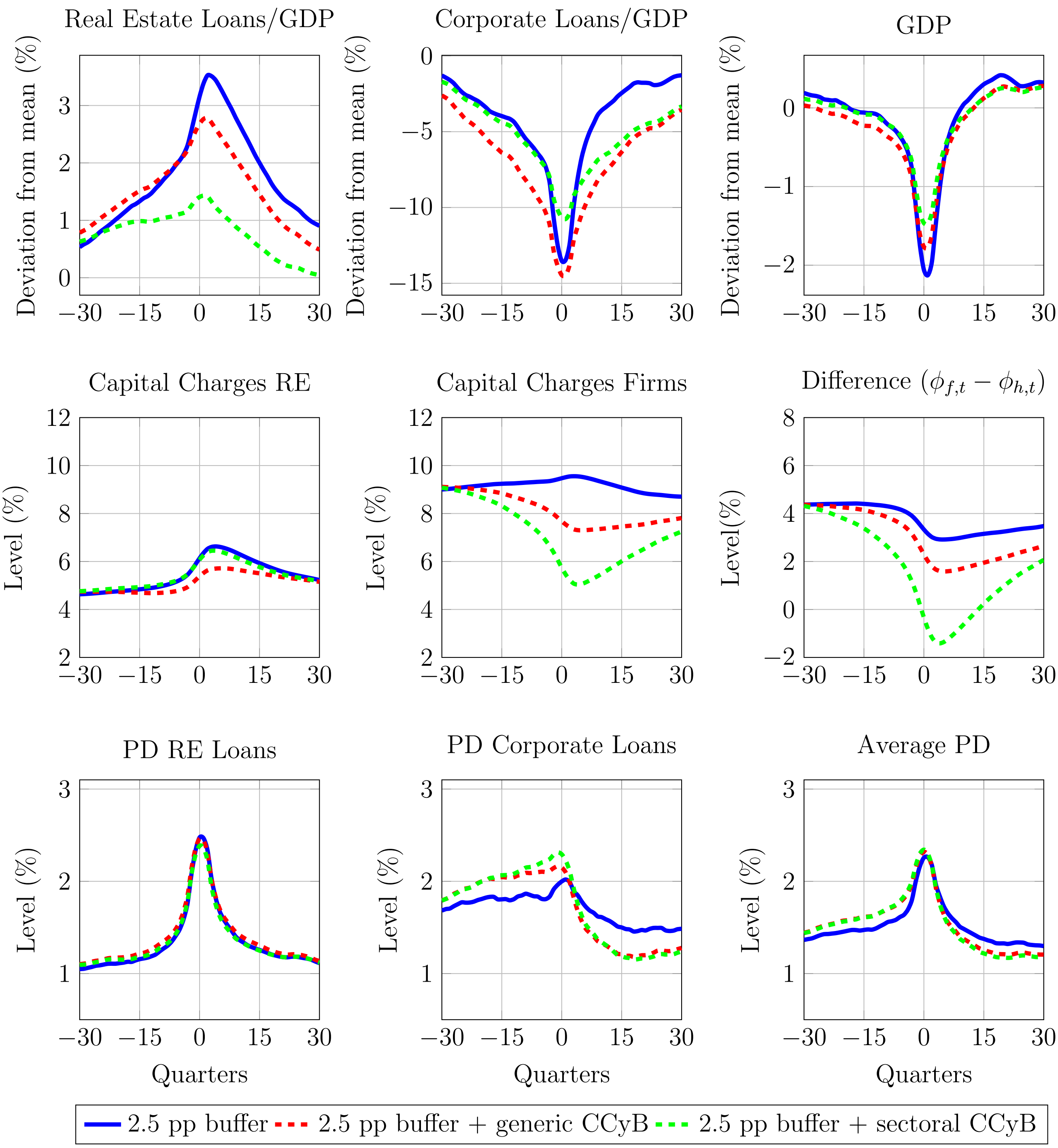
Notes: Solid lines correspond to the baseline model. Dashed lines correspond to capital requirements equal to 10.5% of risk weighted assets (introducing a 2.5% buffer as in the Capital Conservation Buffer of Basel III). Sample paths correspond to shock realizations that generate banking crises in each model.

