Optimal Capital Requirements with Cross Border Banking

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Abstract

This paper studies the welfare implications of changes in regulatory capital requirements in the presence of cross border banking activities. Using a two-country DSGE model with financial frictions, calibrated to match the characteristics of international credit in synthetic Core and Periphery countries in the Euro Area, this paper analyzes the optimal level of Basel-type capital requirements set on corporate loans. Results show that: a) a uniform increase in the level of capital requirements can be welfare improving for both countries, with Core countries preferring lower levels of capital requirements; b) if capital requirements are set in each country separately, it is optimal to impose higher capital requirements for exposures in the Periphery, and c) penalizing the cross border activities of banks with higher capital requirements, even if international loans are more volatile than their domestic counterparts, is not in general welfare improving.

Keywords: Macroprudential Policy, Cross Border Banking, Regulatory Spillovers

JEL codes: F41, F42, G21

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1 Introduction

What is the optimal level of capital requirements when banks can allocate credit across borders? The cross border linkages in the modern banking industry have raised the question on how to properly choose the regulatory limits on bank leverage when financial intermediaries can react to changes in regulation by rebalancing their country portfolios. As documented, for instance in Aiyar et al. (2014), the effectiveness of macroprudential regulation depends crucially on how tightly regulators can control the actions of internationally active banks.

This paper provides a quantitative assessment on how to optimally set the level of capital requirements when banking groups operate bank subsidiaries in two large asymmetric countries. I build a two-country DSGE model featuring bank level distortions and deadweight losses associated to default, and study the welfare implications of changing the levels of capital requirements on corporate loans in a calibrated version for two synthetic countries, representative of Core and Periphery regions in the Euro Area.

The model in this paper builds on the one-country formulation by Mendicino et al. (2018), which is extended to two countries, allowing banks to operate across them. Bank owners in each country choose how to allocate their net worth as equity across bank subsidiaries located in each country. There are thus two classes of subsidiaries en each country, owned by national or foreign bankers, respectively. Each class of banks is specialized in extending risky loans to a subgroup of corporate borrowers (firms). This specialization is consistent with the stability of bank-firm relationships, which are especially intense between firms and foreign banks (Paravisini et al., 2015). Because of such specialization gains, the presence of international banks becomes valuable for both countries.

Capital requirements are motivated by the presence of bank level distortions in the model. First, bank subsidiaries operate under limited liability and finance their lending activity

with net worth internally accumulated by their owners and partially insured bank debt. In addition I assume that, because of the opaqueness of banks' balance sheets, the risk of bank debt is not priced at the margin but on the basis of a taken-as-given expected probability of default.[1] Lastly, I assume that there are bankruptcy costs which create excessive risk taking by banks and makes their financial vulnerability socially costly, as in the financial accelerator models following Bernanke et al. (1999).

As in the financial accelerator tradition, the returns of firms and banks are subject to idiosyncratic shocks that determine their ability to repay their debt obligations. As in Christiano et al. (2014), changes in the cross sectional dispersion of these shocks (or *risk shocks*) generate fluctuations in corporate and bank defaults that, because of the presence of bankruptcy costs and net worth losses, produce declines in consumption and investment. However, risk shifting distortions imply that banks find it profitable to expand their balance sheets in periods of high volatility of bank returns. By limiting bank leverage, regulatory capital requirements play a crucial macroprudential role since they reduce banks' probability of default which is directly connected to the strength of banks' risk taking incentives.

While this type of frictions and the role of capital requirements has been analyzed before in closed economy setups (e.g. in Mendicino et al., 2018; Elenev et al., 2021), the analysis in this paper considers them in a two-country setup, where the importance and variability of borrower-specific and bank-specific default risk varies across countries, and banks can reallocate credit across borders. Does such a reallocation contribute to exacerbate or smooth away the macroeconomic implications of bank vulnerability? Should capital requirements treat domestic and foreign exposures differently? How important is it that capital requirements are set in a coordinated as opposed to in an uncoordinated fashion by the home country authorities responsible for the banks from each country?

[1] This is consistent with rational expectations but does not eliminate bankers incentives to take excessive risk.

These questions are addressed after calibrating the model to match data targets in two synthetic regions in the Euro Area, labeled as Core and Periphery countries, for the period between 2003 and 2019.[2] Countries in the Core are net exporters of credit intermediated by banks, or in other words, net lenders to the rest of the countries in the Euro Area, which are included in the Periphery country. In the period considered in the calibration, international credit is significantly more volatile than domestic credit.[3] Through the lens of the model, the higher volatility in foreign credit is accommodated by assigning international bank exposures a larger sensitivity to bank risk shocks. Moreover, the fact that lending to borrowers in the Core is more stable (credit and spreads are less volatile than their Periphery counterparts) is reflected in the calibration by assigning lower bank risk to exposures in the Core.

The calibrated version of the model is used to analyze the optimal level of capital requirements under three different designs of the regulatory setup. First, I analyze the effects of a *uniform* increase in the level of capital requirements (per unit of risk weighted assets) applicable to exposures in both countries.[4] Second, I analyze the effect of adding specific buffers on exposures of international banks, set uniformly for both countries. Lastly, I study the effects of choosing the levels of capital requirements independently in each country, under a reciprocity arrangement that guarantees that international banking groups are subject in each country to the requirements set by the domestic authority.

The results from the first exercise show that a uniform increase in capital requirements has different welfare implications for the Core and the Periphery. Because the banking system original from the Periphery country is more volatile than its Core counterpart in

[2] Austria, France, Germany and the Netherlands are grouped into the Core country, while the rest of the countries in the Euro Area are included in the Periphery country

[3] This is consistent with the findings of the literature documenting the fickleness of capital flows, for example Bluedorn et al. (2013)

[4] The baseline economy features capital requirements that, as under the Internal Ratings Based (IRB) approach of Basel regulations, make each loan's risk weight a function of some credit risk parameters. The uniform increase on a per unit of risk weighted assets is consistent, for example, with the assessment of the introduction of the Capital Conservation Buffer (CCB) in Basel III, which has been adopted by all Euro Area member states.

the baseline calibration, an increase in capital requirements yields larger welfare gains in the Periphery. Moreover, the Periphery would prefer levels of capital requirements significantly higher than the Core (about 11.5 percent vs 8.5 percent preferred by the Core). Importantly, there are limits to the welfare gains that higher capital capital requirements can create. This follows from the fact that increases in regulatory capital requirements decrease deadweight losses associated with bank risk shifting incentives and bankruptcy costs, but at the same time they restrict access to credit to the financially constrained borrowers.

Second, I analyze the consequences of introducing specific regulatory buffers (add-ons to the baseline requirements) on international exposures. Because in the baseline calibration bank risk shocks have a larger impact on international exposures, bank risk shifting incentives encourage banks to expand their balance sheet abroad. In spite of the fact that banks indeed tilt their lending towards the riskier international exposures I do not find, in general, a welfare improving effect of such regulatory buffers. This result suggests that tightening the regulatory treatment of lending by foreign banks, while potentially stabilizing, would imply too large a sacrifice of profitable investment by firms that depend on foreign banks to fund their productive activities.[5]

Lastly, I analyze the possibility that capital requirements are chosen separately in each country. When conducting this exercise domestic and foreign bank subsidiaries are subject to the regulation set in the country where they are extending credit (not the home country of their bankers). Under this design, I find that an increase in capital requirements in one country has, in general, positive effects on the other country. Gains are especially steep when capital requirements are increased in the (riskier) Periphery country. Also interestingly, the Core would prefer not to raise the level of capital requirements

[5] This result is consistent with the view that not all foreign capital flows are necessarily destabilizing, or at least not decisively so, from an efficiency perspective. For example, Korinek (2018) finds that foreign direct investment is far less fickle than short term debt and that macroprudential regulation should be designed to target the specific risks generated by each class of foreign capital flow.

from the baseline level of 8 percent of risk weighted assets, even though this could have stabilizing effects in the Periphery (at least for a moderate increase). Large increases in capital requirements in the Core countries have negative effects in the Periphery, as there is a contraction in lending by the more stable banking system.

Under this setup, I analyze the levels of capital requirement that would be chosen in each country by a hypothetical single regulatory authority with jurisdiction over both countries, and the ability to set different capital requirements in each country. If such authority had a mandate to maximize a utilitarian version of welfare that assigns weights proportional to country size, then the optimal level of the capital requirements would be higher in both countries, but the increase in the Periphery would be significantly larger. This level is different from the one that would be chosen by individual regulators acting in an uncoordinated fashion. In particular, the Core would prefer not to increase the level of capital requirements on the banks operating in its jurisdiction at all. These results highlight the importance of proper coordination of regulatory actions in the context of economies with integrated banking sectors.

Overall, the results in this paper suggest that, in the presence of cross border lending, bank regulation should be adjusted taking into account the potential spillovers generated by regulatory actions undertaken at a single country level. Moreover, it suggests that without proper coordination, more stable countries would neglect part of the stabilization gains generated (in other jurisdictions) by adopting higher levels of capital requirements. Importantly, however, adopting capital buffers that explicitly penalize cross border exposures implies distortions in the allocation of credit that generally outweigh their stabilization gains.

Related Literature This paper is connected to the macroeconomic literature that studies the optimal level of bank capital requirements (Mendicino et al., 2018; Malherbe, 2020; Mendicino et al., 2021; Elenev et al., 2021, among others). This paper contributes

to this literature by providing a two country analysis of the optimal level of capital requirements in the presence of banks that operate across borders and asymmetries in the risk determining firm and bank defaults in each country.[6] This paper is also related to the large literature studying macroprudential interventions in open economies in typically more stylized settings, such as Jeanne and Korinek (2010), Bengui and Bianchi (2014), Mendoza and Quadrini (2010) and Korinek (2018).[7]

This paper is thus also connected to the strand of the macroeconomic literature that studies the effects of financial integration on financial stability, such as its connection to financial crises (Devereux and Yu, 2020; Perri and Quadrini, 2018), coordination of business cycles (Kalemli-Ozcan et al., 2013), and sovereign debt crises (Morelli et al., 2022).

