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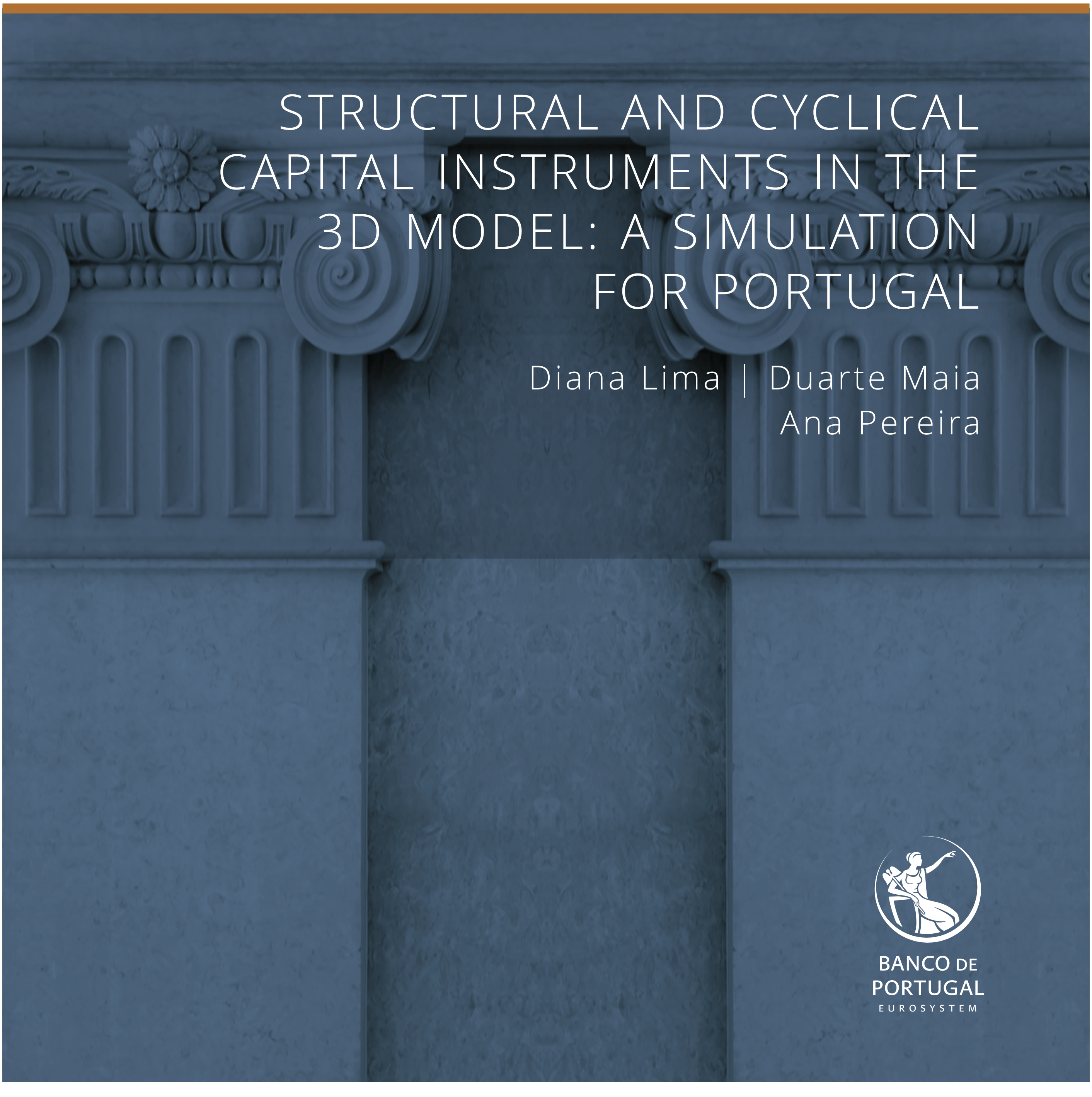

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Structural and cyclical capital instruments in the 3D model: a simulation for Portugal

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Abstract
In this study, we assess the effectiveness of structural and cyclical capital requirements under distinct sources of disturbance. The analysis is based on the model of Clerc *et al.* (2015) with three layers of default (3D model) calibrated for the Portuguese economy. We conclude that an increase in capital requirements, regardless of their structural or cyclical nature, enhances the resilience of the banking sector to adverse shocks and reduces the impact of those disturbances on the well-functioning of the banking sector. Nonetheless, results also indicate that capital requirements can be more effective if the distress emerges from within the financial system, corroborating the idea that prudential policies are not meant to be the first line of defense to address all types of shock. Countercyclical capital buffers also help counter some of the pro-cyclicality in the financial system by smoothing the crunch in credit flows. Structural and cyclical capital instruments can be considered as strategic complements as they reinforce each others' policy goals.

JEL: E3, E44, G01, G21, 052

Keywords: Macroprudential policy, general equilibrium, capital-based instruments, Portugal.

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1. Introduction

This paper presents a macroeconomic model with three layers of default (henceforth 3D model) calibrated for the Portuguese economy. The 3D model was first developed by Clerc *et al.* (2015) and extended by Mendicino *et al.* (2018) and Mendicino *et al.* (2020).[1]

The 3D model introduces financial intermediation and economic agents default into an otherwise standard DSGE model. A distinctive feature of the model is that it provides a clear rationale for capital regulation, which arises as a welfare improving response to two types of distortions: i) banks' limited liability due to the existence of a deposit insurance scheme that guarantees the principal and interest of bank deposits in full and ii) bank funding cost externality in which the deposit rate does not fully depend on the risk of default of each individual bank but on the system-wide bank default risk. Both distortions encourage banks to expand their leverage and extend excessive credit to the economy and/or to lend to risky borrowers, providing a reasoning for imposing a minimum level for bank capital ratio (i.e. regulatory capital requirements). The model also envisages a third distortion related to the possibility of default of economic agents. This feature creates external financing frictions in the form of bankruptcy costs and restricted access to credit that may result in too little credit being granted compared to a first best world without this friction.

Due to these features, the 3D model is being frequently used by central banks and other policy authorities with the purpose of deepening the knowledge about how capital regulation helps mitigating the financial distortions and what sort of costs may also be involved when higher capital requirements are applied by prudential authorities (see, for example, Balfoussia and Papageorgiou (2016); Balfoussia *et al.* (2019) both from the Bank of Greece, Hinterschweiger *et al.* (2021) from the Bank of England, Bennani *et al.* (2017) from the Banque de France and Cozzi *et al.* (2020) from the European Central Bank).

To the extent of our knowledge, this study is the first to use this model to analyse the role of capital instruments for the Portuguese economy. In particular, this study assesses the interaction of structural and cyclical capital instruments in the event of shocks. The distinction between structural and cyclical capital buffers emerges from their policy goals. While cyclical capital requirements create resilience against risks associated with the financial cycle, structural capital requirements are meant to increase resilience against structural vulnerabilities of the financial system.

[1] The model in Clerc *et al.* (2015) was developed in the context of the Macroprudential Research Network (MaRS) of the European System of Central Banks to provide a decision-support framework for the positive and normative analysis of macroprudential policy, with a specific focus on capital requirements. Mendicino *et al.* (2018) extended the original 3D model and calibrated it to the Euro Area (EA) in order to provide a quantitative assessment of increases in total and sectorial capital requirements in a stochastic environment. Building on Clerc *et al.* (2015), Mendicino *et al.* (2018) and also Mendicino *et al.* (2020), the 3D model has been operationalised to EA countries in the context of the Task Force on Operationalising Macroprudential Research.

The interaction between macroprudential policy instruments is a research field that is still poorly taken into account in the related literature. Nonetheless, some work has been done on the calibration of structural and cyclical capital buffers using other modeling approaches, such as stress tests (Couaillier and Scalone 2021). Simulations on the effects of changing structural and cyclical capital requirements reveal, on the one hand, the importance of banks' level of capitalization in smoothing the fluctuations in credit and GDP, and improving the resilience of the banking system. On the other hand, that economic fluctuations in the presence of higher countercyclical capital buffers are smaller (Pozo 2020). The choice of the 3D model is justified by the way capital instruments are motivated in the model. The set of financial distortions embedded in the framework provides a robust rationale to the introduction of microprudential and macroprudential policies based on capital instruments. There are other studies with dynamic stochastic general equilibrium models calibrated for the Portuguese economy, endowed with financial frictions and a banking sector (see, for example, Maria *et al.* 2021), but these models do not consider the default of banks, entrepreneurs and (impatient) households.

Clerc *et al.* (2015) provide a useful literature review on the relatively abundant research concerning the assessment of the impact of higher capital requirements on the financial system and the economy (see e.g., Curdia and Woodford 2010; Gertler and Kiyotaki 2010; Gerali *et al.* 2010). Broadly, regulatory capital requirements intend to minimise the possibility of bank failure, as they make the banks more resilient and better equipped to absorb adverse shocks originating either in the financial system or in other parts of the economy. Furthermore, those requirements act as a backstop to the banks from taking excessive risk. All in all, higher capital requirements increase banks resilience and mitigate the procyclicality of leverage, thereby reducing the economic costs of financial crises (Admati and Hellwig 2014; Drumond 2009).

Although the benefits of introducing regulatory capital requirements are undeniable, there are also costs that should be accounted for. If most banks choose to comply with higher capital requirements chiefly by reducing credit supply instead of effective increases in capital, then more stringent capital requirements may negatively affect economic activity (Kashyap *et al.* 2010; Hanson *et al.* 2011). Indeed, the literature is not fully consensual over the impact of an increase in capital requirements on financial intermediation and economic activity, due to uncertainty over the strategy used by banks to comply with the regulatory changes and the degree of cost pass-through to customers. Nevertheless, it is widely accepted that, up to certain levels, the long-term benefits of capital increments exceed their costs, with a higher marginal benefit from increasing capital requirements when the capital ratios are low (Miles *et al.* 2013; Dagher *et al.* 2016; Cline 2016).

As such, understanding the trade-offs in terms of costs and benefits of introducing higher capital requirements and the interaction of capital instruments that differ in their policy goals is paramount to implementing micro and macroprudential policies, as these policy areas are responsible for setting adequate levels for this class of instruments introduced by the Basel Accords.

The next two sections explain the model in detail and the calibration approach followed for the Portuguese economy. The remaining sections present the policy exercises and simulation results, namely the assessment of higher structural capital requirements and its comparison with countercyclical capital instruments.

2. The model

The model used is based on Clerc *et al.* (2015), Mendicino *et al.* (2018) and Mendicino *et al.* (2020) and was developed with the purpose of incorporating the main fundamentals that motivate the need to adopt policies that regulate the capital ratios of banks, at the micro and macroprudential levels. Figure 1 illustrates the main features of the model, highlighting the key relationships between economic agents.

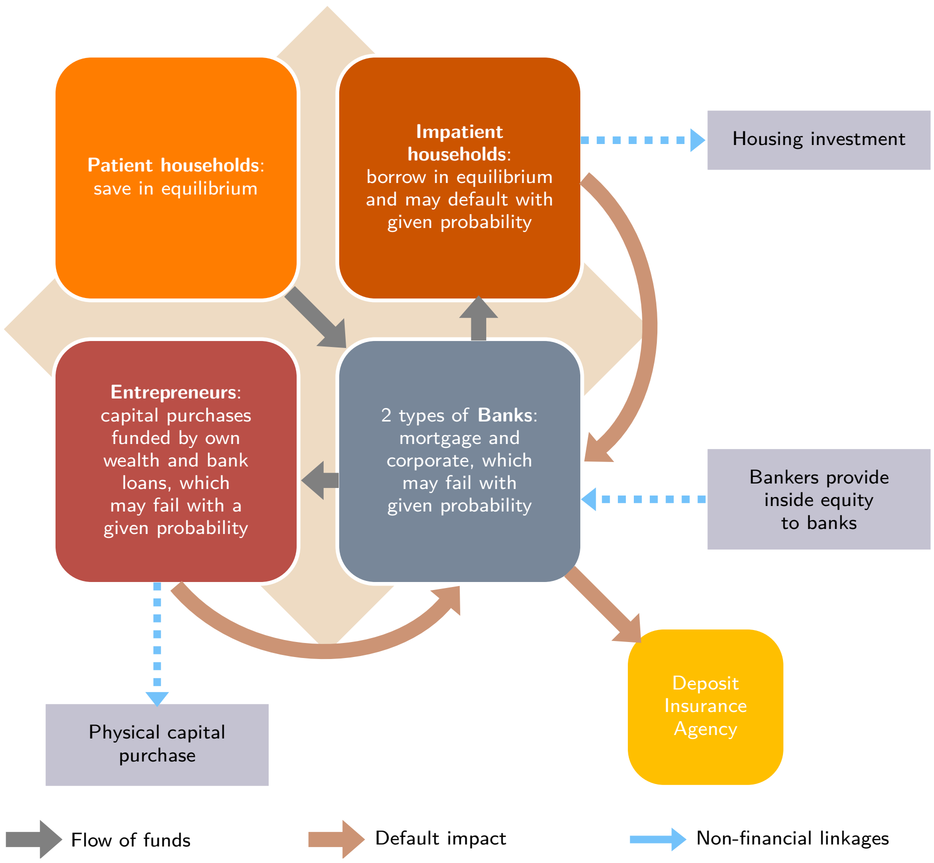


Figure 1: Main features of the 3D model

The economy represented here comprises households, entrepreneurs and banks. Households are divided into two types: patients, who save in equilibrium and deposit their savings in banks (as such they are also referred to as depositors interchangeably hereafter) and those who are impatient and take out loans to finance investments in residential real estate. In the remaining, they have similar characteristics: both consume, invest in housing and work in the productive sector.

The stock of physical capital in this economy is held by entrepreneurs and patient households. While entrepreneurs rent it directly to other companies in the productive sector, patient households use the service delivered by specialized capital management firms and pay a fee for this service. The acquisition of physical capital by entrepreneurs is financed with inherited net worth and loans provided by the banking sector.

There are two types of banks in the model, which are specialized in their credit activity. One type of bank grants credit to impatient households for investment in housing (mortgage loans) and the other type grants credit to entrepreneurs (corporate loans). To finance themselves, banks use deposits and net worth, which can be generated internally through retained earnings, and externally by raising equity from bankers. Banks are subject to regulatory capital constraints and operate with limited liability. They may default due to both idiosyncratic and aggregate shocks to the performance of their loan portfolios.

Deposits are formally guaranteed by a deposit guarantee system, which covers the amount deposited and the corresponding interest. When necessary, the deposit guarantee system is financed through a fixed tax levied on households.This feature of the model creates incentives for banks to engage in excessive risk-taking practices, as it allows banks with a business model more focused on granting credit to higher-risk borrowers to implicitly benefit from a subsidy against banks with a more conservative lending profile.[2] However, it is assumed that, in the context of the model, depositors do not know the risk profile of each bank, observing only the average risk of the sector. In addition, depositors require a risk premium that depends on the default probability of banks, thus increasing the banking sector' funding costs when the default risk is high.

As already mentioned, economic agents that borrow from the banking sector – that is, impatient households and entrepreneurs – can default with a given probability, which can affect their ability to meet their debt obligations. Finally, with respect to the production sector, there are perfectly competitive firms that produce the final good and new physical capital and housing.