Table 3: Comparison across Regulatory Designs

Outcome Variable	**Baseline**	**Basel III (extra 2.5 pp buffer)**	**Generic CCyB**	**Sectoral CCyB**
Frequency of Banking Crises	3.024	1.352	1.4229	1.35
Output Losses in Crises	-13	-14.3	-14.08	-11.28
Capital Charge (Firms)	6.68	8.81	8.99	9.08
Capital Charge (Households)	3.02	4.57	4.68	4.64
Default Rate Banks	1.04	0.96	0.96	0.96
Default Rate Firms	1.54	1.55	1.55	1.54
Default Rate Households	0.81	1	1.02	1.02
Welfare	–	0.055	0.01	0.085

Notes: Output losses are reported in cumulative percentage points of GDP in the three years following a banking crisis. Welfare is reported as the percentage change in permanent consumption that would leave consumers as well off in the Baseline scenario as in each of the different regimes. Default rates are reported in annualized percentage points. Each column corresponds to simulations of the model for 500,000 periods, under each different regulatory regime.

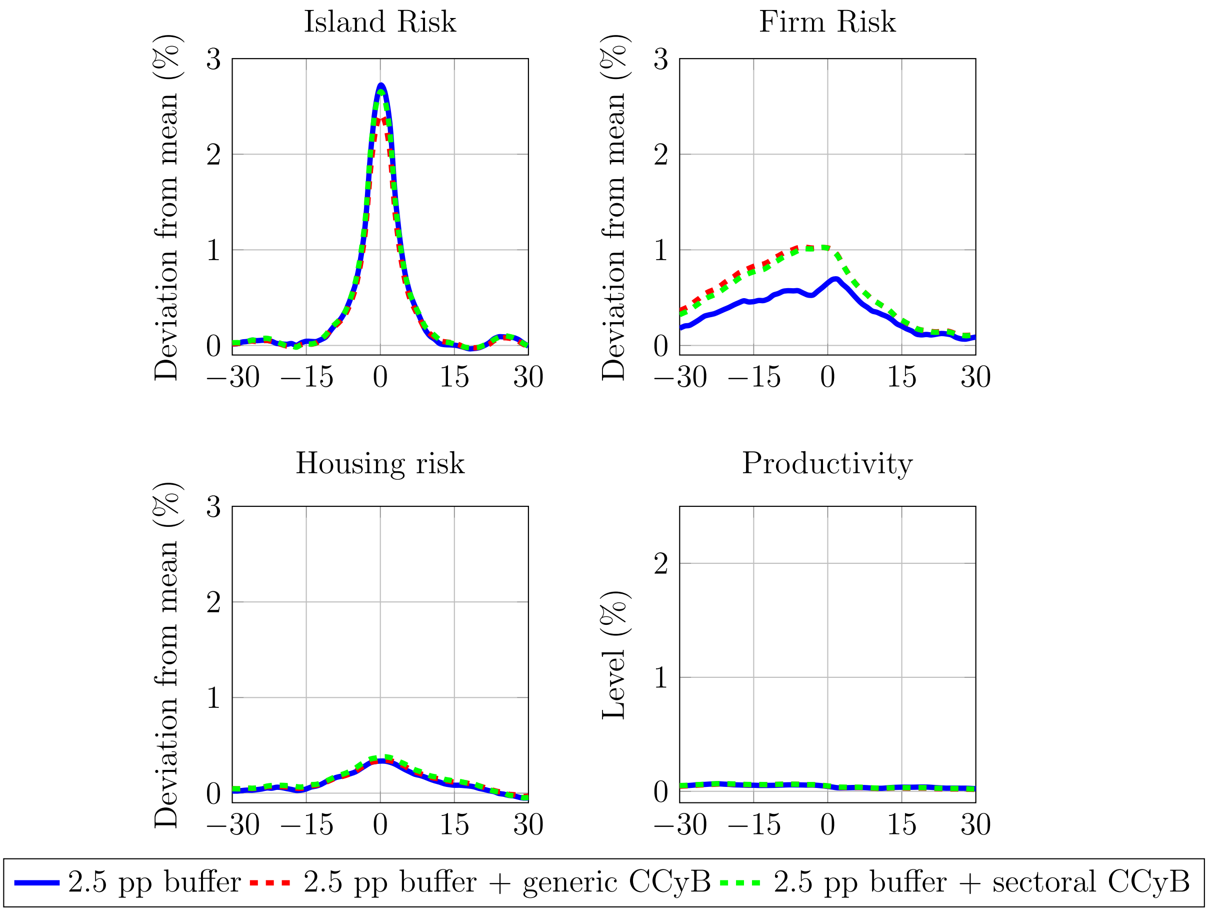
Figure 6: Evaluation of Basel III buffers



Notes: Solid lines correspond to Basel III levels of capital requirements. Red dashed lines correspond to a generic CCyB. Green dashed lines correspond to a sectoral CCyB. Sample paths correspond to shock realizations that generate banking crises in each model.

