The Cross Border Effects of Bank Capital Regulation in General Equilibrium *

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Abstract

We examine the cross-border effects of bank capital requirements using a two-country DSGE model with financial frictions, calibrated to match Euro Area banking flows. Regulation follows a host country principle, applying uniformly to all bank exposures within a country, regardless of the banks' nationality. We find that increasing capital requirements in one country leads to a short run credit contraction in interconnected countries. However, long run credit spillovers are negligible. Instead, we find positive long run welfare spillovers, primarily due to higher bank dividend payouts to foreign bank owners, rather than increased financial stability in the foreign country.

Keywords: Spillovers; Macroprudential Policy; Voluntary Buffers.

JEL codes: G21, F41, F42

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1 Introduction

International spillovers of macroprudential policies have been a key concern for regulators and academics, especially following the broad wave of regulatory reforms introduced after the Global Financial Crisis. Among these policies, capital requirements – designed to limit bank leverage – have attracted special attention due to their potential cross-border effects. While numerous studies have explored the externalities of these requirements on credit allocation (for example, Houston et al., 2012; Aiyar et al., 2014; Buch and Goldberg, 2016; Tripathy, 2020), as well as the scope for coordination among prudential regulators (Acharya, 2003; DellAriccia and Marquez, 2006; Bahaj and Malherbe, 2024, among others), less attention has been given to the broader short- and long-term macroeconomic implications of these spillovers.

This paper quantitatively assesses the cross-border externalities of capital regulation, within a general equilibrium framework. We develop a two-country DSGE model featuring bank and firm level financial frictions, that extends the closed-economy frameworks in Mendicino et al. (2018, 2020). In our model, households in each country own a domestic bank holding company, which allocates equity across subsidiaries operating in the two countries. These subsidiaries provide credit to firms, which rely on financing from either national or foreign banks. We assume that requirements are set under a host-country rule, which implies that regulation applies uniformly to all loans within a country, regardless of the lender's nationality.[1] We calibrate the model to reflect the role of foreign banks in credit provision to non-financial corporations in the Euro Area. We then use it to conduct counterfactual experiments analyzing short- and long-term spillovers of capital requirements across a range of macroeconomic and financial variables.

We find that, in the short run, a tightening of requirements in one country is likely

[1] Bahaj and Malherbe (2024) make a similar assumption. Host country rules apply to the regulation of bank subsidiaries and to the regulation of bank branches and direct cross border lending under certain *reciprocity* arrangements.

to generate bank equity outflows in an interconnected economy, creating a temporary credit contraction and a deterioration of financial conditions abroad; a finding consistent with the theoretical channel explored in Bahaj and Malherbe (2024). However, we also find that these effects are likely to be quantitatively small, under several alternative scenarios. On the other hand, our analysis reveals that, over the long run, credit spillovers are negligible but welfare spillovers are not. Our findings suggest that the main source of this long run externality stems from an increase in bank dividend payouts to foreign households as the level of requirements is increased, rather than from a financial stability externality, which is smaller.

Our results are explained by a series of economic forces, which shape bank equity allocation and lending decisions. As in the closed economy setting of Mendicino et al. (2020), banks price loans to compensate their owners for the value of their net worth invested as bank equity. When capital requirements increase, loan pricing is affected through two channels: (i) banks must use more (costly) equity per unit of lending, passing the higher funding costs onto borrowers, and (ii) increased demand for bank capital raises the value of each unit bank net worth, essentially due to the presence of decreasing returns on credit. This effect stimulates bank net worth accumulation (for example, through more retained earnings), until eventually its value reverts to its long run mean. Consequently, the supply of bank capital is relatively inelastic in the short run but becomes elastic over the long run.

In our novel two-country setting, bank holding companies can meet higher capital requirements using four channels. They can (i) decrease voluntary capital buffers (which they endogenously hold in excess of the regulatory limit), (ii) cut their dividend payouts to the households (potentially issuing equity), (iii) restrict their credit supply, or (iv) reallocate part of their equity capital from other jurisdictions towards the country that tightens the requirements, creating cross border spillovers.

In the short run, adjustments occur through a combination of these channels. Due to frictions in equity financing and diminishing returns on credit, neither equity issuance

nor cross-border equity reallocation fully absorbs the increase in requirements, leading to a temporary credit contraction in both countries. The magnitude of this spillover is small: in our baseline calibration, a one percentage point increase in capital requirements (from a baseline of 8%) in one country leads to a 0.05% credit contraction in the foreign country, although spillovers can be larger when international banks play a more prominent role in credit provision and when the initial level of requirements is high. Interestingly, over the long run, credit spillovers are negligible. Under the host-country rule which we consider, the liability structure of bank subsidiaries is primarily shaped by local regulation. Since bank capital supply is elastic over the long run, loan pricing remains roughly unchanged in the country that does not tighten the requirements.

Despite the absence of long-run credit spillovers, we identify positive consumption and welfare externalities. The benefits to foreign households arise primarily from higher bank dividend payouts. Since higher capital requirements promote bank net worth accumulation without altering long run equity returns – which are determined by underlying frictions in equity financing –households in the foreign country receive larger bank dividend payouts. Importantly, because credit conditions in the foreign country remain largely unaffected in the long run, the impact on economic activity is also very limited.

To strengthen our quantitative findings, we conduct an empirical analysis of capital requirement spillovers using data on international loans in the Euro Area. Specifically, we assess how foreign bank lending responds to changes in capital requirements, following recent activations of the countercyclical capital buffer (CCyB) in some European countries.[2] Unlike prior studies that focus on the contemporaneous impact

[2]The countercyclical capital buffer is a requirement designed to be adjusted by prudential authorities in response to the evolution of macrofinancial conditions, among other factors. Although the original proposal of the Basel Committee on Banking Supervision (BCBS) was to set the buffer contingent on the evolution of the credit to GDP gap (Basel Committee on Banking Supervision, 2010), in practice, authorities do not always follow this indicator to set the requirement. Moreover, a number of jurisdictions have adopted positive levels of the buffer even when the credit to GDP gap is negative (Bedayo and Galán, 2024; Basel Committee on Banking Supervision, 2024).

of regulatory changes, we estimate impulse responses of foreign bank credit using local projection methods (Jordà, 2005). Our findings confirm the presence of negative short-run credit spillovers, consistent with the predictions in our DSGE model.

Our analysis yields several policy implications. For each country, the transition costs of tightening requirements, in terms of a lower credit provision to the economy, are smaller when integration levels are high. This follows from an equity reallocation channel similar as the one discussed in Bahaj and Malherbe (2024). Our quantitative analysis suggests that while the negative impact of requirements on domestic credit is small (roughly -0.10% for a one percentage point increase in the country that tightens the requirements), their impact in a counterfactual closed economy setting (while still small) is significantly stronger (-0.16%). Thus, regulators might have incentives to tighten requirements more aggressively in highly integrated economies, since banks could reallocate equity from their foreign exposures, mitigating the negative impact on domestic credit. On the other hand, our long run results suggest that individual regulators would choose higher levels of requirements in closed economy settings than under financial integration. The presence of the consumption externality in the long run implies that part of the welfare gains in one country "leak" towards the other, as foreign bankers receive larger dividend payouts. This generates a difference of about 0.4 percentage points in the level of welfare maximizing requirements in each country, once we compare the closed and the open economy settings.

Finally, it is worth noting that our model abstracts from certain factors - such as differences in institutional settings and financial markets depth across countries - that could influence the size and direction of regulatory spillovers. As highlighted by Houston et al. (2012), differences in financial development can shape cross border capital flows after regulatory changes. While these considerations are beyond the scope of this paper, our model provides a useful benchmark for understanding capital requirement spillovers in financially integrated regions with arguably harmonized regulatory frameworks, such as the Euro Area.

Contribution to the literature This paper contributes to the literature on the cross-border effects of macroprudential regulation along several dimensions.

First, we relate to studies analyzing macroprudential policy spillovers in a general equilibrium setting (Darracq Paries et al., 2019; Agénor et al., 2024; Rubio, 2020). The closest work to ours is Agénor et al. (2024), who examine the effects of countercyclical capital buffers in a core-periphery DSGE model. They find that expansionary monetary policy shocks in the core increase foreign lending, and that raising the CCyB in the core slightly amplifies this effect.

Our approach complements the previous work in several ways. First, we highlight the distinction between short and long run spillovers of capital regulation. Second, we isolate the effects of capital requirements from other macroeconomic shocks, reflecting the increasing decoupling of tightening decisions from credit cycles (Bedayo and Galán, 2024; Basel Committee on Banking Supervision, 2024) and allowing for a clearer interpretation of the effects. Third, in our framework, bank holding companies can reallocate equity across subsidiaries in different countries, contrasting with frameworks where cross-border banking occurs through interbank lending (Agénor et al., 2024; Darracq Paries et al., 2019). Fourth, we consider a two-country setting where financial frictions justify the adoption of capital requirements from a micro and macropudential perspective, due to the combination of bank risk shifting distortions (Kareken and Wallace, 1978) and net worth dynamics of banks and firms that amplify macroeconomic fluctuations through a financial accelerator channel (Bernanke et al., 1999; Clerc et al., 2015; Mendicino et al., 2018, forthcoming). Our focus on capital requirements also distinguishes our work from Rubio (2020), who examines loan to value limits.

Second, we contribute to the previous empirical literature on the cross-border impact of capital requirements (Houston et al., 2012; Aiyar et al., 2014; Reinhardt and Sowerbutts, 2015; Buch and Goldberg, 2016; Tripathy, 2020, among others). Our main contribution is to provide an impulse response analysis of foreign bank credit following regulatory

changes in the Euro Area. Since capital requirements are often phased in gradually, our approach captures delayed balance sheet adjustments, a dimension often missing in the previous empirical literature.

Finally, we contribute to the closed-economy literature on the effects of capital regulation. Our model features endogenous voluntary capital buffers and dividend payout decisions, which shape the short-run impact of regulation on credit supply. Compared to Mendicino et al. (2020), who study the effects of capital requirements in a closed economy over the short and the long run, our results suggest a much smaller short-run credit contraction. This difference arises because banks can temporarily adjust voluntary buffers and dividend payouts to absorb regulatory changes with a smaller impact on credit supply; two adjustment channels previously unexplored in the literature.

Structure of the paper The remainder of the paper is structured as follows. Section 2 presents a two country DSGE model with cross border banking. Section 3 discusses the calibration of the model. Section 4 presents the results of the counterfactual experiments on the short and long run spillovers of capital requirements. Section 5 provides supporting empirical evidence for some of the conclusions drawn from the DSGE model. Section 6 offers a discussion on the interpretation of our main results and potential extensions of the analysis. Finally, section 7 concludes.

2 The Model

This section presents a two-country, infinite-horizon, discrete-time economy, indexed by t. Countries are labeled as Home and Foreign, respectively. Each country is inhabited by a continuum of identical households of measure one. The final consumption good can be traded across borders without frictions. Physical capital, labor and intermediate goods are non tradeable.

Households Households consume the final good, invest in partially insured bank debt issued in their country and supply labor to domestic firms. They also hold physical capital directly, which they invest in a backyard technology with decreasing returns. Households in each country own a representative bank holding company (BHC) and two representative corporate holding companies (CHCs), from which they receive net dividend payouts. Finally, they own the firms producing the capital good in each country.

Firms and banks In each country, specialized firms which combine capital and labor to produce differentiated intermediate goods in two sectors, relying on financing from Home and Foreign banks, respectively. Firms finance the cost of their production inputs with risky bank loans and firm equity, which is supplied by one of the two specialized CHCs in each country. The terminal value of firm assets is subject to aggregate and idiosyncratic risk, which might trigger costly bankruptcies. This in turn determines the presence of an external finance premium, in the tradition of the costly state verification (Townsend, 1979) and the subsequent financial accelerator Bernanke et al. (1996, 1999) literature. Intermediate goods produced by these firms are combined by competitive producers of the final consumption good in each country.

Each BHC manages specialized bank subsidiaries (called banks, for brevity) in its own country and abroad. Banks issue debt locally, that is, in the country where they extend loans. They are subject to local prudential regulation and, consistently, insured bank debt is guaranteed by the local government. In a similar fashion as firms, banks are subject to idiosyncratic shocks to the terminal value of their assets. This in turn implies that a fraction of each class of banks fail each period, triggering a socially costly resolution process. The cross border ownership of banks is the only source of financial integration in the model.

Aggregate shocks There are three country specific aggregate shocks. First, final good producers are subject to productivity shocks. Second, the dispersion of firm

idiosyncratic shocks changes over time, due to firm risk shocks as in Christiano et al. (2014). Finally, the dispersion of bank idiosyncratic shock also fluctuates, driven by bank risk shocks, as in Clerc et al. (2015) and Mendicino et al. (2018). Firm risk shocks determine the dispersion of idiosyncratic shocks of all firms in a country, irrespective of the ownership of their financing banks. Similarly, bank risk shocks affect the dispersion of idiosyncratic returns of all banks in a country, irrespective of the country of origin of the BHC which manages them.

Notation The notation emphasizes the ownership structure of banks. Unless stated otherwise, subindex i denotes the country of nationality of a BHC and subindex j denotes the country where lending takes place. When employed in variables related to banks, the subindex ij denotes banks owned by the BHC from country i lending to firms in country j. For variables related to firms, the subindex ij denotes firms in country j borrowing from banks owned by the BHC from country i.

2.1 Households

In each country, households choose consumption $c_{j,t}$, labor supply $L_{j,t}$, holdings of partially insured bank debt $d_{j,t}$ and physical capital $k^{hh}_{j,t}$ to maximize

$$V_{j,t} = \mathbb{E}_t \sum_{s=t}^{\infty} \beta^{s-t} \left[\log(C_{j,s}) - \lambda_L \frac{L_{j,s}^{1+\varphi}}{1+\varphi} \right], \tag{2.1}$$

subject to the budget constraint

$$\begin{aligned} c_{j,t} + d_{j,t} + q^k_{j,t} k^{hh}_{j,t} = \\ w_{j,t} L_{j,t} + \tilde{R}^d_{j,t} d_{j,t-1} + (k^{hh}_{j,t-1})^{\alpha_{hh}} + q^k_{j,t}(1-\delta) k^{hh}_{j,t-1} + \Theta^b_{j,t} + \Theta^f_{j,t} + \Theta^k_{j,t} - T_{j,t}, \end{aligned} \tag{2.2}$$

where β is the subjective discount factor of households, λ_L measures the relative disutility of labor and φ is the Frisch elasticity of labor. The price of physical capital in country j is denoted by $q^k_{j,t}$, while $w_{j,t}$ stands for wages. Households invest physical capital in a backyard technology, the efficiency of which is measured by parameter α_{hh}. The depreciation rate of physical capital is denoted by δ. Net dividend payouts by the BHC and the CHCs are denoted by $\Theta^b_{j,t}$ and $\Theta^f_{j,t}$, respectively. Profits from capital good producers are denoted by $\Theta^k_{j,t}$. Lastly, the government in each country collects lump sum taxes $T_{j,t}$ in order to repay the insured fraction of debt of defaulting banks.

Bank debt is issued locally and there is a single promised rate on bank debt in each country. As in Mendicino et al. (2018) we assume that savers do not observe the individual risk of bank subsidiaries in a country and thus only price the average risk of one unit of bank debt.

The realized return on bank debt $\tilde{R}^d_{j,t}$ is composed of the promised return minus the losses stemming from bank default on the fraction of uninsured bank debt, that is,

$$\tilde{R}^d_{j,t} = R^d_{j,t} - (1-\theta)\Omega_{j,t}, \tag{2.3}$$

where θ is the fraction of insured bank debt and $\Omega_{j,t}$ is the average loss on one unit of bank debt due to bank defaults in country j, defined in Online Appendix B.

2.2 Final good producers

Competitive final good producers in each country combine intermediate goods produced by firms financed by banks from Home or Foreign. They maximize profits, given by

$$\Pi^y_{j,t} = Y_{j,t} - p_{jj,t}Y_{jj,t} - p_{ij,t}Y_{ij,t}, \quad i \neq j, \tag{2.4}$$

with

$$Y_{j,t} \equiv A^{\frac{1}{\eta}}_{i,t}\left[\xi_j^{\frac{1}{\eta}} Y_{jj,t}^{\frac{\eta-1}{\eta}} + (1-\xi_j)^{\frac{1}{\eta}} Y_{ij,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \tag{2.5}$$

where $A_{j,t}$ is an AR(1) productivity process and ξ_j is the share of intermediate goods produced by firms financed by domestic banks. The substitutability between firms financed by banks from Home and Foreign is determined by the elasticity of substitution η. Intermediate goods produced by each class of firms are denoted by $y_{ij,t}$, and their price is given by $p_{ij,t}$.

2.3 Firms

Intermediate goods in each sector are produced by a continuum of measure one of firms. Each class of firms is owned and managed by a representative corporate holding company (CHC). Each class of firms relies on bank lending from banks from either Home or Foreign, capturing the specialization in lending relationships documented, for example, in Paravisini et al. (2023) and Blickle et al. (2023).