2.1. The role of financial distortions

In this model, there are several financial distortions that motivate the role of capital regulation policy in the banking sector. One of the distortions is directly related to

[2]Despite these effects, the existence of a deposit guarantee scheme brings benefits for financial stability. By ensuring the repayment of deposits in case of a bank failure, deposit guarantee schemes limit the possibility of bank runs and unwarranted negative spillovers on solvent banks, reducing the probability of bank failures.

the possibility of bankruptcy of economic agents, which translates into costs arising from bankruptcy and limited access to credit. Another distortion arises from the presence of a deposit guarantee system and the incentives it promotes for excessive risk-taking when granting credit.[3] Finally, there are externalities at the level of bank financing costs, which arise from the hypothesis that the interest rate on deposits is determined by the risk of the banking sector as a whole and not by the risk profile of each bank. In equilibrium, the last two distortions may imply excessive lending, while the first distortion may lead to its scarcity when compared to an optimal social situation in which those costs would be internalized.

The model in question synthesizes the main interconnections between the banking sector and the economy, while considering a set of distortions that affect the way in which the banking sector performs its financial intermediation function, with potentially adverse consequences in the allocation of resources in the economy. For example, the possibility of bank default is an innovative feature that allows to assess its consequences for financial stability and for the economy.

This model is, therefore, an appropriate tool for analyzing the effects of micro and macroprudential policy instruments, namely in terms of determining capital requirements. Capital requirements are modelled in such a way that, on the one hand, they reinforce the resilience of the banking sector, making it less vulnerable to shocks and reduce incentives to overlending. On the other hand, their application also entails funding costs for banks that, by assumption, are fully transferred to the economy through higher credit spreads, affecting investment decisions and therefore the amount of output to be produced. The net effects of higher capital requirements will then be determined by the relative strength of these two channels, which is conditional on the calibration.

2.2. Households

In this economy, there are two representative dynasties of ex ante identical infinitely lived households that differ only in the subjective discount factor β. Both type of dynasties are risk averse and maximise time-separable expected utility functions. One dynasty, indexed by the superscript s, is made up of relatively patient households with a discount factor β^s. The other dynasty, identified by the subscript m, consists of impatient households with a discount factor $\beta^m < \beta^s$. In equilibrium, the patient households save and the impatient households borrow from banks. The shares of patient and impatient households in the model are given by n^s and n^m, respectively.

[3]See footnote 2

Patient Households

The dynasty of patient households maximizes its expected lifetime utility – as a function of consumption, housing and labor:

$$\mathbb{E}_t\left[\sum_{i=0}^{\infty}(\beta^s)^{t+i}[\log(c^s_{t+i})+\tau_t\upsilon^s\log(h^s_{t+i-1})-\frac{\phi^s}{1+\eta}(l^s_{t+i})^{1+\eta}]\right] \tag{1}$$

subject to

$$\begin{aligned} c^s_t+q^k_t(K^s_t+s^k_t)+q^H_t h^s_t+d_t \le w_t l^s_t+q^H_t(1-\delta^H_t)h^s_{t-1}+ \\ +(r^k_t+(1-\delta^K_t)q^k_t)K^s_{t-1}+\widetilde{R}^D_t d_{t-1}-T^s_t+\Pi^s_t \end{aligned} \tag{2}$$

where c^s_t is the consumption of non-durable goods, h^s_t denotes the total stock of housing held by the members of the dynasty, l^s_t denotes hours worked in the consumption-good-producing sector, η is the inverse of the Frisch elasticity of labour supply, τ_t is a housing preference shock that is common to both dynasties, υ^s is a housing preference parameter and ϕ^s is a labour preference parameter. In addition, q^H_t is the price of housing, $\delta^H_t \equiv \delta^H+\iota^H_t$ is the depreciation rate of housing units, subject to the shock ι^H_t, and w_t is the real wage rate. Furthermore, q^k_t is the price of physical capital, $\delta^k_t \equiv \delta^K+\iota^K_t$ is the depreciation rate of physical capital units, subject to the shock ι^k_t, K^s_t is the stock of physical capital, and s^k_t is the fee paid to the capital management firms. $\widetilde{R}^D_t$ is defined as $\widetilde{R}^D_t \equiv R^D_{t-1}(1-\gamma PD^b_t)$, where R^D_t is the gross fixed interest rate received at t on the savings deposited at banks at $t-1$, denoted by d_t, and PD^b_t is the economy-wide probability of bank default in period t. In the case of a bank default the principal and the interest of bank deposits are fully guaranteed by a deposit insurance agency (DIA), financed by imposing a lump-sum tax T^s_t. The lump-sum tax is evenly shared with impatient households. It is also assumed that households face linear transaction costs denoted by γ that create a wedge between the return on deposits and the risk-free rate, and a link between the probability of bank default and the cost of funding for banks. Lastly, Π^s_t stands for the donations ("dividends payments"), made by entrepreneurs and bankers, and for the profits received by the patient households, who are the owners of the capital-good producing and capital management firms, and of the housing-producing firms.

Impatient Households

Impatient households have the same utility function as patient households except for the discount factor, which is $\beta^m < \beta^s$. As the patient households, they maximize their expected lifetime utility:

$$\mathbb{E}_t\left[\sum_{i=0}^{\infty}(\beta^m)^{t+i}[\log(c^m_{t+i})+\tau_t\upsilon^m\log(h^m_{t+i-1})-\frac{\varphi^m}{1+\eta}(l^m_{t+i})^{1+\eta}]\right] \tag{3}$$

The budget constraint of the representative dynasty is:

$$c_t^m + q_t^H h_t^m - b_t^m \leq w_t l_t^m - T_t^m \\ + \int_0^\infty \max\{\omega_t^m q_t^H (1-\delta_t^H) h_{t-1}^m - R_{t-1}^m b_{t-1}^m, 0\} dF^m(\omega_t^m) \tag{4}$$

where T_t^m refers to the lump-sum tax imposed to impatient households to cover the losses of the deposit insurance agency, b_t^m is aggregate borrowing from the banks and R_{t-1}^m is the contractual gross interest rate on the mortgage loan agreed upon in period $t-1$, i.e. b_{t-1}^m. ω_t^m is an idiosyncratic shock to efficiency units of housing owned from period $t-1$ that each impatient household experiences at the beginning of each period t. The shock is assumed to be independently and identically distributed across impatient households and to follow a lognormal distribution with density and cumulative distributions functions denoted by $f(\cdot)$ and $F(\cdot)$, respectively. This affects the effective resale value of the housing units acquired in the previous period, $\tilde{q}_t^H = \omega_t^m q_t^H (1-\delta_t^H)$, and makes ex-post default on the loan optimal for the household whenever $\omega_t^m q_t^H (1-\delta_t^H) h_{t-1}^m < R_{t-1}^m b_{t-1}^m$. The term in the integral included in the budget constraint reflects the fact that the housing good and the debt secured against it are assumed to be distributed across the individual households that constitute the dynasty.

After the realization of the shock, each household decides whether to default or not on the individual loans held from the previous period. Then, the dynasty makes the decisions for consumption, housing, labour supply and debt in period t and allocates them evenly across households. Individual households default in period t whenever the idiosyncratic shock ω_t^m satisfies:

$$\omega_t^m \leq \bar{\omega}_t^m = \frac{x_{t-1}^m}{R_t^H} \tag{5}$$

where $R_t^H \equiv \frac{q_t^H(1-\delta_t^H)}{q_{t-1}^H}$ is the ex post average realized return on housing and $x_t^m \equiv \frac{R_t^m b_t^m}{q_t^H h_t^m}$ is a measure of household leverage. The net housing equity after accounting for repossessions of defaulting households can be written as:

$$\Phi_t^m \equiv (1-\Gamma^m(\bar{\omega}_t^m)) R_t^H q_{t-1}^H h_{t-1}^m, \tag{6}$$

where $\Gamma^m(\bar{\omega}_t^m) = \int_0^{\bar{\omega}_t^m} (\omega_t^m f^m(\omega_t^m)) d\omega_t^m + \bar{\omega}_t^m \int_{\bar{\omega}_{t+1}^m}^\infty (f^m(\omega_t^m)) d\omega_t^m$ is the share of gross returns (gross of verification costs accrued by the bank) and $(1-\Gamma^m(\bar{\omega}_t^m))$ is the share of assets accrued to the dynasty. Finally, Φ_t^m is interpreted as net housing equity after taking into account repossessions of households that defaulted.

Since each of the impatient households can default on its loans, the loans taken in period t should satisfy the participation constraint for the lending banks:

$$\mathbb{E}_t[(1-\Gamma^H(\bar{\omega}_{t+1}^H))(\Gamma^m(\bar{\omega}_{t+1}^m) - \mu^m G^m(\bar{\omega}_{t+1}^m))] R_{t+1}^H q_t^H h_t^m \geq \rho_t \phi_t^H b_t^m \tag{7}$$

The left-hand side of the inequality accounts for the total equity returns associated with a portfolio of mortgage loans to the various members of the impatient dynasty. The interpretation of the banking participation constraint is that the expected gross return for bankers should be at least as high as the gross equity return of the funding of the loan from the bankers, $\rho_t \phi_t^H b_t^m$, where ρ_t is the required expected rate of return on equity from bankers (defined below) and ϕ_t^H is the capital requirement on mortgage loans. The term $\mu^m G^m(\omega_{t+1}^m)$ is the expected cost of default, where μ^m is the verification cost and $G^m(\omega_{t+1}^m) = \int_0^{\bar{\omega}_{t+1}^m} (\omega_{t+1}^m f(\omega_{t+1}^m)) d\omega_{t+1}^m$ is the share of assets that belong to households that default. Finally, $(1 - \Gamma^H(\bar{\omega}_{t+1}^H))$ is the share of assets accrued to bankers in the case of a bank default, where $\bar{\omega}_t^H$ is the threshold level to the idiosyncratic shock of banks that specialize in mortgage loans (defined below).

Given the above, as shown in Clerc *et al.* (2015), the problem of the representative dynasty of the impatient households can be rewritten compactly as a contracting problem between the representative dynasty and its bank. In particular, the problem of the dynasty is to maximize utility subject to the budget constraint and the participation constraint of the bank, respectively:

$$\max_{\left\{ \begin{matrix} c_{t+i}^m, \\ h_{t+i}^m, \\ l_{t+i}^m, \\ x_{t+i}^m, \\ b_{t+i}^m \end{matrix} \right\}_{i=0}^{\infty}} \mathbb{E}_t \left[\sum_{i=0}^{\infty} (\beta^m)^{t+i} \left[\log(c_{t+i}^m) + \tau_t \upsilon^m \log(h_{t+i}^m) - \frac{\varphi^m}{1+\eta} (l_{t+i}^m)^{1+\eta} \right] \right] \tag{8a}$$

s.t.

$$c_t^m + q_t^H h_t^m - b_t^m \leq (w_t l_t^m) + \left(1 - \Gamma^m \left(\frac{x_t^m}{R_{t+1}^H} \right) \right) R_{t+1}^H q_t^H h_t^m, \tag{8b}$$

$$\mathbb{E}_t[(1 - \Gamma^H(\bar{\omega}_{t+1}^H))(\Gamma^m(\bar{\omega}_{t+1}^m) - \mu^m G^m(\bar{\omega}_{t+1}^m))] R_{t+1}^H q_t^H h_t^m \geq \rho_t \phi_t^H b_t^m \tag{8c}$$

2.3. Entrepreneurs

Entrepreneurs are risk neutral agents who live for two periods. Each generation of entrepreneurs inherits wealth in the form of bequests, n_t^e, and purchases new physical capital from capital good producers and depreciated capital from the previous generation of entrepreneurs, that they rent out to final good producers. They finance purchases of physical capital with their initial wealth and with loans from banks, b_t^e. The entrepreneurs derive utility from the transfers made to the patient households in period $t+1$ (dividends), c_{t+1}^e, and the bequests left to the next cohort of entrepreneurs (retained earnings), n_{t+1}^e, according to the utility function $(c_{t+1}^e)^{\chi^e} (n_{t+1}^e)^{1-\chi^e}$, with $\chi^e \in (0,1)$ reflecting the entrepreneurs preferences.

Thus, the problem of the entrepreneurs in period $t+1$ is:

$$\max_{\{c^e_{t+1}, n^e_{t+1}\}} \quad (c^e_{t+1})^{\chi^e}(n^e_{t+1})^{1-\chi^e} \tag{9a}$$

$$\text{s.t.}$$

$$c^e_{t+1} + n^e_{t+1} \leq W^e_{t+1}, \tag{9b}$$

where W^e_{t+1} is the wealth in $t+1$ resulting from the activity in the previous period.

The optimization problem of the entrepreneur in period t is to maximize expected wealth:

$$\max_{\{k_t, b^e_t, R^F_t\}} \quad \mathbb{E}(W^e_{t+1}) \tag{10}$$

subject to the period t resource constraint, $q^K_t k_t - b^e_t = n^e_t$, and the banks participation constraint, defined as:

$$W^e_{t+1} = \max\left\{\omega^e_{t+1}(r^K_{t+1} + (1-\delta^k_{t+1})q^K_{t+1})k_t - R^F_t b^e_t, 0\right\}, \tag{11}$$

where q^K_t is the price of physical capital at period t, k_t is the physical capital held by the entrepreneur in period t, b^e_t is the amount borrowed from the bank in period t, r^K_t is the rental rate per efficiency unit of physical capital, δ^k_t is the time-varying depreciation rate of each efficiency unit of physical capital and R^F_t is the contractual gross interest rate of the loans. ω^e_{t+1} is an idiosyncratic shock to the efficiency units of physical capital which is independently and identically distributed across entrepreneurs. This shock is meant to rationalize idiosyncratic shocks to the performance of entrepreneurs and, in this way, to generate a non-trivial default rate on corporate loans. It is realized after the period t loan being granted by the bank and prior to renting the available physical capital to consumption good producers on that date. Similar to the case of borrowing households, entrepreneurs default on their loans whenever the gross returns obtained by the entrepreneur on her investment in physical capital undertaken in the previous period is below the contractual repayments due to the bank, or, mathematically, whenever $\omega^e_{t+1}(r^K_{t+1} + (1-\delta^k_{t+1})q^K_{t+1})k_t < R^F_t b^e_t$. As shown in Clerc *et al.* (2015), the entrepreneur will repay her loan in period $t+1$ whenever the idiosyncratic shock ω^e_{t+1} exceeds the following threshold:

$$\bar{\omega}^e_{t+1} \equiv \frac{R^F_t b^e_t}{R^K_{t+1} q^K_t k_t} \equiv \frac{x^e_t}{R^K_{t+1}}, \tag{12}$$

where $R^K_{t+1} = \frac{r^K_{t+1} + (1-\delta^k_{t+1})q^K_{t+1}}{q^K_t}$ is the gross return per efficiency units of physical capital in period $t+1$ of physical capital owned in period t, $x^e \equiv \frac{R^F_t b^e_t}{q^K_t k_t}$ denotes the entrepreneurial leverage that is defined as the ratio of contractual debt repayment obligations in period $t+1$, $R^F_t b^e_t$, to the value of the purchased physical capital at t, $q^K_t k_t$.