The sector specific countercyclical capital buffers, on the other hand, provides far larger stabilization gains, reducing output losses close to 3 percentage points (roughly 25 %) in

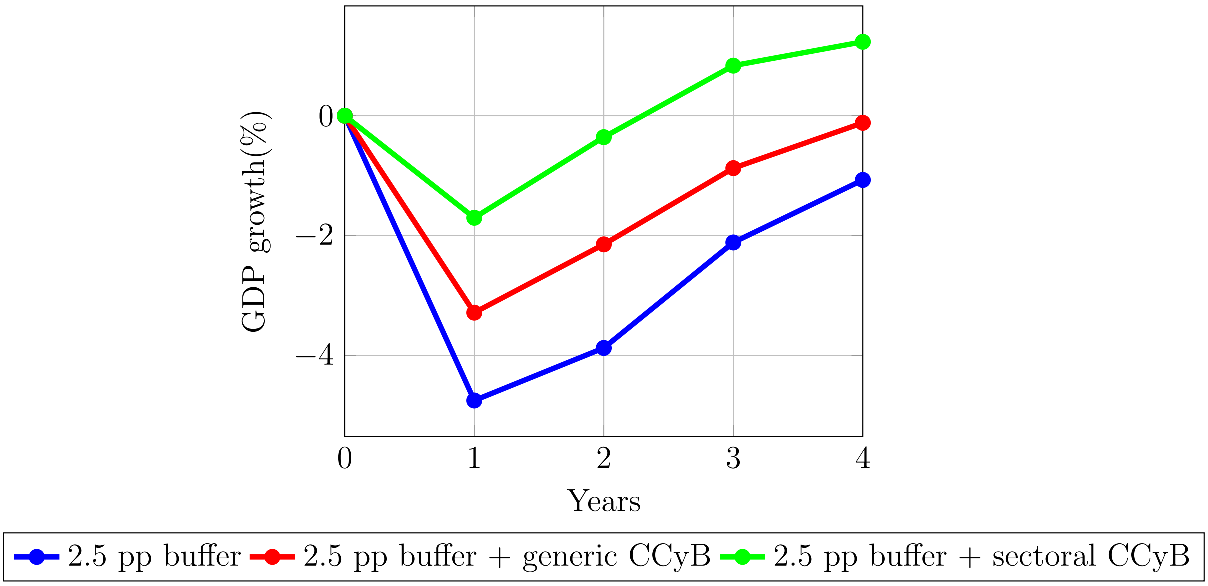
Figure 7: Shocks Leading to Crises with Basel III Buffers



Notes: Solid lines correspond to Basel III levels of capital requirements. Red dashed lines correspond to a generic CCyB. Green dashed lines correspond to a sectoral CCyB. Sample paths correspond to shock realizations that generate banking crises in each model.

the event of a banking crisis. In order to achieve these stabilization gains, an aggressive release of the macroprudential buffer for firms seems to be of first order importance in order to correct banks' incentives to reallocate loans towards the real estate sector. As a result, credit to firms is preserved, and credit to households increases far more moderately. When non-diversifiable risk materializes the effects on the real economy are partially smoothed as banks are less exposed to the real estate sector, where defaults are more correlated. The model implies that implementing the sectoral CCyB has attached welfare gains close to a 0.085% increase in permanent consumption compared to the baseline economy. While modest, these are close to one order of magnitude larger than the ones achieved with a generic CCyB and around 50% greater than the ones achieved

Figure 8: Responses of GDP growth to innovations in Credit to GDP ratios



Note: Impulse responses of GDP growth over a horizon of k years ahead, to innovations in the ratio of real estate credit to GDP in different regulatory regimes regimes, computed using local projections estimates of $\Delta_k GDP_{t+k} = \Sigma_{j=0}^{J} \beta_{k,j}^{h} \Delta b_{h,t-j} + \Sigma_{j=0}^{J} \beta_{k,j}^{f} \Delta b_{f,t-j} + \Sigma_{j=0}^{J} \gamma_{k,j} \Delta GDP_{t-j} + \nu_{t+k}$.

by a time-invarying buffer.

Finally, the introduction of a sectoral CCyB is able to significantly break the association between expansions in real estate credit and subsequent lower GDP growth as depicted in Figure 8. This follows from the fact that expansions in real estate credit to GDP are better accompanied by increases in capital requirements that build buffers against future losses. Therefore, the impact on GDP growth of increases in non-diversifiable risk in the economy is also smoothed. In contrast, the generic CCyB achieves only a moderate correction.