Firms' resource constraint Firms combine physical capital $k_{ij,t}$ and labor $l_{ij,t}$ using a Cobb-Douglas technology, to produce intermediate goods $y_{ij,t+1}$. The cost of production inputs needs to be financed upfront. These funds are supplied in the form of risky bank loans $b_{ij,t}$, provided by banks and firm equity $e^f_{ij,t}$, provided by the CHC. Therefore, the resource constraint of firms is given by

$$q^k_{j,t} k_{ij,t} + w_{j,t} l_{ij,t} = b_{ij,t} + e^f_{ij,t}. \tag{2.6}$$

Terminal net worth of firms The terminal net worth of a firm is given by

$$\pi^f_{ij,t+1}(\omega) = \omega \left(p_{ij,t+1} y_{ij,t+1} + q^k_{j,t+1}(1-\delta) k_{ij,t} \right) - R_{ij,t} b_{ij,t}, \tag{2.7}$$

where ω is a firm idiosyncratic shock to the terminal value of its assets, as in Bernanke et al. (1999) and $R_{ij,t}$ is the promised rate on bank loans. Firm idiosyncratic shocks have a positive support, mean one and stochastic volatility, and are distributed according to

a cdf $F^f_{ij,t}(\cdot)$. The production technology employed by the firms is described by

$$y_{ij,t+1} = k^{\alpha}_{ij,t} l^{1-\alpha}_{ij,t}, \tag{2.8}$$

with α denoting, as usual, the share of physical capital in output.

Firm default Upon a sufficiently low realization of the idiosyncratic shock ω, the terminal net worth of a firm becomes negative. At this point the firm defaults on its loans and its financing banks seize its assets. A fraction μ^f of the residual value of assets of defaulting firms is lost in the liquidation process. Firm default happens for values of the idiosyncratic shock below a threshold $\bar{\omega}^f_{ij,t+1}$ characterized by

$$\pi^f_{ij,t+1}(\bar{\omega}^f_{ij,t+1}) = 0. \tag{2.9}$$

Dynamic problem of the CHCs Each CHC enters a period with net worth $n^f_{ij,t}$. It then chooses the amount of dividends to be paid out to the households and the amount of equity to be allocated to the firms it manages. In addition to this, the CHC chooses the combination of inputs to be used by the firms, as well as their financial structure. When choosing this financial structure, the CHC takes into consideration how loan interest rates increase with leverage, as banks price-in a higher probability of default of the firms.

The dynamic problem of a CHC can be cast in recursive form as

$$V^f_{ij,t}(n^f_{ij,t}) = \max_{x^f_{ij,t}, n^f_{i,t+1}, e^f_{ij,t}, B_{ij,t}, R_{ij,t}, k_{ij,t}, l_{ij,t}} \left\{ x^f_{ij,t} n^f_{ij,t} + \mathbb{E}_t \Lambda_{j,t+1} V^f_{ij,t+1}(n^f_{i,t+1}) \right\} \quad \text{s.t.} \tag{2.10}$$

$$e^f_{ij,t} + x^f_{ij,t} n^f_{ij,t} = n^f_{ij,t} - \frac{\kappa^f}{2}\left(x^f_{ij,t} - \bar{x}^f\right)^2 n^f_{ij,t}, \tag{2.11}$$

$$n^f_{ij,t+1} = \rho^f_{ij,t+1} e^f_{ij,t}, \tag{2.12}$$

$$\mathbb{E}_t \Lambda^b_{i,t+1} \rho^b_{ij,t+1} \geq v^b_{i,t}, \tag{2.13}$$

and the resource constraint of firms in (2.6).

The fraction of net worth paid out as dividends to the households is denoted by $x^f_{ij,t}$. If a CHC deviates from a dividend target $\bar{x}^f$, it incurs a quadratic cost, with an intensity governed by parameter κ^f. CHCs discount future payoffs with the stochastic discount factor of the households in their country, given by $\Lambda_{j,t}$.

Constraint (2.13) requires that the properly discounted returns on bank equity invested in banks owned by the BHC from country i lending to firms in country j, compensate the BHC for the shadow value of its net worth. This inequality describes the menu of loan contracts available to the firm, and can be interpreted as a participation constraint for the banks financing these firms.[3] In an equilibrium with competitive banks, this constraint holds with equality, as banks would undercut each other in providing more favorable loan terms until the BHC is indifferent between providing equity funding to extend the loans or not.

Finally, net worth allocated to a well diversified portfolio of firm equity generates average gross returns given by

$$\rho^f_{ij,t+1} = \frac{\Pi^f_{ij,t+1}}{e^f_{ij,t}}, \tag{2.14}$$

with

$$\Pi^f_{ij,t+1} \equiv \int_{\bar{\omega}^f_{ij,t+1}}^{\infty} \pi^f_{ij,t+1}(\omega) dF^f_{ij,t+1}(\omega), \tag{2.15}$$

which completes the definition of the law of motion for the net worth of CHCs in (2.12).

[3] More details on this constraint can be found in section 2.4, which discusses Banks.

2.4 Banks

Households in each country own a representative bank holding company (BHC). Each BHC owns and manages two classes of banks, specialized in lending to firms in either Home or Foreign.[4] Each of these is composed of a continuum of measure one of banks.

Bank subsidiaries Within each continuum, an atomistic bank has a simplified balance sheet consisting of risky loans $B_{ij,t}$, which are financed with partially insured debt $D_{ij,t}$ and bank equity $e^b_{ij,t}$. Bank debt is held by domestic households, and is issued at a promised gross rate $R^d_{j,t}$. All claims have a maturity of one period.

Terminal net worth of individual banks The terminal net worth of a bank is given by

$$\pi^b_{ij,t+1}(\omega) \equiv \omega \tilde{R}_{ij,t+1} B_{ij,t} - R^d_{j,t} D_{ij,t}, \tag{2.16}$$

where ω is a bank idiosyncratic shock and $\tilde{R}_{ij,t+1}$ is the realized return on a well diversified portfolio of loans extended the previous period. Bank idiosyncratic shocks capture, in a tractable manner, any factors that might introduce dispersion in the returns on loan portfolios.[5] These shocks have a strictly positive support, mean one and stochastic volatility, and are distributed according to a cdf $F^b_{ij,t+1}(\cdot)$.

The realized return on bank loans comprise both the returns on performing loans and the residual value of repossessed firm assets on the fraction of defaulting loans. That is, the realized return on loans is given by

[4] In other words, there are four classes of subsidiaries in the global economy: owned by the BHC from Home, lending in Home; owned by the BHC from Home, lending in Foreign; owned by the BHC from Foreign, lending in Home, and owned by the BHC from Foreign, lending in Foreign.

[5] For example, a pattern of sectoral or geographic specialization, as documented in Blickle et al. (2023) could originate imperfect diversification and therefore differences in the returns on bank assets. The shocks are introduced following the approach in Bernanke et al. (1999) and, more recently, Clerc et al. (2015) and (Mendicino et al., 2018, 2020) in the context of models with bank default.

$$\tilde{R}_{ij,t+1}B_{ij,t} \equiv \int_{\bar{\omega}^f_{ij,t+1}}^{\infty} R_{ij,t}B_{ij,t}dF^f_{ij,t+1}(\omega)+$$
$$(1-\mu_f)\int_0^{\bar{\omega}^f_{ij,t+1}} \omega\left[p_{ij,t+1}y_{ij,t+1}+q^k_{j,t+1}(1-\delta)k_{ij,t}\right]dF^f_{ij,t+1}(\omega). \quad (2.17)$$

Bank capital regulation Domestic regulators set capital requirements applicable to all exposures in a country, irrespective of the nationality of the BHC which owns the bank originating the loans, that is, regulation follows a *host country principle*.

Requirements are verified on an ex post basis, that is, after shocks have realized. Banks are regarded as well capitalized if their terminal net worth is greater than or equal to a fraction $\hat{\phi}_{j,t}$ of the book value of their loans. This implies, in turn, that banks with sufficiently low realizations of their idiosyncratic shocks will be under-capitalized. The threshold $\hat{\omega}_{ij,t+1}$ for the bank idiosyncratic shock that characterizes under-capitalized banks satisfies

$$\pi^b_{ij,t+1}(\hat{\omega}_{ij,t+1}) = \hat{\phi}_{j,t}B_{ij,t}. \quad (2.18)$$

If a bank is under-capitalized, then the BHC faces costs stemming from the lack of compliance with the regulation. This modeling approach is similar to the one explored in a closed economy framework in Mendicino et al. (forthcoming). These costs capture frictions such as increased scrutiny by supervisors, reputation costs faced by the BHC, potential market backlash, among other factors associated with a failure to meet regulatory standards.[6]

Bank failure While a breach of requirements is costly for the BHC, it does not immediately lead to the liquidation of an under-capitalized bank. In most jurisdictions, bank resolution only happens upon a *severe* breach of requirements.[7] It is therefore

[6]See for instance Couaillier et al. (2024)

[7]Under the current Basel standards, for example, a breach of the minimum requirements of 4.5% of risk weighted assets would typically lead to a regularization process or even the resolution of the bank. However, a breach of additional capital buffers, such as the 2.5% capital conservation buffer which sits on top of the minimum requirements, only triggers restrictions on the distribution of dividends. See Basel Committee on Banking Supervision (2010) for details.

assumed that liquidation only takes place when the terminal net worth of a bank falls below a fraction ϕ_{min} of the book value of its loans.[8] This minimum requirement can be interpreted as a hard-deck for the capital of a bank, below which the bank is deemed insolvent by supervisors. The minimum requirement is static and common across countries.

Upon a breach of the minimum requirement, supervisors close the bank and liquidate its assets in order to repay insured deposits. In the liquidation process, a fraction μ_b of bank assets is lost in the form of deadweight losses associated with the resolution procedure. Any additional funds needed to repay insured deposits are covered with lump sum taxes, collected by the government from the country where the bank operated.

The resolution process is thus triggered for values of the bank idiosyncratic shock below a threshold $\bar{\omega}^b_{ij,t+1}$, which satisfies

$$\pi^b_{ij,t+1}(\bar{\omega}_{ij,t+1}) = \phi_{min} B_{ij,t}. \tag{2.19}$$

Dynamic problem of the BHCs Each BHC enters a given period with net worth $n^b_{i,t}$. It then chooses the amount of dividends to be payed out to the households and the amount of bank equity to be allocated to each class of banks under its management. In addition to this, each BHC chooses the ex ante capital ratio of each class of banks, defined as

$$\phi_{ij,t} \equiv \frac{e^b_{ij,t}}{B_{ij,t}}. \tag{2.20}$$

When choosing this capital ratio, the BHC takes into account the costs associated with non compliance with capital regulation ex post.

[8] It is often assumed in the literature featuring models with bank default that banks fail when their terminal net worth is negative. Such cases are nested within this framework, for $\phi_{min} = 0$.

The dynamic problem of a BHC can be stated in recursive form as

$$V^b_{i,t}(n^b_{i,t}) = \max_{\substack{x^b_{i,t}, e^b_{i\,Home,t}, e^b_{i\,Foreign,t}, \\ \phi_{i\,Home,t}, \phi_{i\,Foreign,t}, n^b_{i,t+1}}} \left\{ x^b_{i,t} n^b_{i,t} + \mathbb{E}_t \Lambda_{i,t+1} V^b_{i,t+1}(n^b_{i,t+1}) \right\} \quad \text{s.t.} \tag{2.21}$$

$$e^b_{i\,Home,t} + e^b_{i\,Foreign,t} + x^b_{i,t} n^b_{i,t} = n^b_{i,t} - \frac{\kappa^b}{2} \left(x^b_{i,t} - \bar{x}^b \right)^2 n^b_{i,t}, \tag{2.22}$$

$$n^b_{i,t+1} = \rho^b_{i\,Home,t+1} e^b_{i\,Home,t} + \rho^b_{i\,Foreign,t+1} e^b_{i\,Foreign,t}, \tag{2.23}$$

where $V^b_{i,t}(n^b_{i,t})$ is the value associated with a level of net worth $n^b_{i,t}$ and $x^b_{i,t}$ is the fraction of net worth paid out as dividends to the households in country i.[9] The BHC from country i discounts future dividend payouts using the stochastic discount factor of its owners, that is households in country i, given by $\Lambda_{i,t+1}$. If the BHC deviates from a dividend target $\bar{x}^b$, it incurs a quadratic cost, as in Elenev et al. (2021). The intensity of this cost is governed by parameter κ^b.[10]

Bank equity allocated to each class has an average (across individual banks in the continuum) gross return given by

$$\rho^b_{ij,t+1} \equiv \frac{\Pi^b_{ij,t+1}}{e^b_{ij,t}}, \tag{2.24}$$

with

$$\Pi^b_{ij,t+1} \equiv \int_{\bar{\omega}^b_{ij,t+1}}^{\infty} \pi^b_{ij,t+1}(\omega) dF^b_{ij,t+1}(\omega) - \zeta \int_0^{\hat{\omega}^b_{ij,t+1}} \left[\hat{\phi}_{j,t} B_{ij,t} - \pi^b_{ij,t+1}(\omega) \right] dF^b_{ij,t+1}(\omega), \tag{2.25}$$

[9] No restriction on the sign of $x^b_{i,t}$ is imposed, so that negative values correspond to an equity issuance by the BHC.

[10] These costs capture potential informational and agency frictions in the corporate governance of banks, which lead to the adoption of targets on payout ratios. See, for example, Easterbrook (1984).

where the last term in (2.25) captures the costs of non compliance with regulatory requirements, which are proportional to the capital shortfall of under-capitalized banks, and are governed by parameter ζ.

Equilibrium bank leverage, dividend payout and equity allocation The first order conditions of the problem in (2.21)-(2.23) characterize the choice of capital ratios and the equity allocation across each class of banks, as well as the dividend payout decision of the BHC. In particular, the solution is characterized by

$$\mathbb{E}_t \Lambda^b_{i,t+1} \frac{\partial \rho^b_{ij,t+1}}{\partial \phi_{ij,t}} = 0, \tag{2.26}$$

$$v^b_{i,t} = \mathbb{E}_t \Lambda^b_{i,t+1} \rho^b_{ij,t+1}, \tag{2.27}$$

$$x^b_{i,t} = \bar{x}^b + \frac{1}{\kappa^b} \left(\frac{1}{v^b_{i,t}} - 1 \right), \tag{2.28}$$

where the stochastic discount factor associated to the BHC from country i is defined as

$$\Lambda^b_{i,t+1} = \Lambda_{i,t+1} \left(\bar{x}^b + (1 - \bar{x}^b) v^b_{i,t+1} + \frac{1}{2\kappa^b} \frac{(1 - v^b_{i,t+1})^2}{v^b_{i,t+1}} \right) \tag{2.29}$$

and $v^b_{i,t}$ is the Lagrange multiplier of restriction (2.22) which is also the shadow value of one unit of net worth invested as bank equity, as in Gertler and Kiyotaki (2010).

Equation (2.26) requires that the properly discounted marginal benefits of increasing bank leverage equal the marginal costs generated to the BHC in terms of non compliance with capital requirements ex post. For a sufficiently high value of ζ, this condition implies that the banks will maintain voluntary buffers above regulatory requirements.

Condition (2.27) defines the shadow value of bank net worth, which is equal to the properly discounted returns on bank equity invested in either class of banks. This condition also implies that, in equilibrium, a BHC is indifferent between allocating its net worth as equity in its bank subsidiaries in Home or Foreign.

The dividend policy of the BHC in (2.28) has also a very intuitive interpretation. When the value of having net worth inside the BHC is high relative to paying it out as dividends (that is, when $v^b_{i,t}$ is large) bank dividends are lower.[11] This happens in states of the economy where bank equity is relatively scarce. Conversely, when bank net worth is relatively abundant, which is reflected in a low shadow value of net worth, then the BHC pays out more dividends.

Finally, the stochastic discount factor of the BHCs in (2.29) reflects the expected path of the dividend payout decision by the BHC, which in turn depends on the relative scarcity of net worth in the future, captured by its shadow value $v^b_{ij,t}$.

2.5 Capital good producers

Capital good producers in each country combine investment $I_{j,t}$ and capital outstanding from the previous period $K_{j,t-1}$ to produce new physical capital. Capital good producers solve

$$\max_{I_{j,t}} q^k_{j,t} K_{j,t} - I_{j,t}, \tag{2.30}$$

with

$$K_{j,t} = S\left(\frac{I_{j,t}}{K_{j,t-1}}\right) K_{j,t-1} + (1-\delta) K_{j,t-1}, \tag{2.31}$$

where function $S(\cdot)$ captures capital adjustment costs as in Jermann (1998) and is given by

$$S\left(\frac{I_{j,t}}{K_{j,t-1}}\right) = \frac{a_1}{1-\frac{1}{\psi}} \left(\frac{I_{j,t}}{K_{j,t-1}}\right)^{1-\frac{1}{\psi}} + a_2, \tag{2.32}$$

where a_1 and a_2 are chosen to guarantee that, in the deterministic steady state of the model, $q^k_j = 1$ and that investment is a fraction δ of the capital stock. Parameter ψ governs the strength of capital capital adjustment costs.