Given the above, the maximization problem of the entrepreneurs in period t can be compactly written as:

$$\max_{\{x_t^e, k_t\}} \quad \mathbb{E}_t \left[\left(1 - \Gamma^e \left(\frac{x_t^e}{R_{t+1}^K} \right) \right) R_{t+1}^K q_t^K k_t \right] \tag{13a}$$

s.t.

$$\begin{aligned} &\mathbb{E}_t \left[(1 - \Gamma^F(\bar{\omega}_{t+1}^F))(\Gamma^e(\bar{\omega}_{t+1}^e) - \mu^e G^e(\bar{\omega}_{t+1}^e)) \right] R_{t+1}^K q_t^K k_t = \\ &\quad = \rho_t \phi_t^F (q_t^K k_t - n_t^e) \end{aligned} \tag{13b}$$

where $\Gamma^e(\bar{\omega}_{t+1}^e) = \int_0^{\bar{\omega}_{t+1}^e} (\omega_{t+1}^e f^e(\omega_{t+1}^e)) d\omega_{t+1}^e + \bar{\omega}_{t+1}^e \int_{\bar{\omega}_{t+1}^e}^{\infty} (f^e(\omega_{t+1}^e)) d\omega_{t+1}^e$ is the share of gross return that will accrue to the bank, $G^e(\bar{\omega}_{t+1}^e) = \int_0^{\bar{\omega}_{t+1}^e} (\omega_{t+1}^e f^e(\omega_{t+1}^e)) d\omega_{t+1}^e$ is the fraction of the returns coming from the defaulted loans of entrepreneurs, μ^e denotes the verification costs incurred by the bank and $(1 - \Gamma^F(\bar{\omega}_t^F))$ is the share of assets accrued to bankers in the case of a bank default, where $\bar{\omega}_t^F$ is the default threshold level for the idiosyncratic shock of banks that specialize in corporate loans (defined below). Similar to the case of impatient households, the interpretation of the participation constraint is that, in equilibrium, the expected return of loans must equal to the expected rate of return on equity, ρ_t, that the bankers require for their contribution to the funding of loans, $\phi_t^F(q_t^K k_t - n_t^e)$, where ϕ_t^F is the capital requirement applied on each unit of corporate loans.

The final wealth of the entrepreneurs that start up in period t can be written as

$$W_{t+1}^e = \frac{(1 - \Gamma^e(\bar{\omega}_{t+1}^e)) R_{t+1}^K}{1 - E_t \left\{ (1 - \Gamma^F(\bar{\omega}_{t+1}^F))(\Gamma^e(\bar{\omega}_{t+1}^e) - \mu^e G^e(\bar{\omega}_{t+1}^e)) \frac{R_{t+1}^k}{\rho_t \phi_t^F} \right\}} n_t^e \tag{14}$$

and, since a fraction $(1 - \chi^e)$ of such wealth is left as a bequest to the next generation of entrepreneurs, the law of motion of entrepreneurs' aggregate initial net worth can be written as

$$n_{t+1}^e = (1 - \chi^e) \frac{(1 - \Gamma^e(\bar{\omega}_{t+1}^e)) R_{t+1}^K}{1 - E_t \left\{ (1 - \Gamma^F(\bar{\omega}_{t+1}^F))(\Gamma^e(\bar{\omega}_{t+1}^e) - \mu^e G^e(\bar{\omega}_{t+1}^e)) \frac{R_{t+1}^k}{\rho_t \phi_t^F} \right\}} n_t^e \tag{15}$$

2.4. Bankers and Banks

Bankers

Similarly to entrepreneurs, bankers belong to a sequence of overlapping generations of risk-neutral agents and live for two periods. They invest their initial wealth, inherited in the form of bequest from their previous generations of bankers, n_t^b, as bank's inside equity capital. In period $t+1$ the bankers derive utility from transfers to the patient households in the form of dividends, c_{t+1}^b, and the bequests left to the next generation of bankers (retained earnings), n_{t+1}^b, according to the utility function $(c_{t+1}^b)^{\chi^b}(n_{t+1}^b)^{1-\chi^b}$, where $\chi^b \in (0,1)$ reflects the bankers preferences. Thus, the problem of the banker in period $t+1$ is:

$$\max_{\{c_{t+1}^b, n_{t+1}^b\}} \quad (c_{t+1}^b)^{\chi^b}(n_{t+1}^b)^{1-\chi^b} \tag{16a}$$

$$\text{s.t.}$$

$$c_{t+1}^b + n_{t+1}^b \leq W_{t+1}^b \tag{16b}$$

where W_{t+1}^b is the wealth of the banker in period $t+1$.

Regarding the decision problem of the bankers in period t, the banker born in period t with initial wealth, n_t^b, decides how much of this wealth to allocate as inside equity capital across banks that specialize in mortgage loans (banks of type H) and banks that specialize in corporate loans (banks of type F). Let e_t^F be the amount of initial wealth, n_t^b, invested as inside equity in F banks and the rest, $n_t^b - e_t^F$, in H banks. The net worth of the banker in period $t+1$ is $W_{t+1}^b = \tilde{\rho}_{t+1}^F e_t^F + \tilde{\rho}_{t+1}^H (n_t^b - e_t^F)$, where $\tilde{\rho}_{t+1}^F$ and $\tilde{\rho}_{t+1}^H$ are the ex post gross return on the inside equity invested in banks F and H, respectively.

The maximization problem of the banker is to decide on the allocation of their initial wealth in order to maximize the expected wealth:

$$\max_{\{e_t^F, e_t^H\}} \mathbb{E}_t(W_{t+1}^b) = \mathbb{E}_t\left(\tilde{\rho}_{t+1}^F e_t^F + \tilde{\rho}_{t+1}^H (n_t^b - e_t^F)\right) \tag{17}$$

An interior solution in which both types of banks receive positive equity requires that $\mathbb{E}_t\left(\tilde{\rho}_{t+1}^F\right) = \mathbb{E}_t\left(\tilde{\rho}_{t+1}^H\right) = \rho_t$, where ρ_t denotes the required expected gross rate of return on equity investment at time t. This expected return is endogenously determined in equilibrium but is taken as given by bankers and individual banks.

Banks

Banks are institutions that provide loans to impatient households and entrepreneurs. There are two types of banks: banks indexed by H are specialized in mortgage loans and banks indexed by F are specialized in corporate loans. Both types of banks ($j = H, F$) issue equity bought by bankers and receive deposits from patient households. A bank is an investment project created at t and concluded at $t+1$.

Each bank maximizes the expected equity payoff, $\pi_{t+1}^j = \omega_{t+1}^j \tilde{R}_{t+1}^j b_t^j - R_t^D d_t^j$, that is, the difference between the return from loans and the deposit repayments, where ω_{t+1}^j is an idiosyncratic portfolio return shock, which is i.i.d. across banks and follows a log-normal distribution with mean one and a distribution function

$F^j(\omega^j_{t+1})$, b^j_t and d^j_t are respectively the loans granted and deposits taken by bank at period t, R^D_t is the gross interest rate paid on deposits taken in period t and $\tilde{R}^j_{t+1}$ is the realized return on a well-diversified portfolio of loans of type j.

Each bank faces a regulatory capital constraint:

$$e^j_t \geq \Xi^j_t b^j_t, \tag{18}$$

where Ξ^j_t is the capital requirement of banks of type j. The regulatory capital constraint states how much equity a bank must keep as a fraction of the loans made in period t.

Differently from Clerc *et al.* (2015), we assume that market and reputational reasons compel banks to have a voluntary buffer on top of capital requirements.[4] We can then replace equation (18) by the banks capital constraint:

$$e^j_t \geq \phi^j_t b^j_t, \tag{19}$$

where $\phi^j_t = \Xi^j_t + \phi^j_{vol}$ is the sum of the regulatory capital requirements, Ξ^j_t, and the voluntary buffer, ϕ^j_{vol}, which we assume to be invariant over time.

The problem of each bank j can be written as:

$$\pi^j_{t+1} = \max\left\{\omega^j_{t+1}\tilde{R}^j_{t+1}b^j_t - R^D_t d^j_t, 0\right\} \tag{20}$$

subject to the aforementioned banks capital constraint.

In equilibrium, the constraint will be binding so that the loans and deposits can be expressed as $b^j_t = e^j_t/\phi^j_t$ and $d^j_t = (1-\phi^j_t)e^j_t/\phi^j_t$, respectively. Accordingly, the threshold level of ω^j_t below which the bank of type j defaults is $\bar{\omega}^j_{t+1} = (1-\phi^j_t)R^D_t/\tilde{R}^j_{t+1}$ and the probability of default of each bank of type j is $F^j\left(\bar{\omega}^j_{t+1}\right)$. Thus, bank default is driven by fluctuations in the aggregate return, $\tilde{R}^j_{t+1}$, and the bank idiosyncratic shock ω^j_{t+1}. When a bank defaults, its deposits are taken by DIA.

Given the above, the equity payoffs can then be rewritten as:

$$\begin{aligned}\pi^j_{t+1} &= \max\left\{\omega^j_{t+1} - \bar{\omega}^j_{t+1}, 0\right\}\left(\frac{\tilde{R}^j_{t+1}}{\phi^j_t}\right)e^j_t \\ &= \left[\int_{\bar{\omega}^j_{t+1}}^{\infty}\left(\omega^j_{t+1}f^j\left(\omega^j_{t+1}\right)\right)d\omega^j_{t+1} - \bar{\omega}^j_{t+1}\int_{\bar{\omega}^j_{t+1}}^{\infty}\left(f^j\left(\omega^j_{t+1}\right)\right)d\omega^j_{t+1}\right] \\ &\quad\times\left(\frac{\tilde{R}^j_{t+1}}{\phi^j_t}\right)e^j_t\end{aligned} \tag{21}$$

[4] The voluntary buffer is the difference between the banks' capital ratio and the regulatory capital requirements.

where $f^j\left(\omega^j_{t+1}\right)$ denotes the density distribution of ω^j_{t+1}. Then, the equity payoffs can be written as:

$$\pi^j_{t+1} = \frac{\left[1-\Gamma^j\left(\bar{\omega}^j_{t+1}\right)\right]\tilde{R}^j_{t+1}}{\phi^j_t}e^j_t \tag{22}$$

and the required ex post rate of return from the bankers that invest in bank j is:

$$\tilde{\rho}^j_{t+1} = \frac{\left[1-\Gamma^j\left(\bar{\omega}^j_{t+1}\right)\right]\tilde{R}^j_{t+1}}{\phi^j_t}, \tag{23}$$

where

$$\begin{aligned}\Gamma^j\left(\bar{\omega}^j_{t+1}\right) = &\int_0^{\bar{\omega}^j_{t+1}}\left(\omega^j_{t+1}f^j\left(\omega^j_{t+1}\right)\right)d\omega^j_{t+1}\\ &+\bar{\omega}^j_{t+1}\int_{\bar{\omega}^j_{t+1}}^{\infty}\left(f^j\left(\omega^j_{t+1}\right)\right)d\omega^j_{t+1}\end{aligned} \tag{24}$$

and

$$G^j\left(\bar{\omega}^j_{t+1}\right) = \int_0^{\bar{\omega}^j_{t+1}}\left(\omega^j_{t+1}f^j\left(\omega^j_{t+1}\right)\right)d\omega^j_{t+1}. \tag{25}$$

Finally, the average default rate for the banking sector can be written as:

$$PD^b_t = \frac{d^H_{t-1}PD^H_t + d^F_{t-1}PD^F_t}{d^H_{t-1}+d^F_{t-1}} \tag{26}$$

and the realized returns on loans after accounting for loan losses is given by:

$$\tilde{R}^H_{t+1} = \left(\Gamma^m\left(\frac{x^m_t}{R^H_{t+1}}\right)-\mu^m G^m\left(\frac{x^m_t}{R^H_{t+1}}\right)\right)\left(\frac{R^H_{t+1}q^H_t h^m_t}{b^m_t}\right) \tag{27}$$

$$\tilde{R}^F_{t+1} = \left(\Gamma^e\left(\frac{x^e_t}{R^K_{t+1}}\right)-\mu^e G^e\left(\frac{x^e_t}{R^K_{t+1}}\right)\right)\left(\frac{R^K_{t+1}q^K_t k_t}{q^K_t k_t - n^e_t}\right) \tag{28}$$

2.5. Production sector

The final good in this economy is produced by perfectly competitive firms that use physical capital rented from entrepreneurs, k_{t-1}, and labour supplied by households, l_t. The production technology is given by a standard Cobb-Douglas function:

$$y_t = A_t k^{\alpha}_{t-1} l_t^{(1-\alpha)} \tag{29}$$

where A_t is total factor productivity and α is the output elasticity of capital.

Optimality in the use of the physical capital and labour input requires

$$r_t^K = \alpha \frac{y_t}{k_{t-1}} \tag{30}$$

and

$$w_t = (1-\alpha)\frac{y_t}{l_t} \tag{31}$$

2.6. Physical capital and housing production

Physical capital and housing producing firms are owned by patient households. These firms produce new units of physical capital and housing combining a fraction of the final goods – which they use as investment good – with the existing specific stock, and sell them to entrepreneurs and households, respectively, at prices q_t^K and q_t^H. With the purpose of producing new physical capital and new housing, the respective representative firm spends resources of

$$\left[1 + g^K\left(\frac{I_t^k}{I_{t-1}^K}\right)\right] I_t^K \tag{32}$$

and

$$\left[1 + g^H\left(\frac{I_t^H}{I_{t-1}^H}\right)\right] I_t^H, \tag{33}$$

where I_t^K is the investment from physical capital producers, and I_t^H the investment to produce new units of housing.

The objective of the representative physical capital producing firms is to maximize expected profits:

$$\mathbb{E}_t \sum_{i=0}^{\infty} (\beta^s)^i \left(\frac{c_t^s}{c_{t+i}^s}\right) \left\{ q_{t+i}^K I_{t+i}^K - \left[1 + g^K\left(\frac{I_{t+i}^K}{I_{t+i-1}^K}\right)\right] I_{t+i}^K \right\} \tag{34}$$

And the maximization problem of the representative housing producing firm is:

$$\mathbb{E}_t \sum_{i=0}^{\infty} (\beta^s)^i \left(\frac{c_t^s}{c_{t+i}^s}\right) \left\{ q_{t+i}^H I_{t+i}^H - \left[1 + g^H\left(\frac{I_{t+i}^H}{I_{t+i-1}^H}\right)\right] I_{t+i}^H \right\} \tag{35}$$

2.7. Capital management firms

Additionally, the model also entails firms that manage the physical capital, and which are owned by patient households. They manage the capital directly held by households in exchange for a fee, s_t^k, per unit of capital.