This paper offers a quantitative contribution to the literature studying the potential spillovers from macroprudential regulation and the potential shortcomings of uncoordinated policy actions by national authorities such as in Dell'Ariccia and Marquez (2006), Bahaj and Malherbe (2021) and Clayton and Schaab (2022). In the setting in my paper, actions by national regulators might create create credit spillovers and leaks in the form of portfolio rebalancing by banks. In my setting, countries with more stable banking systems might choose lower levels of capital requirements, disregarding the potential stabilization gains that higher levels of capital requirements could have on other countries. The relevance of spillovers of bank capital regulation has been documented for example in Aiyar et al. (2014) and Buch and Goldberg (2016).

[6] Among the few studies studying capital regulation in multi-country setups, Agénor et al. (2017) and Darracq Paries et al. (2019) develop macroeconomic models, where economies are connected through interbank markets. This paper adds to this discussion by analyzing a framework where banks and firms can default and where frictions at the bank level contribute to an increase in volatility under financial integration.

[7] Papers in literature typically have potentially credit-constrained agents and cross-border credit flows but not explicit credit intermediaries or explicit default risk.

Outline of the paper The remainder of this paper is structured as follows. Section 2 presents a two-country macroeconomic model with financial frictions. Section 3 describes the mapping of the model to the data (using data from the Euro Area and interpreting each of its two countries as a stylized representation of its Core and Peripheral countries) and its solution under a baseline calibration where all bank are subject to a common capital requirement. Section 4 presents the optimal level of capital requirements under different designs of the buffers, while section 5 discusses the potential spillovers that regulatory actions in one country can have on the other. Section 6 concludes.

2 Model

The model presented in this section is a two-country extension of the framework introduced in Mendicino et al. (2018). The economy is populated by two long-lived dynasties of agents, each inhabiting a country or *region* labeled as Core (c) and Periphery (p), respectively. Time is discrete and the horizon is infinite.

Entrepreneurs and bankers are long lived members of the dynasties, with the ability of owning and managing entrepreneurial firms and banks, respectively. Entrepreneurs and bankers invest their net worth in equity of firms and banks until, with some exogenous probability they retire, rebating their terminal net worth to their dynasty. In this sense, and following Gertler and Kiyotaki (2010) net worth, which is the only source of inside equity financing for firms and banks, remains scarce in the economy. Thus the external financial frictions introduced below are relevant in determining the dynamics of credit, investment and consumption.

Financial integration is introduced through two main channels. First, bankers in each country can allocate their net worth as equity across bank subsidiaries located in either their country of nationality (domestic subsidiary) or abroad (international subsidiary).

Second, bank debt issued by any of the four (2×2) bank subsidiaries can be held by any of the two dynasties, subject to an asset management cost. The presence of management costs in bank debt holdings is designed to capture the home bias in holdings of financial assets, as documented for example in Coeurdacier and Rey (2013).

The final consumption good is tradeable, but both physical capital and labor are country specific.

2.1 Dynasties

The preferences of each dynasty are given by its lifetime utility

$$V_{i,t} = \mathbb{E}_t \sum_{s=t}^{\infty} \beta^s \log(c_{i,s}), \tag{2.1}$$

where β is the subjective discount factor and $c_{i,t}$ denotes consumption of the dynasty in country $i = c, p$.

Dynasty's resource constraint Each dynasty chooses consumption $c_{i,t}$, holdings of physical capital $k^h h_{i,t}$ and deposits in domestic and foreign subsidiaries $d_{ci,t}, d_{pi,t}$ to maximize their lifetime utility subject to a resource constraint given by

$$\begin{aligned} c_{i,t} + d_{ci,t} + d_{pi,t} + \frac{\gamma_{d,ci}}{2} d_{ci,t}^2 + \frac{\gamma_{d,pi}}{2} d_{pi,t}^2 + q_{i,t} k_{i,t}^{hh} + \frac{\gamma_k}{2} \left(k_{i,t}^{hh}\right)^2 \leq \\ w_{i,t} L_{i,t} + \tilde{R}_{c,t}^d d_{ci,t-1} + \tilde{R}_{p,t}^d d_{pi,t-1} + R_{i,t}^k q_{i,t-1} k_{i,t-1}^{hh} + \Psi_{i,t} + \Theta_{i,t} - T_{i,t}, \end{aligned} \tag{2.2}$$

where $w_{i,t}$ are wages received on the country inelastic labor supply $L_{i,t}$, $\tilde{R}_{i,t}^d$ denotes the realized return on bank debt issued by banks from country i and $R_{i,t}^k \equiv \frac{r_{i,t}^k + q_{i,t}(1-\delta)}{q_{i,t-1}}$ is the gross return on physical capital holdings.

The terms $\Psi_{i,t}$ and $\Theta_{i,t}$ collect net transfers from entrepreneurs and bankers, and profits from capital good producers (which will be defined in section 2.2), respectively. Each dy-

nasty pays lump sum taxes $T_{i,t}$ to finance the deposit insurance scheme of banks extending loans in its country.

Finally, holdings of bank debt and physical capital are subject to management costs $\gamma_{d,ij}$ and γ_k. The first are designed to capture the home bias in holdings of bank debt while the latter captures the relative (compared to firms) inefficiency of households in managing physical capital.

2.2 Production

Final good producers Competitive producers of the final consumption good in each country operate a constant returns to scale technology in capital and labor of the form

$$y_{i,t} = A_{i,t} k_{i,t-1}^{\alpha} l_{i,t}^{1-\alpha}, \tag{2.3}$$

where $A_{i,t}$ is an aggregate productivity shock and $k_{i,t}$ and $l_{i,t}$ denotes physical capital and labor employed by producers. Parameter α denotes, as usual, the capital share in output.

Final good producers pay the rental rate on capital$r_{i,t}^k$ and wages $w_{i,t}$ on their inputs. They optimally choose their input mix so that in equilibrium we have

$$r_{i,t}^k = \frac{\partial y_{i,t}}{\partial k_{i,t}} \tag{2.4}$$

$$w_{i,t} = \frac{\partial y_{i,t}}{\partial l_{i,t}}. \tag{2.5}$$

Capital good producers Competitive producers of the capital good use transform $I_{i,t}$ units of final consumption good into new capital to solve

$$\max_{I_{i,t}} q_{i,t}K_{i,t} - I_{i,t}, \tag{2.6}$$

$$\text{s.t.} K_{i,t} = S\left(\frac{I_{i,t}}{K_{i,t-1}}\right)K_{i,t-1} + (1-\delta)K_{i,t-1}, \tag{2.7}$$

where function $S(.)$ captures capital adjustment costs as in Jermann (1998). The profits generated by the operation of this technology are denoted by $\Theta_{i,t}$ and are rebated to the dynasty in country i each period.

2.3 Entrepreneurs and firms

The entrepreneurial sector in the economy own and manage one period ventures called firms. Such firms invest in physical capital and one period afterwards receive stochastic returns renting and reselling such capital.

Entrepreneurs A continuum of measure one of long lived entrepreneurs in each country manage their net worth until with exogenous probability $1-\theta_e$ they retire, rebating their net worth back to their dynasty. Exiting entrepreneurs get replaced by an identical mass of new entrepreneurs endowed with an initial amount of wealth provided by the dynasty.

Each period a fraction ξ_i of entering entrepreneurs specialize in providing equity to firms that obtain their debt financing from an international bank subsidiary; the rest invest their net worth in equity of firms that borrow from a domestic bank subsidiary.[8] This assumption is consistent with the empirical observation that some firms are better matched with foreign banks, as noted for instance in Paravisini et al. (2015). Entrepreneurs stick to the class of firms the are specialized in until they retire.

[8] The remaining fraction $1-\xi_i$ own firms that borrow from national banks.

An active entrepreneur in country j owning firms financed by a bank from country i starts period t with net worth $n^e_{ij,t}(f)$. She chooses how to allocate such net worth, either by investing it in a well diversified portfolio of firm equity $a_{ij,t}$ or by paying out dividends $div_{ij,t}$ to the dynasty. Her value function satisfies the Bellman equation

$$V^e_{ij,t}(n^e_{ij,t}(f)) = \max_{a_{ij,t}(f), div_{ij,t}(f), n^e_{ij,t+1}(f)} div_{ij,t} + \mathbb{E}_t \Lambda_{j,t+1} \left[(1-\theta_e) n^e_{ij,t+1}(f) + \theta_e V^e_{ij,t+1}(n^e_{ij,t}(f))\right] \tag{2.8}$$

$$\text{s.t. } div_{ij,t}(f) + a_{ij,t}(f) \leq n^e_{ij,t}(f), \tag{2.9}$$

$$n^e_{ij,t+1}(f) = \rho^e_{ij,t+1} a_{ij,t}(f), \tag{2.10}$$

where $\Lambda_{j,t+1}$ is the country j dynasty's discount factor and $\rho^e_{ij,t+1}$ are the returns on a well diversified portfolio of equity of firms in country j financed by banks from country i.

It can be guessed (and verified) as in Gertler and Kiyotaki (2010) that the value function above is linear in net worth. Then the problem above becomes

$$v^e_{ij,t} n^e_{ij,t}(f) = \max_{a_{ij,t}(f), div_{ij,t}(f), n^e_{ij,t+1}(f)} div_{ij,t} + \mathbb{E}_t \Lambda_{j,t+1} \left[(1-\theta_e) n^e_{ij,t+1}(f) + \theta_e v^e_{ij,t+1} n^e_{ij,t}(f)\right] \tag{2.11}$$

$$\text{s.t. } div_{ij,t}(f) + a_{ij,t}(f) \leq n^e_{ij,t}(f), \tag{2.12}$$

$$n^e_{ij,t+1}(f) = \rho^e_{ij,t+1} a_{ij,t}(f), \tag{2.13}$$

where $v^e_{ij,t}$ can be interpreted as the shadow value of one unit of entrepreneurial net worth invested in firms of country j financed by banks from country i. As long as $v^e_{ji,t} > 1$ entrepreneurs, who receive consumption insurance from their dynasty, prefer not to pay out dividends, and instead wait for their net worth to grow until they retire. Therefore,

after substitution of the constraints, we find that

$$v^e_{ij,t} = \mathbb{E}_t \Lambda^e_{j,t+1} \left[(1-\theta_e) + \theta_e v^e_{ij,t+1} \right] \rho^e_{ij,t+1}, \tag{2.14}$$

$\Lambda^e_{j,t+1} = \Lambda_{j,t+1} \left[(1-\theta_e) + \theta_e v^e_{ij,t+1} \right]$ is the stochastic discount factor associated to entrepreneurs.