The profits generated by the operation of this technology are rebated to the households in country j.

[11] Indeed, dividends can be negative, which we interpret as equity issuance.

2.6 Aggregation and Equilibrium

Details on model aggregation as well as the full list of equilibrium conditions are provided in Online Appendix B.

3 Calibration

This section offers details on the calibration of the model, as well as a discussion of how the moments targeted by the calibration identify key model parameters.

Shocks processes We assume, following an approach similar as the one in Christiano et al. (2014) that firm and bank idiosyncratic shocks follow a log-normal distribution, with mean one and stochastic volatility, that is,

$$\log \omega \sim \mathcal{N}\left(-\frac{(\sigma^{\upsilon}_{ij,t})^2}{2}, \sigma^{\upsilon}_{ij,t}\right), \quad \upsilon = f, b, \tag{3.1}$$

where the volatility of the shocks, captured by $\sigma^{\upsilon}_{ij,t}$, follows a first order autoregressive process of the form

$$\log\left(\frac{\sigma^{\upsilon}_{ij,t+1}}{\bar{\sigma}^{\upsilon}_{j}}\right) = \varrho^{\upsilon} \log\left(\frac{\sigma^{\upsilon}_{ij,t}}{\bar{\sigma}^{\upsilon}_{j}}\right) + \varsigma^{\upsilon} \varepsilon^{\upsilon}_{j,t+1}, \quad \upsilon = f, b. \tag{3.2}$$

We denote $\bar{\sigma}^{\upsilon}_{j}$ as the long run level of the cross sectional dispersion of idiosyncratic shocks in country j, and $\varepsilon^{\upsilon}_{j,t}$ is a standard normal country-specific risk shock, ς^{υ} governs the volatility of these risk shocks and ϱ^{υ} governs their persistence.

Finally, aggregate productivity in each country is subject to country specific shocks. In particular, productivity follows a first order autoregressive process of the form

$$\log(A_{j,t+1}) = \varrho^{A} \log(A_{j,t}) + \varsigma^{A}_{j} \varepsilon^{A}_{j,t+1}, \tag{3.3}$$

where, as usual, ϱ^A captures the persistence of the standard normal shocks $\varepsilon^A_{j,t+1}$ and ς^A_j captures their volatility.

3.1 Solution and calibration procedure

The model is solved using a pruned state-space system for the second order approximation around its deterministic steady state, following the approach in Andreasen et al. (2018), to rule out explosive sample paths. Policy functions are approximated using perturbation methods. We then simulate the model for 100,000 periods to obtain unconditional moments under the ergodic distribution of the model.

In order to calibrate the model, we follow a two step procedure. In the first step, a subset of parameters is chosen following the previous literature in related fields. In the second step, the rest of parameters are estimated using the simulated method of moments (SMM), where we target moments for real and financial variables in the Euro Area. We use data at a quarterly frequency, between 2003Q1 and 2015Q4, roughly corresponding to the period in which capital regulation followed Basel II guidelines. In our baseline exercise, we calibrate the countries Home and Foreign as completely symmetric. [12] The full list of parameters, as well as their source is reported in Table 3.1.

[12] We allow for differences in some parameters in Online Appendix A.4 to study the case of asymmetric credit flows, resembling a Core-Periphery structure. We find similar qualitative results, although the magnitude of spillovers is larger for Periphery countries.

Table 3.1: Parameters

Symbol	Description	Value	Source
Banks			
$\bar{x}^b$	Bank dividend target	0.038	Estimated
κ^b	Bank equity adj. cost	9.848	Estimated
$\bar{\sigma}^b$	Dispersion iid bank shocks	0.027	Estimated
ς^b	Std. bank risk shocks	0.078	Estimated
ϱ^b	Persistence bank risk shock	0.900	Mendicino et al. (2018)
θ	Fraction of insured bank debt	0.540	Demirgüç-Kunt et al. (2015)
μ_b	Cost of bank failure	0.300	Granja et al. (2017)
ζ	Cost of bank undercapitalization	0.036	Estimated
ϕ_{min}	Minimum CET1 requirements	0.040	BCBS (2004)
Firms			
$\bar{x}^f$	Firms dividend target	0.291	Estimated
κ^f	Firms equity adj. cost	0.546	Estimated
$\bar{\sigma}^f$	Dispersion iid firms shocks	0.335	Estimated
ς^f	Std. firms risk shocks	0.029	Estimated
ϱ^f	Persistence firms risk shocks	0.900	Mendicino et al. (2018)
μ_f	Cost of firms failure	0.300	Djankov et al. (2008)
Final good producers			
α	Capital share of output	0.300	Standard
η	Elast. of substitution domestic/foreign	1.000	See Online Appendix A
ξ_i	Share firms dependent on domestic banks	0.833	Pre-set
ς^A	Std. productivity shock	0.012	Estimated
ϱ^A	Persistence productivity shock	0.900	Mendicino et al. (2018)
Households			
β	Discount factor	0.995	Standard
α_{hh}	Efficiency of backyard technology	0.076	Estimated
λ	Disutility of labor	1.000	Normalization
φ	Frisch elasticity of labor	1.000	Standard
Capital good producers			
ψ	Capital adj. cost	15.834	Estimated
δ	Capital deprec. Rate	0.030	Standard

Notes: The unconditional standard deviation of productivity shocks and bank and firm risk shocks is given by $\varsigma^v/\sqrt{1-\varrho^v}$, with $v = A, b, f$.

Pre-set parameters We set the share of insured bank debt θ to 0.54 following Demirgüç-Kunt et al. (2015). Bankruptcy costs of banks and firms μ^b and μ^f are set to 0.3, following the estimates in Djankov et al. (2008) and Granja et al. (2017). The persistence of all aggregate shocks is set to 0.9, as in Mendicino et al. (2018). The capital share in output α is set to 0.3, while the depreciation rate of capital δ is set to 0.025 and the Frisch elasticity of labor φ is set to one, all standard values in the macroeconomic literature. The discount factor of households is set to 0.995, consistent with an annualized risk free rate of 2% in steady state. The disutility of labor in the preferences of households is normalized to one. The size of the international banking sector in each country, that is, the proportion of total credit extended by banks owned by a foreign bank holding company, is determined by the value of ξ. In the baseline calibration, we set this value to 0.83, consistent with an average share of 17% of loans to non financial corporations being extended by foreign banks. Finally, the elasticity of substitution between intermediate goods produced by firms which rely on domestic and foreign banks η, is set one. In the Online Appendix A we perform a sensitivity analysis with respect to this parameter and find that our results are not substantially modified for a wide range of values of η.

Capital Requirements We set the threshold for bank liquidation ϕ_{min} to 4%, consistent with the minimum requirements on Tier 1 capital under Basel II.[13]

For the broader definition of capital requirements $\hat{\phi}_{ij,t}$, which might trigger regulatory and market backlash, but not the immediate resolution of the bank, the baseline calibration considers a constant level of 8% of bank assets. This level is consistent with Basel II requirements on total capital (Tier 1 and Tier 2) of risk weighted assets.[14]

[13]Tier 1 capital includes common equity, retained earnings and preferred stock.

[14]Tier 2 capital includes, among others, some forms of subordinated debt and hybrid capital instruments.

Estimated parameters We estimate the remaining parameters using the simulated method of moments. In particular, we consider a vector of parameters $\gamma_{k\times 1}$, a vector of empirical moments $\mathbf{M}_{p\times 1}$ and their model counterpart $\mathbf{m}(\gamma)_{p\times 1}$. We then choose $\hat{\gamma}$ to solve

$$\hat{\gamma} = \underset{\gamma}{\operatorname{argmin}} \left(\mathbf{M} - \mathbf{m}(\gamma)\right)' \mathbf{W}_{p\times p} \left(\mathbf{M} - \mathbf{m}(\gamma)\right), \tag{3.4}$$

where $\mathbf{W}$ is a weighting matrix.[15] Targeted moments are reported in Table 3.2.

Table 3.2: Targeted moments

Moment	Data	Model	Moment	Data	Model
Mean Loans/GDP	1.789	1.801	Std. GDP growth	0.700	0.791
Mean Firm spreads	1.550	1.820	Std. Loan growth	1.322	2.088
Mean Dividend ratio banks	0.680	0.715	Std. Bank dividends	0.160	0.189
Mean Bank failure rate	0.660	0.592	Std. Firm dividends	0.240	0.504
Mean Capital ratio	12.010	12.238	Std. Firm spreads	0.383	0.281
Mean Dividend ratio firms	1.790	0.595	Std. (Investment/GDP)	0.500	0.419
Mean Capital held by households	0.186	0.203			

Notes: Spreads on firm debt, bank failure rates and dividend ratios are expressed in annualized percentage points. The growth rate of GDP and loans and the standard deviation of investment/GDP are expressed in quarterly percentage points. The capital ratio of banks is expressed in percentage points.

Although internally calibrated parameters are chosen simultaneously using SMM, most of them have a data target that closely identifies it. The dividend targets of banks and firms, $\bar{x}^b$ and $\bar{x}^f$ are associated with the mean dividend payout ratios in the data. In a similar fashion, κ^b and κ^f, which determine the strength of the dividend adjustment costs, are connected to the standard deviation of dividend payouts in the data. The bank failure rate responds to the dispersion of bank idiosyncratic shocks, $\bar{\sigma}^b$, while spreads on firm debt are closely associated with the dispersion of firm idiosyncratic shocks $\bar{\sigma}^f$. The observed capital ratio of banks disciplines the value of ζ, which determines

[15] We follow a common approach in the literature and pick $\mathbf{W}$ to be a diagonal matrix, where the ith element of the diagonal is given by $1/M_i$. See, for example, Macnamara et al. (2024)

the costs associated with non compliance with capital regulation. The efficiency of the backyard technology available to households, α_{hh} is pinned down by the fraction of capital directly owned by households. The strength of physical capital adjustment costs ψ helps match the volatility of investment. Finally, the standard deviation of firm, bank and productivity shocks, are associated with the volatility of spreads, credit and output, respectively.

In order to increase the transparency of our estimation, we follow the approach advocated by Andrews et al. (2017) and report the sensitivity of the targeted moments to the estimated parameters in Online Appendix A.

4 Quantitative results

We now present our main set of results, which distinguish between the short run and the long run spillovers of capital requirements. Throughout the analysis, we focus on the effects of a change in one country, for a constant level of the requirements in the other.

4.1 Short run spillovers

We begin by examining the short run effects of an increase in requirements in one country. Without loss of generality, we assume that capital requirements are increased by one percentage point in Home, from their baseline level of 8%. The policy change is captured as a highly persistent shock to the long run level of requirements, although we allow for a gradual transition towards this level. Agents in the model understand that shocks to capital requirements can take place.

We assume that the capital requirement in Home follows the process

$$\hat{\phi}_{Home,t} = \varrho_\phi(\bar{\phi}_{Home} + \nu_t) + (1 - \varrho_\phi)\hat{\phi}_{Home,t-1} \tag{4.1}$$

$$\nu_t = 0.999\nu_{t-1} + 0.01\varepsilon_{\phi,t} \tag{4.2}$$

The speed of the transition to the new level of requirements is determined by parameter ϱ_ϕ. We choose a value of ϱ_ϕ such that 99% of the transition is complete over 8 quarters.[16]

Short run credit spillovers An increase in requirements in Home has effects on credit supply in both countries; see Figure 4.1. To gain intuition on what drives the cross border effects of requirements, it is useful to first focus on the case of a closed economy. As shown in the black dashed lines in Figure 4.1, banks react to the increase in requirements by adjustments in both the numerator and the denominator of their capital ratio. By cutting dividend payouts, banks accumulate more equity. At the same time, loans decrease as their pricing reflects the increased funding costs for banks, in the form of higher corporate spreads. The increase in requirements creates a relative scarcity of bank equity capital needed to invest in profitable loans, which in turn is reflected in higher returns on bank equity. As bank net worth accumulates, the return on bank equity reverts to its long run mean. At the same time, the effects on credit also become smaller with time, as the pricing of loans gradually reflects the accumulation of bank net worth.[17] These effects are consistent with the findings in Mendicino et al. (2020) in a closed economy context. The key difference in our setting is the presence of voluntary capital buffers and endogenous dividend payout decisions, which result in an elasticity of credit to capital requirements one order of magnitude smaller than in their findings.

[16] This speed of transition is consistent with the gradual phase in of new capital requirements still being implemented after the adoption of Basel III.

[17] Section 4.2 shows that the effects do not revert back to zero entirely, but rather become small in the long run.

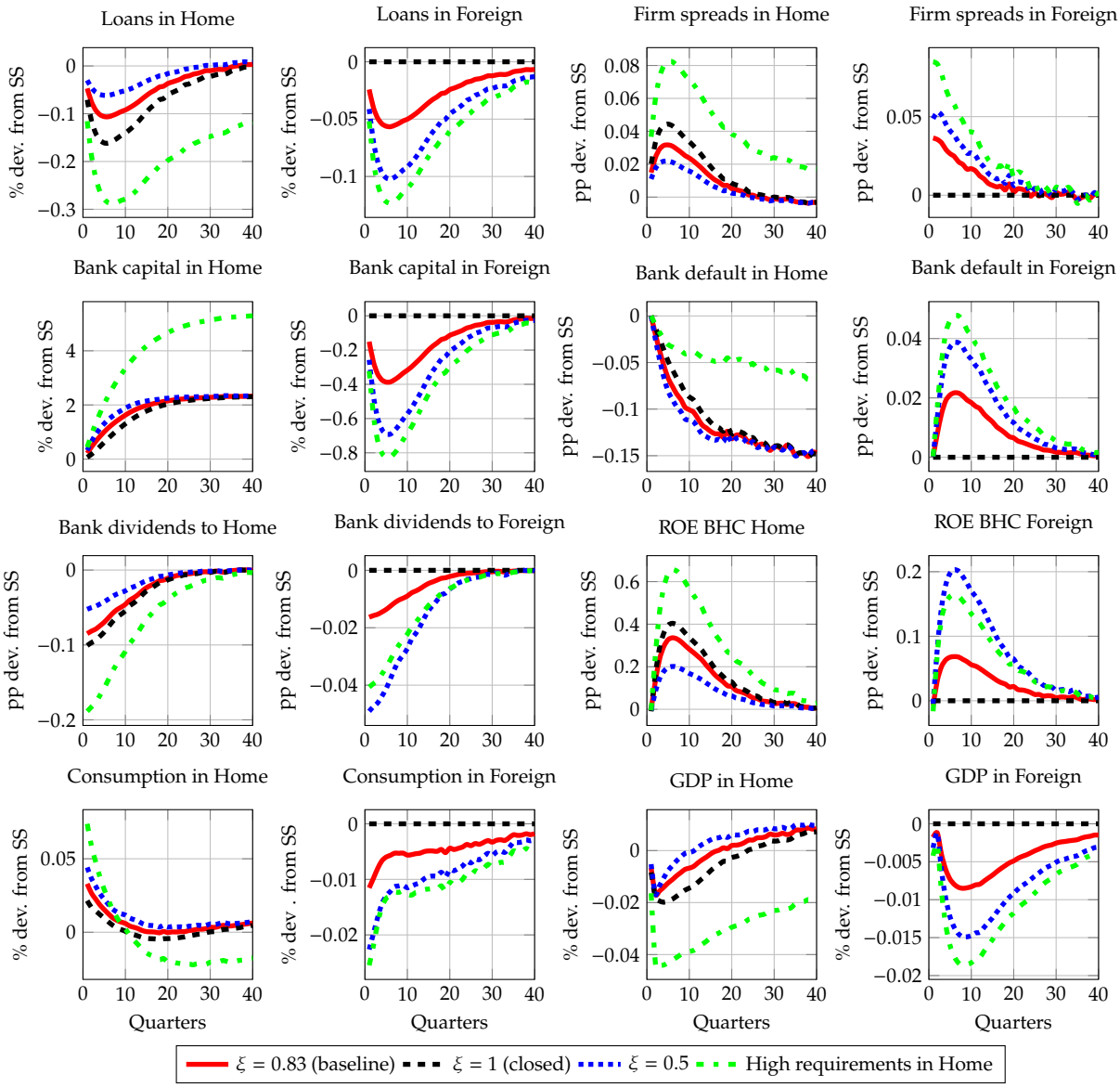

Figure 4.1: Short run spillovers of capital requirements

Notes: The figure displays the responses of key variables in each country, after a shock that increases capital requirements in Home by one percentage point from their baseline level of 8%, implemented with a gradual transition of 8 quarters. Red solid lines correspond to the baseline calibration of the model. Black dashed lines correspond to a counterfactual economy without cross border banking. Blue dotted lines correspond to a counterfactual economy in which cross border banks extend one half of total credit. Green dash-dotted lines correspond to an economy with the baseline level of cross border banking, but an initial level of capital requirements of 10.5%. The simulations used to compute the impulse response functions are obtained using a second order approximation around the deterministic steady state of the model, following the approach in Andreasen et al. (2018). The responses are expressed in terms of the deviation of variables with respect to their mean under the ergodic distribution of the model.