The profits of physical capital management firms are given by:

$$PI_t^k = s_t^k K_t^s - z_t^k \tag{36}$$

The revenues (per unit of capital) of capital management firms are represented by:

$$s_t^k = \xi^K K_t^{s^{\phi^K - 1}} \tag{37}$$

And the costs of capital management firms are given by:

$$z_t^k = \frac{\xi^K k_t^s}{\phi^K K_t^{s^{\phi^K}}} \tag{38}$$

2.8. Bank's capital policy rule

The setting of bank's capital requirements on bank lending is shared between micro and macroprudential authorities. In particular, capital requirements in period t are set according to the following rule:

$$\phi_t^j = \underbrace{\bar{\phi}_0^j + \bar{\phi}_1^j \left[\log(b_t) - \log(\bar{b})\right]}_{\Xi_t \equiv \text{Capital requirements}} + \bar{\phi}_{vol}^j \tag{39}$$

where ϕ_t^j stands for the capital ratio of bank j at time period t, $\bar{\phi}_0^j$ is the reference level of structural capital requirements, entailing both micro and macroprudential requirements, and $\bar{\phi}_1^j > 0$ is the feedback parameter that captures the countercyclical adjustment in capital requirements that depends on the state of the economy and is set by the macroprudential authority. In this case, we assume that the countercyclical component of capital requirements responds to the deviations of total credit, $b_t = b_t^H + b_t^F$, from its steady state value, $\bar{b}$. On top of capital requirements, we have $\bar{\phi}_{vol}^j$, which refers to the voluntary buffer.[5]

2.9. Market clearing and DIA

2.9.1. Final good market. In the goods market, total output, y_t, should equal the total consumption demands of the patient households, c_t^s, and the impatient households, c_t^m, plus the resources used in the production of new capital, I_t^K, and new housing, I_t^H, plus the resources lost by lenders in the recovery of the proceeds associated with defaulted loans, in transaction costs by depositors at failed banks,

[5]For the purpose of the analysis conducted, we assume that the voluntary buffer is invariant over time, i.e., it is kept fixed at the steady state level.

or by the deposit insurance agency in the recovery of assets from failed banks:

$$\begin{aligned}y_t =& c_t^s + c_t^m + \left[1 + g^K\left(\frac{I_t^K}{I_{t-1}^K}\right)\right] I_t^K + \left[1 + g^H\left(\frac{I_t^H}{I_{t-1}^H}\right)\right] I_t^H \\ &+ \mu^e G^e(\bar{\omega}_t^e) R_t^K q_{t-1}^K K_{t-1} + \mu^m G^m \frac{x_{t-1}^m}{R_t^H} R_t^H q_{t-1}^H h_{t-1}^m \\ &+ \gamma P D_t^b R_{t-1}^D d_{t-1} + \mu^B \left[G^H\left(\bar{\omega}_t^H\right) \tilde{R}_t^H \left(\frac{q_{t-1}^H h_{t-1}^m x_{t-1}^m}{R_{t-1}^m}\right)\right. \\ &\left. + G^F(\bar{\omega}_t^F) \tilde{R}_t^F \left[q_{t-1}^H K_{t-1} - (1-\chi^e) W_{t-1}^e\right]\right]\end{aligned} \tag{40}$$

We also consider a measure of net output, $\tilde{y}_t$, which is equal to y_t net of the expenditure associated to default:

$$\tilde{y}_t = c_t^s + c_t^m + \left[1 + g^K\left(\frac{I_t^K}{I_{t-1}^K}\right)\right] I_t^K + \left[1 + g^H\left(\frac{I_t^H}{I_{t-1}^H}\right)\right] I_t^H \tag{41}$$

2.9.2. Labour market. The total demand for households' labour by the consumption-good-producing firms, $(1-\alpha)\frac{y_t}{w_t}$, must be equal to the labour supply of the two types of households:

$$(1-\alpha)\frac{y_t}{w_t} = l_t^s + l_t^m \tag{42}$$

2.9.3. Capital good market. The law of motion of physical capital is given by $k_t = (1-\delta_t^k)K_{t-1} + I_t^K$, and market clearing requires k_t to equal the demand for this good coming from entrepreneurs at time t, which, in turn, equals the amount of physical capital rented to the consumption-good-producing firms at $t+1$.

2.9.4. Housing good market. The stock of housing evolves according to $h_t = (1-\delta_t^H)h_{t-1} + I_t^H$, and market clearing requires $h_t = h_t^s + h_t^m$.

2.9.5. Deposit market. The deposits held by the patient households (d_t) must equal the sum of the demand for deposit funding from the banks granting loans to impatient households, $d_t^H = (1-\phi_t^H)(q_t^H h_t^m x_t^e / R_t^m)$, and from the banks granting loans to entrepreneurs, $d_t^F = (1-\phi_t^F)[q_t^K k_t - (1-\chi^e)Wt^e]$:

$$d_t = (1-\phi_t^F)[q_t^K k_t - (1-\chi^e)W_t^e] + (1-\phi_t^H)\left(\frac{q_t^H h_t^m x_t^m}{R_t^m}\right) \tag{43}$$

2.9.6. Banks' inside equity market. The total equity provided by bankers should equal the sum of the demand for bank equity from the banks granting loans to impatient households and from the banks granting loans to entrepreneurs:

$$(1-\chi^b)W_t^b = \phi_t^F[q_t^K k_t - (1-\chi^e)W_t^e] + \phi_t^H\left(\frac{q_t^H h_t^m x_t^m}{R_t^m}\right) \tag{44}$$

2.9.7. Aggregate banks' balance sheet. The balance sheet of the aggregate banking sector is given by:

$$n_t^b + n^s\, d_t = n^m\, b_t^m + (q_t^k\, k_t - n_t^e). \tag{45}$$

2.9.8. Deposit insurance agency. The failing banks (H and F) lead to losses to the deposit insurance agency, which are given by

$$T_t^H = [\bar{\omega}_t^H - \Gamma^H(\bar{\omega}_t^H) + \mu^H G^H(\bar{\omega}_t^H)]\tilde{R}_t^H \left(\frac{q_{t-1}^H h_{t-1}^m x_{t-1}^m}{R_{t-1}^m}\right) \tag{46}$$

and

$$T_t^F = [\bar{\omega}_t^F - \Gamma^F(\bar{\omega}_t^F) + \mu^F G^F(\bar{\omega}_t^F)]\tilde{R}_t^F [q_{t-1}^K k_{t-1} - (1-\chi^e)W_{t-1}^e] \tag{47}$$

respectively. To cover these losses, lump-sum taxes are imposed on both patient and impatient households, requiring $T = T^s + T^m = T_t^H + T_t^F$.

The presence of a deposit risk premium raises the funding cost for banks, while the fact that this premium depends on the banking sector default risk rather than the default risk of individual banks induces an incentive for banks to take excessive risk and provides a rationale, in particular, for a macroprudential policy mandate.

2.9.9. Stochastic environment. Shocks to productivity, A_t, housing preferences, τ_t, the depreciation rates, ι_t^H and ι_t^K and risk shocks follow an $AR(1)$ process of the form:

$$\ln(S_t) = \rho^S \ln(S_{t-1}) + \varepsilon_t^S, \tag{48}$$

where $S_t = \{A_t, \tau_t, \iota_t^{K,H}, \bar{\omega}_t^e, \bar{\omega}_t^m, \bar{\omega}_t^H, \bar{\omega}_t^F\}$, ρ^S is the persistence parameter and $\varepsilon_t^S \sim (0, \sigma_t^S)$.

3. Calibration of the model

This section reports the results of the calibration of the 3D model for the Portuguese economy using data from 2001 to 2018 (see Appendix A for data sources and definitions). To calibrate the set of parameters in the model we proceed with a two-step approach. In the first step some of the parameters are preset following existing literature and conventions, and in the second step the remaining parameters are tightly linked to the first (mean) and second (standard deviation) empirical moments of key macro-financial variables.[6] These latter values are the calibration targets.

[6]The parameters in the second step are calibrated by minimizing a loss function that weighs equally the relative distance between the targeted empirical moments and the corresponding unconditional moments generated by the model approximation.

Table 1 reports the calibration targets along with the values obtained from the model. Overall, the model fits the first and second moments of the data well, since the theoretical first (mean) and second (volatility) moments computed from the model are equal, or very close, to the targeted empirical moments.

Description	**Definition**	**Data**	**Model**	**Diff.**
	(A) Means			
Fraction of impatient households (%)	$[1 - 1/(1 + n^m)] \cdot 100$	46.05	46.05	-
Return on average bank equity (%, ann)	$\rho \cdot 400$	7.12	7.12	-
Structural capital requirements (%)	$\bar{\phi}_0^F \cdot 100$	4.96	4.96	-
CET1 capital ratio (%)	$\phi \cdot 100$	8.17	8.17	-
Write-off rate for mortgage loans (%, ann)	$\Upsilon^m \cdot 400$	0.25	0.35	0.08
Write-off rate for corporate loans (%, ann)	$\Upsilon^e \cdot 400$	1.00	1.48	0.48
Mortgage loans to GDP (ratio)	$n^m b^m / GDP$	2.93	2.99	0.06
Corporate loans to GDP (ratio)	$n^e b^e / GDP$	2.24	2.24	-
Housing investment to GDP (ratio)	I^H / GDP	0.04	0.04	-
Impatient HH housing wealth share	$n^m q^H h^m$	0.53	0.51	0.02
Spread mortgage loans (pp., ann)	$(R^H - R^d) \cdot 4$	0.81	1.00	0.19
Spread corporate loans (pp., ann)	$(R^F - R^d) \cdot 4$	2.59	2.00	-0.59
Average bank default (%)	$\mathcal{F}^j(\bar{\omega}^j) \cdot 100$	2.00	2.00	-
	(B) Standard deviations $[\sigma(\cdot)]$			
STD(House prices)/STD(GDP)	$\sigma(q_t^H)/\sigma(GDP_t)$	2.63	2.60	0.03
STD(Mortgage loans)/STD(GDP)	$\sigma(b_t^m)/\sigma(GDP_t)$	4.86	4.92	0.06
STD(Corporate loans)/STD(GDP)	$\sigma(b_t^e)/\sigma(GDP_t)$	5.95	6.07	0.12
STD(Mortgage spreads)/STD(GDP)	$\sigma(R_t^M - R_t^d)/\sigma(GDP_t)$	0.08	0.07	0.01
STD(Corporate spreads)/STD(GDP)	$\sigma(R_t^F - R_t^d)/\sigma(GDP_t)$	0.08	0.09	0.01
STD(GDP)	$\sigma(GDP_t) \cdot 100$	2.76	2.78	0.02

Note: The variable Return on Average Bank Equity is based on positive values of the return on equity (ROE) and results from taking the time series average of the cross-sectional median ROE. Aggregate values for the banking sector are obtained considering a weighted average across banks, with weights given by the share of bank assets in total assets. HH stands for households, GDP for Gross Domestic Product, CET1 for Common Equity Tier 1, STD for standard deviation and Ann is short for annualized. The differences between the data and the model moments (*Diff.* column) are in absolute terms.

Table 1. Calibration targets

The fraction of impatient households is assumed to be around 46.05%, which corresponds to the average of the fraction of indebted households reported in the Household Finance and Consumption Survey (HFCS) for 2010 and 2013.[7] The share of housing wealth held by this type of households is set at 53% and it is also obtained from HFCS using information for the value of the main residence of borrowers. The ratio between housing investment and GDP is obtained from National Accounts and assumed to be 4%, i.e. the average ratio within the sample

[7] We assumed an average of the 1^{st} and 2^{nd} waves' values (46.05%) for Portugal, since the 2017 (3^{rd}) and the 2020 (4^{th}) waves' results were not available at the time the calibration was conducted. Nonetheless, the average across the four waves is very close to the one used (46.1%).

period. The importance of housing investment in GDP steadily declined up to mid-to-late 2014, reflecting the consequences of the Global Financial Crisis. Thereafter, it exhibits a very mild improvement until the end of 2018. This situation follows from increasing housing demand fostered by, among other things, tourism and foreign investment. The indebtedness levels of the household and corporate sectors, expressed in terms of GDP, are approximated by the amount of outstanding loans to households and non-financial corporations adjusted for sales and securitisation, respectively. In both sectors, two trends emerge over the sample period: a rapid increase in indebtedness levels in the run-up to the Global Financial Crisis and thereafter a consistent deleveraging path.

With respect to the bank variables, the sample of banks used comprises the other systemically important institutions (thereafter O-SII), as identified by the Banco de Portugal.[8] For this sample of resident banks, the return on average equity (thereafter ROAE) ratio is 7.12% for the time span of 2001-2017. The write-off rate for loans to impatient households and entrepreneurs is set, respectively, to 0.25% and 1%.[9] These rates increased over the last years of the time span considered for the calibration of the model, although more significantly for corporate loans. This increase is related with the action taken by resident banking groups to reduce the high levels of non-performing loans, especially those linked to non-financial corporations that are a legacy from the financial and sovereign debt crises. The spreads applied to loans to impatient households and entrepreneurs are set, respectively, to 0.81 and 2.59 percentage points.[10]

In addition, the calibration targets a Common Equity Tier 1 (thereafter CET 1) capital ratio (measured as a percentage of risk-weighted assets) of 8.17%, the average obtained across the sample of banks used for the period 2001-2017.[11] Nevertheless, the CET 1 capital ratio has been gradually increasing in the period considered on the back of tighter regulatory standards that were introduced in the aftermath of the Global Financial Crisis, among others, bank

[8]The banking groups identified as O-SII are listed at https://www.bportugal.pt/en/page/o-sii-capital-buffer.

[9]These rates are computed based on confidential data. The rate is defined as the sum of monthly adjustments (write-off) over the quarter divided by the outstanding amount of mortgage or corporate loans (monthly adjusted for sales and securitisation) at the end of the quarter.

[10]The spreads are computed as the difference between a composite lending rate and a composite risk-free rate. The composite lending rate for mortgage loans is the loan amount weighted average of mortgage lending rates for distinct maturities. The composite lending rate for corporate loans is calculated in a similar way. The composite risk-free rate is the loan amount weighted average of the Euribor rate for short maturities and the German bond yields for long maturities. The period considered for the calibration of the spreads spans from 2001 to 2018, but spreads have varied considerably over this period. Between 2001 and 2009, the spreads for corporate loans and mortgage loans were 1.60 pp and 0.26 pp, respectively, while between 2010 and 2018, these spreads increased and stood at 3.59 pp and 1.35 pp, respectively.

[11]The information time span ends in 2017, and therefore it does not include the impact of the supervisory measures taken in the context of the COVID-19 pandemic on bank capital ratios.

specific Pillar 2 requirements and macroprudential buffers.[12] During most of the time span used for calibration, the macroprudential surveillance mandate was not explicitly assigned to an authority, but there were already policy measures enacted with a macroprudential nature, as documented in the Macroprudential Policies Evaluation Database (MaPPED) (Budnik and Kleibl 2018). These policies most likely affected the level of capital ratio targeted by banks. The structural capital requirements defined in terms of CET 1 are set at 4.96%, the average of micro and macroprudential requirements in force in the period considered for the calibration.[13] The remaining value of CET 1 capital ratio is assumed to be the average voluntary buffer built-up by the banks used in the sample. The average probability of bank default is targeted to be 2.00% as in Clerc *et al.* (2015).

In terms of volatility targets, one finds that the house price volatility seems to be consistent with the positive developments in the residential real estate market after 2013, fostered, inter alia, by tourism and foreign investment.

Table 2 reports the parameter values that result from the calibration exercise. Panel (A) focuses on the parameters that were preset, while panel (B) shows the parameters that were calibrated using the data targets.

The labour disutility parameter, $\varphi^{\varkappa}$, is normalized to one for both households' type, as it only affects the scale of the economy, while the weight of housing in impatient households' utility function, υ^{s}, is set at 0.1. The Frisch elasticity of labour, η, is normalized as well. The share of capital in the production function, α, is set equal to 0.3, and the physical capital depreciation, δ^{K}, is equal to 0.03. The shocks follow a AR(1) process with the persistence parameter, ρ^{S}, set equal to 0.9. The capital requirements for mortgage and corporate loans, Ξ^{H} and Ξ^{F} are set to 2.48% and 4.96%, respectively. These targets are associated with a risk weight of 100% for corporate loans (full weight level of Basel I and the treatment of not rated corporate loans in Basel II and III) and of 50% for mortgages (weight level for Basel I), as in Clerc *et al.* (2015), to reflect the less stringent risk weights defined in the regulation for the latter type of loans. This choice of risk weights is aligned with the literature (see, for example, Balfoussia and Papageorgiou 2016; Mendicino *et al.* 2020) and, thereby, it does not reflect exactly the current practices in the Portuguese banking sector. Also, setting different levels for the risk weights, namely for mortgage loans, would not change qualitatively the conclusions.