Aggregate law of motion of entrepreneurial net worth Entrepreneurial net worth in each country and for each class of firms $N^e_{ij,t}$ evolves according to

$$N^e_{ij,t+1} = \theta_e \rho^e_{ij,t+1} N^e_{ij,t} + \iota^e_{ij,t+1}, \tag{2.15}$$

where

$$\iota^e_{ij,t+1} = (1-\theta_e)\chi_{e,j} \left[\mathbb{1}_{i=j}(1-\xi_j) + \mathbb{1}_{i \neq j} \xi_j \right] \left[\rho^e_{cj,t+1} N^e_{cj,t} + \rho^e_{pj,t+1} N^e_{pj,t} \right] \tag{2.16}$$

denotes the endowment provided by the country j dynasty to entering entrepreneurs managing firms financed by banks from country i.

Firms As in Bernanke et al. (1999), firms operating between any two dates t and $t+1$ use equity and debt to acquire physical capital at t and rent and resell the capital at $t+1$. The riskiness of their investment is captured as a non-negative mean one iid multiplicative shock to the effective units of physical capital obtained at $t+1$. The variance of these shocks evolves over time as in Christiano et al. (2014).

When choosing their optimal capital structure, firms are presented by their financing bank with a menu of contracts, specifying combinations of leverage and a promised gross rate on the loans extended by such bank. Because of the presence of bankruptcy costs in the spirit of Bernanke et al. (1999), banks offer menus of contracts that adequately

compensate them for the default risk of firms.

The problem of an individual firm in country j borrowing from a bank subsidiary from country i is to maximize the properly discounted terminal net worth generated to entrepreneurial equity $a_{ij,t}$, subject to its balance sheet and the participation constraint of its financing bank. In other words, firms solve

$$\max_{k^f_{ij,t}, B_{ij,t}, R_{ij,t}} \mathbb{E}_t \Lambda^e_{ij,t+1} \max[\omega^e R^k_{j,t+1} q_{j,t} k^f_{ij,t} - R_{ij,t} B_{ij,t}, 0], \tag{2.17}$$

$$\text{s.t. } q_{j,t} k^f_{ij,t} = B_{ij,t} + a_{ij,t}, \tag{2.18}$$

$$\mathbb{E}_t \Lambda^b_{i,t+1} \rho^b_{ij,t+1} \geq v^b_{i,t}, \tag{2.19}$$

where $R_{ij,t}$ denotes the promised gross rate on loans $B_{ij,t}$ and $k^f_{ij,t}$ is capital managed by the entrepreneurial sector in country j financed by a bank subsidiary from country i. Inequality (2.19) is the participation constraint of the banks, which comprises the pricing of loans for each possible loan amount and that will be explained in section 2.4. The shock ω^e is iid across firms with mean one and stochastic variance.

Finally, the returns on a well diversified portfolio of entrepreneurial equity of firms of the class ij conditional on the realization of aggregate shocks, are defined as

$$\rho^e_{ij,t+1} = \frac{1}{a_{ij,t}} \int_0^\infty \max[\omega^e R^k_{j,t+1} q_{j,t} k^f_{ij,t} - R_{ij,t} B_{ij,t}, 0] dF^e_{ij,t+1}(\omega^e). \tag{2.20}$$

2.4 Bankers and Banks

In each country a continuum of measure one of long lived bankers own and manage bank subsidiaries. Such subsidiary can be located in the home country of bankers or abroad. Bankers use their accumulated net worth to invest in bank equity and, in a similar

fashion as entrepreneurs, they retire and give back their net worth to their dynasty with some exogenous probability. Upon retirement, they get replaced by an identical mass of entering bankers endowed with some wealth provided by the dynasty.

Problem of individual bankers Individual bankers begin each period with some net worth $n^b_{i,t}(b)$ and choose how to allocate it, either by paying dividends $div^b_{i,t}$ to the dynasty or to invest it as bank equity. Unlike entrepreneurs, who enter the market tied to a class of firms, banks can choose their position in bank equity in subsidiaries at home or abroad. The value function of an individual banker from country i satisfies

$$V^b_{i,t}(n^b_{i,t}(b)) = \max_{e_{ic,t}(b), e_{ip,t}(b), div^b_{i,t}(b), n^b_{i,t+1}(b)} div^b_{i,t} + \mathbb{E}_t \Lambda_{i,t+1} \left[(1-\theta_b) n^b_{i,t+1}(b) + \theta_b V^b_{i,t+1}(n^b_{i,t}(b)) \right] \tag{2.21}$$

$$\text{s.t. } div_{i,t}(b) + e_{i,t}(b) \leq n^b_{i,t}(b), \tag{2.22}$$

$$n^b_{i,t+1}(b) = \rho^b_{ic,t+1} e_{ic,t}(b) + \rho^b_{ip,t+1} e_{ip,t}(b), \tag{2.23}$$

where $e_{ij,t}(b)$ is equity invested in subsidiaries in country j, owned by bankers from country i, and $\rho^b_{ij,t+1}$ are the returns on such equity.

Following arguments analogous to those analyzed for the case of entrepreneurs, we can guess and verify the linearity of this value function in net worth. After noting that in equilibrium bankers must be indifferent between allocating their net worth as equity at home or abroad, we find that the shadow value of bank equity satisfies

$$v^b_{i,t} = \mathbb{E}_t \Lambda^b_{i,t+1} \rho^b_{ic,t+1} = \mathbb{E}_t \Lambda^b_{i,t+1} \rho^b_{ip,t+1}, \tag{2.24}$$

where $\Lambda^b_{i,t+1} \equiv \Lambda_{i,t+1} \left[(1 - \theta_b + \theta_b v^b_{i,t+1}) \right]$ is the stochastic discount factor associated to bankers from country i.

Law of motion of bankers' net worth Aggregating across bankers and taking into account that a mass $(1-\theta_b)$ retire each period, the law of motion of aggregate net worth of bankers in country i obeys

$$N^b_{i,t+1} = \theta_b \left[\rho^b_{ic,t+1} e_{ic,t} + \rho^b_{ip,t+1} e_{ip,t}\right] + \iota^b_{i,t}, \tag{2.25}$$

where $\iota^b_{i,t+1} \equiv (1-\theta_b)\chi_b \left[\rho^b_{ic,t+1} e_{ic,t} + \rho^b_{ip,t+1} e_{ip,t}\right]$ is the wealth endowment that the dynasty of country i provides new bankers with.

Banks In each country j anks in country j there is a continuum of measure one of bank subsidiaries owned by bankers from country i. These are one period ventures, which operate under limited liability in each country and combine bank equity provided by bankers with partially insured bank debt to invest in a well diversified portfolio of risky loans, extended to their matched class of entrepreneurial firms in each country.[9] The balance sheet of a bank subsidiary from country i extending loans in country j is given by

$$B_{ij,t} = D_{ij,t} + e_{ij,t}. \tag{2.26}$$

Banks are subject to capital requirements that set a limit to the amount of debt in their balance sheets, that is,

$$e_{ij,t} \geq \varphi_{ji,t} B_{ji,t}, \tag{2.27}$$

where $\varphi_{ji,t}$ is the effective capital charge on loans extended by banks from country i in country j.

Banks' payoffs In a similar fashion as firms, banks' payoffs are subject to iid shocks which determine the value of their loan portfolios after uncertainty is realized. Properly

[9] For example, bankers from the Core operate subsidiaries in the Periphery, which extend loans to the firms in the Periphery that are matched to the Core banks.

discounted expected bank payoffs are given by

$$\mathbb{E}_t \Lambda^b_{i,t+1} \max \left[\omega^b \tilde{R}_{ij,t+1} B_{ij,t} - R^d_{i,t} D_{ij,t}, 0 \right], \tag{2.28}$$

where ω^b is a mean one iid shock, the variance of which changes over time.[10]. Bank debt has attached a gross promised return $R^d_{i,t}$. Importantly, bank debt is not priced at the subsidiary level, but rather at the nationality-of-bankers level.[11] In other words, there is some opacity in banks' balance sheets from the point of view of investors in bank debt.

The realized return on a portfolio of loans is denoted by $\tilde{R}_{ij,t+1}$, are composed of the promised return on loans $R_{ij,t}$ on the corporate loans that do not default plus the residual value of the assets of defaulting firms, net of repossession costs. In other words,

$$\tilde{R}_{ij,t+1} B_{ij,t} \equiv R_{ij,t}(1 - F^e_{ij,t+1}(\bar{\omega}^e_{ij,t+1})) + (1-\mu) R^k_{j,t+1} q_{j,t} k^f_{ij,t} \int_0^{\bar{\omega}^e_{ij,t+1}} \omega^e dF^e_{ij,t+1}, \tag{2.29}$$

with $\bar{\omega}^e_{ij,t+1} \equiv \frac{R_{ij,t} B_{ij,t}}{R^k_{j,t+1} q_{j,t} k^f_{j,t}}$.