What changes when we introduce lending by foreign banks? The key difference once BHCs own subsidiaries in both countries is that now bank equity can be reallocated across borders in response to the change in requirements in one country. The red solid lines in Figure 4.1 display the response of the key variables to the increase in requirements in Home, in a setting where lending by foreign banks represents roughly 17% of credit (baseline calibration). In this case, banks in Home can increase their capital ratios by cutting domestic lending, but also by reallocating part of their equity in Foreign to subsidiaries in Home. Since, in equilibrium, each BHC must be indifferent between allocating its net worth as equity in its subsidiaries in Home and Foreign, then equity flows to Home to restore this no arbitrage condition. This is reflected in a temporary decline in bank equity in Foreign, and a credit contraction in this country. Also, the equity outflows generate a small increase in the default probability of banks in Foreign, as banks lend with a temporarily lower capital ratio. When we allow for a much larger presence of foreign banks, as in the blue dotted lines in Figure 4.1, the spillovers are exacerbated.

The cross border reallocation of bank equity in response to changes in requirements in one country has implications for the impact on credit in the country that imposes the higher requirements. Indeed, results show that the negative impact on credit in Home is significantly mitigated by equity inflows from Foreign. This result suggests that, in principle, bank regulators might engage in a more aggressive tightening of capital regulation if they understand that part of the negative impact on credit will be borne by countries with a passive stance on their policy (Bahaj and Malherbe, 2024).

In terms of the magnitude of the effects, however, the impact of changes in requirements on credit is quantitatively small, in both the closed and the open economy settings. We find that the effects on credit in the country that tightens the requirements are likely to be around -0.1% and -0.2% for a one percentage point increase with an 8 quarter phase in period. The credit spillovers in the country that does not tighten the requirements are around -0.05% and -0.1%, also small in magnitude, but a significant fraction of the

impact in the country that performs the tightening.

The impact of changes in requirements, both in Home and Foreign, are larger when the initial level of requirements is higher. When we repeat the exercise starting from an initial level of requirements in Home of 10.5% of assets, we find that the impact on credit is about -0.3% in Home and roughly -0.15% in Foreign. Intuitively, if initial requirements are higher, the financial stability gains of further increases are smaller, and thus the impact on credit is more pronounced. Also, as requirements increase, banks hold lower voluntary buffers because the distance to the resolution threshold is larger and overall, the economy is more stable. Thus, it is harder for banks to meet higher requirements with voluntary buffers in this context. This fact notwithstanding, the overall size of the effect on credit remains relatively small.

Short run spillovers on consumption and output The bottom panels of Figure 4.1 also show the effects of the increase in requirements on consumption and output in each country. Consumption in Home increases after the shock to capital requirements. This result is a combination of two partially offsetting effects. On the one hand, higher requirements decrease the probability of bank failure and its associated resolution costs, which is reflected in the budget constraint of households as lower lump sum taxes collected to bail out failing banks. On the other hand, the negative effect on output through the contraction in investment due to the more restrictive credit supply, creates a negative impact on consumption. However, the first effect is dominant, and therefore consumption increases in Home. In Foreign, however, both consumption and output decline after the increase in requirements in Home. In the case of Foreign, the decline in credit is accompanied by an increase in the failure probability of banks. Thus, both effects operate in the same direction.

The reallocation of bank equity towards Home moderates the decline in output and creates a larger expansion in consumption, at the expense of a negative externality on consumption and output in Foreign. As with the impact on credit, the results are

amplified in the case of economies exhibiting a larger presence of international banks.

4.2 Long run spillovers

We have established and quantified the presence of a negative credit and consumption externality of capital requirements in the short run. We now explore the spillovers of requirements in the long run.

As with the short run experiments, we examine the effects of changes in requirements in Home, holding requirements in Foreign constant. However, this exercise compares the long run mean of key variables in the model, for different values of capital requirements in Home.

Credit spillovers in the long run Figure 4.2 shows the effect of higher requirements in Home over key variables in the model. As with the short run effects, it is useful to first understand the effects in a closed economy context, represented by the black dashed lines in Figure 4.2.

Starting from the baseline level of 8%, increasing requirements can initially have a slightly positive impact on the long run level of credit, although for high enough levels of requirements, the effect becomes negative. For low levels of capital requirements, the initial increase generates significant declines in bank failure rates. The cost of bank debt declines as a consequence of the lower probability of default, in a manner that may offset the costs of using more equity to finance loans. However, as banks become safer, the second effect becomes dominant, and thus spreads increase, and loans fall with requirements. Under the baseline calibration of the model, increasing requirements from their baseline level of 8% to a level of 25% involves a long run level of credit roughly 2% lower than the baseline, *irrespective* of the relative size of foreign banks.[18]

Turning now to the impact on the Foreign economy, we find that the effect on credit

[18]Under the regulation introduced in Basel III, the level of capital requirements can reach and sometimes exceed 20% of risk weighted assets. See Basel Committee on Banking Supervision (2010)

in the long run is negligible. This result stands in sharp contrast with the negative effects observed in the short run. Intuitively, since bank net worth can be accumulated over time, there is an elastic supply of bank equity in the long run. The capital ratio of subsidiaries in Foreign is barely affected by the level of requirements in Home, and thus the funding costs of these banks are also largely unaffected. In turn, this implies that corporate spreads and loans in Foreign have little variation in the long run after changes in requirements in Home.

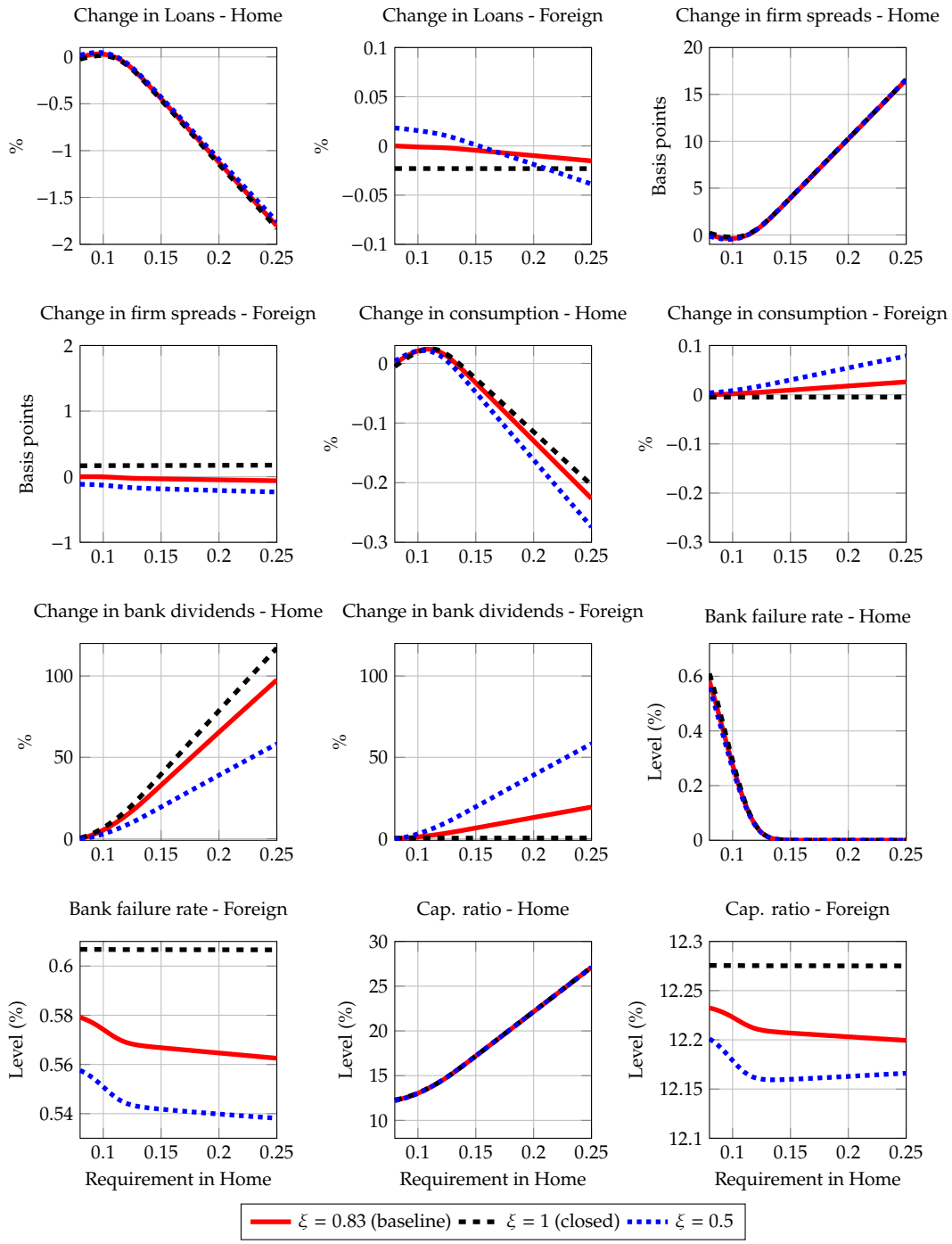

Figure 4.2: Long run spillovers of capital requirements

Notes: The change in the mean of loans, spreads, consumption, and bank dividends are expressed as deviations from the economy with a level of requirements of 8% under the baseline level of financial integration. Bank failure rates and capital ratios are expressed in levels. Red solid lines correspond to the baseline level of integration. Black dashed lines correspond to the counterfactual economy without cross border banking. Blue dotted lines correspond to a counterfactual economy in which cross border banks extend half of total credit. The mean of each variable is computed over 100,000 periods, for each level of the capital requirement in Home.

Welfare spillovers in the long run While our findings suggest that credit spillovers in the long run are negligible, we find, perhaps surprisingly, that there are non trivial consumption and welfare spillovers, as displayed in Figures 4.2 and 4.3.

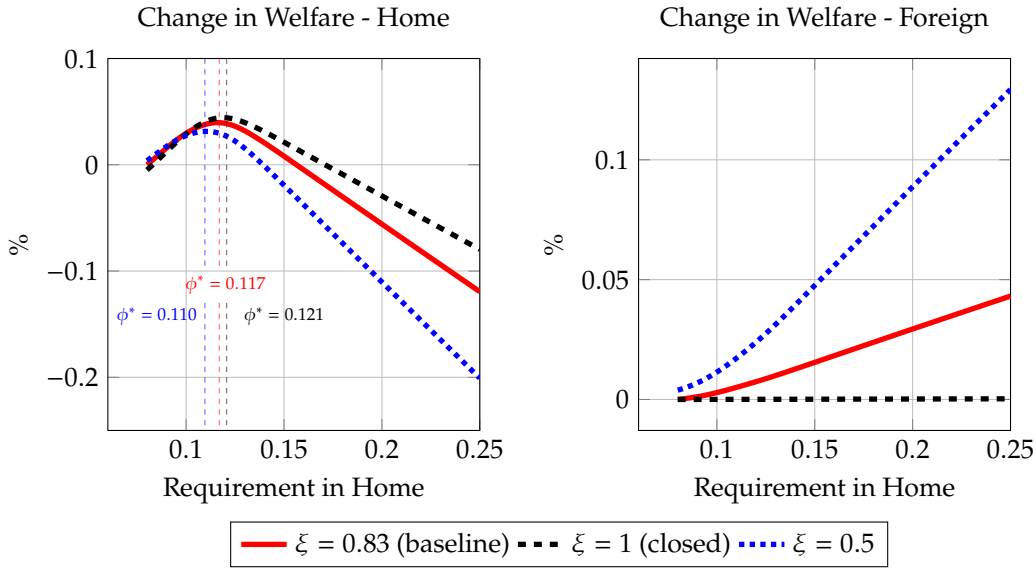

Figure 4.3: Long run effects of requirements on welfare

Notes: This figure displays the change in the mean of welfare in each country, for different values of the capital requirements in Home, expressed in percent change in permanent consumption with respect to welfare under the baseline label of requirements of 8% and the baseline share of foreign banks. Red solid lines correspond to the baseline level of integration. Black dashed lines correspond to the counterfactual economy without international bank presence. Blue dotted lines correspond to the counterfactual economy with a 50% share of international bank lending in total loans. The mean is computed over simulations with a length of 100,000 periods.

The non-monotonic effect on consumption and welfare in Home, even in the case of a closed economy, can be explained by the tradeoff between increasing financial stability and restricting the supply of credit to the financially constrained firms. But also, as capital requirements increase, the accumulation of bank net worth leads to an increase in total bank dividends paid to the households. In the long run, the dividend ratio paid by banks is roughly constant for different levels of the requirements.[19]

When we look at the case of economies with cross border banking, this means that

[19]Indeed, in the deterministic steady state of the model dividend ratios are independent of the level of requirements. With aggregate uncertainty, banks pay a slightly lower dividend ratio as requirements increase, but this second order effect is small.

households in Foreign can receive a higher dividend income from the banks that they own in Home through their BHC, without any significant costs in terms of a more restrictive credit supply in Foreign. This is reflected in an increase in both consumption and welfare in Foreign as the level of requirements in Home increases. In other words, part of the welfare gains associated with higher levels of requirements in Home leak towards Foreign households, due to this consumption externality. If we were to assume that banks bank dividends are excluded from household income, then this externality is largely shut down.[20]

Implications for optimal requirements In the absence of cross border banking, the level of welfare maximizing requirements in Home is roughly 12.1% of bank assets.[21] Once we allow for the presence of cross border banks, the level of welfare maximizing requirements in Home falls. For the baseline calibration of the model, with 17% of the credit extended by foreign banks, the optimal level of requirements in Home falls to 11.7%. In the counterfactual case where half of the loans are extended by international banks, optimal requirements for Home are about 11% of assets.

Intuitively, the positive consumption externality generated by the increase in requirements will create incentives for individual regulators to set requirements below their socially optimal level. We therefore compute the requirements that would be chosen by a global regulator maximizing the joint welfare of both countries and compare this result to the level of requirements chosen by individual regulators in a non-cooperative fashion. The results of this exercise are reported in Table 4.1.

[20]Online Appendix A.3 presents results with risk neutral bankers which are not part of the households.

[21]This value is consistent with the level of welfare maximizing requirements for corporate loans in Mendicino et al. (2018) although lower than the optimal level suggested in Mendicino et al. (forthcoming). The model in the latter reference features stronger amplification of financial shocks to the real sector in periods of high bank default and thus creates a stronger macroprudential rationale for the requirements.

Table 4.1: Coordination among regulators and optimal requirements

	Coordination			Nash		
	$\xi = 0.5$	$\xi = 0.83$	$\xi = 1$	$\xi = 0.5$	$\xi = 0.83$	$\xi = 1$
Requirements	0.1179	0.1179	0.12079	0.1084	0.1147	0.12079
Change in welfare	0.0422	0.0452	0.0492	0.0392	0.0448	0.0492
Change in loans	-0.0792	-0.0641	-0.0426	-0.0107	-0.0382	-0.0426
Bank default prob.	0.0608	0.0637	0.0676	0.1462	0.0887	0.0676

Notes: Requirements are the reported at their welfare maximizing level under coordination and as the Nash equilibrium of the game in which regulators in each country set requirements independently, for different sizes of the foreign banking sector (measured by $1 - \xi$). The change in welfare is reported as the percentage change in permanent consumption relative to the baseline level of requirements of 8%, for each value of ξ. The change in loans is expressed as the the percentage change relative to the baseline level of 8%, for each value of ξ. Bank default probabilities are expressed in percentage points.

The level of requirements chosen in the Nash equilibrium of the interaction between regulators is below the level chosen under coordination, except for the case in which we shut down cross border banking ($\xi = 1$), where there are no externalities. The discrepancy between the coordination and the Nash level of requirements is larger once we allow for a higher presence of foreign banks, as the consumption externality is exacerbated. From a quantitative perspective, requirements set under coordination are roughly 0.3 percentage points higher than those set in the Nash equilibrium, suggesting a small effect of the consumption externalities when the size of the foreign banking sector is moderate. In a counterfactual scenario where foreign banks extend one half of total credit, the difference is close to one percentage point, a sizable difference.

Under-regulation results in higher credit and higher bank default probabilities in the Nash equilibrium. Our results suggest that, under the baseline level of integration, regulators would tolerate a bank default probability close to 0.09%, compared to a 0.06% default probability under coordination. When foreign banks extend 50% of total credit, bank default probabilities without coordination climb to 0.15%, compared to the

0.06% under coordination. Our results therefore highlight the relevance of cooperation among regulators, especially when countries exhibit significant levels of integration.