[12] Banco de Portugal (2023). "Portuguese banking sector: latest developments – 1st quarter 2023", June. In the first quarter of 2023, the Portuguese banking sector as a whole reported a CET 1 capital ratio of 15.6%. This capital ratio is used to comply with the following CET 1 requirements: Pillar 1 requirements, bank-specific Pillar 2 requirements, capital conservation buffer, bank-specific O-SII buffer, bank-specific Pillar 2 guidance and shortfalls of AT1/T2 requirements.

[13] We assume that the structural capital requirement of 4.96% comprises the CET1 Pillar 1 requirement, the phasing-in of the capital conservation buffer (CCoB), the asset-weighted average of the bank specific O-SII buffer and the asset-weighted average of bank specific CET1 Pillar 2 requirements. This level should be seen as a lower bound for capital requirements as bank specific Pillar 2 guidance and additional requirements associated to AT1/T2 shortfalls are not considered.

Description	Par.	Value	Description	Par.	Value
		(A) Preset parameters			
Housing weight in s utility	υ^s	0.1	HH bankruptcy cost	μ^m	0.3
Disutility of labour ($\varkappa = s, m$)	$\varphi^{\varkappa}$	1	Entrep. bankruptcy cost	μ^e	0.3
Frisch elasticity of labour	η	1	Bank M bankruptcy cost	μ^H	0.3
Physical Cap. share in prod.	α	0.3	Bank F bankruptcy cost	μ^F	0.3
Physical Cap. depreciation	δ^K	0.03	Shocks persistence	ρ^S	0.9
Patient HH discount factor	β^s	0.995	Cap. req. mortgage loans (%)	Ξ^H	2.48
			Cap. req. corporate loans (%)	Ξ^F	4.96
		(B) Calibrated parameters			
Share of impatient HH	n^m	0.854	HH transaction cost	γ	0.0003
Impatient HH discount factor	β^m	0.982	Entrepreneurs' endowment	χ^e	0.043
Housing weight in m utility	υ^m	0.2674	Bankers' endowment	χ^b	0.0175
Housing adjustment cost	ξ^H	9.515	Physical Cap. adjust. cost	ξ^K	9.915
Housing depreciation	δ^H	0.004	STD banks' risk shock	σ^b	0.0649
STD productivity shock	σ^z	0.0765	STD housing pref. shock	σ^τ	0
STD of i.i.d HH shocks	$\bar{\sigma}^{\omega^m}$	0.21	STD housing depr. shock	σ^{δ^H}	0.0032
STD of i.i.d entrep. shocks	$\bar{\sigma}^{\omega^e}$	0.23	STD capital depr. shock	σ^{δ^K}	0.0021
STD of i.i.d bank M shocks	$\bar{\sigma}^{\omega^H}$	0.0159	STD Imp. HH risk shock	σ^m	0.012
STD of i.i.d bank F shocks	$\bar{\sigma}^{\omega^F}$	0.0323	STD Entrep. risk shock	σ^e	0.0608

Note: The model contains nine sources of shocks and all of them are set with the same shock persistence of 0.9. The disutility of labour is the same for patient and impatient households. HH stand for households, STD stands for standard deviation and i.i.d. stands for independent and identically distributed. s and m stand for the households' type, savers and borrowers, respectively.

Table 2. Parameters

Despite the calibrated parameters in panel (B) of Table 2 being set simultaneously, some can be directly linked to one of the targets presented in Table 1. The share of impatient households in total households, n^m, matches the fraction of impatient households (proportion of indebted households). The bankers' endowment, χ^b, is set to attain the value for the ROAE for the O-SII group of the Portuguese banking sector. The households' transaction cost (or bankruptcy cost parameter), γ, is set in order to account for losses of 10% of face value of deposits at failed banks as in Clerc *et al.* (2015). The housing weight in the utility of impatient households, υ^m, is calibrated by targeting the share of housing held by the indebted households (value of the main residence of impatient households) in Portugal. The impatient households' discount factor, β^m, and the new entrepreneurs' endowment, χ^e, are used to match, respectively, the mortgage loans to GDP and corporate loans to GDP ratios. The housing depreciation rate, δ^H, is calibrated in order to match the ratio of housing investment to GDP. The standard deviations along with the housing and physical capital adjustment costs are used to match the remaining targets in panel (B) of Table 1.

Provided with a calibration for the model, in the next two sections we assess how higher capital requirements improve the resilience of the financial system in face of adverse scenarios. In the EU capital regulation framework, all capital-based instruments imply higher absorption capacity. Nonetheless, they are linked to different policy goals, which influences their design and modality of application. For example, time-varying capital buffers (e.g. CCyB) should be built-up in periods of increasing systemic risk from excessive credit growth and released upon a negative shock that may disrupt the flow of credit to the economy. As such, they are designed to lean against the wind and reduce the likelihood of a worse-than-expected economic outcome. In turn, structural buffers (e.g. CCoB and G-SII/O-SII buffers) should be applied to mitigate systemic risk of a more permanent nature that makes the financial system more vulnerable to shocks.[14] They are thus designed to reduce the likelihood of a bank failure that could amplify the effects of a shock, which contrasts with the goal of time-varying capital buffers.

4. Assessing the impact of higher structural capital requirements

We start by assessing the role of higher structural capital requirements. More specifically, we are interested in understanding how shocks propagate under lower and higher structural bank capital requirements and whether the latter affect the transmission of shocks. It is important to point though, as stressed by an extensive literature on optimal structural capital requirements, that bank capital requirements should not increase indefinitely, because, after a certain level, the costs may surpass the benefits (Mendicino *et al.* 2020; Soederhuizen *et al.* 2021; Malherbe 2020, among others). An adequate level of structural capital requirements depends on the prevailing level of capital requirements and should be set at a level that maximises net benefits.

We compare two economies that differ on the level of capital requirements: a benchmark economy in which capital requirements are set at the calibrated structural level (4.96%), and an economy featuring a 1 percentage point (p.p.) higher level of structural capital requirements, set at 5.96%. Based on the bank's

[14] In the current macroprudential policy framework, the CCoB fits within the set of structural capital-based instruments. However, in the context of the European Commission mandate to review the macroprudential provisions in Capital Requirements Regulation (CRR) and the Capital Requirements Directive (CRD), the ECB supports creating additional macroprudential policy space to enhance the ability of the financial system to withstand large and disruptive systemic shocks that may go beyond the unwinding of domestic imbalances (unknown unknowns). One of the three policy options put forward is to turn the CCoB fully or partially releasable. For more details on this proposal, see: `https://www.ecb.europa.eu/pub/pdf/annex/ecb.annex_2_reportofdraftingteam_ecbresponsetothecallforadvice.en.pdf`.

capital policy rule defined in (39) we consider two steady states for banks' capital ratios: [15,16]

Benchmark.

$$\phi^F = \underbrace{4.96\%}_{\bar{\phi}_0^F} + \underbrace{3.21\%}_{\bar{\phi}_{vol}^F} \text{ and } \phi^H = 1/2 \cdot \phi^F;$$

Higher structural capital requirements.

$$\phi^F = \underbrace{5.96\%}_{\bar{\phi}_0^F} + \underbrace{3.21\%}_{\bar{\phi}_{vol}^F} \text{ and } \phi^H = 1/2 \cdot \phi^F.$$

We consider two adverse scenarios, each one corresponding to a different shock that impels the financial system and the economy to deviate from the steady state. These scenarios are envisaged to provide insight on which circumstances economic agents may benefit most from imposing higher structural capital requirements on the banking sector. We start by considering a stress event that directly affects the banking sector – a shock to the risk of banks' returns. Then, we assess the implications of a shock affecting directly the aggregate economy – a productivity shock. The choice of shocks is not arbitrary. The aim is to compare the stabilising effect of more resilient financial systems (i.e. with higher structural capital requirements) under distinct disturbance sources: one that at first impacts on the financial system and then propagates to the economy vis-à-vis the other shock that starts by perturbing the economy and then spill overs to the financial system. The next subsections present the results of the simulation exercises for each source of disturbances (see also Appendix B for more simulation results).

4.1. Scenario of financial turbulence

In the scenario of financial turbulence, we consider a shock to the risk of banks' return, which will increase the probability of bank default, causing a distress in the banking sector. This scenario resembles a large stress event originating within the financial system and then propagating to the economy. Macroprudential capital buffers are precisely designed to prevent and mitigate systemic risk stemming from the financial system and, as such, we should expect that economies characterised

[15] In this exercise, we only change the level of capital requirements in the calibration, while we keep the other calibrated parameters fixed. Then, we compute a new steady state that is consistent to the changed calibration for capital requirements. The assumption that other parameters are kept fixed at their original calibrated values can be considered a reasonable one for two reasons. First, the change in capital requirements is not substantial and, second, the modelling options assume a representative bank.

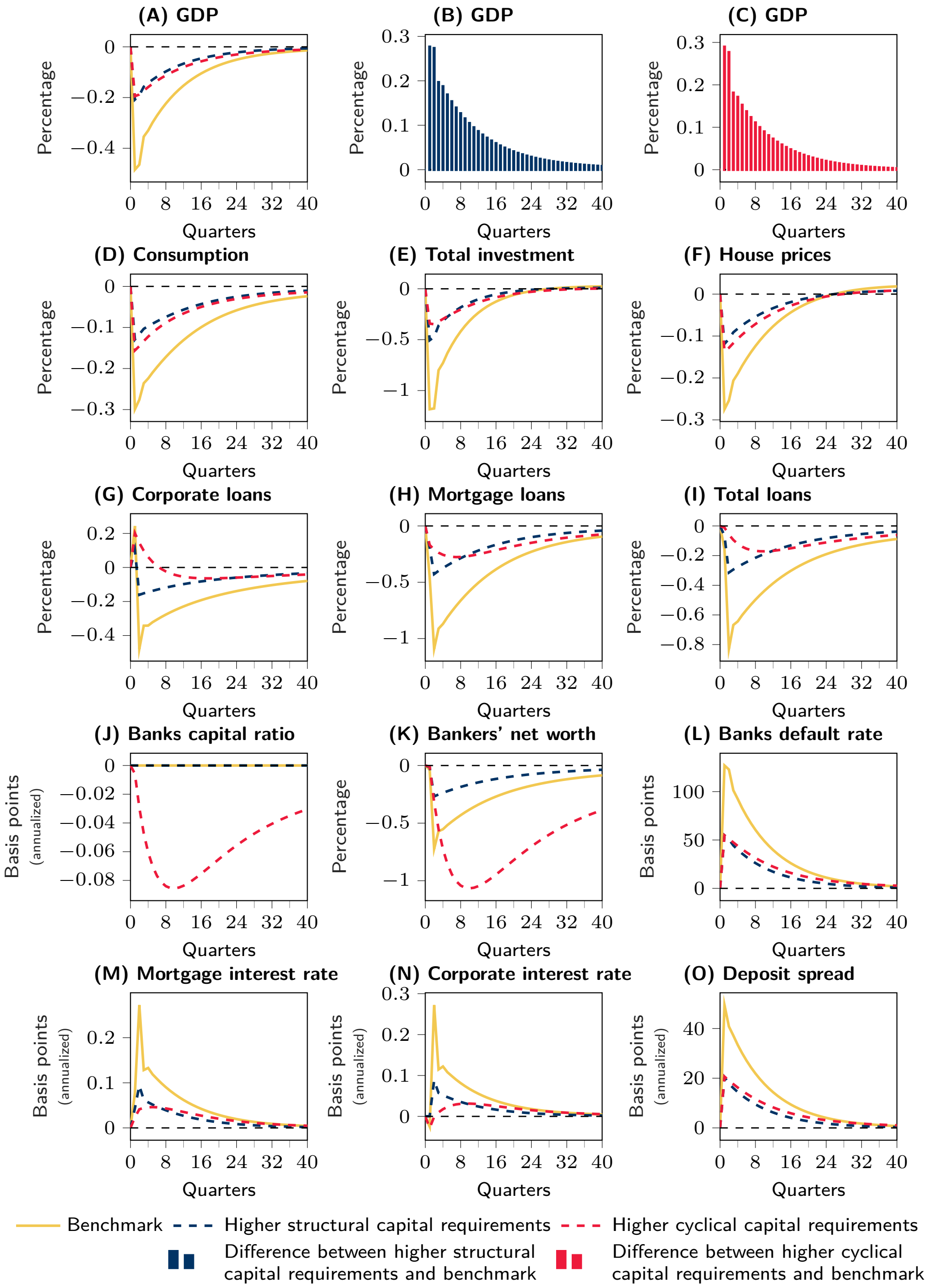
[16] Notice that for the purpose of the exercise it is indifferent whether we consider the add-on of 1 p.p. in the structural capital requirement or in the voluntary buffer, as we assume that both are kept fixed over time and fulfill their primordial objective of increasing banks' resilience. In addition, as already mentioned, we set lower capital requirements for mortgage loans, ϕ^H, compared to corporate loans, ϕ^F, to reflect the less stringent risk weights defined in regulation for the former type of loans.

by increased banking sector resilience due to higher structural capital requirements should be able to withstand better the impact of shocks originated within the financial system. Specifically, the shock consists of an increase of 10% in the risk of banks' returns, translating a scenario of high uncertainty about loan portfolio performance.

Figure 2 displays the impulse response functions (thereafter IRF) for a set of financial and macroeconomic variables. The IRF show the deviation from the steady state for each variable under analysis in response to a given shock. The solid yellow line illustrates how the economy would evolve under the calibrated capital requirements policy (benchmark), while the dashed blue line displays the response under higher structural capital requirements. Panel (B) of figure 2 displays the absolute difference between the GDP response of the economy with higher structural capital requirements and the GDP response of the benchmark economy in a scenario of financial turbulence.

Benchmark. A shock to the risk of banks' return causes a rise in bank default risk and produces a loss to the bankers' net worth. Overall, higher deposit funding costs and the reduced availability of bank capital lead to a decrease in both mortgage and corporate loans, which is channelled to the economy in the form of lower GDP. It is important to note, though, that the response of mortgage and corporate banks is quite distinct in the quarters following the shock: corporate loans increase immediately after the shock, while mortgage loans decrease. This situation results from two model constraints that jointly determine the allocation of credit in each period (see Appendix C). First, the total amount of credit that banks are allowed to grant is constrained by the need to balance bankers' assets (loans) to liabilities (net worth plus deposits). Second, the allocation of credit is determined by the need to comply with capital requirements, i.e. bankers' net worth must equal the amount of risk-weighted assets. The shock immediately reduces bankers' net worth and the amount of deposits, which impact negatively on the liability side of bankers' balance sheet. To restore the equilibrium in the balance sheet, total credit needs to reduce and there is a reallocation of credit towards the corporate sector vis-à-vis the household sector, as the former delivers higher returns than the latter. In parallel, the fall in bankers' net worth also dictates a reduction in total credit via the capital requirements constraint and a reallocation of the loan portfolio towards the household sector given the lower risk weights. In the first quarter after the shock, these channels taken together lead to effects on mortgage loans and corporate loans with opposite signs. In that period, the effects induced via the balance sheet constraint dominate the effects implied by the capital requirements constraint. In subsequent periods, bankers' net worth keeps decreasing, exerting negative effects on credit via the balance sheet and the capital requirements constraints, ultimately leading to a decrease of corporate loans as well.