Because of the presence of safety net guarantees in the form of partial deposit insurance to bank debt, banks will choose to increase their leverage up to their regulatory maximum so that capital requirements bind in equilibrium. Therefore returns on one unit of bank equity invested by bankers from country i in a well diversified portfolio of banks extending loans to firms in country j can be written as

$$\rho^b_{ij,t+1} = \int_0^{\infty} \max \left[\omega^b \tilde{R}_{ij,t+1} \frac{1}{\varphi_{ij,t}} - R^d_{i,t} \frac{1-\varphi_{ij,t}}{\varphi_{ij,t}}, 0 \right] dF^b_{ij,t+1}(\omega^b). \tag{2.30}$$

Notice that because of the scarcity of bankers' net worth, banks from i will find it prof-

[10] Risk shocks as in Christiano et al. (2014)

[11] One possible interpretation is that a bank holding company issues a fix bundle of debt of its subsidiaries at a common interest rate and then distributes the proceeds from the sale of such bundle to its subsidiaries in proportion to the face value of their debts, effectively allowing them to be financed at a common interest rate.

itable to extend loans to firms in j provided that the condition

$$\mathbb{E}_t \Lambda^b_{i,t+1} \rho^b_{ij,t+1} \geq v^b_{i,t} \tag{2.31}$$

is met. This explains the so-called banks' participation constraint in (2.19). Importantly, a tightening of capital requirements both reduces the probability that a bank will find itself unable to meet its obligations to its creditors, as well as it restricts the menu of possible contracts that banks offer to firms.

Details on the processes followed by shocks and the specification of the capital requirements appear in the calibration section below. Market clearing conditions and mathematical derivations can be found in the Appendix. This would conclude the specification of the model.

3 Calibration

This section describes the processes followed by shocks, specifies the capital requirements, and discusses the calibration and numerical solution of the model.

3.1 Shocks processes

Productivity shocks in the economy follow an AR(1) process that satisfies

$$\log(A_{i,t+1}) = \varrho \log(A_{i,t}) + \varsigma_{A,i} \varepsilon^A_{i,t+1}. \tag{3.1}$$

Risk shocks Firm and bank idiosyncratic shocks are assumed to follow log-normal distributions, with mean one and stochastic dispersion. The conditional variance of firm iid shocks evolves according to

$$\log\left(\frac{\sigma^e_{ij,t+1}}{\bar{\sigma}^e_j}\right) = \varrho \log\left(\frac{\sigma^e_{ij,t}}{\bar{\sigma}^e_j}\right) + \varsigma^e_j \varepsilon^e_{j,t}, \tag{3.2}$$

where $\bar{\sigma}^e_j$ is associated to the long run variance of firm iid shocks. In the tradition of Christiano et al. (2014), I refer to $\varepsilon^e_{j,t}$ as a firm risk shock, which has an impact on

dispersion measured by ς_j^e.

In a similar fashion, the dispersion of bank iid shocks evolves according to

$$\log\left(\frac{\sigma_{ij,t+1}^b}{\bar{\sigma}_i^b}\right) = \varrho \log\left(\frac{\sigma_{ij,t}^b}{\bar{\sigma}_i^b}\right) + (\varsigma_i^b + \varsigma^* \mathbb{1}_{i\neq j})\varepsilon_t^b, \tag{3.3}$$

where $\bar{\sigma}_i^b$ controls the long run variance of banks' iid shocks. I assume that bank risk shocks ε_t^b are common across the two countries, reflecting the large correlation observed in financial cycles.[12] I allow, however, flexibility in terms of how bank risk shocks affect each financial system. Moreover, I allow for a differential impact on international exposures through parameter ς^*.

3.2 Capital Requirements

Capital requirements are calibrated following the IRB approach of Basel II (see BCBS, 2004), also applied under Basel III (BCBS, 2010). I assume that capital requirements partially adjust each period, so that they follow

$$\varphi_{ij,t} = \eta\varphi_{ij,t-1} + (1-\eta)\varphi_{ij,t}^*, \tag{3.4}$$

where η is the partial adjustment coefficient and where

$$\varphi_{ij,t}^* = M_{ij} \times IRB(PD_{ij,t}), \tag{3.5}$$

are the capital requirements as defined in the regulation. The probabilities of default of corporate loans of class ij are denoted by $PD_{ij,t}$ and they are computed as the conditional expectation of firm default rates at period t. The factor M_{ij} captures the effect of additional capital buffers. In the baseline calibration, $M_{ij} = 1$, which corresponds to a level of capital requirements set to 8 percent of risk weighted assets (see the Appendix for details).

[12] See, e.g. Miranda-Agrippino and Rey (2020)

3.3 Data used in calibration

The model is calibrated to match first and second moments of financial and real variables in the Euro Area, at a quarterly frequency, between 2003 and 2017. I split the countries in the Euro Area into a Core and a Periphery region. Countries included in the Core region are Germany, France, the Netherlands and Austria, whose banking systems constitute the larger net financiers to the rest of the Euro Area. The remaining countries are included in the Periphery region.

I interpret the international activities of banking groups in a broad sense, inclusive of activities undertaken by subsidiaries and branches located in foreign countries as well as direct cross border lending. In order to construct a measure of international loans to non financial corporations for each region in the Euro Area, I use both the BIS consolidated banking statistics and the Balance Sheet Indicators from the European Central Banks. I use the total international loans (subsidiaries, branches and direct cross border lending) reported by BIS to compute the relative sizes of the international sector in each of the areas. I then scale back the total amount of loans to match the share of total bank loans to non-financial corporations as reported by the ECB.

In order to have a proxy of the cost of bank debt for the banking systems of each of the synthetic areas, I use the credit risk indicators reported by Gilchrist and Mojon (2018). While they report averages of bank debt yields only for Germany, France, Spain and Italy, I use the weighted average of the yields for Germany and France as a proxy of bank debt returns in Core and those from Spain and Italy for the periphery.

The rest of data sources are standard and are reported in the Appendix.

3.4 Solution and calibration procedure

The model is solved using a second order approximation around its deterministic steady state. In order to find policy functions and compute means and standard deviations of variables used in the calibration, I simulate the model for 500,000 periods.

A subset of parameters is chosen following the previous literature in related fields, while the rest of parameters is calibrated using the simulated method of moments. Calibration

targets are reported in Table 1, while the resulting parameters are reported in Table 2.

Parameters in the production technology, specifically the capital share of output and the depreciation rate are standard in the literature. The discount factor, β is set to reflect a risk free rate of about two percent in steady state, consistent with the calibration period. The survival rate of bankers and entrepreneurs, θ_b and θ_e, as well as the persistence of shocks ϱ and the capital adjustment costs ψ are taken from Mendicino et al. (2018). Bankruptcy costs are chosen in line with the estimates in Djankov et al. (2008).

Although internally calibrated parameters are chosen simultaneously using a simulated method of moments (SMM), most of them have a data target that closely identifies it. In particular, the overall level of loans in the economy is connected to the relative abundance of entrepreneurial net worth, captured by $chi_{e,i}$. Bank equity returns help identify the endowment of entering bankers, χ_b. Deposit management costs help match both the share of external bank liabilities in held by households as well as the overall returns on bank debt. Capital management costs γ_k are associated to the fraction of physical capital managed directly by the dynasties.

The cross sectional dispersion of firm and bank iid shocks is reflected on the average value of firm and bank debt spreads. The parameters related to the variance of risk shocks are associated the variance of such spreads. Similarly, the standard deviation of productivity processes help match the standard deviation of GDP. [13] The labor supply in the periphery L_p is chosen to match the relative size of the two economies.

In the international dimension of the model, the size of international banking groups is controlled by the fraction of net worth of entering entrepreneurs that is devoted to the foreign-financed sector. The differential volatility of international loans is targeted by the variance add-on ς^* introduced in (3.3). Finally, the partial adjustment parameter affecting capital requirements helps match the overall variance of loans.

Overall, the calibration assigns higher risk parameters (both in the cross section as in the time series dimension) to the financial sector of the Periphery region. In other words, through the lens of the model, banks from the Periphery tend to be riskier. This result will be determinant to understand the consequences of modifying capital requirements,

[13] In order to avoid the counterintuitive impact of bankruptcy costs on output, I define $GDP_{i,t} = c_{i,t} + I_{i,t}$

as will be discussed in the following sections.

Table 1: Targeted Moments

Moments	**Core**		**Periphery**	
A. Country Specific Targets	**Model**	**Data**	**Model**	**Data**
Mean Loans/GDP	2.194	1.410	1.780	1.970
Mean Share of International Loans	0.085	0.086	0.156	0.179
Mean Spread Loans	0.779	1.110	1.088	1.490
Mean Bank Debt Returns	2.055	2.436	2.625	3.097
Std. GDP	0.027	0.017	0.055	0.031
Std. Loans/Std. GDP	2.358	1.790	2.520	3.870
Std. International Loans/ St. GDP	5.665	15.143	2.692	4.774
Std. Spread Loans/ Std. GDP	0.012	0.020	0.023	0.023
Std. Bank Debt Returns/ Std. GDP	0.033	0.0126	0.051	0.027
B. Euro Area Targets	**Model**		**Data**	
Mean Bank Equity Returns	8.887		5.49	
Mean Share of Capital Managed by Households	0.21		0.21	
Mean Share of Cross Border Bank Liabilities	0.35		0.31	
Mean GDP Periphery/ GDP Core	0.699		0.78	

Notes: This table shows the data targets used in the calibration, as well as their model counterparts. Corporate spreads, returns on bank debt and returns on equity are reported in annualized percentage points. Standard deviation of log(GDP) is reported in quarterly terms. Cross border bank liabilities refer to the average share of bank debt issued by foreign bankers in the portfolio of the dynasties. All variables have been linearly detrended.