5 Empirical exploration

This section provides an empirical assessment of the impact of changes in capital requirements on lending by foreign banks in countries in the Euro Area. The exercise uses impulse response analysis to assess the impact of changes in the countercyclical capital buffer and other capital measures on credit to non financial corporations in the period between 2012Q1 and 2019Q4.

5.1 Data

We summarize here the description of the main variables used in the empirical analysis. A detailed description of the data sources and all the adjustments on the data can be found in Online Appendix C.

International Loans We use data from a restricted version of the Bank for International Settlements (BIS) consolidated banking statistics (CBS), which considers loans to non financial corporations. The advantage of using consolidated statistics is that loans from subsidiaries are recorded as loans originating in the country where the controlling bank holding company is incorporated. Therefore, international loans in a given country are defined as the sum of loans extended by local bank subsidiaries owned by a foreign entity, loans extended by foreign branches and direct cross border lending.

International loans represent on average roughly 10% of the GDP of the country of destination of these loans (at the country pair level); see Table 5.1. However, there is significant dispersion across country pairs. For example, more than 75% of the

relationships comprise loans which represent less than 7.5% of GDP in the destination country, while in some cases, they can exceed 100% of GDP.

Table 5.1: Summary statistics

	Mean	SD	Min	Max	P5	P25	P50	P75	P95
Loans NFC/GDP	0.1029	0.2596	0.0000	2.7882	0.0001	0.0015	0.0137	0.0766	0.5065
GDP Growth (parent)	0.5552	1.4559	-2.9486	19.4386	-0.5408	0.1620	0.4751	0.7231	1.4597
GDP Growth (destination)	0.7158	1.3784	-2.9486	19.4386	-0.6439	0.2200	0.5594	0.9697	2.2558
Current account surplus/GDP (parent)	0.0147	0.0700	-0.4834	0.2253	-0.0832	-0.0115	0.0103	0.0439	0.1208
Current account surplus/GDP (destination)	0.0234	0.0834	-0.4834	0.3641	-0.0943	-0.0131	0.0207	0.0671	0.1418
Bank Assets/GDP (parent)	11.0351	2.9644	6.3094	22.7953	7.4270	8.7979	10.3063	12.9427	15.7315
Bank Assets/GDP (destination)	14.4148	15.9327	2.4210	76.0533	3.3989	8.2961	10.1971	14.5285	71.4532
Loan Interest Rates (parent)	2.6395	0.9331	1.3267	5.7200	1.4767	1.9567	2.4200	3.1300	4.6000
Loan Interest Rate (destination)	2.8213	1.0753	1.3267	6.4933	1.4467	2.0400	2.5500	3.3300	4.8967
Observations	3925								

Notes: The ratio of loans to GDP considers international loans as defined in section 5.1 divided by the GDP in the country of destination of the loans. We report separately the statistics for the control variables for parent and destination countries of flows, because the two groups do do not overlap exactly. Parent countries are: Austria, Belgium, Finland, France, Greece, Ireland, Italy, The Netherlands, Portugal and Spain. Destination countries are: Austria, Belgium, Croatia, Cyprus, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, The Netherlands, Portugal, Slovenia and Spain. GDP growth is expressed in quarterly percentage points. Interest rates are expressed in annualized percentage points.

Changes in capital requirements We use data from the Integrated Macroprudential Policy (iMapp) database (Alam et al., 2019), which collects information on changes on a wide range of macroprudential measures. We examine the effects of announcements of changes in the countercyclical capital buffer, as well as a broader set of capital measures. The advantage of considering the CCyB separately, is that it constitutes a requirement that is applied uniformly over all the banks in a jurisdiction, unlike other measures that often apply to a subset of banks or exposures.

Since requirements are usually implemented with a gradual phase-in and transitional arrangements, we consider the date of the *announcement* of the change in regulation, rather than the date of enforcement. We manually recover the dates of these announce-

ments, using the information in the iMapp database.

Macroeconomic and financial controls Macroeconomic and financial controls include GDP growth, total bank assets in a given country, current account surplus, a country level index of financial stress, interest rates on loans to non financial corporations and exchange rates vis-à-vis the Euro for countries which were not part of the Euro Area at the beginning of the sample, but joined at some point during the period considered.[22].

The sample considered includes both expansions and recessions (around the time European debt crises), as well as broad variation in terms of the current account position of the countries considered and the overall size of their banking system, measured in terms of assets to GDP; see Table 5.1.

5.2 Impulse responses to a change in requirements

In order to analyze the effect of changes in requirements on international lending, we estimate local projection models (Jordà, 2005) of the form

$$b_{ij,t+h} - b_{ij,t-1} = \beta_h Tightening_{s,t-1} + \sum_{k=1}^{9} \theta_k (b_{ij,t-k} - b_{ij,t-k-1}) + \mathbf{X_{s,t-1}}'\gamma + \delta_s + \delta_{s',t} + \varepsilon_{ij,t}, \quad h = 0, \ldots, 8, \quad s \neq s', \quad (5.1)$$

where $b_{ij,t}$ denotes loans extended by banks controlled by parent entities in country i to the non financial corporations in country j, divided by the GDP of country j, in period t. We look at the effects of both a tightening in the parent country of the banks ($s = i$) or the destination country ($s = j$).

The variable $Tightening_{s,t}$ is a dummy that takes a value of one if a there was an

[22]These controls are added at either the parent country or the destination country level, in addition to the fixed effects in equation 5.1

announcement of a tightening of requirements in country s in period t. Since changes in requirements often take place at the end of a quarter in our sample, we include the lag of $Tightening_{i,t}$ as our preferred impulse measure, to account for this mismatch in the timing of policy and bank lending decisions within a quarter. Macroeconomic and financial controls are included in $X_{s,t}$. Finally δ_s and $\delta_{s',t}$ denote country and country-time fixed effects, respectively.[23]

Effects of a tightening of requirements in the parent country Figure 5.1 displays the estimated impulse response functions and the 90 and 95% confidence interval around the estimate at each horizon. The results suggest an overall negative effect on international lending activities of banks, after a tightening of requirements in the parent country of the bank holding company controlling the banks. The effects are similar after we consider both the tightening of the countercyclical capital buffer or a broader set of capital measures.

This effect is consistent with the results of our quantitative model, in which a tightening of requirements in one country can generate bank equity outflows from other countries, effectively generating a negative credit externality abroad. The relatively short sample prevents us from looking at very long horizons to study the impact of changes in regulation in the long run.

[23]The notation in equation 5.1 is independent of the notation used in the model in Section 2.

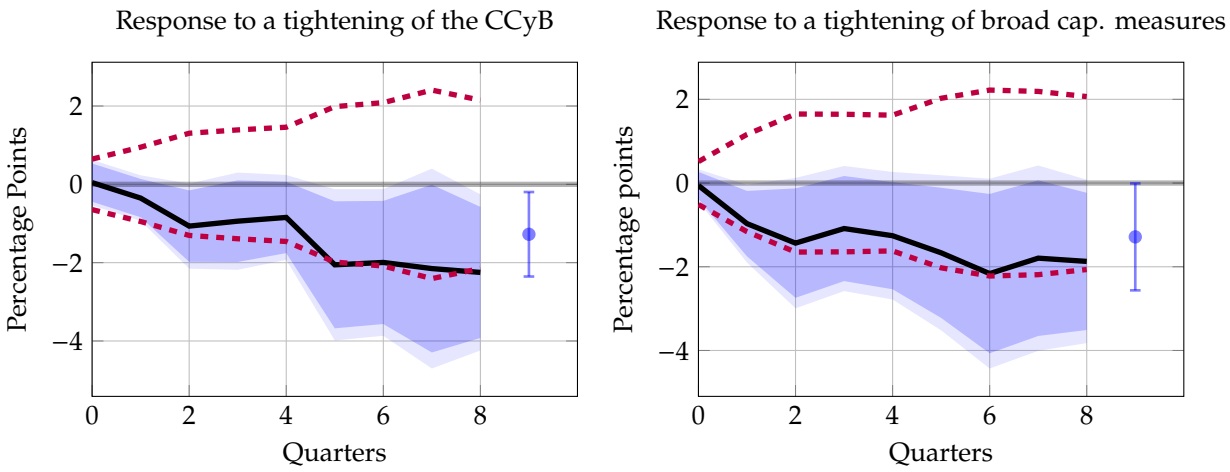

Figure 5.1: Response of international credit to a change in capital regulation in the parent country.

Notes: The left hand panel shows the response of credit to non financial corporations extended by foreign banks after the announcement of a tightening of the CCyB in the parent country of the banks. The right hand panel uses the announcement of a broad set of capital measures, including the CCyB, the capital conservation buffer, limits on the leverage ratio, changes in loan loss provisioning regulation, limits on credit growth and other broad capital measures. The blue shaded areas correspond to 90% and 95% confidence intervals for individual coefficients. Dashed red lines correspond to 90% confidence bands for the joint significance of the coefficients, obtained using Scheffé (1953) method, as suggested in Jordà (2023). The estimated coefficients for the average response over the 9 horizons and their 90% confidence bands are displayed to the right of each panel, in blue.

Effects of a tightening of requirements in the destination country When we re estimate equation 5.1 to study the effect of the changes in the regulation of the destination country of flows, our results become not significant. This effect is also consistent with the equity allocation mechanism highlighted in this paper. For a bank holding company, an increase in requirements over foreign exposures might have a small incidence on the consolidated capital constraints of the group, because it represents only a small share of its assets. When the change in requirements takes place in the parent country of a BHC, it affects a large share of its assets. As a result, it is intuitive to observe larger effects in this latter case.

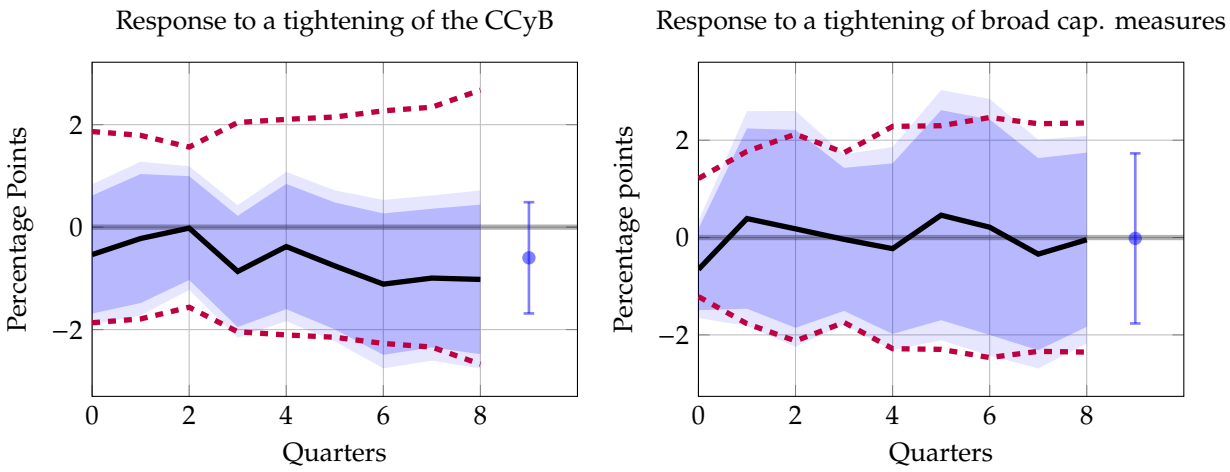

Figure 5.2: Response of international credit to a change in capital regulation in the host country of the banks.

Notes: The left hand panel shows the response of credit to non financial corporations extended by foreign banks after the announcement of a tightening of the CCyB in the host country of the banks. The right hand panel uses the announcement of a broad set of capital measures, including the CCyB, the capital conservation buffer, limits on the leverage ratio, changes in loan loss provisioning regulation, limits on credit growth and other broad capital measures. The blue shaded areas correspond to 90% and 95% confidence intervals for individual coefficients. Dashed red lines correspond to 90% confidence bands for the joint significance of the coefficients, obtained using Scheffé (1953) method, as suggested in Jordà (2023). The estimated coefficients for the average response over the 9 horizons and their 90% confidence bands are displayed to the right of each panel, in blue.

6 Discussion of results

This section discusses some caveats in the interpretation of our results and provides an analysis of our most relevant modeling assumptions.

First, while the assumption of a host country principle for capital regulation is broadly consistent with the international standards adopted after de GFC, home regulators retain the legal capacity to impose requirements on the exposures of banks incorporated under their jurisdiction, even if reciprocity applies to some requirements such as the CCyB. Modifying this assumption does not substantially affect the short run results in terms of the negative credit spillovers created by regulation. However, the long run credit spillovers are no longer negligible in this case. Under a home country principle,

banks from the country that increases the requirements face a higher average cost of funds in all the jurisdictions where they extend credit and, consequently, they tighten credit conditions in all countries.

Second, we assume that countries are homogeneous in terms of their institutional and financial development and that there are no restrictions to bank equity flows. While this assumption fits well with the arguably harmonized regulatory framework in the Euro Area, extrapolating these results to other settings requires certain caveats. In particular, if banks were to face, for example, expropriation risk or restrictions to capital flows that hinder their ability to transfer dividends to their parent BHC, then our results might be modified. Intuitively, foreign banks may not be willing to expose as much equity in countries with weaker property rights, as argued by Houston et al. (2012), as requirements increase.

Third, we assume that frictions on equity financing are independent of the leverage ratio of banks and firms. Our results might change if, for example, bank dividend targets and its adjustment costs depended on the banks' capital ratio. Unfortunately, it is not clear how this dependence would look like. A higher capital ratio might result in stronger frictions in the corporate governance of banks if, for example, minority equity holders were concerned about unfair treatment by managers or controlling shareholders (Easterbrook, 1984). On the other hand, a higher capital ratio might alleviate the debt overhang (Myers, 1977) problem that may arise as banks try to improve their capital positions, which would suggest that dividend adjustment costs should be lower with higher capital ratios. We therefore follow the literature (Gertler and Kiyotaki, 2010; Mendicino et al., 2018, 2020; Elenev et al., 2021, among others) in assuming that these frictions are independent of the leverage of banks in the long run.

Finally, this work could be extended along several dimensions. First, while we have focused on the spillovers of regulation in the context of a tightening of requirements, another important question is related to the effects of the release of requirements in the presence of cross border banking. We do not explicitly address this question in this

paper, in part because such release episodes often coincide with simultaneous extraordinary policy measures, such as dividend payout restrictions, which may interact with the effect of requirements. Another related avenue for further research is related to the globally optimal level of requirements in the presence of cross border banking flows, compared to the one prevailing in financial autarky. Such an analysis would require considering potential frictions arising under financial integration, such as excessive volatility in capital flows, which are beyond the scope of this paper. In addition to this, while we have focused on integration through the ownership of internationally active banks, extensions of this work could consider other forms of integration, such as cross border debt flows.

7 Conclusion

This paper highlights the relevance of studying the spillovers of macroprudential policies in a general equilibrium setting. One of the main findings of our quantitative analysis is related to the contrast between the nature of spillovers of host country based regulation in the short and the long run. In the short run, a tightening of requirements in one country is likely to generate a negative credit spillover abroad, but this negative credit externality washes away in the long run, as banks accumulate net worth.

The second relevant finding of our analysis is centered on the welfare spillovers created by the regulation. Our findings suggest that an increase in requirements in one country might create positive welfare spillovers in other countries. Our results suggest that the primary source of the welfare externality is an increase in total dividend payouts by banks to foreign bank owners. These results highlight the need to develop a better understanding of the ownership structure of banks in order to assess the impact of requirements on consumption in the context of financially integrated economies.

Finally, our findings have important policy implications. The small estimated impact of the increase of requirements on credit, both in closed and open economy settings,

suggests that the transition towards higher levels of requirements, such as those envisioned in Basel III reforms, could be performed at a relatively low cost in terms of their impact on economic activity. Our results on the short run effects of the policies therefore suggest that the concerns of uncoordinated actions by policymakers with regard to the tightening of requirements could be minor, at least in settings where the participation of foreign banks in credit is moderate. On the other hand, our findings also suggest that the positive long run welfare spillovers of requirements create incentives for under-regulation by uncoordinated authorities. Our quantitative analysis suggests that the size of the deviation from the optimal policy depends on the relative participation of foreign banks in total credit, thus highlighting the importance of cooperation between countries with strongly integrated banking sectors.

References

Acharya, V. V. (2003). Is the international convergence of capital adequacy regulation desirable?, *The Journal of Finance* **58**(6): 2745–2782.

Agénor, P.-R., Jackson, T. P. and da Silva, L. A. P. (2024). Cross-border regulatory spillovers and macroprudential policy coordination, *Journal of Monetary Economics* p. 103582.