Higher structural capital requirements. Although qualitatively the response to the shock is similar to the benchmark case of lower structural capital requirements, quantitatively results are very different. The banks' default rate still increases for



Note: Impulse responses from an increase of 10% on banks' idiosyncratic risk, which affects the volatility of banks' expected returns and consequently their probability of default.

Figure 2: IRF on a scenario of financial turbulence

the higher structural capital requirements economy, but much less than for the benchmark case. By keeping bank defaults lower and bankers' net worth losses less sizable, higher levels of capital requirements reduce the contractionary impact of the increase in bank funding costs and of the decline in credit supply that would have otherwise occurred. The lower impact on banks' default rate related to higher structural capital requirements is thus translated into a less fragile economy, reflecting the reduced impact on credit to impatient households and entrepreneurs. The credit response explains the slight fall in investment and consumption and, hence, in GDP. All those factors account for a significantly lower impact on GDP over the stress event in the case in which banks are better capitalized, compared to an economy featuring a more leveraged banking sector (Panel (B) of figure 2). According to these results, higher structural capital requirements produce sizable benefits in terms of a small output reduction and a smaller variation in bank failures. As banks have more capital to tackle the potential losses, credit restrictiveness as a response to the shock becomes less severe. Therefore, the impact of the financial crisis on the economy is more moderate and the recovery towards the steady state is faster in comparison with the benchmark case. Capital requirements also have a stabilizing effect on the economy through investment. Notwithstanding, there are limits to the level of structural capital required by the policymaker given that further increases, after a certain level, yield more costs than benefits.

4.2. Scenario of economic slowdown

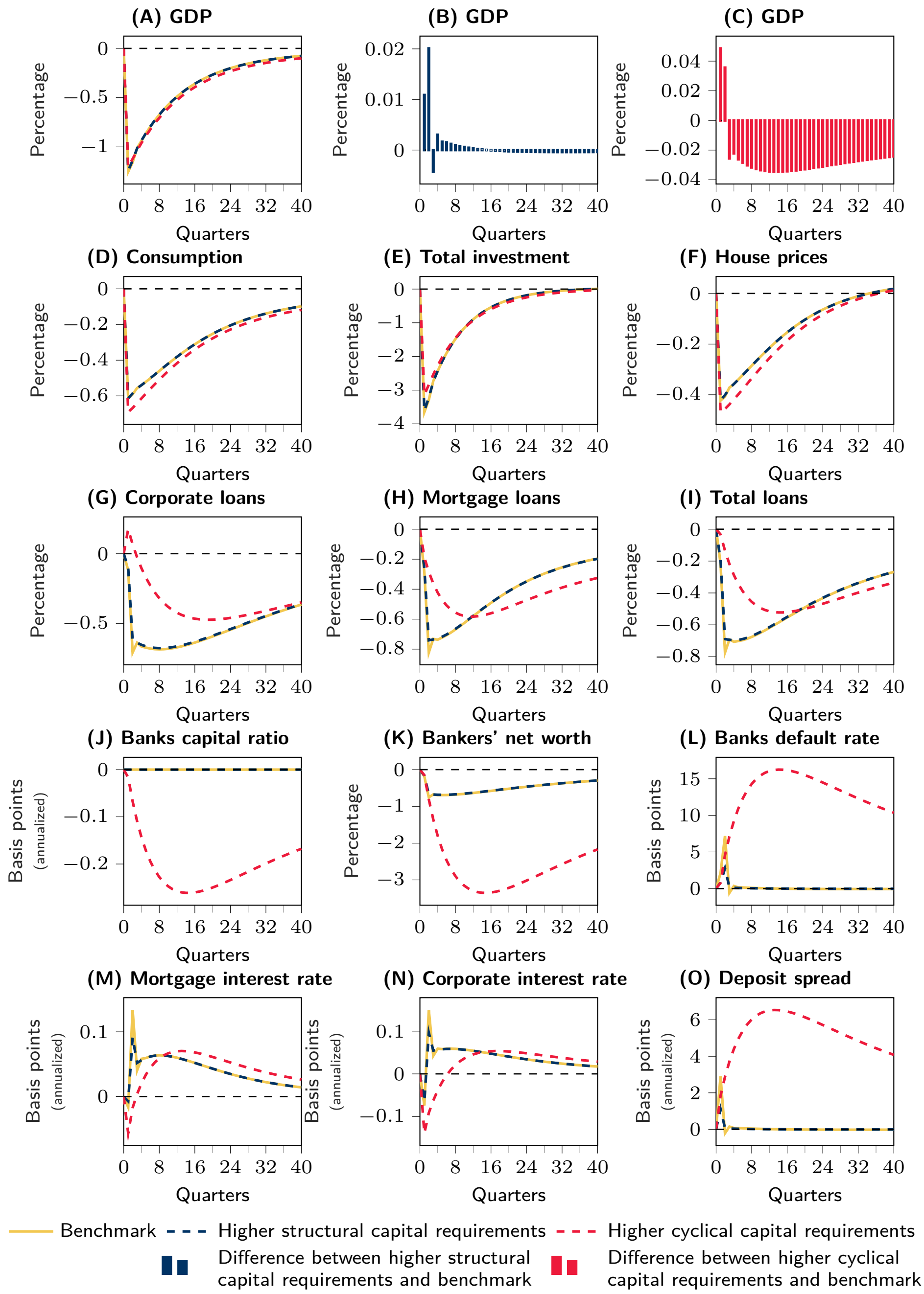
The tightening of macroprudential regulation is meant to increase the resilience of the financial system against adverse shocks, reducing the potential impairment of the financial system that can spillover to the economy. Besides the analysis of stress events originated in the financial system and propagating to the economy, it is also relevant to assess the resilience of the financial system to shocks that come from the economy side. One possible way to simulate a shock originating in the economy is through a disturbance in the total productivity factor (TPF). By decreasing the productivity of both production factors, this shock reduces economic activity and might undermine both expected returns of entrepreneurs and households. Induced by the consequent limitations in the respective budget constraints, the capacity of both entrepreneurs and impatient households to fulfil their obligations will be adversely affected. Figure 3 displays the IRF for a set of variables when the economy is hit by a negative TPF shock of 1%. The results for the benchmark economy are presented under the solid yellow lines, while the results for the economy with higher structural capital requirements are presented under the dashed blue lines. As previously, Panel (B) shows the absolute difference in the GDP response to a TPF shock of the two economies considered.

Benchmark. The negative TPF shock considered resembles a mild economic downturn and affects directly and immediately the economic variables, such as GDP, consumption and investment. A reduction on aggregate productivity leads to a decrease in spending and production, which decreases the relative prices of housing and physical capital. Consequently, the demand for loans decreases and the default of impatient households and entrepreneurs on their loans increases, reducing bank capital. Bank default rate also increases driven by the lower capital ratios, inducing a higher deposit funding cost required by patient households, which leads to higher credit spreads charged by banks. Taken together, these channels decrease further the price of houses and physical capital, leading to higher default rates of impatient households and entrepreneurs. These effects in the banking sector feed back to the economy through the reduction of investment.

Higher structural capital requirements. Simulation results indicate that a more stringent capital regulation allows banks to better withstand the shocks emerging from outside of the financial system avoiding their amplification. This is due to the less severe impact experienced by a better capitalized banking sector, namely on banks' default rate and thereby on loan spreads. Despite the small magnitude of the shock, there are benefits of the improved resilience in the financial system driven by the banks' higher capital ratios. The benefits on the other economic sectors are not so evident as in the financial turbulence scenario, but they exist as shown in panel (B) of Figure 3. We argue that the more muted role of higher capital requirements to counteract the effects of the shock on the real side of the economy follows from the shock's nature. Prudential policies are not meant to be the first line of defense to address the effects stemming from aggregate demand shocks, this is within the scope of other policy areas. Nevertheless, a more resilient banking sector prevents the amplification of shocks reinforcing the effects of other more adequate policies not considered in this analysis. A case in point being the role that banks had in successfully channelling some of the COVID-19 support measures that were key to prevent a even worse economic outcome. As such, results indicate that the origin of the shock plays a role in the assessment of the effectiveness of capital regulation in counteracting their negative impact on the economy side.

4.3. Main remarks of the assessment of the impact of higher structural capital requirements

The analysis conducted in this section entails interesting insights concerning the effectiveness of capital regulation policies and their limitations. The first conclusion is that a more resilient banking sector is able to better withstand the impact of adverse shocks, regardless of their origin, although it is much more effective in mitigating its impact on the real side of the economy if the distress is triggered by the financial system. In this latter case, the lower rate of bank default in the higher structural capital requirements economy vis-à-vis the benchmark economy brings deposits funding costs down and dominates the higher costs with equity to be borne by the banks following the shock. As a consequence, the impact on lending and output is lower and the economy tends to converge faster towards the steady state vis-à-vis the benchmark case. This outcome underscores the importance of the



Note: Impulse responses from a decrease of 1% in the total productivity factor, affecting directly the output of the economy.

Figure 3: IRF on a scenario of economic slowdown

complementary role of micro and macroprudential capital regulation in fostering financial stability.

Second, improving the resilience of banks via a tightening of structural capital requirements helps curbing the spill over effects of economic shocks to the financial system avoiding amplification effects, since the effects on the banks' default rate are more contained under the higher structural capital requirements case vis-à-vis the benchmark economy.

Third, simulation results indicate that the economy also benefits from a more resilient banking sector, as less constrained total credit moderates, to some extent, the negative impact on output of shocks arising from the rest of the economy. Against this background, there are benefits stemming from a more resilient banking sector. Nonetheless, the source of the disruption is a key aspect to consider when assessing the effectiveness of capital regulation, particularly in what concerns the mitigation of the feedback loops between the financial system and the economy. As clearly shown in the context of the Covid-19 pandemic, a resilient banking sector is also a key condition for the success of other policy measures, such as monetary and fiscal policies.

5. The comparative assessment of structural and cyclical capital requirements

Now that we have assessed the role of structural capital requirements in mitigating the first and second round effects of a variety of economic shocks, we are also interested in evaluating the effectiveness of time-varying capital instruments, together with structural ones. Given that these different capital buffers often coexist in the macroprudential toolkit, understanding the interactions between these instruments is important to achieve a consistent approach to macroprudential policy. This can be done by exploiting synergies and complementarities between the different types of capital add-ons, thereby reinforcing their impact and limiting their unintended effects.

The analysis conducted in this section is based on the same two scenarios of economic and financial distress previously defined, but entails the comparison of three bank capital policy rules. The first two capital rules consider only structural capital requirements, as previously defined: the first is the benchmark policy rule where the structural capital requirements are set at the calibrated level and the second is the higher capital requirements policy rule where the structural capital requirements are tightened by 1 p.p.. The third case is new and refers to a policy rule that includes not only structural capital requirements, but is also extended to feature a time-varying component as defined in (39). More precisely, we define the third policy rule as:

Higher capital requirements with a countercyclical component.

$$\phi_t^F = \underbrace{4.96\%}_{\bar{\phi}_0^F} + \overbrace{1\%}^{\text{Cyclical buffer}} + \underbrace{1.25}_{\bar{\phi}_1^F} \cdot \left[\log(b_t) - \log(\bar{b})\right] + \underbrace{3.21\%}_{\bar{\phi}_{vol}^F} \text{ and } \phi^H = 1/2 \cdot \phi^F;$$

Specifically, we assume that prior to the shock a surge in cyclical systemic risk motivated the accumulation of the countercyclical capital buffer of up to 1%. This additional resilience is time-varying and thereby is now available to be used by the banks following a perturbation to the economy or financial system. This time-varying component reacts countercyclically to the behaviour of total credit, by responding, by a factor of 1.25 ($\bar{\phi}_1^F$), to deviations of total credit (b_t) from its steady state value ($\bar{b}$).[17] This mechanism resembles the way the countercyclical capital buffer was introduced in the European macroprudential framework. For simplicity, and since we are only assessing the effects of shocks that negatively affect the financial system and the economy, we consider that a fraction of the cyclical component of the capital requirements, no greater than 1%, can be released. In this way, the time-varying component of capital requirements will decrease if, after a shock, total credit dynamics are below its steady state value, resembling the purpose of a countercyclical capital buffer.

Based on scenarios of financial turbulence and economic slowdown, the simulation exercises described below provide a comparative assessment of the effectiveness of structural and cyclical capital requirements under distinct sources of disturbances, focusing on their impact on relevant variables underlying the key policy objectives (see also Appendix B for more simulation results).

5.1. Scenario of financial turbulence

As in the previous section, in the scenario of financial turbulence the shock consists of an increase of 10% in the risk of banks' returns, resulting in a scenario of high uncertainty about loan portfolio performance. The dashed red line in Figure 2 displays the IRF for a set of financial and macroeconomic variables for the economy under higher countercyclical capital requirements. The comparison between the two dashed lines allows contrasting the shock response of two economies that have the same level of capital requirements, but in one case they consist of only structural buffers whereas in the other case they result from a mix between structural and cyclical buffers. Despite the different policy goals of the two instruments, they both increase bank's capacity to absorb potential losses resulting from adverse shocks. Panel (C) of Figure 2 presents the absolute difference in GDP response to

[17] The choice of the response factor of 1.25 was made in an ad hoc manner, with the purpose of approximating to the operational aspects of the countercyclical capital buffer foreseen in the regulation. Nonetheless, the response factor can be defined in such a way that takes into account the credit volatility and the buffer cap of 2.5% of risk-weighted assets. In qualitative terms, the results would not change significantly if another value for the adjustment factor was chosen.

a scenario of financial turbulence between an economy under higher cyclical capital requirements and the benchmark economy.

In contrast with the case of higher structural capital requirements, where the buffer above the baseline calibration remains at a constant level throughout the whole simulation exercises' horizon, in the higher countercyclical capital requirements the capital surplus of 1 p.p. can be reduced (fully or partially) as a response to a contraction in total credit. Therefore, following the police rule defined in (39), the amount by which capital requirements will fall is a function of how deep the contraction in total loans will be.

In the case of higher cyclical capital requirements, the response of the macroeconomic variables with respect to their steady state values still holds qualitatively and quantitatively compared to the case of higher structural capital requirements. The presence of higher capital requirements in the banking sector is the key factor contributing to reduce the magnitude of the impact of the shock on economic variables. The fact that the nature of the policy instrument used to achieve higher resilience is less significant for the results, points to the presence of substitutability effects between structural and cyclical capital buffers,when the policy goal is to enhance the resilience of the banking system.

In terms of financial variables, the response of the economy under higher cyclical capital requirements is for most variables qualitatively similar to the response of the economy under higher structural capital requirements. There is, though, a marginal smoothing effect in some variables, such as interest rates and corporate and mortgage loans, compared to an economy characterised by higher structural capital requirements. This smoothing effect stems from the possibility to release the countercyclical component of capital requirements in response to the shock and is achieved at the expenses of a reduction in bankers' net worth. Together with the marginal rise in impatient households' and entrepreneurs' default rates, the lower interest rates induce a fall in banks' income, while the deposits' spread remains unchanged, vis-à-vis the higher structural capital requirement case.[18] Taken together, these effects lead to higher depletion of bankers' net worth and a slightly higher banks' default rate than in the economy under higher structural capital requirements.