Table 2: Parameter values

Pre-set Parameters	**Description**	**Values**	
α	Capital Share in Production	0.3	
δ	Depreciation Rate of Capital	0.025	
β	Discount Factor	0.995	
θ_b	Survival Probability Bankers	0.975	
θ_e	Survival Probability Entrepreneurs	0.975	
μ	Bankruptcy Costs	0.3	
ψ	Capital Adjustment Costs	4.5	
κ	Fraction of Insured Bank Deposits	0.54	
M_{ij}	Multiplicative capital buffers	1	
ϱ	Persistence of Shocks	0.9	
Calibrated Parameters			
A. Common across countries			
χ_b	Entering Bankers' Endowment	0.134	
$\gamma_{d,ii}$	Deposit Management Cost (Domestic)	$1.25 \times 10^{-}5$	
$\gamma_{d,i\neq j}$	Deposit Management Cost (International)	$2.28 \times 10^{-}5$	
γ_k	Capital Management Costs	0.0188	
ς_b^*	Std. Bank Risk Shocks (International)	0.097	
η	Adjustment Coefficient Capital Requirements	0.91	
B. Country Specific		**Core**	**Periphery**
$\chi_{e,i}$	Entering Entrepreneurs' Endowment	0.403	0.61
ξ_i	Fraction of entrepreneurs' net worth in international sector	0.09	0.14
L_2	Relative size of Periphery		0.61
$\bar{\sigma}_{e,i}$	Cross sectional dispersion Firm iid shocks	0.374	0.58
$\bar{\sigma}_{b,i}$	Cross sectional dispersion Bank iid shocks	0.019	0.024
$\varsigma_{e,i}$	Std. Firm Risk Shocks	0.032	0.041
$\varsigma_{b,i}$	Std. Bank Risk Shocks	0.044	0.077
$\varsigma_{A,i}$	Std. Productivity Shocks	0.0122	0.025

4 Optimal Level of Capital Requirements

Next, I turn to the analysis of the optimal level of risk based capital requirements in the presence of financial integration. The nature of the first exercise considered is to choose a uniform regulatory buffer $M_{i,j} > 1$ in order to maximize a utilitarian version of total welfare given by

$$V_t = xV_{c,t} + (1-x)V_{p,t}, \tag{4.1}$$

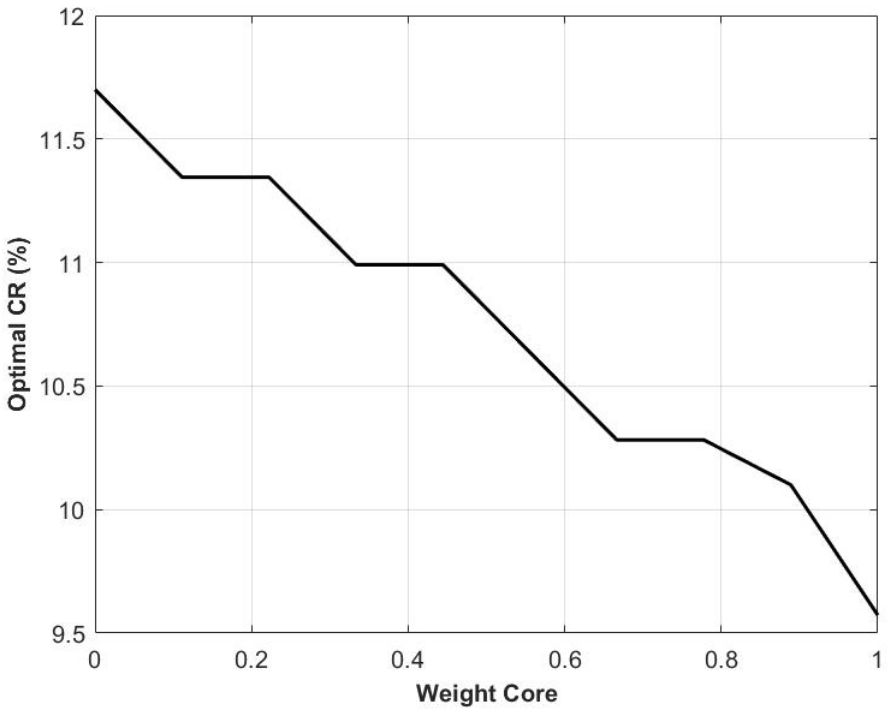
where x is the weight of the Core country in the utility function of the planner, and $V_{i,t}$ is the value function of the representative dynasty in country i, defined in (2.1).

Figure 1 summarizes the optimal level of capital requirements on risk weighted assets for different weights of Core and Periphery in the planners' function. The first striking fact about the analysis is that there are large divergences in terms of the optimal level of

capital requirements that would be preferred by each country. The Core, whose banking systems is more stable, prefers lower levels of capital requirements. The Periphery, in contrast, profits significantly from the decrease in bank default following an increase in capital requirements.

Notice however, from the top panels in Figure 2 that an increase in the level of capital requirements would be Pareto improving. Both countries would benefit from an increase in capital requirements. However, going beyond the 10 percent of risk weighted assets mark is detrimental for welfare in the Core, as the credit supply falls beyond the gains from decreasing bankruptcy costs. The Periphery, on the other hand, would prefer a level of capital requirements of about 11.6 percent of risk weighted assets, that is, significantly higher than the 10.5 percent level in Basel III (see (BCBS, 2010)).

Figure 1: Optimal level of regulatory capital requirements for different relative weights of the Core in total welfare.



Notes: This figure shows the optimal level of capital requirements, set uniformly across the two countries, to maximize a utilitarian version of welfare with the weights on the utility of the Core country displayed on the horizontal axes.

4.1 Analysis of buffers on international exposures

The nature of bank level distortions are such that banks prefer exposures where the variance of bank shocks is greater. In the calibrated version of the model, international exposures are the ones more strongly affected by bank risk shocks. Therefore, banks expand credit abroad in response to increases in the volatility of their returns.

The nature of banks' incentives raises the question on whether it would be optimal to ask for banks to hold additional capital buffers against exposures of their subsidiaries operating in a foreign country. I next ask what are the welfare effects of introducing a buffer

$$M_{ij} = 1 + \lambda \text{ if } i \neq j \tag{4.2}$$

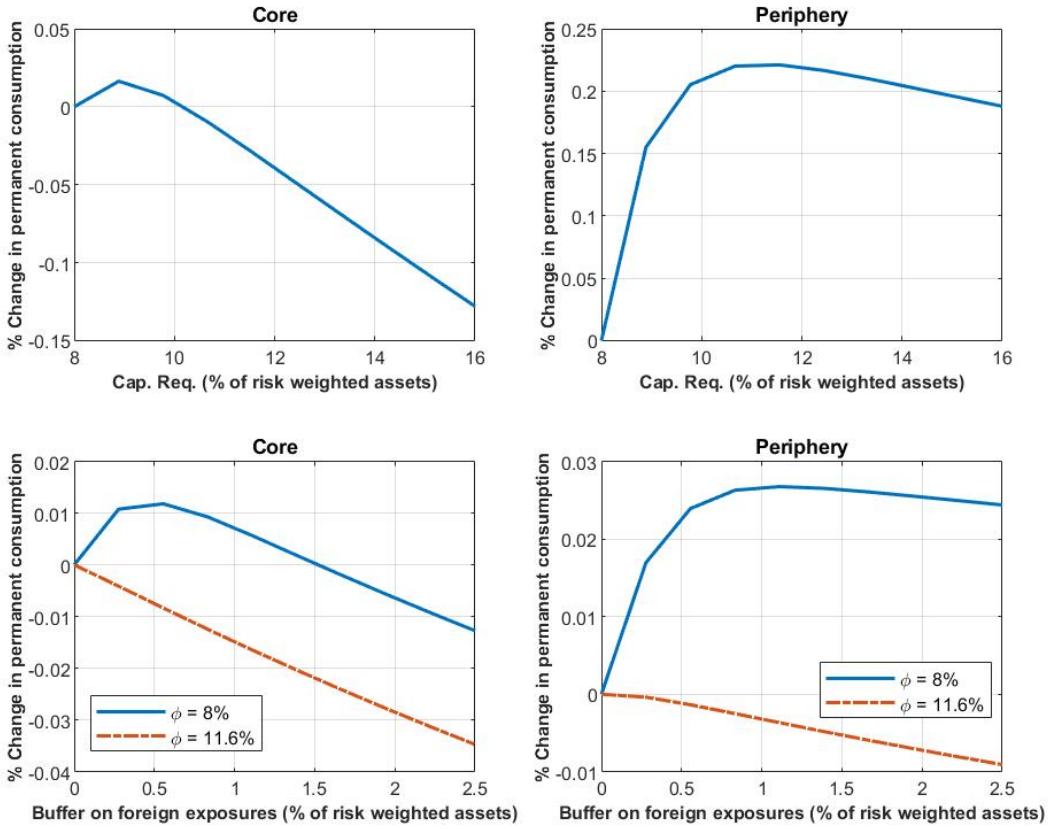
with $\lambda = 0$ otherwise. The bottom panel of Figure 2 shows the effects on welfare of such an increase.

First, if capital requirements are at their baseline level of 8% of risk weighted assets, then introducing an additional buffer on the activities of foreign subsidiaries can be welfare improving. However, once a higher level (such as the 11.6 percent preferred by the Periphery) of capital requirements is implemented, then setting additional buffers is detrimental to welfare in both countries.

The rationale for this result is that while it is true that international credit is more volatile and international bank subsidiaries are more strongly affected by bank risk shocks, there are gains from the presence of foreign banks. Because a fraction of firms is matched to foreign banks, restricting credit supply of those subsidiaries has detrimental effects on their investment levels.

This result suggests that while a regulatory add-on on foreign lending could stabilize credit flows and protect banks' capital, its negative effects on firms that depend on foreign bank lending would make it undesirable from a welfare perspective.

Figure 2: Welfare effects of uniform increases of capital requirements and buffers on international exposures of banks.



Notes: This figure presents the welfare change (in equivalent permanent consumption units) of modifying the level of capital requirements. Top panels display the change in welfare for the Core and the Periphery when there is a uniform increase in capital requirements in the two countries. The bottom panel shows the change in welfare when a capital add on is required for international exposures, for two different levels of baseline capital requirements.