6 Concluding Remarks

This paper highlights the macroprudential dimension of capital regulation in the presence of bank level distortions that affect the sectoral allocation of credit. The calibrated model, which assigns a greater relative importance to non-diversifiable risk as a driver of credit risk in real estate loans, shows that during periods of increased volatility banks reallocate credit towards real estate borrowers at the expense of lending to firms. As a result, the economy becomes more exposed to correlated defaults in the real estate sector. This paper also shows that the microprudential design of bank capital regulation can amplify this effect, as it focuses on the risk profile of individual exposures, which appear typically "safer" (that is with lower PDs and LGDs) in the real estate sectors.

The tension between the micro and macroprudential dimensions in bank capital regulation is emphasized by the finding that sectoral specific macroprudential buffers are quite successful in terms of preventing sharp output losses during banking crises episodes. These type of buffers effectively provide resilience to the financial system by preventing excessive credit reallocation towards the real estate sector, in which the risk of a large number of correlated defaults is neglected by banks protected by limited liability and benefiting from insured deposit funding.

Finally, this paper finds that in order to correct the cross sectoral distortions that arise when banks have incentives to expand their real estate lending, releasing buffers on the corporate sector when PDs start to rise due to diversifiable risk and lending standards become tighter in that sector, is as important as tightening the requirements on housing when non-diversifiable risk rise and lending standards become looser in this sector. Therefore, this paper also suggests that existing regulation not only could be too loose for real estate in the path to crises, but also too tight on firm credit during episodes of increased non-diversifiable risk.

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A Mathematical details

A.1 Definitions in the Dynasty's problem

This appendix presents the definitions used in the problem of the household, not explained in the main body of the paper.

Net transfers from entrepreneurs and bankers Net transfers entrepreneurs and bankers to the dynasty, denoted by Θ_t in the main body of the paper is defined as

$$\Theta_t \equiv (1-\theta_e)(1-\chi_e)\Pi_t^e + (1-\theta_b)(1-\chi_b)\Pi_t^b, \tag{A.1}$$

where Π_t^e and Π_t^b have been defined in the main body of the paper.

Profits from producers of physical capital and housing units Profits from producers of stock $X = K, H$ are given by

$$\Upsilon_{x,t} \equiv q_{x,t}X_t - I_{x,t}, \tag{A.2}$$

with

$$S\left(\frac{I_{x,t}}{X_{t-1}}\right) \equiv a_{1,x}\left(\frac{I_{x,t}}{X_{t-1}}\right)^{1+\frac{1}{\psi}} + a_{2,x}, \tag{A.3}$$

where $a_{1,x}$ and $a_{2,x}$ are chosen in such a way that the stock of capital and housing are stationary. Parameter ψ captures adjustments costs as in Jermann (1998).

A.2 First order conditions

This section outlines the first order conditions in the problem of the dynasty and firms, as well as the market clearing conditions in the economy.

First order conditions in the dynasty's problem The first order conditions in the problem of the dynasty are characterized by

$$(C_t): \quad \zeta_t - \frac{1}{C_t} = 0, \tag{A.4}$$

$$(D_t): \quad -\zeta_t + \mathbb{E}_t \beta \zeta_{t+1} R_{d,t} = 0, \tag{A.5}$$

$$(l_t): \quad -\lambda_L l_t^{\varphi} + \zeta_t w_t = 0, \tag{A.6}$$

$$(H_t): \quad \lambda_H \frac{1}{H_t} + \xi_{h,t} q_{h,t} + \mathbb{E}_t \zeta_{t+1} \frac{\partial \Pi_{t+1}^h}{\partial H_t} + \kappa_{h,t} \mathbb{E}_t \Lambda_{t+1}^b \frac{\partial \Pi_{h,t+1}^b}{\partial H_t} = 0, \tag{A.7}$$

$$(B_t): \quad -\xi_{h,t} + \mathbb{E}_t \zeta_{t+1} \frac{\partial \Pi_{t+1}^h}{\partial B_{h,t}} + \kappa_{h,t} \mathbb{E}_t \Lambda_{t+1}^b \frac{\partial \Pi_{h,t+1}^b}{\partial B_{h,t}} = 0, \tag{A.8}$$