Nonetheless, since the fall in total loans that is observed in the benchmark scenario is already largely reduced by the higher structural capital requirements policy rule, the benefits stemming from the release of the cyclical component of capital requirements are subdued. Still, the marginal reduction in the capital requirements due to the release of the countercyclical capital buffer in response to the shock allows for a small but non-negligible reduction in a number of the variables in the model, highlighting the complementarity between structural and cyclical capital requirements in mitigating the adverse impact of the shock and its

[18] The deposit spread is given by the difference between the deposit interest rate and the risk free rate.

propagation to the economy. The main exception is the more marked response of the bankers' net worth, whose adjustment allows for the smoothing effects on the other variables.

In summary, the results obtained for the higher structural capital requirements policy rule highlight the benefits from having a resilient financial system, able to absorb losses without disrupting the flow of credit granted to the economy. Under a more resilient banking sector, the need for macroprudential authorities to act and relax cyclical capital requirements in face of a stress event originating in the financial system is reduced. Despite the build-in phase of the countercyclical capital buffer being outside of the scope of this exercise, our results show that its (ex-ante) implementation helps to further reduce the adverse effects from stress events originated inside of the financial system itself by smoothing the effects.[19]

5.2. Scenario of economic slowdown

To complement the analysis based on a shock originating in the financial system, we now focus on a negative and mild productivity shock to assess the effects of structural and cyclical capital requirements under a stress event that breaks out in the economy (see Figure 3). The shock response of the economy with higher cyclical capital requirements is displayed by the dashed red lines in 3. Furthermore, Panel (C) of 3 presents the absolute difference in GDP response to a scenario of economic slowdown between an economy with higher cyclical requirements and the benchmark economy.

As shown before, under the higher structural capital requirements economy, banks are able to better withstand the economic slowdown, since a better capitalization of the banking sector helps to reduce the increase in the default rate of banks, as more capital is available to absorb losses. The higher cyclical capital requirements policy rule, and the inherent flexibility it provides, produces almost the same effects on the economy as the two other alternative economies. It stands out, however, that the impact of the shock is smoothed by considerably flattening the swings in credit flows to both impatient households (mortgage loans) and entrepreneurs (corporate loans). This smoothing effect helps limiting the transmission of the effects of a disturbance originated in the economy to the banking system, allowing banks to fulfill their role as financial intermediaries.

The lower fall in corporate loans, in comparison with the other two cases, contributes to a reduction in entrepreneurs' net worth losses, helping to stabilize the stock of physical capital and, consequently, to reduce, even if mildly, the decline

[19] Principle 1 of the Recommendation of the European Systemic Risk Board of 18 June 2014 on guidance for setting countercyclical buffer rates (2014/C 293/01) establishes the objective for an appropriate assessment and setting of the countercyclical buffer rates applicable in the respective Member State. It defines the protection of the banking sector against potential losses associated with a build-up of cyclical systemic risk, in order to support a sustainable provision of credit to the economy throughout the financial cycle, as primary objective.

in production. On the impatient households' side, the lower impact on mortgage credit allows for reducing the negative impact on their housing stock. Still, housing investment and, thereby, the total housing stock decline by more, due to lower demand of housing by patient households. These dynamics in the housing market push house prices slightly further down.

The flexibility provided by the countercyclical component of capital requirements, helping to contain amplification effects, implies an increase in banks' default rate, due to the fall of both banks' capital ratio and bankers' net worth. The higher bank default rate imposes larger deposit insurance costs borne by households, while their budget constraint imposes more restrictions on goods consumption – and on housing consumption, in the specific case of patient households. This mechanism translates that banks with lower levels of capitalisation are typically perceived as riskier by the market and therefore would face higher probabilities of default and higher costs for raising equity.

Allowing a countercyclical response of capital requirement has small effects on mitigating the fall in GDP on the short term, compared to an economy in which capital requirements cannot be released. This finding is explained by the larger fall in housing investment and consumption, that offsets the better response of business investment.

Nonetheless, our results show that, under a higher capital requirements policy rule, either structural or cyclical, the starting point is a more resilient financial system that prevents the emergence of amplification effects of the shock. Also, if the banking sector is capitalised in an appropriate manner prior to the shock, the probability of default will be small and its temporary increase after the release of the countercyclical capital buffer will be also low, not putting at stake the solvency of the banking sector. This insight provides support for combining the two types of policy instruments and reaping the benefits of exploring their substitutability – in increasing resilience in the build up phase – and complementarity – in smoothing the effect on credit in a crisis event. If the economy is only subject to more stringent structural capital requirements, we can think that macroprudential authorities may be more constrained in releasing part of the structural requirements in face of a shock. However, in the case there is, on top of structural capital buffers, a countercyclical capital buffer, macroprudential authorities will be able to release that time-varying component, smoothing the impact on credit flowing to the economy and, through this channel, it will be able to amplify the effects of capital resilience in counteracting the propagation of shocks in the economy.

5.3. Main remarks of the comparative assessment of structural and cyclical capital requirements

The analysis conducted in this section highlights the drivers for the use of macroprudential capital instruments and the importance of considering countercyclical capital instruments in combination with structural ones. First, when the disturbances occur inside the financial system itself, most of the improvements come from the increased resilience that higher capital requirements provide, regardless of their structural or countercyclical nature. Higher capital requirements diminish the potential impact of the disturbances on the functioning of banks and consequently on the flow of funds supplied to the economy, and thereby reduce the need to use the countercyclical component of capital requirements. This result highlights the strategic complementariness of the two capital-based instruments, but also the presence of substitutability effects.

Second, in the presence of a stress event with origin in the economy, while higher structural capital requirements reduce potential contagious and feedback effects from the financial system, the release of countercyclical buffers permits to smooth the disturbances in the credit supplied by banks, attenuating the effects on investment decisions from entrepreneurs. Despite the marginal effect on GDP, it helps to alleviate the burden in agents financing costs.

Nonetheless, the flexibility granted in reducing capital requirements should be wisely used as it might increase temporarily the banks' default rate with potential costs for households in the form of insurance deposits. Therefore, the transmission effects of countercyclical capital requirements entail both benefits and costs. In order to mitigate the costs of releasing countercyclical capital requirements, our results suggest that the capitalization of the banking sector may be improved through the combination of countercyclical capital buffers and structural ones, ensuring that the banks' default rate remains at low levels, despite of its increase as a result of the release of the countercyclical buffer.

Third, the results highlight that the usefulness of countercyclical capital requirements are closely appended on the source of the disturbances, similarly to what we concluded for the structural capital requirements. If disturbances have root on the economy, their usefulness will be noticed in the mitigation of the pro-cyclical behaviour of banks. If they arise in the financial system itself, their effectiveness is mainly related to the improved resilience of the banking sector along the build-up phase, determining a higher absorption capacity of the banking sector. In case systemic risk materialises within the financial system, banks will be more able to fulfill their role of financial intermediaries and the need for using the flexibility provided by the release of the countercyclical buffer is reduced.

Overall, our results suggest that the countercyclical capital buffer achieves the policy objective of reinforcing resilience of the banking sector in the expansion phase of the credit cycle, helping the banks to better withstand the negative effects of adverse shocks. In the contraction phase of the credit cycle, this instrument is able to smooth the crunch in credit flows, mitigating the feedback loops between the banking sector and the rest of the economy.

6. Conclusions

The assessment of how higher structural capital requirements improve the resilience of the banking sector under adverse scenarios provides three main insights. First, regardless of the origin of the stress event, the increase in banking sector resilience helps to better withstand the impacts of shocks by avoiding amplification effects. This insight provides support for combining the two types of policy instruments and reaping the benefits of exploring their substitutability – in increasing resilience in the build up phase – and complementarity – in smoothing the effect on credit in a crisis event. However, the increase in capital requirements by the policymaker is not unbounded. After a certain capital ratio level, the net benefits of further increases become negative as shown by the literature.

Second, the effectiveness of a better capitalized banking sector is highly enhanced when the stress event emanates from the financial system itself, reducing the propagation of the shock to the economy. This result underscores the importance of the source of distress to the effectiveness of bank capital instruments and their potential limitations for the mitigation of feedback loop effects between the financial system and the rest of the economy. Prudential policies are not meant to be the first line of defense to address, for example, the effects stemming from aggregate demand shocks, this is within the scope of other policy areas. Nevertheless, a more resilient banking sector prevents the amplification of shocks reinforcing the effects of other more adequate policies not considered in the analysis. As clearly shown in the context of the Covid-19 pandemic, a resilient banking sector is also a key condition for the effectiveness of other policy measures, such as monetary and fiscal policies.

Finally, the results also suggest that structural and cyclical capital-based instruments are strategic complements. Although they target different policy goals, they both reinforce the resilience of the banking sector and its capacity to withstand the shocks. Moreover, if (both micro and macroprudential) structural requirements are set in an appropriate manner, the space for using the countercyclical capital buffer in the event of a shock is wider, since the potential costs associated to an increase of the bank default rate will be lower, according to the results obtained with this model.

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Appendix A: The data

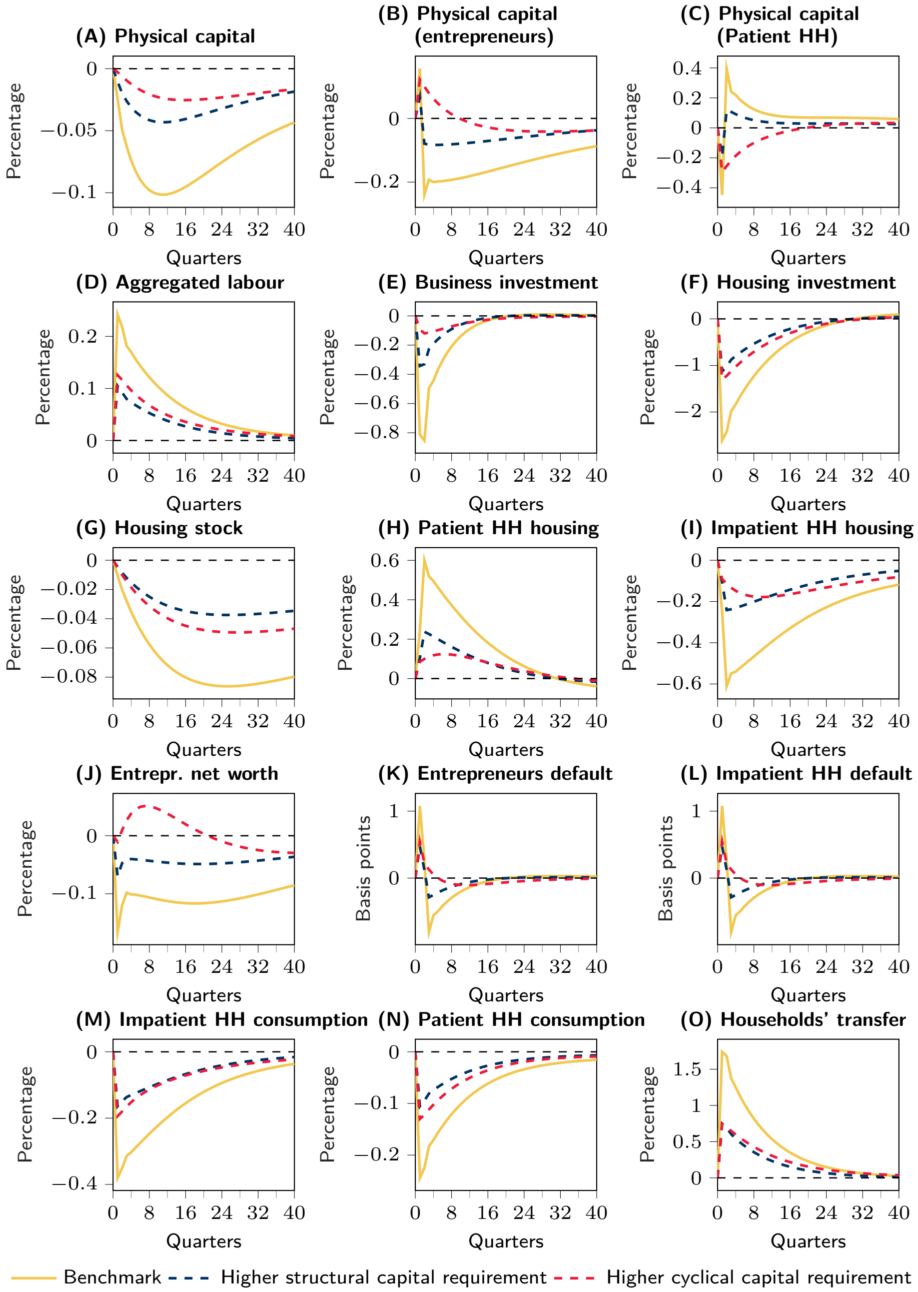
Description	Frequency	Sample	Source
Total mortgage loans	Monthly	2001M1 - 2018M12	ECB SDW
Total corporate loans	Monthly	2001M1 - 2018M12	ECB SDW
Mortgage loans write-offs	Monthly	2001M1 - 2018M12	Confidential data
Corporate loans write-offs	Monthly	2001M1 - 2018M12	Confidential data
Spread on mortgage loans	Monthly	2001M1 - 2018M12	ECB SDW and OC
Spread on corporate loans	Monthly	2001M1 - 2018M12	ECB SDW and OC
GDP	Quarterly	2001Q1 - 2018Q4	SP
Housing investment	Quarterly	2001Q1 - 2018Q4	ECB SDW
House prices index	Quarterly	2001Q1 - 2018Q4	BIS and SP
Return on average equity (ROAE)	Annual	2001 - 2017	Banco de Portugal
CET1 capital ratio	Annual	2001 - 2017	Banco de Portugal
Fraction of impatient HH	–	{2010, 2013}	HFCS
Housing wealth held by imp. HH	–	{2010, 2013}	HFCS

Notes: SDW stands for Statistical Data Warehouse, OC stands for own calculations, SP stands for Statistics Portugal, HFCS stands for Household Finance and Consumption Survey, ECB stands for European Central Bank, and BIS stands for Bank for International Settlements.

Table A.1. Data description

Appendix B: Impact of higher structural and cyclical capital requirements

B.1. Scenario of financial turbulence



Note: Impulse responses from an increase of 10% on banks' idiosyncratic risk, which affects the volatility of banks' expected returns and consequently their probability of default. HH stands for households.