Aiyar, S., Calomiris, C. W. and Wieladek, T. (2014). Does macro-prudential regulation leak? Evidence from a UK policy experiment, *Journal of Money, Credit and Banking* **46**(s1): 181–214.

Alam, Z., Alter, A., Eiseman, J., Gelos, G., Kang, H., Narita, M., Nier, E. and Wang, N. (2019). Digging deeper - evidence on the effects of macroprudential policies from a new database, *Journal of Money, Credit and Banking* .

Andreasen, M. M., Fernández-Villaverde, J. and Rubio-Ramírez, J. F. (2018). The pruned state-space system for non-linear DSGE models: Theory and empirical applications, *The Review of Economic Studies* **85**(1): 1–49.

Andrews, I., Gentzkow, M. and Shapiro, J. M. (2017). Measuring the sensitivity of parameter estimates to estimation moments, *The Quarterly Journal of Economics* **132**(4): 1553–1592.

Bahaj, S. and Malherbe, F. (2024). The cross-border effects of bank capital regulation, *Journal of Financial Economics* **160**: 103912.

Basel Committee on Banking Supervision (2010). *Basel III: A global regulatory framework for more resilient banks and banking systems*, Bank for International Settlements.

Basel Committee on Banking Supervision (2024). *Range of practices in implementing a positive neutral countercylical capital buffer*, Bank for International Settlements.

Bedayo, M. and Galán, J. (2024). The impact of the countercyclical capital buffer on credit: Evidence from its accumulation and release before and during covid-19.

Bernanke, B. S., Gertler, M. and Gilchrist, S. (1996). The financial accelerator and the flight to quality, *The Review of Economics and Statistics* **78**(1): 1–15.

Bernanke, B. S., Gertler, M. and Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework, *Handbook of Macroeconomics* **1**: 1341–1393.

Blickle, K., Parlatore, C. and Saunders, A. (2023). Specialization in banking, *Technical report*, National Bureau of Economic Research.

Buch, C. M. and Goldberg, L. (2016). Cross-border prudential policy spillovers: how much? How important? Evidence from the international banking research network, *Working Paper 22874*, National Bureau of Economic Research.

Christiano, L. J., Motto, R. and Rostagno, M. (2014). Risk shocks, *American Economic Review* **104**(1): 27–65.

Clerc, L., Derviz, A., Mendicino, C., Moyen, S., Nikolov, K., Stracca, L., Suarez, J. and Vardoulakis, A. (2015). Capital regulation in a macroeconomic model with three layers of default, *International Journal of Central Banking* **11**(3): 9–65.

Couaillier, C., Lo Duca, M., Reghezza, A. and Rodriguez D'Acri, C. (2024). Caution: Do not cross! distance to regulatory capital buffers and corporate lending in a downturn, *Journal of Money, Credit and Banking* .

Darracq Paries, M., Kok, C. and Rancoita, E. (2019). Macroprudential policy in a monetary union with cross-border banking.

DellAriccia, G. and Marquez, R. (2006). Competition among regulators and credit market integration, *Journal of Financial Economics* **79**(2): 401–430.

Demirgüç-Kunt, A., Kane, E. and Laeven, L. (2015). Deposit insurance around the world: A comprehensive analysis and database, *Journal of financial stability* **20**: 155–183.

Djankov, S., Hart, O., McLiesh, C. and Shleifer, A. (2008). Debt enforcement around the world, *Journal of Political Economy* **116**(6): 1105–1149.

Easterbrook, F. H. (1984). Two agency-cost explanations of dividends, *The American economic review* **74**(4): 650–659.

Elenev, V., Landvoigt, T. and Van Nieuwerburgh, S. (2021). A macroeconomic model with financially constrained producers and intermediaries, *Econometrica* **89**(3): 1361–1418.

Gertler, M. and Kiyotaki, N. (2010). Financial intermediation and credit policy in business cycle analysis, *Handbook of Monetary Economics* **3**: 547–599.

Gilchrist, S. and Mojon, B. (2018). Credit risk in the euro area, *The Economic Journal* **128**(608): 118–158.

Granja, J., Matvos, G. and Seru, A. (2017). Selling failed banks, *The Journal of Finance* **72**(4): 1723–1784.

Houston, J. F., Lin, C. and Ma, Y. (2012). Regulatory arbitrage and international bank flows, *The Journal of Finance* **67**(5): 1845–1895.

Jermann, U. J. (1998). Asset pricing in production economies, *Journal of Monetary Economics* **41**(2): 257–275.

Jordà, Ò. (2005). Estimation and inference of impulse responses by local projections, *American economic review* **95**(1): 161–182.

Jordà, Ò. (2023). Local projections for applied economics, *Annual Review of Economics* **15**(1): 607–631.

Kareken, J. H. and Wallace, N. (1978). Deposit insurance and bank regulation: A partial-equilibrium exposition, *Journal of Business* **51**(3): 413–438.

Macnamara, P., Pidkuyko, M. and Rossi, R. (2024). Marginal tax rates and income in the long run: Evidence from a structural estimation, *Journal of Monetary Economics* **142**: 103514.

Malovaná, S., Hodula, M., Bajzík, J. and Gric, Z. (2024). Bank capital, lending, and regulation: A meta-analysis, *Journal of Economic Surveys* **38**(3): 823–851.

Mendicino, C., Nikolov, K., Rubio Ramirez, J., Suarez, J. and Supera, D. (forthcoming). Twin defaults and bank capital requirements, *Journal of Finance* .

Mendicino, C., Nikolov, K., Suarez, J. and Supera, D. (2018). Optimal dynamic capital requirements, *Journal of Money, Credit and Banking* **50**(6): 1271–1297.

Mendicino, C., Nikolov, K., Suarez, J. and Supera, D. (2020). Bank capital in the short and in the long run, *Journal of Monetary Economics* **115**: 64–79.

Myers, S. C. (1977). Determinants of corporate borrowing, *Journal of financial economics* **5**(2): 147–175.

Paravisini, D., Rappoport, V. and Schnabl, P. (2023). Specialization in bank lending: Evidence from exporting firms, *The Journal of Finance* **78**(4): 2049–2085.

Reinhardt, D. and Sowerbutts, R. (2015). Regulatory arbitrage in action: Evidence from banking flows and macroprudential policy.

Rubio, M. (2020). Cross-country spillovers from macroprudential regulation: Reciprocity and leakage, *Journal of International Money and Finance* **103**: 102134.

Scheffé, H. (1953). A method for judging all contrasts in the analysis of variance, *Biometrika* **40**(1-2): 87–110.

Townsend, R. M. (1979). Optimal contracts and competitive markets with costly state verification, *Journal of Economic Theory* **21**(2): 265–293.

Tripathy, J. (2020). Cross-border effects of regulatory spillovers: evidence from mexico, *Journal of International Economics* **126**: 103350.

Internet Appendix

The Cross Border Effects of Bank Capital Regulation in General Equilibrium

Appendix A Sensitivity Analysis and Robustness

A.1 Parameter sensitivity analysis

In order to increase the transparency of our results, we follow the approach recommended by Andrews et al. (2017) and report how our targeted moments react to changes in estimated parameters.

As in Elenev et al. (2021), we consider the symmetric finite difference

$$\frac{\log(\mathbf{m}(\theta \circ \mathbf{e}^{\iota_i \varepsilon})) - \log(\mathbf{m}(\theta \circ \mathbf{e}^{-\iota_i \varepsilon}))}{2\varepsilon}, \tag{A.1}$$

where $\mathbf{m}$ is the vector of targeted moments, which depends on the vector of parameters θ. The selector vector ι_i takes a value of 1 in the i'th position and zero elsewhere, so that the elements of θ are modified one at a time. We move each parameter 1% up and down with respect to its calibrated value, and therefore we set $\varepsilon = 0.01$. Figure A.1 presents the resulting variation in each of the moments, for the change in each parameter.

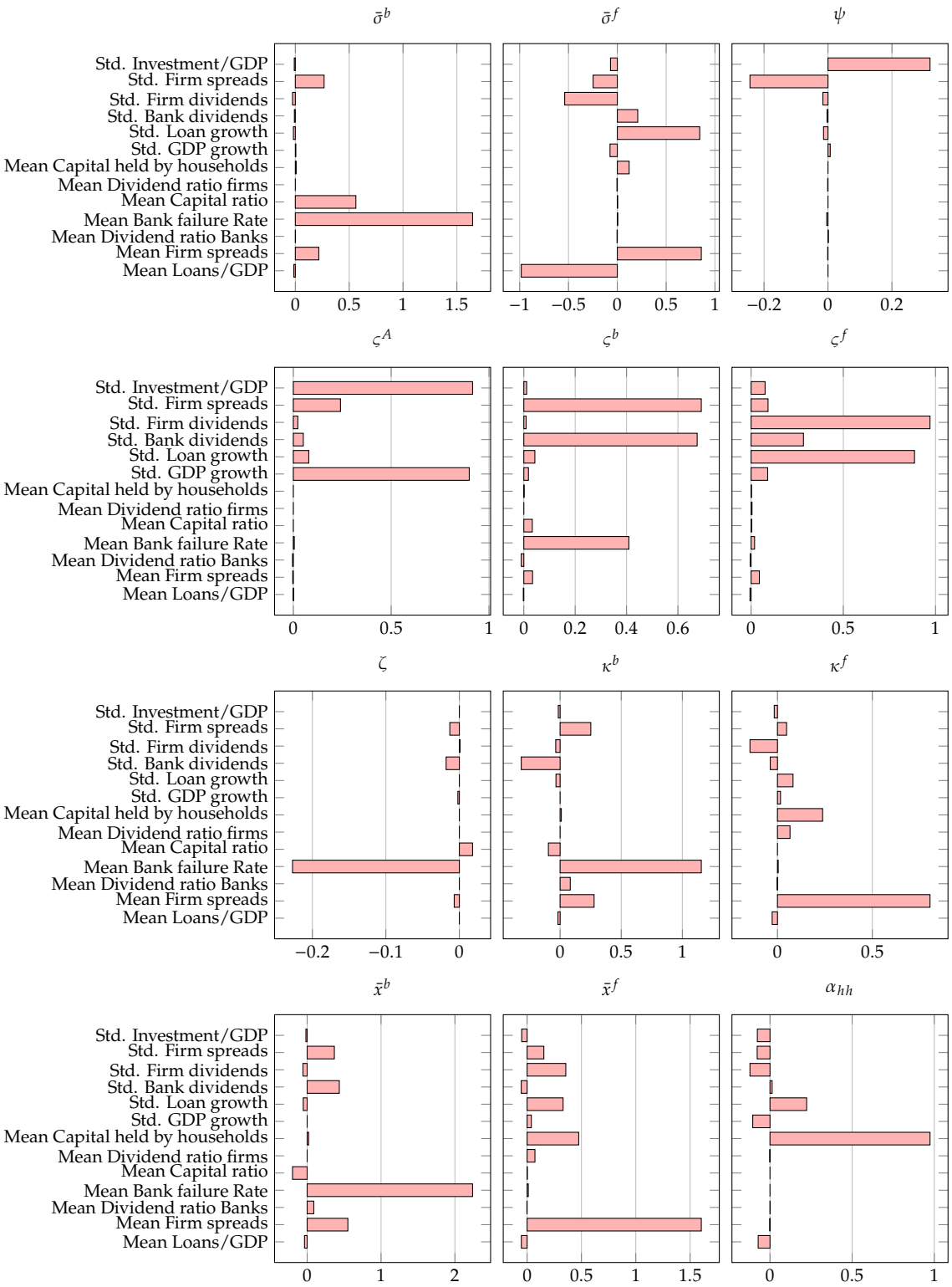

Figure A.1: Sensitivity analysis of calibrated parameters.

Notes: The figure presents the percent deviation of each targeted moment to a one percent deviation to each of the estimated parameters of the model. The exercise is performed under the symmetric calibration of the model.

Some parameters are clearly identified by the variation in a single moment. For example, capital adjustment costs ψ are clearly identified by the standard deviation of investment, and the productivity of the household backyard technology α_{hh} by the average share of capital held directly by the households.

In other cases, it is possible to identify a subset of moments closely related with a subset of parameters. For example, the mean bank failure rate and the mean bank capital ratio, identify the average dispersion of bank iid shocks $\bar{\sigma}^b$ and the costs of non compliance ζ. Then the average dividend payout of banks and its standard deviation help identify $\bar{x}^b$ and κ^b, which govern bank dividend targets and its adjustment costs. Similarly, mean firm spreads and the ratio of loans to GDP help pin down the average dispersion of firm iid shocks $\bar{\sigma}^f$ and the firms' dividend target $\bar{x}^f$. Then, κ^f is identified by the standard deviation of credit growth. Finally, the standard deviation of productivity shocks ς^A, and the standard deviation of bank and firm risk shocks (ς^b and ς^f), are tied to the volatility of GDP growth, spreads on firm debt and firm dividends, respectively.

A.2 Sensitivity to the elasticity of substitution η

We now explore the relevance of the elasticity of substitution between sectors financed by banks from each country η, in shaping the short run spillovers of requirements. The results of this exercise are displayed in Figure A.2.

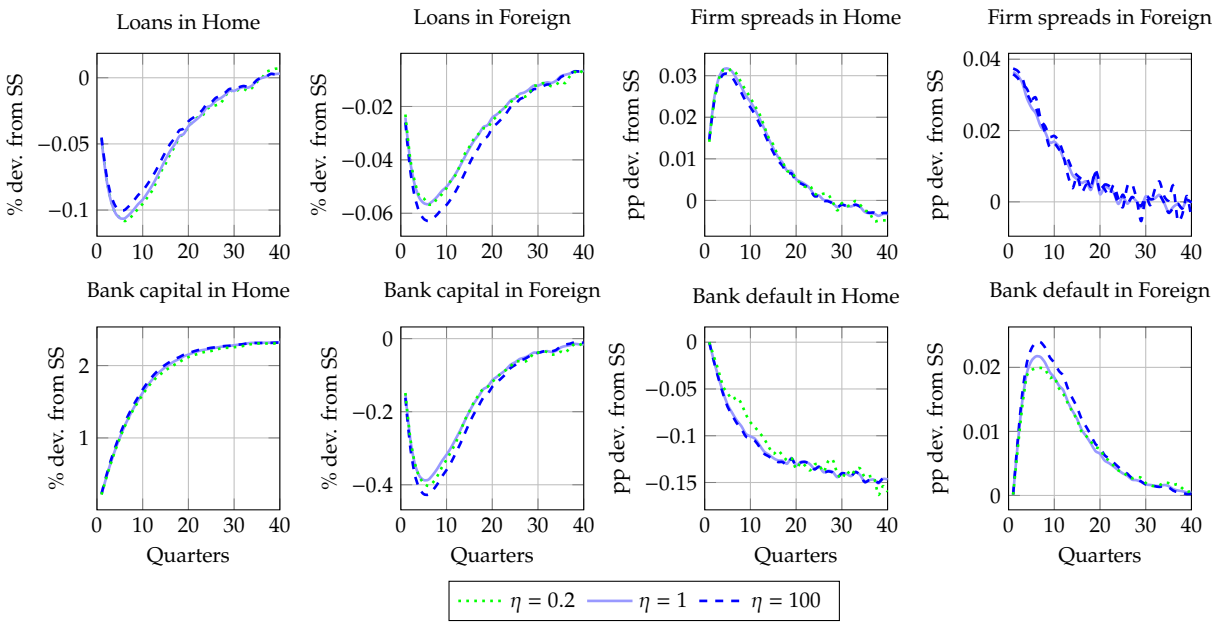

Figure A.2: Sensitivity analysis with respect to the elasticity of substitution between sectors.

Notes: The figure presents the impulse response of each variable to a one percentage point increase in requirements in Home (with a gradual phase-in of 8 quarters), keeping the requirements in Foreign constant, for different values of the elasticity of substitution between sectors financed by each class of banks.

The higher the elasticity of substitution between the two sectors, the stronger the spillovers observed after a tightening of requirements. This effect is very intuitive. To see why this is the case, consider an increase in requirements in Home. The BHC from Home is more exposed to the change in requirements than the BHC from Foreign, because exposures in Home represent a larger share of its portfolio. Therefore, banks owned by the BHC from Home tighten their credit more than their Foreign counterparts. With high substitutability, a larger share of credit in Home can be easily provided by banks from Foreign. Therefore, bank capital is more aggressively reallocated from Foreign towards Home when the elasticity of substitution is higher.

Quantitatively, this robustness exercise suggests that our results do not vary dramatically with this elasticity of substitution. If anything, it places our estimated cross border spillovers on the conservative side, as higher values of η exhibit stronger spillovers.

A.3 Sensitivity to the ownership of BHCs

We have assumed in the paper that BHCs are owned by the households in each country, which receive their net dividend payouts. This assumption is important in order to compute the effects that regulation has on welfare. However, it might be the case that regulators either disregard the consumption of bank owners or that the ownership structure of banks is so complex, that it is impossible to trace the nationality of controlling entities.