$$(R_{h,t}^l): \quad \mathbb{E}_t \zeta_{t+1} \frac{\partial \Pi_{t+1}^h}{\partial R_{h,t}^l} + \kappa_{h,t} \mathbb{E}_t \Lambda_{t+1}^b \frac{\partial \Pi_{h,t+1}^b}{\partial R_{h,t}^l} = 0, \tag{A.9}$$

where ζ_t, $\xi_{h,t}$ and $\kappa_{h,t}$ are the Lagrange multipliers associated with the resource constraint of the dynasty, the constraint associated with the purchase of housing units and the participation constraint of mortgage specialized banks, respectively. The characterization of the first order conditions of the dynasty's problem is completed with the resource constraints (2.2), (2.4) and the participation constraint of mortgage specialized banks (2.8) in the main body of the paper, all holding with equality.

First order conditions of the firms' problem The first order conditions of the firms' problem are characterized by

$$(K_{f,t}): \quad \mathbb{E}_t \Lambda_{t+1}^f \frac{\partial \Pi_{t+1}^f}{\partial K_{f,t}} + \xi_{f,t} q_{k,t} + \kappa_{f,t} \mathbb{E}_t \Lambda_{t+1}^b \frac{\partial \Pi_{f,t+1}^b}{\partial K_{f,t}} = 0, \tag{A.10}$$

$$(L_t): \quad \mathbb{E}_t \Lambda_{t+1}^f \frac{\partial \Pi_{t+1}^f}{\partial L_t} + \xi_{f,t} w_t + \kappa_{f,t} \mathbb{E}_t \Lambda_{t+1}^b \frac{\partial \Pi_{f,t+1}^b}{\partial L_t} = 0, \tag{A.11}$$

$$(B_{f,t}): \quad \mathbb{E}_t \Lambda_{t+1}^f \frac{\partial \Pi_{t+1}^f}{\partial B_{f,t}} - \xi_{f,t} + \kappa_{f,t} \mathbb{E}_t \Lambda_{t+1}^b \frac{\partial \Pi_{f,t+1}^b}{\partial B_{f,t}} = 0, \tag{A.12}$$

$$(R_{f,t}^l): \quad \mathbb{E}_t \Lambda_{t+1}^f \frac{\partial \Pi_{t+1}^f}{\partial R_{f,t}^l} + \kappa_{f,t} \mathbb{E}_t \Lambda_{t+1}^b \frac{\partial \Pi_{f,t+1}^b}{\partial R_{f,t}^l} = 0, \tag{A.13}$$

$$\tag{A.14}$$

where $\xi_{f,t}$ and $\kappa_{f,t}$ are the Lagrange multipliers associated with the firms' financing constraint and the participation constraint of the corporate specialized bank subsidiaries, respectively. The characterization of the first order conditions of the firms' problem is completed with the financing constraint (2.16) and the participation constraint of corporate specialized bank subsidiaries (2.19).

A.3 Market clearing conditions

Physical capital The clearing in the market of physical capital requires

$$K_{f,t} + K_{hh,t} = K_t, \tag{A.15}$$

Equity markets The clearing of bank equity markets requires

$$EQ^b_{h,t} = \int EQ^b_{h,t}(i)di \tag{A.16}$$

$$EQ^b_{f,t} = \int EQ^b_{f,t}(i)di, \tag{A.17}$$

while clearing of firm equity markets requires

$$EQ^f_t = \int EQ^f_t(i)di. \tag{A.18}$$

Labor market Clearing of the labor market requires

$$L_t = l_t. \tag{A.19}$$

Final consumption good

$$Y_t = C_t + I_{k,t} + I_{h,t} + \Sigma_{f,t} + \Sigma_{h,t} + \Sigma_{b,t}, \tag{A.20}$$

where

$$\Sigma_{f,t} = \mu_f \int_0^\infty \int_0^{\bar{\omega}_{f,t}(\omega_f^j)} \omega_f \omega_f^j \left[Y_t + q_{k,t}(1-\delta_k)K_{f,t-1}\right] dF_{f,t}(\omega_f) dF_{f,t}^j(\omega_f^j), \tag{A.21}$$

$$\Sigma_{h,t} = \mu_h \int_0^\infty \int_0^{\bar{\omega}_{h,t}(\omega_h^j)} \omega_f \omega_h^j \left[q_{h,t}(1-\delta_h)H_{t-1}\right] dF_{h,t}(\omega_h) dF_{h,t}^j(\omega_h^j), \tag{A.22}$$

$$\Sigma_{b,t} = \Sigma_{f,t}^b + \Sigma_{h,t}^b \tag{A.23}$$

are bankruptcy costs associated to the default of firms, households and banks, respectively, with

$$\Sigma_{s,t}^b = \mu_b \int_0^{\bar{\omega}_{s,t}^j} B_{s,t-1} \tilde{R}_{s,t}^l(\omega_s^j) dF_{s,t}^j(\omega_s^j). \tag{A.24}$$