Figure B.1: IRF on a scenario of financial turbulence

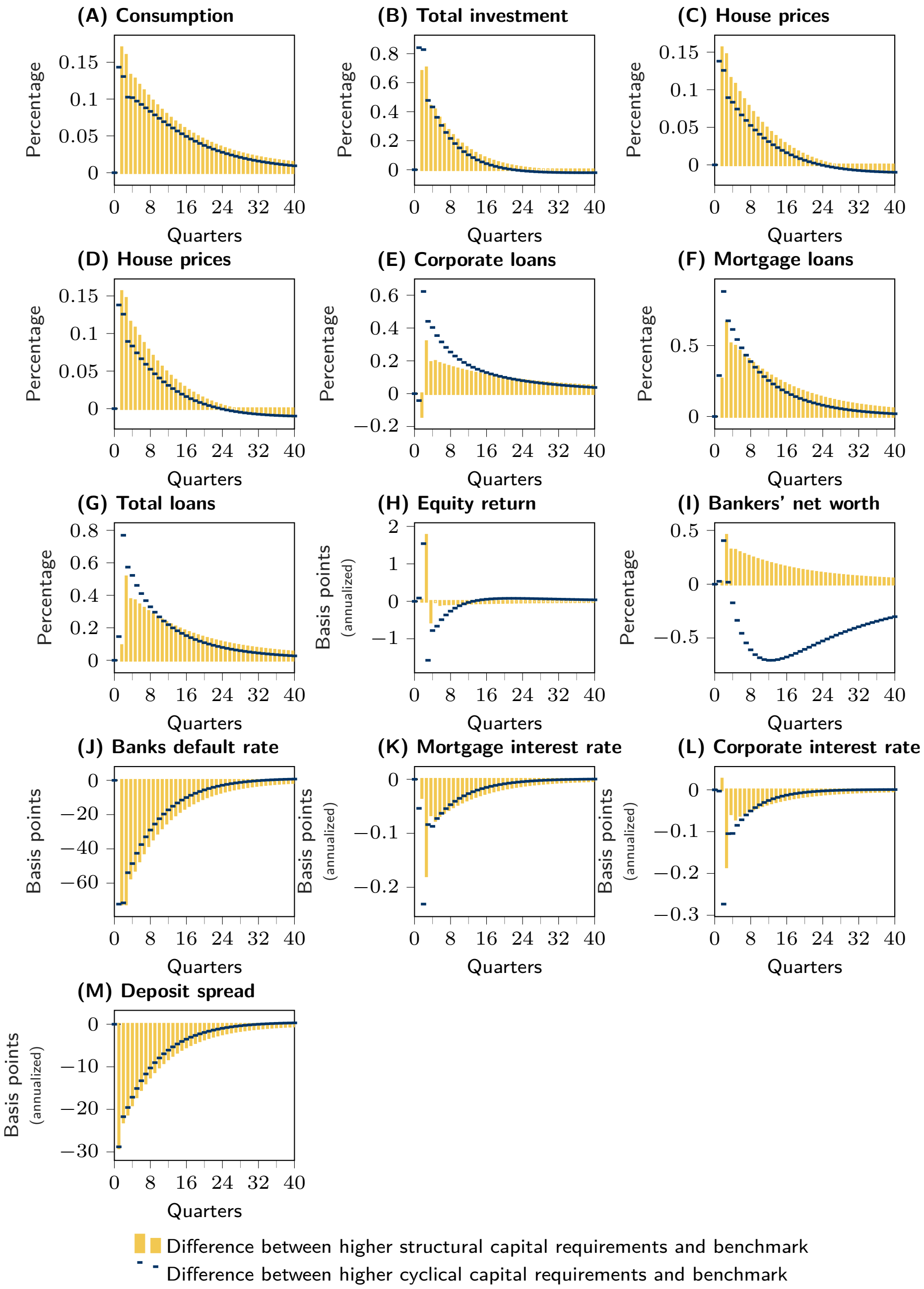
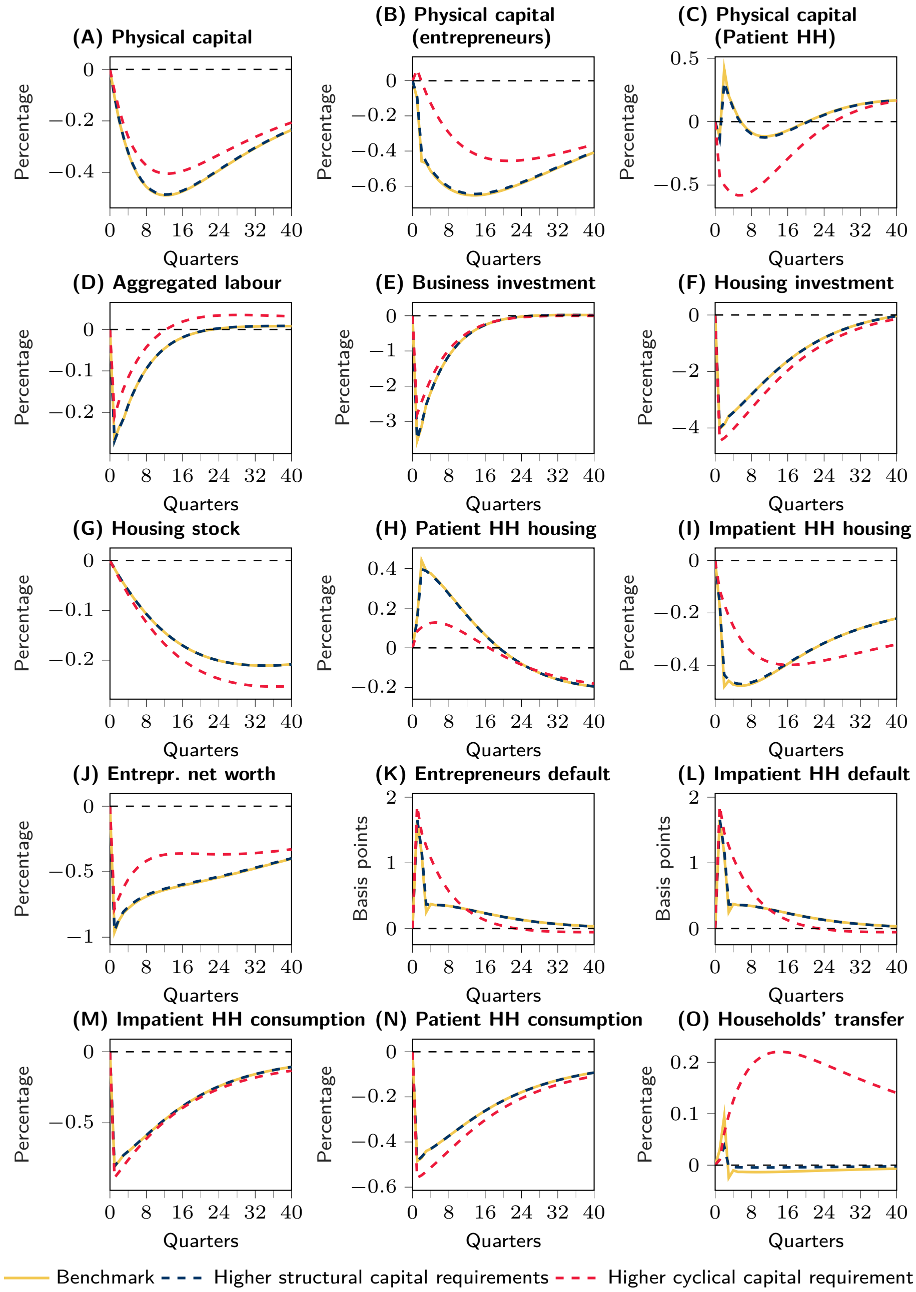


Figure B.2: Impact of higher structural capital requirements under a scenario of financial turbulence

B.2. Scenario of economic slowdown



Note: Impulse responses from a decrease of 1% in the total productivity factor, affecting directly the output of the economy. HH stands for households.

Figure B.3: IRF of a scenario of economic slowdown

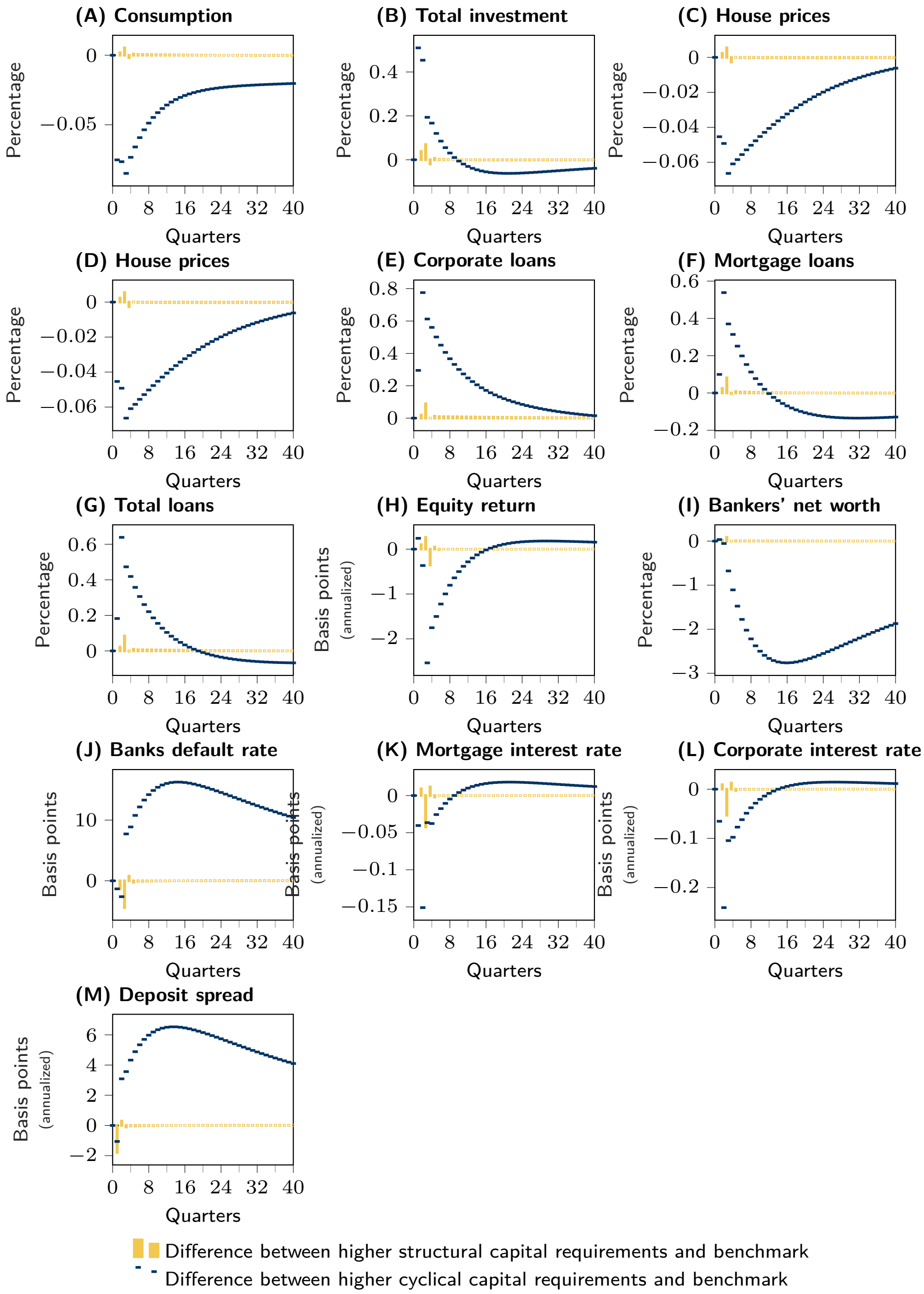


Figure B.4: Impact of higher structural capital requirements under a scenario of economic slowdown

Appendix C: Credit allocation in a scenario of financial turbulence

In equilibrium, banks face two constraints that jointly affect the allocation of resources, i.e. the amount of mortgage and corporate loans. Firstly, the balance sheet constraint limits the amount of total credit that banks are allowed to grant:

$$n_t^b + n^s \, d_t = b_t^e + n^m \, b_t^m.$$

Secondly, for a given level of bankers' net worth, the need to comply with capital requirements forces a specific allocation of credit between impatient households and entrepreneurs. Namely, the banks face the following constraint at the aggregate level:

$$n_t^b = \phi_t^F \, b_t^e + \phi_t^H \, n^m \, b_t^m.$$

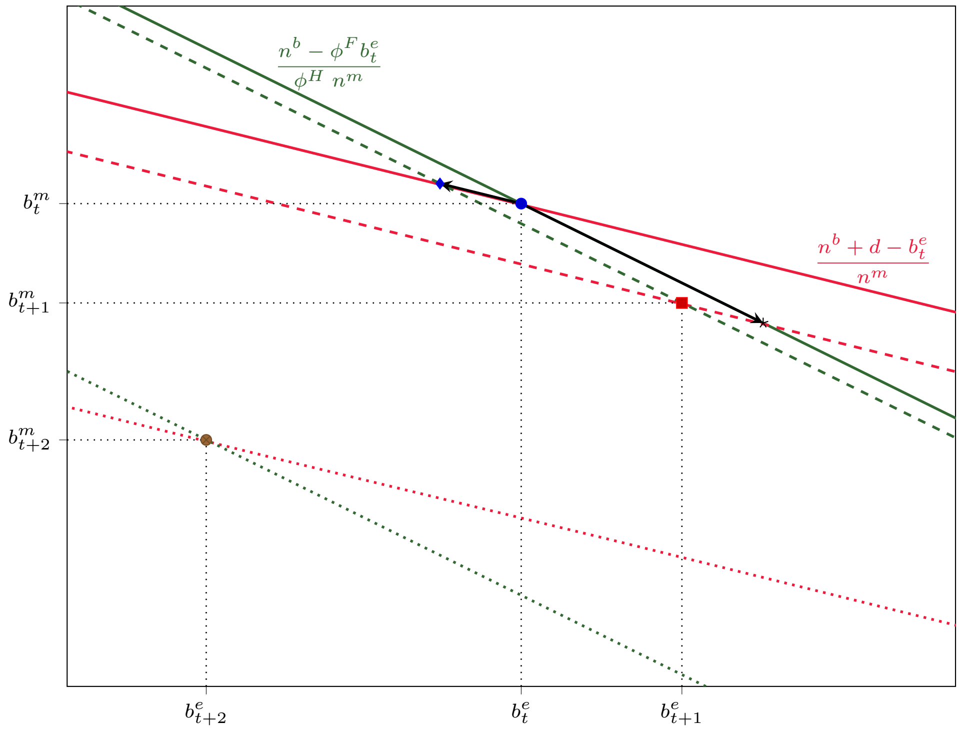


Figure C.1: Credit dynamics on the first two quarters after the financial turbulence shock

Figure C.1 illustrates how credit allocation is determined in the model by the two previous constraints in the two quarters after a financial turbulence shock. Let's assume that the economy is in equilibrium in quarter t (blue dot) and it is hit by a shock. This shock induces changes in credit allocation in quarters $t+1$ and $t+2$. The green and red lines represent the possible allocations between mortgage and corporate credit, taken as given bankers' net worth and deposits in each period.

The two constraints play a role in transition dynamics and the effects on the two types of credit may differ depending on how bankers' net worth and deposits are affected by the shock. The nature of the shock implies a fall in banker's net worth and deposits, resulting in the emergence of two opposing forces. On the one hand, the banks balance sheet constraint exerts a reallocation of assets that triggers a higher reduction of mortgage credit in detriment of corporate credit. On the other hand, the capital requirements constraint exerts a force in the opposite direction, privileging mortgage credit due to the lower risk weight assigned to this type of loan. The sum of the two opposite forces determines the path for mortgage and corporate credit. In the first quarter after the shock, the outcome is an increase in corporate loans and a fall in mortgage loans, due to the stronger adjustment in the balance sheet constraint. Subsequently, further deterioration of bankers' net worth and the developments in deposits impose a stronger contraction on both loan segments.

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