4.2 Analysis of reciprocity arrangements

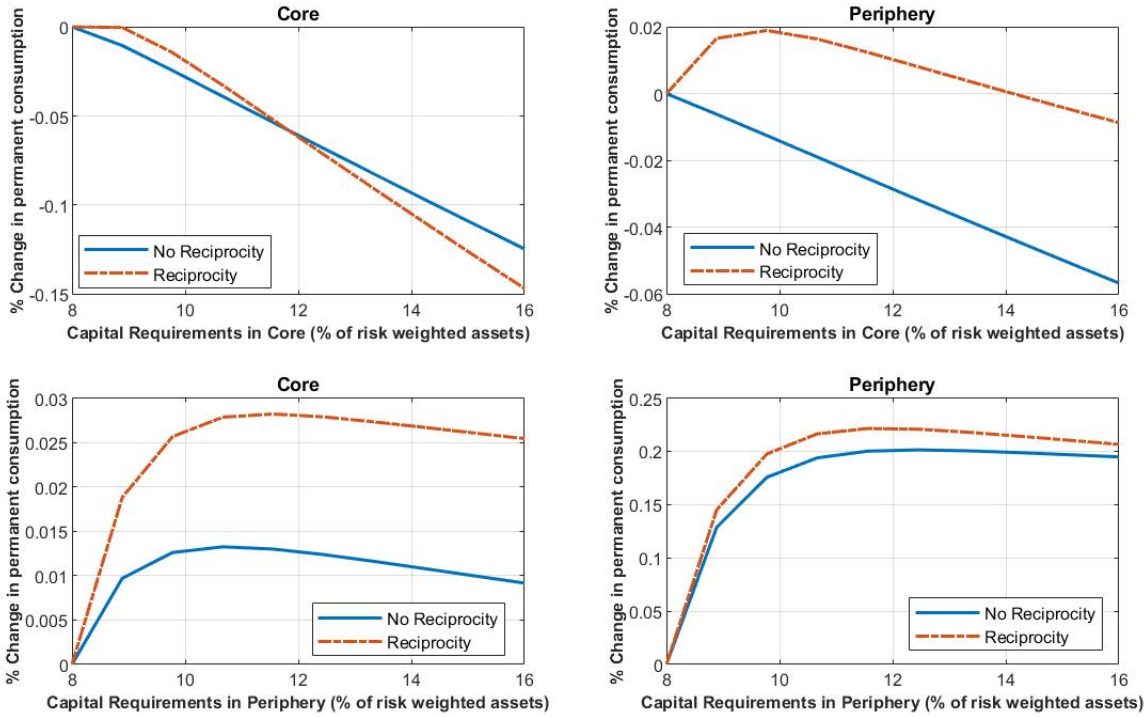
Under the Basel framework, however, there are reciprocity provisions that allow countries to increase the level of the capital requirements applicable to all loans granted to domestic borrowers either by domestic or foreign banks. In this section I analyze the effects on welfare of increasing capital requirements separately in each region, with and without this type of reciprocity arrangements in place. In the absence of reciprocity, in the depicted policy experiment, the increase applied by the domestic authority would only apply to the domestic lending of domestic banks. With reciprocity, the increase applies to the

lending of both domestic and foreign banks to domestic borrowers. The results appear in Figure 3.

The first lesson that can be learned from the exercise is that, in general, the welfare improvements generated by an increase in capital requirements are enhanced by the application of reciprocity arrangements. There are two main factors that determine this result.

In the case of an increase of capital requirements in Core countries, without reciprocity , Core banks respond by increasing their lending to the Periphery, while Periphery banks respond by increasing their lending to the Core. So the policy has "spillovers" (effects on the other country) and "leakages" (offsetting effects coming from the unaffected banks from the other country) that may diminish its effectiveness in improving financial stability in the Core (while having ambiguous implications for the stability of the Periphery). In welfare terms, both countries lose from the increase in the requirements.

Figure 3: Welfare effects of reciprocity



Notes: This figure shows the welfare effects of modifying capital requirements in each country separately, taking into account the effects of adopting reciprocity rules. Changes in welfare are reported in terms of percentage changes in permanent consumption. Top panels show the effects of modifying capital requirements in the Core, while bottom panels display the effects of modifying capital requirements for exposures in the Periphery.

With reciprocity, in contrast, the Periphery gains, up to some point, from the increase of the capital requirements in the Core. This occurs because reciprocity reduces the incentives of Periphery banks to shift lending towards the Core. The Core still loses welfare simply because the baseline 8% capital requirement turns out to be above its welfare maximizing level.

For the case of an increase in the capital requirements in the Periphery, the effects on welfare are unambiguously positive, up to the 11 percent mark, with or without reciprocity. The effects are largely explained by the fact that banks and lending in the Periphery are significantly riskier than banks and lending in the Core. Reciprocity in this case increases significantly the welfare gains obtained by the Core since it prevents its banks from shifting excessive lending to the (riskier) Periphery.

5 The Value of International Coordination

This section analyzes the potential spillovers stemming from regulatory decisions (subject to reciprocity) undertaken by authorities in each region. The exercise consists of increasing capital requirements applicable to exposures of banks in a region (both domestic and international subsidiaries), while the other region leaves its regulatory stance unchanged.

Figure 4 and 5 show the effects on financial and real variables in the ergodic distribution of the model, under different levels of capital requirements in each region. In Core countries, an increase in capital requirements in the Periphery is accompanied by an expansion in domestic credit, GDP and consumption. The increase in capital requirements in the Periphery increases bank incentives to shift their credit towards the less regulated Core, generating an expansion in international credit.

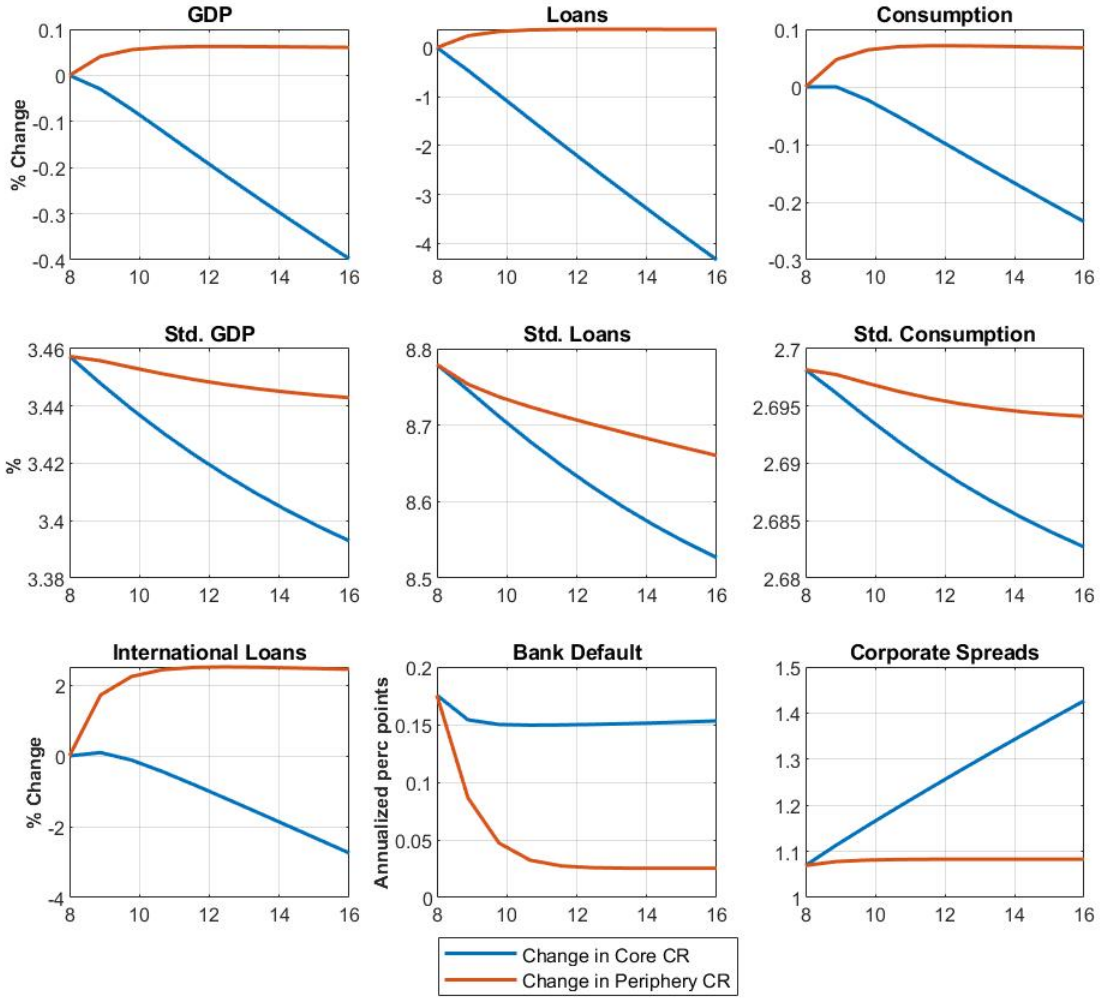
At the same time, the buildup of capital buffers in the banking sector *abroad* decreases the variance of output, credit and consumption. This highlights a positive externality generated by macroprudential buffers built in the (riskier) Periphery. The increase in regulatory buffers in the Periphery banks also decreases the average probability of default of the Core banks, because of the buildup of buffers on their risky exposures abroad. Finally, the impact on corporate spreads in Core is modest, compared to the effects generated by an increase in domestic capital requirements.

We now turn to the analysis of the effects of an increase in the capital requirements in the Core on the Periphery. There is a credit expansion in the Periphery, which follows from a rebalancing of bank portfolios towards the Periphery. Notice, however, that the expansion in capital requirements in the Core also has the indirect effect of *increasing* the volatility of consumption and GDP in the Periphery. To understand this effect, it is important to note that if there were no frictions in the allocation of credit in the corporate sector (matching between banks and firms), then it would always be more efficient to finance credit through the banks from Core countries (because on average they fail less).