Bank deposits Clearing of the bank deposits market requires

$$D_t = D_{f,t} + D_{h,t}. \tag{A.25}$$

Bankers' net worth

$$N_t^b = \phi_{f,t} B_{f,t} + \phi_{h,t} B_{h,t}, \tag{A.26}$$

and

$$EQ_{f,t}^b = \phi_{f,t} B_{f,t}, \tag{A.27}$$

$$EQ_{h,t}^b = \phi_{h,t} B_{h,t}. \tag{A.28}$$

Entrepreneurs' net worth

$$N_t^f = EQ_t^f. \tag{A.29}$$

A.4 Law of motion of aggregate net worth of entrepreneurs and bankers

Law of motion of aggregate bankers' net worth The law of motion of the aggregate net worth of bankers is given by

$$N_{t+1}^{b} = \theta_b \left(\rho_{h,t+1}^{b} EQ_{h,t}^{b} + \rho_{f,t+1}^{b} EQ_{f,t}^{b} \right) + \iota_t^{b} - T_{t+1}, \tag{A.30}$$

where

$$\iota_{t+1}^{b} = (1-\theta_b)\chi_b \left(\rho_{h,t+1}^{b} EQ_{h,t}^{b} + \rho_{f,t+1}^{b} EQ_{f,t}^{b} \right), \tag{A.31}$$

is the wealth with which the dynasty endows entering bankers and T_t are taxes levied by prudential authorities in order to pay for the costs to the deposit insurance scheme generated by bank defaults, given by

$$T_{t+1} = T_{f,t+1} + T_{h,t+1}, \tag{A.32}$$

with

$$T_{s,t+1} = D_{s,t} R_{d,t} F_{s,t+1}^{j}(\bar{\omega}_{s,t+1}^{j}) - (1-\mu_b) \int_0^{\bar{\omega}_{s,t+1}^{j}} \tilde{R}_{s,t+1}^{l}(\omega_s^{j}) B_{s,t} dF_{s,t+1}^{j}(\omega_s^{j}). \tag{A.33}$$

Law of motion of aggregate entrepreneurial net worth

$$N_{t+1}^{f} = \theta_f \rho_{t+1}^{f} EQ_t^{f} + \iota_t^{f}, \tag{A.34}$$

where

$$\iota_{t+1}^{f} = (1-\theta_f)\chi_f \rho_{h,t+1}^{f} EQ_{h,t}^{f}, \tag{A.35}$$

A.5 Capital requirements

Capital requirements are set following the internal ratings based approach in the Basel framework. Capital charges in each sector are computed as

$$\phi_{s,t} = \eta\phi_{s,t-1} + (1-\eta)\phi^*_{s,t}, \tag{A.36}$$

where

$$\phi^*_{s,t} = M_{s,t}\mathrm{LGD}_s\left[\Phi\left(\frac{\Phi^{-1}(\mathrm{PD}_{s,t}) + \sqrt{\nu_{s,t}}\Phi^{-1}(0.999)}{\sqrt{1-\nu_{s,t}}}\right)\right]. \tag{A.37}$$

Parameter η captures partial adjustment dynamics in capital charges.[17] Parameters $\nu_{f,t}$ and $\nu_{h,t}$ measure the correlation of defaults in loan portfolios and are set according to

$$\nu_{f,t} = 0.12\frac{1-\exp(-50PD_{s,t})}{1-\exp(-50)} + 0.24\left[1 - \frac{1-\exp(-50PD_{s,t})}{1-\exp(-50)}\right], \tag{A.38}$$

and $\nu_{h,t} = 0.15$. Probabilities of default are computed as the conditional expectation as of period t, of the (annualized) default frequency of loans in each category, that is

$$PD_{s,t} = 4E_t\left[\int_0^\infty \int_0^{\bar{\omega}_{s,t+1}(\omega_s^j)} dF_{s,t+1}(\omega_s)dF^j_{s,t+1}(\omega^j_s)\right]. \tag{A.39}$$

The loss given default of each class of loans are set at 0.45 for corporate loans and 0.35 for real estate exposures, following the foundation IRB approach.