We therefore repeat our analysis, but assume that instead of being owned by the households, bank subsidiaries are owned by risk neutral investors with the same discount factor as the households. We exclude the consumption of these investors from the welfare computation and repeat compute the effects of changes in requirements over the long run. The results of this exercise are reported in A.3.

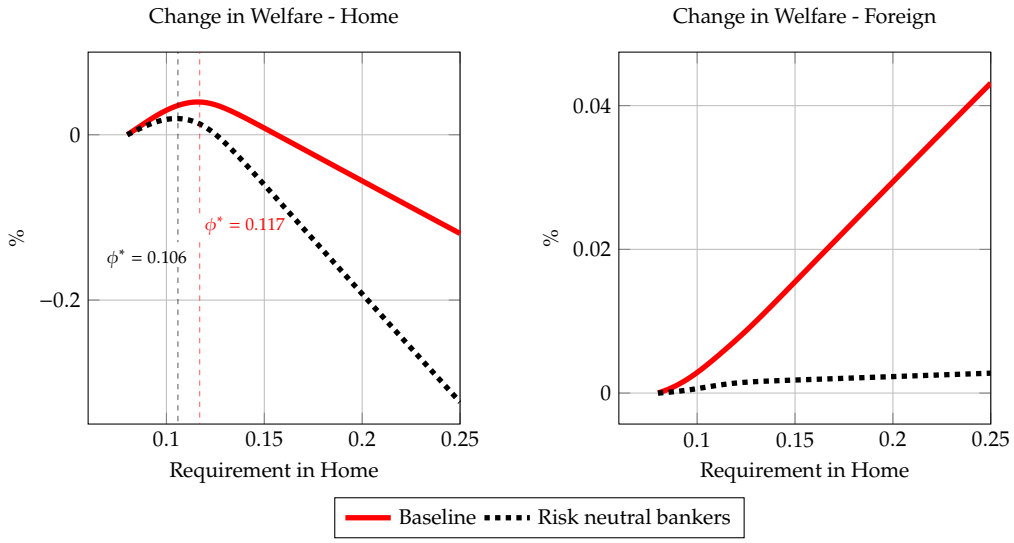

Figure A.3: Sensitivity analysis with respect to the ownership structure of banks.

Notes: The figure presents the welfare change in each country, for different levels of requirements in Home, when bank dividends are excluded from the household budget constraint. The change in welfare is expressed as the percent change in permanent consumption with respect to the baseline level of requirements of 8%.

First, it is important to highlight that the welfare in Home is maximized for a lower

level of requirements once we exclude the consumption of bank owners from the utility of households. This is due to the fact that bank dividends are a fraction of total bank net worth, which increases with requirements. On the other hand, the positive welfare spillovers on Foreign are dramatically reduced. This follows from the fact that as requirements in Home increase and the BHCs accumulate net worth, bank dividend payouts to Foreign do not increase in this case. The spillovers, however, are not entirely shut down. There is a small welfare spillover which follows from the benefits of a more stable Home economy and the mild decline in bank failure probability in Foreign, as in Figure 4.2 in the main body of the paper.

A.4 Asymmetric setting

In this appendix, we consider an asymmetric calibration of the model, in which we relabel countries as Core and Periphery. The Core comprises the economies of Austria, Belgium, France, Germany and the Netherlands, while the rest of the countries in the Euro Area are included in the Periphery. In order to keep the analysis tractable, we only allow for differences between countries along a limited number of dimensions. The Core and Periphery countries differ in the share of firms financed by foreign banks, in the average risk of their banks and in the relative size of their economies.[24] These differences are reflected in the calibration, by targeting country specific shares of international loans, different bank funding costs and the GDP of the Core relative to the Periphery. [25]

Short run spillovers with asymmetry We begin by examining the strength of credit spillovers in the short run, as depicted in Figure A.4. Since countries are asymmetric, it is useful to examine the effects of changes in requirements in the Core and the

[24]We introduce different sizes for the economies, by assigning a different mass to each household, and adjusting the cross border equations accordingly. See the online appendix for details.

[25]We target a share of foreign to total credit of 8.4% in the Core and roughly 17% in the Periphery, and a difference in the cost of bank debt between the BHCs of the Core and the Periphery of

Periphery separately.

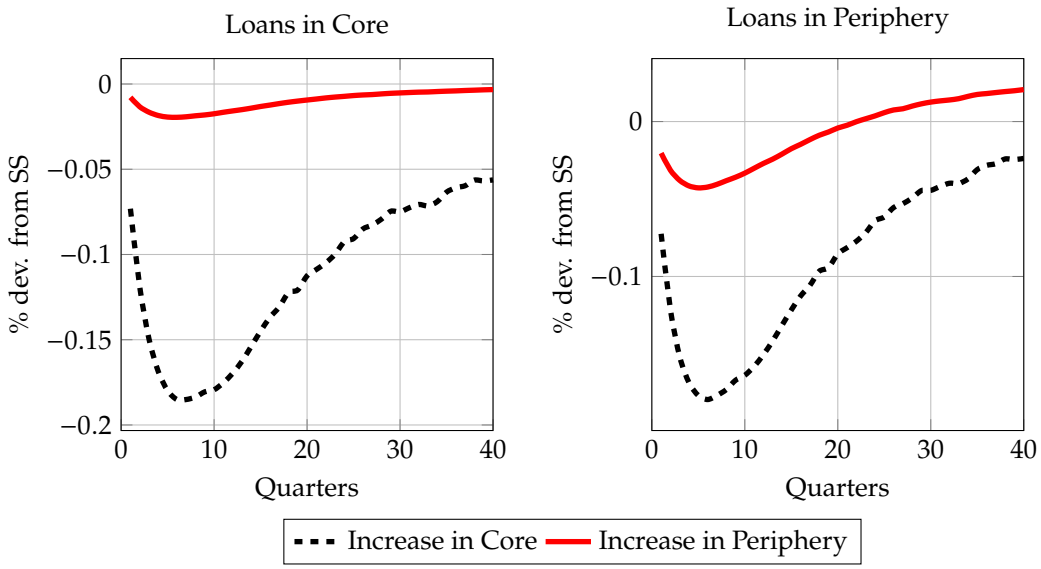

Figure A.4: Credit spillovers in the asymmetric setting

Notes: The figure displays the response of loans in each country, after a shock that increases capital requirements in either the Core or the Periphery by one percentage point, implemented with a gradual transition of 8 quarters. Red solid lines correspond to an increase in the Periphery. Black dashed lines correspond to an increase in the Core. The simulations used to compute the impulse response functions are obtained using a second order approximation around the deterministic steady state of the model and pruning to rule out explosive paths. The responses are expressed in terms of the deviation of variables with respect to their mean under the ergodic distribution of the model.

An increase in requirements in either region generates a negative credit spillover in the other region, through the same channels that we have highlighted in the symmetric case. However, there are substantial differences in terms of the size of the effects in each country.

A tightening of requirements in the Core generates much larger spillovers than a tightening in the Periphery, consistent with the asymmetric presence of foreign banks in each country. Interestingly, the effect on credit in the Periphery is larger after a change in requirements in the Core than after a change of requirements in the Periphery itself. To understand this effect, it is important to note that Core banks are safer than Periphery banks in this asymmetric calibration. Therefore, increasing requirements in the Core has smaller financial stability gains and hence the tradeoff with economic

activity is stronger. Indeed, the negative impact in the Core after a change in its domestic requirements is twice as large as the impact in the Periphery after a change in its requirements.

This exercise highlights not only the potentially asymmetric nature of spillovers, but also the fact that countries with different risk characteristics in their banking industry might experience different real effects after a change in requirements. This insight sheds light, for example, on the large cross country variation found in empirical studies that look at the real effects of changes in requirements (see, for example, Malovaná et al., 2024).

Long run spillovers with asymmetry We now analyze the long run effects of changes in requirements in the Core and the Periphery separately; see Figure A.5. The absence of significant long run credit spillovers is still present in the case of asymmetric economies. However, requirements have different welfare implications in the Core and the Periphery. Indeed, the level of welfare maximizing requirements in the Periphery are significantly higher than those in the Core, because of the differences in the level of bank risk in each region. Moreover, the size of the consumption externality generated by requirements is different in each region.

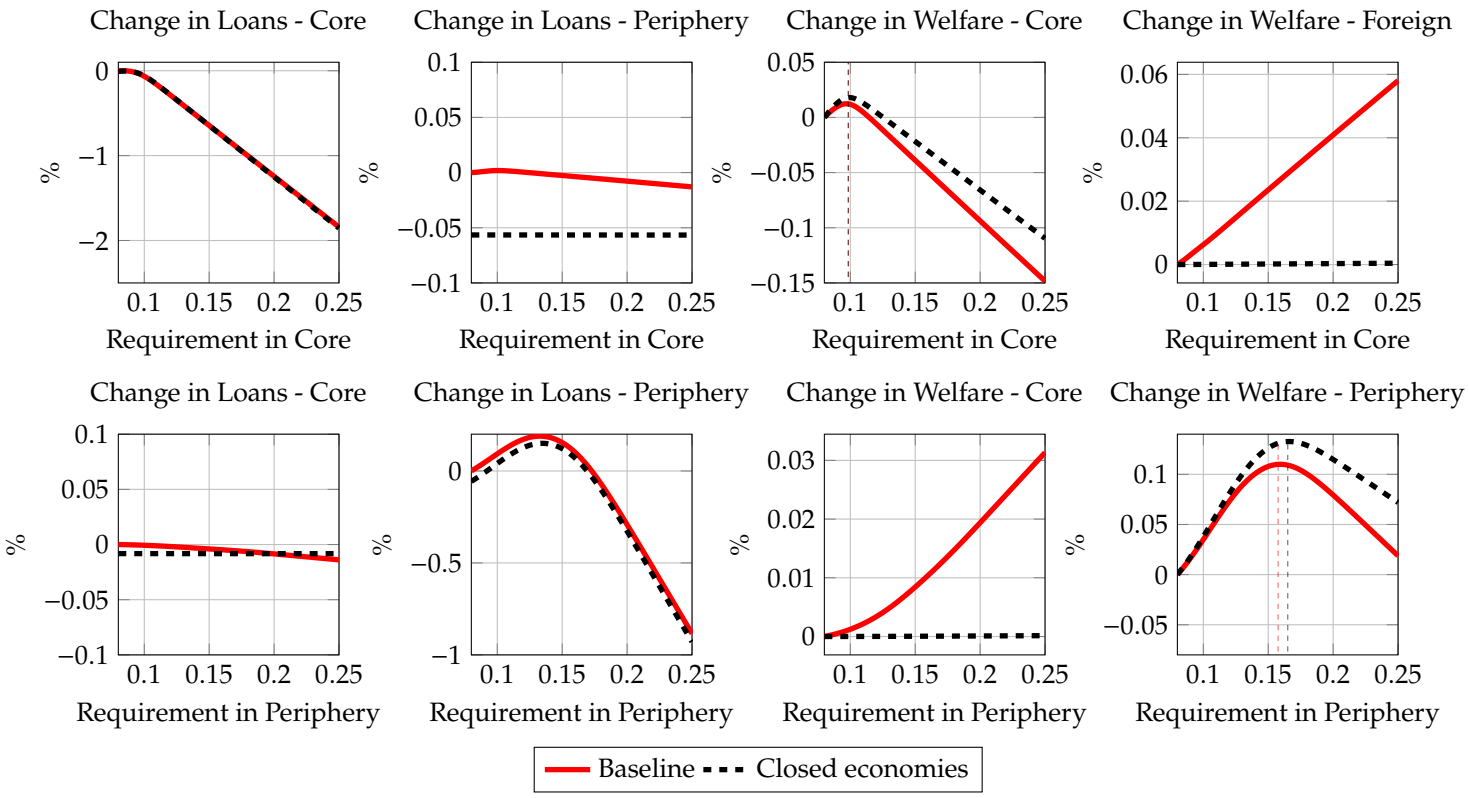

Figure A.5: Long run effects in the asymmetric setting

Notes: The change in the mean of loans, spreads is expressed in terms of the deviation with respect to the economy with a level of requirements of 8% under the baseline level of financial integration in the asymmetric calibration. The change in welfare is expressed as the change in permanent consumption with respect to the baseline economy, needed to leave consumers indifferent. Black dashed lines correspond to the counterfactual economy without international bank presence. The mean of each variable is computed over 100,000 periods, for each level of the capital requirement in either the Core or the Periphery.

While an increase in requirements in each country creates a positive consumption externality over the other, increases in the Core have a larger impact on the Periphery than vice-versa. This happens because the Core is a large economy relative to the Periphery. Therefore, the amount of net dividends received by the Periphery households from the activities of its banks in the Core are a more significant fraction of their budget than in the case of Core banks lending in the Periphery.[26]

[26]Under our asymmetric calibration, loans from the Core to the Periphery represent roughly 11% of the Core GDP, while loans from the Periphery to the Core represent about 13% of the Periphery GDP.

At the same time, the Core would choose basically the same level of requirements under financial integration and in the close economy setup. The Periphery instead, would choose lower requirements under financial integration. Since a large fraction of the loans in the Periphery is extended by Core banks, a larger part of the welfare gains are transferred to the Core households. Similarly, because Periphery banks are small in the Core, the welfare externality is small from the point of view of the Core households.

All in all, the results in the asymmetric case broadly coincide with the intuitions derived from the symmetric calibration. However, these results also highlight the differences that may arise across jurisdictions with a heterogeneous presence of foreign banks and with varying levels of risk, in terms of the long run impact of capital requirements on welfare.

Appendix B Aggregation, market clearing and steady state equations

B.1 Definition of equilibrium

A decentralized equilibrium is characterized by a sequence of prices $\left\{p_{ij,t}, w_{j,t}, q^k_{j,t}\right\}^{\infty}_{t=0}$, interest rates $\left\{R_{ij,t}, R^d_{j,t}\right\}^{\infty}_{t=0}$ and quantities

$$\left\{B_{ij,t}, e^f_{ij,t}, l_{ij,t}, N^b_{i,t}, N^f_{ij,t}, y_{ij,t}, e^b_{ij,t}, K_{j,t}, c_{j,t}, d_{j,t}, k_{hh,t}\right\}^{\infty}_{t=0}$$

such that given the laws of motion for the net worth of BHCs and CHCs, physical capital and aggregate shocks, households maximize their utility in (2.1) subject to their budget constraints in (2.2); BHCs solve the problem in (2.21)-(2.25); CHCs solve the problem in (2.10)-(2.13); final good producers maximize profits in (2.4); capital good producers maximize their profits in (2.30); the government in each country collects lump sum

taxes to pay for the insured fraction of debt of defaulting banks, and the markets for bank equity, firm equity, loans, deposits, labor, physical capital, intermediate goods and the final consumption good clear each period.