Overall, results in this section suggest that there are cross border externalities associated with the capital requirements imposed in each country and, specifically, that there are positive financial stability externalities on the Core country of imposing higher capital

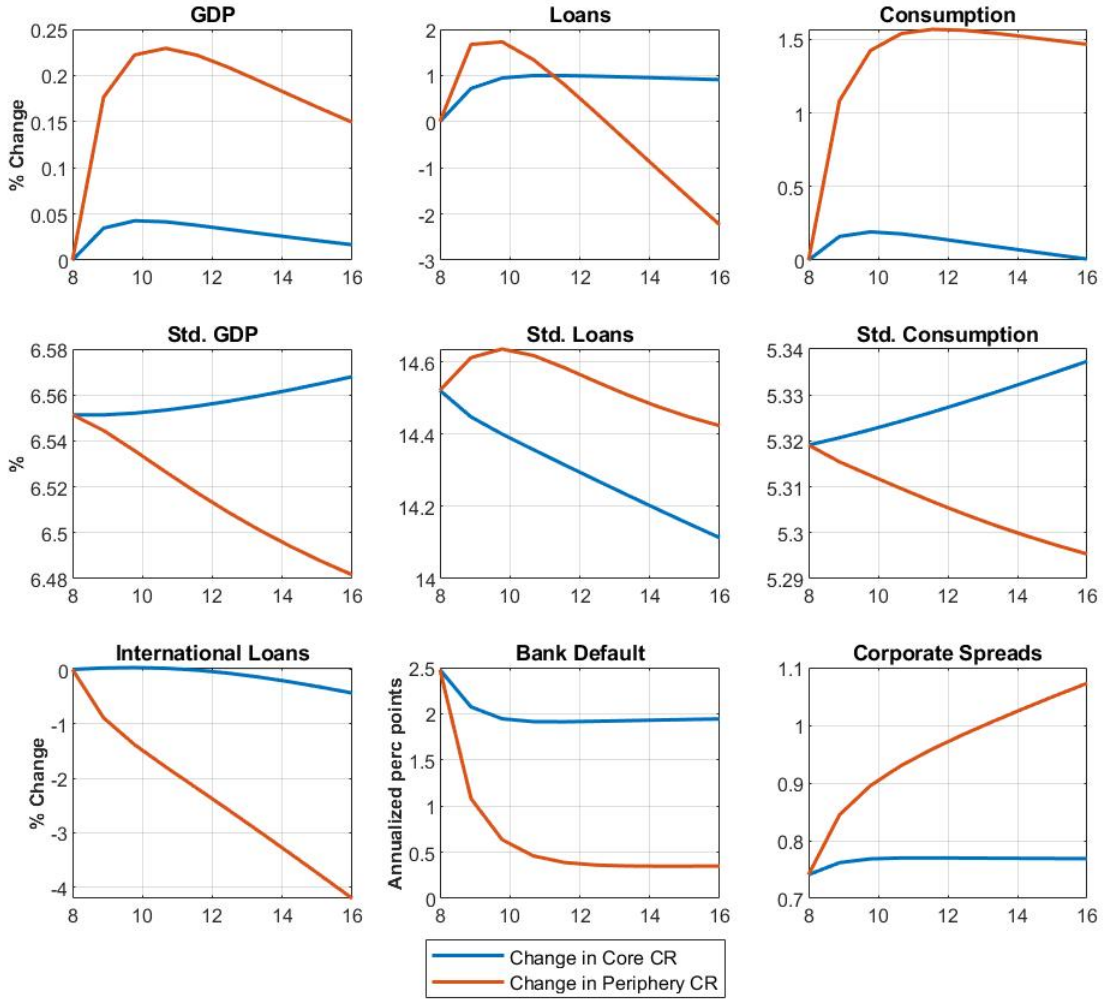
requirements in the Periphery country. The natural question that follows is what are the capital requirements on the lending in each country that a social planner interested in maximizing the joint welfare of both countries would fix.

Figure 4: Effects in the Core country from changes in the capital requirements in each country under reciprocity.



Notes: This figure shows the effects on financial and real variables in the Core of modifying the level of capital requirements in each country, under the assumption of regulatory reciprocity. Loans, GDP and consumption are reported in terms of their percentage change with respect to their baseline levels. Standard deviations are reported in percent. Bank default rates and corporate spreads are reported in annualized percentage points.

Figure 5: Effects in the Periphery country from changes in the capital requirements in each country under reciprocity



Notes: This figure shows the effects on financial and real variables in Periphery economies of modifying the level of capital requirements in each region, under the assumption of regulatory reciprocity. Loans, GDP and consumption are reported in terms of their percentage change with respect to their baseline levels. Standard deviations are reported in percent. Bank default rates and corporate spreads are reported in annualized percentage points.

Optimal country-specific levels of capital requirements This section analyzes the optimal level of capital requirements chosen by a regulator choosing simultaneously the level of capital requirements in Core and Periphery countries, respecting reciprocity between domestic and international subsidiaries in each country. In other words the regulator chooses the level of multiplicative buffers $M_{ij} > 1$ in order to maximize (4.1), subject to restrictions

$$M_{cc} = M_{pc}$$

Table 3: Change in real and financial variables in each country after implementing the optimal country specific level of capital requirements.

Variables	**Core**	**Periphery**
Capital Requirements	0.82	3.56
Welfare	0.0464	0.2674
Std. Consumption	-0.0181	-0.1006
Std. GDP	-0.0548	-0.1900
Loans/GDP	-0.1587	-2.2180
Default Frequency Banks	-0.0082	-0.0340
Default Frequency Firms	0.0033	0.0123
Corporate Spreads	0.0335	0.2224

Notes: This table presents the effects of implementing the optimal level of capital requirements in each country, under a reciprocity arrangement. The optimal level of welfare is found assuming a weight of 55% for the Core in total welfare, resulting in a minimum capital requirement of 8.82 and 11.56 percent on risk weighted assets in the Core and the Periphery, respectively. Changes in capital requirements are reported in percentage points. Changes in the welfare of each country are reported in percentage points of equivalent permanent consumption. The change in standard deviation of GDP and consumption is reported in percentage points (that is, changes in the standard deviation of log consumption and log GDP, expressed in percent). Default rates and corporate spreads are reported in annualized percentage points.

and

$$M_{pp} = M_{cp}$$

.

Weights in the utility function of the global regulator are chosen to reflect the population shares of each of the regions in the Euro Area (which implies a 55% weight for the Core). The impact on welfare and financial and real variables of implementing the optimal levels of capital requirements are reported in Table 3.

The optimal level of capital requirements (on risk weighted assets) is set to 11.6 percent for exposures in the Periphery and roughly 9 percent in Core countries. Results show that welfare gains stem fundamentally from the fact that there are savings in terms of the bankruptcy costs from failing banks in the Periphery, but also, to some extent to the fact that firms also fail less, on average. The result in equilibrium is higher average consumption in both economies. Moreover, as better capitalized banks can extend credit even after shocks have eroded their profitability, the volatility of consumption also decreases in equilibrium.

In terms of welfare gains, the equivalent increase in permanent consumption that inhabi-

tants of the Periphery would require to be as well off as in the regime with higher capital requirements is about 0.2% of their baseline level of consumption. For Core countries the gains are much more modest, about 0.04% of their baseline consumption.

Finally, under the optimal calibration there is a somewhat smaller presence of foreign banks in the Periphery, because the relative increase in capital requirements in the region results in incentives for banks to reallocate their exposures back to the Core regions.

6 Concluding Remarks

This paper analyzes the welfare effects of changes in capital requirements set on corporate exposures when bank equity can be allocated across bank subsidiaries in different countries.

Results in this paper show that, when default risks of firms and banks differ across countries, macroprudential regulation should address such specific risks by setting different levels of capital requirements in each country.

It also shows that the externalities associated to changes in the level of capital requirements in each country call for proper coordination of regulatory actions. Spillovers and leakages of macroprudential regulation are manifested as a reallocation of credit towards the least regulated jurisdictions and as a substitution of domestic by foreign credit. These effects are particularly relevant if capital requirements are tightened on exposures in the relatively safer Core country, as exposures shift to the (riskier) Periphery.

Finally, this paper shows that even in the presence of risk shifting incentives that make banks prefer riskier international exposures, the adoption of capital buffers that penalize such exposures may be detrimental to welfare. If there is value in bank-firm relationships, then the financial stability gains from higher regulatory capital requirements need to be weighed against the potential distortions in the allocation of credit to firms dependent on international banks to finance their investment.

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A Market clearing conditions

Each period market clearing requires that

- Capital markets clear:

$$K_{i,t} = k^f_{ci,t} + k^f_{pi,t} + k^{hh}_{i,t}; \tag{A.1}$$

- Deposits market clear:

$$B_{ic,t}(1-\varphi_{ic,t}) + B_{ip,t}(1-\varphi_{ip,t}) = d_{ic,t} + d_{ip,t}; \tag{A.2}$$

- Bank equity markets clear:

$$N^b_{i,t} = e_{ic,t} + e_{ip,t}, \tag{A.3}$$

  with $e_{ij,t} = \int_0^1 e_{ij,t}(b)db$;

- Firm equity markets clear:

$$N^e_{ij,t} = a_{ij,t}, \tag{A.4}$$

  with $a_{ij,t} = \int_0^1 a_{ij,t}(f)df$;

- Labor markets clear:

$$L_{i,t} = l_{i,t}; \tag{A.5}$$

- Market for the final consumption good clears:

$$\begin{aligned} &\sum_i y_{i,t} = \sum_i c_{i,t} + \sum_i I_{i,t} + \\ &\mu\left[\sum_{i,j} R^k_{j,t} q_{j,t-1} k^f_{ij,t-1} \int_0^{\bar{\omega}^e_{ij,t}} \omega^e dF^e_{ij,t}(\omega^e) \sum_{i,j} \tilde{R}^b_{ij,t} B_{ij,t-1} \int_0^{\bar{\omega}^b_{ij,t}} \omega^b dF^b_{ij,t}(\omega^b)\right], \end{aligned} \tag{A.6}$$

  with $\bar{\omega}^b_{ij,t+1} \equiv \frac{R^d_{i,t}(1-\varphi_{ij,t})}{\tilde{R}_{ij,t+1}}$

B First order conditions of dynasties, capital good producers and entrepreneurial firms.