The term $M_{s,t}$ denotes additional capital buffers introduced by regulation. In particular, $M_{s,t} = 1$ in the baseline calibration of the model. The capital conservation buffer of 2.5 percent of risk weighted assets is introduced as $M_{s,t} = \frac{0.08+0.025}{0.08}$.[18] The generic counter

[17] These may be due, for example, to the fact that some banks choose a point in time, while others use a through the cycle approach to computing PDs.

[18] This follows from the way in which risk weighted assets (RWA) are computed in the current guidelines.

cyclical capital buffer is introduced as

$$M_{s,t} = \frac{0.105 + ccyb_t}{0.08}, \tag{A.40}$$

with

$$ccyb_t = 0.025 \frac{\exp\left[b_0\left(\log((B_{f,t} + B_{h,t})/GDP_t) - \log(\overline{(B_f + B_h)/GDP})\right) - b_1\right]}{1 + \exp\left[b_0\left(\log((B_{f,t} + B_{h,t})/GDP_t) - \log(\overline{(B_f + B_h)/GDP})\right) - b_1\right]}, \tag{A.41}$$

where b_0 and b_1 are chosen to approximate the shape of the actual countercyclical buffer function and $\overline{(B_f + B_h)/GDP}$ is the steady state level of credit to GDP.

Sector specific countercyclical buffers Sector specific macroprudential buffers are computed following a similar rule as the generic CCYB, replacing the total credit to GDP gap by a sector specific credit to GDP gap, that is

$$M_{s,t} = \frac{0.105 + ccyb_{s,t}}{0.08}, \tag{A.42}$$

with

$$ccyb_{s,t} = 0.025 \frac{\exp\left[b_0\left(\log(B_{s,t}/GDP_t) - \log(\overline{B_s/GDP})\right) - b_1\right]}{1 + \exp\left[b_0\left(\log(B_{s,t}/GDP_t) - \log(\overline{B_s/GDP})\right) - b_1\right]}. \tag{A.43}$$

B Data

This appendix details the data sources and the transformations of variables used in the calibration.

Corporate Loans Euro area (changing composition), 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, data Neither seasonally nor working day adjusted.

Household Loans : Euro area (changing composition), 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 and S.15) sector, denominated in Euro, data Neither seasonally nor working day adjusted

Corporate Spreads Spreads are computed as the weighted average of differences between the interest rate agreed on loans and the risk free rate, for different maturities. The weights are given by the outstanding amount of loans for each given maturity. For corporate loans, the following time series on interest rates are used:

- Euro area (changing composition), Annualised agreed rate (AAR) / Narrowly defined effective rate (NDER), Credit and other institutions (MFI except MMFs and central banks) reporting sector - Loans, Up to 1 year original maturity, Outstanding amount business coverage, Non-Financial corporations (S.11) sector, denominated in Euro –

- Euro area (changing composition), Annualised agreed rate (AAR) / Narrowly defined effective rate (NDER), Credit and other institutions (MFI except MMFs and central banks) reporting sector - Loans, Over 1 and up to 5 years original maturity, Outstanding amount business coverage, Non-Financial corporations (S.11) sector, denominated in Euro–

- Euro area (changing composition), Annualised agreed rate (AAR) / Narrowly defined effective rate (NDER), Credit and other institutions (MFI except MMFs and central banks) reporting sector - Loans, Over 5 years original maturity, Outstanding amount business coverage, Non-Financial corporations (S.11) sector, denominated in Euro.

Mortgage Spreads Spreads are computed as the weighted average of differences between the interest rate agreed on loans and the risk free rate, for different maturities. The weights are given by the outstanding amount of loans for each given maturity. For mortgage loans, the following time series on interest rates are used:

- Euro area (changing composition), Annualised agreed rate (AAR) / Narrowly defined effective rate (NDER), Credit and other institutions (MFI except MMFs and central banks) reporting sector - Lending for house purchase excluding revolving loans and overdrafts, convenience and extended credit card debt, Up to 1 year initial rate fixation, New business coverage, Households and non-profit institutions serving households (S.14 and S.15) sector, denominated in Euro.
- Euro area (changing composition), Annualised agreed rate (AAR) / Narrowly defined effective rate (NDER), Credit and other institutions (MFI except MMFs and central banks) reporting sector - Lending for house purchase excluding revolving loans and overdrafts, convenience and extended credit card debt, Over 1 and up to 5 years initial rate fixation, New business coverage, Households and non-profit institutions serving households (S.14 and S.15) sector, denominated in Euro–
- Euro area (changing composition), Annualised agreed rate (AAR) / Narrowly defined effective rate (NDER), Credit and other institutions (MFI except MMFs and central banks) reporting sector - Lending for house purchase excluding revolving loans and overdrafts, convenience and extended credit card debt, Over 5 and up

to 10 years initial rate fixation, New business coverage, Households and non-profit institutions serving households (S.14 and S.15) sector, denominated in Euro–