B.2 First order conditions of optimization problems

Households The first order conditions of the problem of households are given by

$$\mathbb{E}_t \Lambda_{j,t+1} \tilde{R}^d_{t+1} = 1, \tag{B.1}$$

$$\mathbb{E}_t \Lambda_{j,t+1} \left[\alpha_{hh} (k^{hh}_{j,t})^{\alpha_{hh}-1} + q^k_{j,t+1}(1-\delta) \right] = 1, \tag{B.2}$$

$$\frac{w_{j,t}}{c_{j,t}} - L_{j,t} = 0, \tag{B.3}$$

with

$$\Lambda_{j,t+1} = \beta \frac{c_{j,t}}{c_{j,t+1}}$$

. The definition of the unit loss on bank debt in default $\Omega_{j,t}$ in equation (2.3) is given by

$$\Omega_{j,t} \equiv \frac{\Omega_{Homej,t} D_{Homej,t} + \Omega_{Foreignj,t} D_{Foreignj,t}}{d_{j,t}}, \tag{B.4}$$

with

$$\Omega_{ij,t} \equiv \frac{\tilde{R}_{ij,t} \left[\bar{\omega}^b_{ij,t} - \Gamma^b_{ij,t}(\bar{\omega}^b_{ij,t}) + \mu_b G^b_{ij,t}(\bar{\omega}^b_{ij,t}) \right] - \phi_{min} F^b_{ij,t}(\bar{\omega}^b_{ij,t})}{1 - \phi_{ij,t-1}}, \tag{B.5}$$

where we follow the notation in Bernanke et al. (1999) in defining

$$G_t(x) \equiv \int_0^x \omega dF_t(\omega)$$

$$\Gamma_t(x) \equiv G_t(x) + x(1 - F_t(x)).$$

Final good producers The profit maximization of final good producers leads to the usual marginal conditions

$$p_{ij,t} = \left(\xi_j \frac{Y_{j,t}}{y_{ij,t}}\right)^{\frac{1}{\eta}}, \quad i = j \tag{B.6}$$

$$p_{ij,t} = \left((1-\xi_j) \frac{Y_{j,t}}{y_{ij,t}}\right)^{\frac{1}{\eta}}, \quad i \neq j. \tag{B.7}$$

Firms The first order conditions in the problem of the firms solve the problem in equations (2.10)-(2.27). These conditions are given by

$$\mathbb{E}_t \Lambda^f_{ij,t+1} \frac{\partial \Pi^f_{ij,t+1}}{\partial k_{ij,t+1}} - \lambda^f_{ij,t} \mathbb{E}_t \Lambda^b_{ij,t+1} \frac{\partial \Pi^b_{ij,t+1}}{\partial k_{ij,t+1}} + \vartheta^f_{ij,t+1} q^k_{j,t} = 0, \tag{B.8}$$

$$\mathbb{E}_t \Lambda^f_{ij,t+1} \frac{\partial \Pi^f_{ij,t+1}}{\partial l_{ij,t+1}} - \lambda^f_{ij,t} \mathbb{E}_t \Lambda^b_{ij,t+1} \frac{\partial \Pi^b_{ij,t+1}}{\partial l_{ij,t+1}} + \vartheta^f_{ij,t+1} w_{j,t} = 0, \tag{B.9}$$

$$\mathbb{E}_t \Lambda^f_{ij,t+1} \frac{\partial \Pi^f_{ij,t+1}}{\partial b_{ij,t+1}} - \lambda^f_{ij,t} \mathbb{E}_t \Lambda^b_{ij,t+1} \left(\frac{\partial \Pi^b_{ij,t+1}}{\partial b_{ij,t+1}} - v^b_{i,t} \phi_{ij,t}\right) - \vartheta^f_{ij,t+1} = 0, \tag{B.10}$$

$$\mathbb{E}_t \Lambda^f_{ij,t+1} \frac{\partial \Pi^f_{ij,t+1}}{\partial R_{ij,t+1}} - \lambda^f_{ij,t} \mathbb{E}_t \Lambda^b_{ij,t+1} \frac{\partial \Pi^b_{ij,t+1}}{\partial R_{ij,t+1}} = 0, \tag{B.11}$$

$$x^f_{ij,t+1} = \bar{x}^f + \frac{1}{\kappa^f} \frac{1 - v^f_{ij,t}}{v^f_{ij,t}}, \tag{B.12}$$

$$v^f_{ij,t} = \mathbb{E}_t \Lambda_{j,t+1} \left(\bar{x}^f + (1-\bar{x}^f) v^f_{ij,t+1} + \frac{1}{2\kappa^f} \frac{(1 - v^f_{ij,t+1})^2}{v^f_{ij,t+1}}\right) \rho^f_{ij,t+1} \tag{B.13}$$

where $\lambda^f_{ij,t}$ and $\vartheta^f_{ij,t}$ are the Lagrange multipliers associated with constraints (2.6) and (2.27).

Banks The first order conditions of banks are laid out in equations (2.26) - (2.28) in the main body of the paper.

Capital good producers Capital good producers choose investment to solve the problem in (2.30)-(2.31). This leads to a first order condition for the price of capital given by

$$q^k_{j,t} = S'\left(\frac{I_{j,t}}{K_{j,t-1}}\right). \tag{B.14}$$

B.3 Laws of motion of net worth, capital and shocks

Law of motion of aggregate net worth of banks and firms The law of motion of net worth of BHCs in each country is given by

$$N^b_{i,t+1} = \rho^b_{iHome,t+1} e^b_{iHome,t} + \rho^b_{iForeign,t+1} e^b_{iForeign,t}, \tag{B.15}$$

and the law of motion of net worth of CHCs in each sector is given by

$$N^f_{ij,t+1} = \rho^f_{ij,t+1}\left(1 - x^f_{ij,t} - \frac{\kappa^f}{2}\left(x^f_{ij,t} - \bar{x}^f\right)^2\right) N^f_{ij,t}. \tag{B.16}$$

Law of motion of physical capital The law of motion of physical capital in each country is given in (2.31).

Law of motion of aggregate shocks The law of motion of aggregate shocks are provided in equations (3.2)-(3.3).

B.4 Market clearing

Loans

$$b_{ij,t} = B_{ij,t}. \tag{B.17}$$

Bank equity

$$e^b_{iHome,t} + e^b_{iForeign,t} = N^b_{i,t} - \frac{\kappa^b}{2}\left(x^b_{i,t} - \bar{x}^b\right)^2 N^b_{i,t} - x^b_{i,t} N^b_{i,t} \tag{B.18}$$

Firm equity

$$e^f_{ij,t} = N^f_{ij,t} - \frac{\kappa^f}{2}\left(x^f_{ij,t} - \bar{x}^f\right)^2 N^f_{ij,t} - x^f_{ij,t} N^f_{ij,t} \tag{B.19}$$

Deposits

$$d_{j,t} = D_{Homej,t} + D_{Foreignj,t}. \tag{B.20}$$

Labor

$$l_{Homej,t} + l_{Foreignj,t} = L_{j,t}. \tag{B.21}$$

Physical capital

$$k_{Homej,t} + k_{Foreignj,t} + k^{hh}_{j,t} = K_{j,t}. \tag{B.22}$$

Intermediate goods

$$y_{ij,t} = Y_{ij,t}. \tag{B.23}$$

Final consumption good

$$\begin{aligned}\sum_j \left(Y_{j,t} + (k^{hh}_{j,t})^{\alpha_{hh}}\right) = \sum_j \left(c_{j,t} + I_{j,t}\right) - \\ \sum_i \sum_j \mu^f (p_{ij,t} y_{ij,t} + q^k_{j,t}(1-\delta)k_{j,t-1}) G^f_{ij,t}(\bar{\omega}^f_{ij,t}) - \\ \sum_i \sum_j \mu^b \tilde{R}_{ij,t} B_{ij,t} G^b_{ij,t}(\bar{\omega}^b_{ij,t}) - \sum_i \sum_j \zeta \tilde{R}_{ij,t} B_{ij,t} (\hat{\omega}^b_{ij,t} - \Gamma^b_{ij,t}(\hat{\omega}^b_{ij,t})) - \\ \sum_i \sum_j \frac{\kappa^f}{2}\left(x^f_{ij,t} - \bar{x}^f\right)^2 N^f_{ij,t} - \sum_j \frac{\kappa^b}{2}\left(x^b_{j,t} - \bar{x}^b\right)^2 N^b_{j,t}.\end{aligned} \tag{B.24}$$

B.5 Adjustment of equations in the case of asymmetric countries

In the case of the calibration of asymmetric economies, we consider different measures for the continuum of households in the Core and the Periphery, denoted χ_j. In this setting, the equations that involve cross border activities of banks need to be adjusted to account for the different sizes of the countries.

Therefore, we redefine the capital ratio of bank subsidiaries as

$$\phi^b_{ij,t} = \frac{e^b_{ij,t}\chi_i}{B_{ij,t}\chi_j}, \tag{B.25}$$

to account for the fact that bank equity corresponds to the country with measure χ_i and loans to the country with measure χ_j.

Similarly, gross returns on bank subsidiaries are adjusted so that

$$\Pi^b_{ij,t+1} \equiv \frac{\chi_j}{\chi_i}\int_{\bar{\omega}^b_{ij,t+1}}^{\infty} \pi^b_{ij,t+1}(\omega)dF^b_{ij,t+1}(\omega) - \frac{\chi_j}{\chi_i}\zeta\int_0^{\hat{\omega}^b_{ij,t+1}} \left[\hat{\phi}_{j,t}B_{ij,t} - \pi^b_{ij,t+1}(\omega)\right] dF^b_{ij,t+1}(\omega), \tag{B.26}$$

represents the average return on subsidiaries from country i lending in country j.

Equation (REF to the one in the appendix) must also be adjusted so that

$$\mathbb{E}_t\Lambda^f_{ij,t+1}\frac{\partial\Pi^f_{ij,t+1}}{\partial b_{ij,t+1}} - \lambda^f_{ij,t}\mathbb{E}_t\Lambda^b_{ij,t+1}\left(\frac{\partial\Pi^b_{ij,t+1}}{\partial b_{ij,t+1}} - v^b_{i,t}\phi_{ij,t}\frac{\chi_j}{\chi_i}\right) - \vartheta^f_{ij,t+1} = 0. \tag{B.27}$$

Finally, the market clearing condition for the final consumption good is now written as

$$\sum_j \chi_j \left(Y_{j,t} + (k_{j,t}^{hh})^{\alpha_{hh}} \right) = \sum_j \chi_j \left(c_{j,t} + I_{j,t} \right) -$$
$$\sum_i \sum_j \chi_j \mu^f (p_{ij,t} y_{ij,t} + q_{j,t}^k (1-\delta) k_{j,t-1}) G_{ij,t}^f(\bar{\omega}_{ij,t}^f) -$$
$$\sum_i \sum_j \chi_j \mu^b \tilde{R}_{ij,t} B_{ij,t} G_{ij,t}^b(\bar{\omega}_{ij,t}^b) - \sum_i \sum_j \chi_j \zeta \tilde{R}_{ij,t} B_{ij,t} (\hat{\omega}_{ij,t}^b - \Gamma_{ij,t}^b(\hat{\omega}_{ij,t}^b)) -$$
$$\sum_i \sum_j \chi_j \frac{\kappa^f}{2} \left(x_{ij,t}^f - \bar{x}^f \right)^2 N_{ij,t}^f - \sum_j \chi_j \frac{\kappa^b}{2} \left(x_{j,t}^b - \bar{x}^b \right)^2 N_{j,t}^b. \quad \text{(B.28)}$$

Appendix C Data sources

Share of loans extended by foreign banks In order to approximate the share of credit to non financial corporations extended by foreign banks in the Euro Area (EA), we combine data from two sources.

The first of these sources is the BIS Consolidated Banking Statistics (CBS). We use a restricted version of this dataset, which contains information on bank exposures vis-a-vis non financial corporations (NFCs). The reporting countries in the Euro Area in this dataset are Austria, Belgium, France, Finland, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. The dataset reports the exposures of the banks controlled by entities in the reporting countries, vis-a-vis NFCs in counterparty countries, which do not necessarily report to the BIS CBS.

For each country in the Euro Area, we sum the exposures vis-a-vis NFCs originating in the Euro Area reporting countries, to construct a measure of the claims of foreign banks. This measure includes direct cross border claims, claims of foreign branches and claims of subsidiaries of foreign entities (international claims in the BIS terminology).

Since the CBS do not contain statistics on the domestic loans of non reporting countries, we merge this dataset with the ECB Balance Sheet Items (BSI) database, which contains (unconsolidated) information on the claims of monetary financial institutions (MFIs) vis a vis NFCs in the Euro Area.

We approximate the share of credit to NFCs extended by foreign banks in each period as

$$1 - \xi_t = \frac{\sum_{i \in \text{Reporting countries}} \sum_{j \in \text{EA countries}} \text{International claims vis a vis NFC}_{ij,t}}{\text{Total claims of MFIs vis a vis NFCs in the EA}_t}, \quad \text{(C.1)}$$

where the numerator is obtained from the BIS CBS and the denominator is obtained from the ECB BSI. Total claims comprise primarily loans, but also include debt securities and equity holdings. Since the BIS reports total claims, we use an analogous measure for the data coming from the ECB.

Unfortunately, the BIS CBS data on exposures to NFCs starts around 2013Q4 for most countries, and therefore this computation overlaps only partially with our calibration period of 2003Q1-2015Q4. In an effort to provide an estimate in a comparable time period, we use the variation in total exposures, for which a longer sample is available, to approximate claims vis a vis NFCs before 2013Q4. We plot the two time series in Figure C.1.

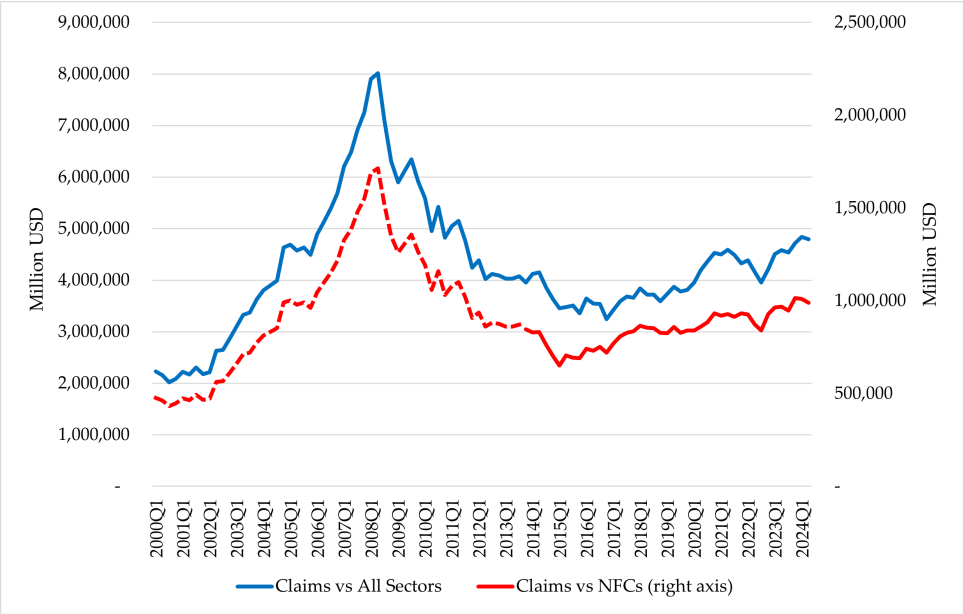

Figure C.1: International claims in the Euro Area

Notes: International claims comprise the sum of claims of bank subsidiaries, bank branches and direct cross border lending, from each reporting Euro Area country in the BIS consolidated banking statistics, to the other countries in the Euro Area. Claims vis a vis non financial corporations are reported from 2013Q4 onward (red solid line). We use the variation in claims vis a vis all sectors (blue solid line) before 2013Q4, to approximate the variation in claims vis a vis NFCs (red dashed line).

For the overlap period, the two series exhibit a strong positive correlation. We therefore simply link the time series for exposures with NFCs with the series for exposures with all sectors using the ratio of the two series at the first overlap period. We then compute the dashed line in Figure C.1 which preserves the level estimated using exposures with NFCs but uses the variation coming from total exposures before 2013Q4. We use this approximation to compute the share of credit by foreign banks in equation (C.1), and then simply take the average across the sample period.

Core-Periphery adjustment In the case of the Core-Periphery calibration, we repeat the previous steps, but instead of using the full Euro Area sample, we partition it into a Core group (Austria, Germany, France and the Netherlands) and a Periphery group (rest of the countries in the Euro Area as of December 2024). We then compute the average share of exposures by foreign banks in each group. This yields a share of

foreign credit of 12.5% in the Core, and 21% in the Periphery.

Loans to NFCs (ECB) Outstanding amounts at the end of the period (stocks), MFIs excluding ESCB reporting sector - Loans, Total maturity, All currencies combined - Euro area (changing composition) counterpart, Non-Financial corporations (S.11) sector, denominated in Euro, data neither seasonally nor working day adjusted.

Corporate Spreads Bank lending margins are constructed using data from ECB on interest rates on corporate loans and deposit rates, grouped into two categories according to the maturity of loans and deposits: less than one year and greater for both loans and deposits; and greater than one year for loans and two for deposit rates. Then, we compute a weighted average according to the total loans granted at each maturity.

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

GDP, GDP Deflator and Investment We use data from the IMF International Financial Statistics. In order to determine the relative size of the Core and the Periphery in the asymmetric calibration, we use a PPP adjusted measure of GDP.

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

$$\text{LR} = \frac{\text{NFC Net Debt Securities} + \text{NFC Net Loans} + \text{NFC Net Insurance Guarantees}}{\text{NFC Net Assets}}. \tag{C.2}$$

The measure of bank funding received by the corporate sector is

$$BF = \frac{\text{MFI Loans to NFCs}}{\text{NFC Net Assets}}. \tag{C.3}$$

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

Dividend ratios For the net dividend ratio of firms and banks, we follow the procedure in Mendicino et al. (forthcoming). We use the Euro Area Flow of Funds statistics (ECB quarterly sectoral accounts), and consider dividend distributions and share buybacks, net of equity issuance. We express this net payout as a fraction of the previous period equity of financial and non financial corporations.

Bank failure rate We use the value of 0.66% reported in Mendicino et al. (forthcoming), which is computed using Moody's KMV expected default frequencies for publicly listed banks. This measure is constructed using the implied default probability in the pricing of credit default swaps of bank bonds.

Capital ratio We use the value of 12% reported in Mendicino et al. (forthcoming). They use data from Bankscope and Bankfocus on the capital position and the risk weighted assets of individual banks in the Euro Area.

Spreads on bank debt For the asymmetric calibration of the model, we target different costs of bank debt. We use publicly available data on bank bond spreads compiled by Gilchrist and Mojon (2018). We use the spreads on French and German bank bonds as an approximation of the cost of bank debt for the Core and the spreads on Spanish and Italian banks as an approximation for the Periphery.