First order condition with respect to bank debt The pricing of bank debt from country i held by the dynasty in country j satisfies

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

where the average return on bank debt issued by banks from i is defined as

$$\tilde{R}^d_{i,t+1} = R^d_{i,t} - (1-\kappa)\Omega_{i,t+1}, \tag{B.2}$$

where

$$\Omega_{i,t+1} = \frac{D_{ic,t}\Omega_{ic,t+1} + D_{ip,t}\Omega_{ip,t+1}}{D_{ic,t} + D_{ip,t}}$$

, with $D_{ij,t} = B_{ij,t}(1-\varphi_{ij,t})$ in equilibrium and

$$\Omega_{ij,t+1} = \left[\bar{\omega}^b_{ij,t+1} - \Gamma^b_{ij,t}(\bar{\omega}^b_{ij,t+1}) + \mu G_{ij,t+1}(\bar{\omega}^b_{ij,t+1})\right] \tilde{R}_{ij,t+1}/(1-\varphi_{ij,t}),$$

where as in Bernanke et al. (1999) I define

$$G(\bar{\omega}) = \int_0^{\bar{\omega}} \omega dF(\omega) \tag{B.3}$$

and

$$\Gamma(\bar{\omega}) = G(\bar{\omega}) + \bar{\omega}\left[1 - F(\bar{\omega})\right]. \tag{B.4}$$

The stochastic discount factor of the household is simply given by

$$\Lambda_{i,t+1} = \beta \frac{c_{i,t}}{c_{i,t+1}} \tag{B.5}$$

First order condition of dynasties with respect to holdings of physical capital Dynasties hold physical capital directly, subject to management costs satisfying the Euler

equation

$$\mathbb{E}_t \Lambda_{i,t+1} \frac{R^k_{i,t+1}}{1+\gamma_k k^{hh}_{i,t}} = 1. \tag{B.6}$$

Problem of entrepreneurial firms Firms solve the problem stated in (2.17) in the main body of the paper. The Lagrangian associated to this problem can be written as

$$\mathcal{L}_{ij,t} = \mathbb{E}_t \Lambda^e_{ij,t+1} \rho^e_{ij,t} - \lambda_{ij,t}(q_{j,t} k^f_{ij,t} - B_{ij,t} - a_{ij,t}) + \zeta_{ij,t}(\Lambda^b_{i,t+1} \rho^b_{ij,t+1} - v^b_{i,t}), \tag{B.7}$$

which yields the first order conditions

$$\mathbb{E}_t \Lambda^e_{ij,t+1} \frac{\partial \rho^e_{ij,t+1}}{\partial B_{ij,t}} + \lambda_{ij,t} + \zeta_{ij,t} \mathbb{E}_t \Lambda^b_{i,t+1} \frac{\partial \rho^b_{i,t+1}}{\partial B_{ij,t}} = 0, \tag{B.8}$$

$$\mathbb{E}_t \Lambda^e_{ij,t+1} \frac{\partial \rho^e_{ij,t+1}}{\partial k^f_{ij,t}} - \lambda_{ij,t} q_{j,t} + \zeta_{ij,t} \mathbb{E}_t \Lambda^b_{i,t+1} \frac{\partial \rho^b_{i,t+1}}{\partial k^f_{ij,t}} = 0, \tag{B.9}$$

$$\mathbb{E}_t \Lambda^e_{ij,t+1} \frac{\partial \rho^e_{ij,t+1}}{\partial R_{ij,t}} + \zeta_{ij,t} \mathbb{E}_t \Lambda^b_{i,t+1} \frac{\partial \rho^b_{i,t+1}}{\partial k^f_{ij,t}} = 0, \tag{B.10}$$

where $\lambda_{ij,t}$ and $\zeta_{ij,t}$ are the Lagrange multipliers associated to the financing constraint of firms and the participation constraint of banks, respectively.

First order condition of capital good producers Capital good producers choose investment to maximize the period profits generated to the dynasty, as stated in the problem in (2.6). The first order condition associated to this problem is

$$q_{i,t} = S' \left(\frac{I_{i,t}}{K_{i,t-1}} \right), \tag{B.11}$$

with

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

Parameters a_1 and a_2 capital is stationary and its price is one in the deterministic steady state of the model.

B.1 Taxes and net transfers from entrepreneurs and bankers

Taxes levied by the deposit insurance agency to repay the insured fraction of bank debt upon default of financial intermediaries are defined as:

$$T_{i,t} = T_{ci,t} + T_{pi,t}, \tag{B.12}$$

with

$$T_{ij,t} = \kappa \Omega_{ij,t} D_{ij,t}. \tag{B.13}$$

Net transfers from bankers Net transfers from exiting bankers to the dynasty in country i can be defined as

$$\Psi^b_{i,t} \equiv (1-\theta_b)\left[\rho^b_{ic,t+1} e_{ic,t} + \rho^b_{ip,t+1} e_{ip,t}\right] - \iota^b_{i,t}, \tag{B.14}$$

while net transfers from entrepreneurs are given by

$$\Psi^e_{i,t} = \Psi^e_{ci,t} + \Psi^e_{pi,t}, \tag{B.15}$$

with

$$\Psi^e_{ij,t} = (1-\theta_e)\rho^e_{ij,t+1} N^e_{ij,t} - \iota^e_{ij,t+1}. \tag{B.16}$$

Total transfers to each dynasty from bankers and entrepreneurs and simply

$$\Psi_{i,t} = \Psi^b_{i,t} + \Psi^e_{i,t}.$$

C Data Sources and Construction of Foreign Loans

Foreign Loans Foreign loans to non financial corporations are constructed using data from the Consolidated Banking Statistics (CBS) from the Bank for International Settlements. Data on individual counterparty countries at a quarterly frequency are available only for total claims, that is, loans and debt securities against all counterparty sectors. I collect this data for the Euro Area countries reporting to the BIS: Austria, Belgium,

France, Finland, Germany, Greece, Italy, Netherlands, Spain and Portugal, against all 19 countries in the Euro Area. Then I combine this data with ECB data on loans to non financial corporations as a share of total bank loans and debt securities in the reference country. Then I assume that the share of total claims from CBS that corresponds to non financial corporations in the destination country is the same as the share of bank loans to non financial corporations held by monetary financial institutions in that reference area. In other words

$$\text{Foreign Loans to NFC}_{ji,t} = \underbrace{\text{Share of Loans to NFC}_{i,t}}_{\text{From ECB, MFI aggregate balance sheet}} \times \underbrace{\text{Total claims}_{ji,t}}_{\text{From BIS CBS}}. \tag{C.1}$$

In order to determine the Core and periphery groups I follow the following procedure:

1. Countries in EA not reporting to the CBS are included in the Periphery country.

2. The rest of countries are sorted in order to maximize

$$\lambda(Loans_{cp} + Loans_{pc}) + \frac{Loans_{cp}}{Loans_{cp} + Loans_{pp}} - \frac{Loans_{pc}}{Loans_{cc} + Loans_{pc}}, \tag{C.2}$$

   where $Loans_{ij}$ denotes the total amount of loans to non financial corporations originating in countries included in the set j with destination in the countries in the set i.

   For a wide range of values of λ that do not end up in corner solutions to this problem (meaning that you get only one country in either the Core or the Periphery areas), I get the partition given by $Core = \{\text{Austria, France, Germany, Netherlands}\}$.

Corporate Loans For each country in the Euro Area, 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 For each country 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, for each representative country (Core and Periphery) I compute a weighted average using the share of individual countries in total loans of the aggregate.

- For each country in the Euro Area, 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 –
- For each country in the Euro Area, 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–
- For each country in the Euro Area, 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.

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

GDP, GDP Deflator and Investment Taken from EuroStat quarterly national accounts. In order to determine the relative size of Core and Periphery countries I use PPP adjusted GDP.

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

$$\text{LR} = \frac{\text{NFC Net Debt Securities} + \text{NFC Net Loans} + \text{NFC Net Insurance Guarantees}}{NFCNetAssets}. \tag{C.3}$$

The measure of bank funding received by the corporate sector is

$$BF = \frac{\text{MFI Loans to NFCs}}{\text{NFC Net Assets}}. \tag{C.4}$$

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

D Regulatory formulas

The Internal Ratings Based (IRB) approach formulas in the Basel framework are a function of the probability of default (PD) of individual corporate loans. These formulas are used to determine the risk weight of assets. These risk weights are then used to compute the effective level of capital that banks need to hold against their credit portfolio.

The functional form used to determine asset risk weights is given by

$$IRB(PD_{ij,t}) = LGD\Phi\left(\frac{\Phi^{-1}(PD_{ij,t})}{\sqrt{1-\rho_t}} + \frac{\sqrt{\rho_t}\Phi^{-1}(0.999)}{\sqrt{1-\rho_t}}\right), \tag{D.1}$$

with

$$PD_{ij,t} = 4 \times \mathbb{E}_t F^e_{ij,t+1}(\bar{\omega}^e_{ij,t+1}), \tag{D.2}$$

while the correlation of portfolios adjustment factor is defined as

$$\rho_t = 0.12\frac{1-\exp\left(-50PD_{ij,t}\right)}{1-\exp(-50)} + 0.24\frac{\exp(-50PD_{ij,t})}{1-\exp(-50)}. \tag{D.3}$$

Finally, loss given default of corporate loans (LGD) is set to be equal to 0.45, following the foundation IRB approach.

Basel formulas are such that the minimum amount of bank capital required in Basel II is computed as

Minimum regulatory capital = 8%×Risk Weighted Assets = $IRB(PD)$×Exposure at Default.

In other words, we have that

$$\text{Risk Weighted Assets} = \frac{IRB(PD)}{8\%} \times \text{Exposure at Default},$$

so that, upon the introduction of a buffer that Raises the level of capital requirements on risk weighted assets the effect on the IRB formula is multiplicative. For example, with the capital conservation buffer of 2.5 percent of risk weighted assets, the minimum regulatory capital is given by

$$\frac{10.5\%}{8\%} \times IRB(PD) \times \text{Exposure at Default},$$

which explains why additional buffers are introduced as a factor greater than one in the welfare analysis in the main body of the paper.