- Euro area (changing composition), Annualised agreed rate (AAR) / Narrowly defined effective rate (NDER), Credit and other institutions (MFI except MMFs and central banks) reporting sector - Lending for house purchase excluding revolving loans and overdrafts, convenience and extended credit card debt, Over 10 years initial rate fixation, New business coverage, Households and non-profit institutions serving households (S.14 and S.15) sector, denominated in Euro–

GDP Gross domestic product at market prices - Euro area 19 (fixed composition) - Domestic (home or reference area), Total economy, Euro, Chain linked volume (rebased), Non transformed data, Calendar and seasonally adjusted data – Gross domestic product at market prices - Euro area 19 (fixed composition) - Domestic (home or reference area), Total economy, Euro, Current prices, Non transformed data, Calendar and seasonally adjusted data.

Investment Gross fixed capital formation- Euro area 19 (fixed composition) - Domestic (home or reference area), Total economy, Euro, Chain linked volume (rebased), Non transformed data, Calendar and seasonally adjusted data – Gross domestic product at market prices - Euro area 19 (fixed composition) - Domestic (home or reference area), Total economy, Euro, Current prices, Non transformed data, Calendar and seasonally adjusted data.

Write-off rates Write off rates are computed dividing the adjustments on the book value of loans reported by banks by the outstanding loan amount. Adjustments can be found at:

Data Source in SDW: https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=117.

BSI.M.U2.N.U.A20.A.7.U2.2250.Z01.E&periodSortOrder=ASC

Data Source in SDW: https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=117.BSI.M.U2.N.U.A20.A.7.U2.2240.Z01.E&periodSortOrder=ASC.

Returns on Bank Equity Taken from IMF Financial stability indicators. Available at: https://data.imf.org/?sk=51B096FA-2CD2-40C2-8D09-0699CC1764DA

Housing Wealth Euro area 19 (fixed composition), reporting institutional sector Households, non-profit institutions serving households - Closing balance sheet - Household housing wealth (net) - 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, Neither seasonally nor working day adjusted. Data Source in SDW: https://sdw.ecb.europa.eu/browseTable.do?org.apache.struts.taglib.html.TOKEN=7e62c879004e4573c19df941a2ae83a2&df=true&ec=&dc=&oc=&pb=&rc=&DATASET=0&removeItem=&removedItemList=&mergeFilter=&activeTab=IEAQ&showHide=&REF_AREA.111=I8&ESA95TP_ASSET.111=TU&ESA95TP_ASSET.111=TY&MAX_DOWNLOAD_SERIES=500&SERIES_MAX_NUM=50&node=3443000&SERIES_KEY=158.IEAQ.Q.I8.N.V.LE.TU.S1M.A1.S.1.X.E.Z&SERIES_KEY=158.IEAQ.Q.I8.N.V.LE.TY.S1M.A1.S.1.X.E.Z&periodSortOrder=ASC

Share of household held capital I follow the procedure in Mendicino et al (2018) to find the proportion of assets of non financial corporations which is not financed by banks. In order to do so, I first produce a "net" balance sheet in which, in order to remove the effects of the cross-holdings of corporate liabilities, different types of corporate liabilities that appear as assets of the NFC sector get subtracted from the corresponding "gross" liabilities of the corporate sector. Then the following measure of corporate leverage is computed:

$$\text{LR} = \frac{\text{NFC Net Debt Securities} + \text{NFC Net Loans} + \text{NFC Net Insurance Guarantees}}{NFCNetAssets}. \tag{B.1}$$

The measure of bank funding received by the corporate sector is

$$BF = \frac{\text{MFI Loans to NFCs}}{\text{NFC Net Assets}}. \tag{B.2}$$

The measure of corporate assets not funded through banks can then be found as $1 - (LR/BF)$. Finally, I assume that the fraction of NFC assets not financed through banks follows the same split between equity and debt funding. Then the fraction of capital not funded by banks in the model is simply $1 - (LR/BF)$.

Risk free rates In order to compute corporate spreads, the risk free rates used for each loan maturity are the following:

- 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).

Real Estate Price index Taken from BIS statistics: https://stats.bis.org/statx/srs/table/h2?m=628