The Cross-border Effects of Bank Capital Regulation

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Abstract

We propose a model for studying the international coordination of bank capital regulation under the principle of reciprocity. In such a regime countries compete for scarce bank equity capital. Raising capital requirements in a country may generate bank capital outflows as well as inflows. We pin down the condition for the sign of the capital flow and the associated externality, and highlight the implications for macroprudential regulation. Compared to collaboration, overshooting is likely: countries have an incentive to increase Basel III's Counter-Cyclical Capital Buffer too much in good times and cut it too much in bad times.

1 Introduction

International standards for bank capital regulation have evolved over the past four decades from a simple, common 8% minimum capital requirement to a

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broad, complex toolkit. Macroprudential considerations have been a driving force behind this evolution. Prudential risks and macroeconomic cycles differ across countries, which suggests the need for heterogeneous and time-varying capital requirements. Under the current regime (Basel III) the stance of macroprudential regulation is effectively set by national regulators. However, in order to maintain a level playing field, the Basel Committee has introduced the principle of reciprocity: the capital requirement set by a regulator applies to all bank loans made in its jurisdiction, irrespective of which jurisdiction the bank belongs to. This principle fundamentally alters strategic incentives among regulators.

The existing literature has studied non-reciprocal regimes. In these circumstances, international competition for market share within a country is a key driver of strategic incentives: Regulators can give an advantage to banks in their jurisdiction by cutting capital requirements as this allows them to operate at a cheaper cost than banks from other jurisdictions. So, to the extent that regulators care about the profits of the banks they regulate, they have an incentive to undercut one another in order for their banks to steal market share (Dell'Ariccia and Marquez (2006)). The introduction of reciprocity is designed to eliminate this market-share externality when regulators have discretion. Still, in the current regime, regulators and policymakers regularly express concerns about the international spillovers of capital requirements. Yet there is little agreement on what the relevant externalities are and a formal framework for assessing them is needed.[1]

We find that, under reciprocity, what matters is not competition for market share but competition for bank capital. Key is how much equity capital is allocated to lending in different jurisdictions. Changes in capital requirements alter this allocation and effectively generate bank equity capital flows. We propose a model to study such capital flows and their implications for strategic interactions between regulators. The model has two dates and two countries (*Home* and *For-*

[1]Typical concerns associated with higher capital requirements in a given country go from impairing the competitiveness of the domestic financial system (Osborne (2015)) to a reduction in domestic banks' foreign exposures, therefore impairing the functioning of foreign financial systems (de Guindos (2019)), and to cross-border relocation of risk-shifting activities (ESRB (2018), page 90).

eign), in which banks finance loans with a mix of insured deposits and equity capital. These banks face capital requirements in a reciprocity regime. Bank equity capital is mobile and there is global competition for it.

Our contribution is threefold: First, we show that, perhaps against conventional wisdom, an increase in the capital requirement in a country does not necessarily generate outflows of bank equity capital – *inflows* are possible too. We pin down the conditions under which either case occurs. Second, as bank equity capital is scarce, changes to capital requirements in a country impose, through capital flows, an externality onto the other country. We show that this *capital flow externality* is central to the incentive for national regulators to deviate from a collaborative optimum. If higher requirements generate positive externality, there is an incentive to deviate downwards, i.e., to undercut the other country (and vice versa if the externality is negative). Third, we point out the implications for the coordination of macroprudential capital regulation. In particular, under reciprocity and absent coordination, macroprudential capital requirements are likely to be raised too much in good times *and* cut too much in troubled times, when bank equity capital is particularly scarce.

To understand these results, let us expose the main mechanism of the model, starting from the perspective of a single country. The banking sector is perfectly competitive and, at the banking sector level, the returns to lending are diminishing. Consider the revenue banks receive from loans, net of repayments to creditors. This constitutes the resources available to pay the investors in the banks' equity, so we refer to it as investor revenue. This investor revenue is hump-shaped in aggregate lending in much the same fashion as a monopolist's profit is hump-shaped in quantities. Now, holding aggregate bank equity fixed, an increase in capital requirements contracts lending. Given the hump shape, this can either increase or decrease investor revenue. This means that, ceteris paribus, there is an investor revenue maximising capital requirement. Moreover, hump-shaped investor revenue implies that the return on bank equity is hump-shaped in lending too. It turns out the revenue and return maximising requirements are the same. The bottom line is that if the capital requirement is initially below the return maximising level, then an increase will raise returns (and, vice versa, it will lower returns if we start above the return maximising level).

Now take the case of two countries with equity capital that can be freely allocated by banks to lending in either one. Consider a competitive equilibrium for a given pair of capital requirements. A basic no-arbitrage argument implies that return on equity be equalised across countries. If, for some reason, the return on equity increases in a country, capital will be reallocated to it to restore equilibrium. So if, ceteris paribus, a higher Home capital requirement increases Home returns, this will trigger capital inflows (and outflows if returns decrease). This implies that the sign of the capital flow induced by a capital requirement change hinges on whether the initial requirement is greater or less than the revenue maximising requirement.

In our model, banks issue equity competitively and the global aggregate supply of bank equity is upward sloping. Hence, in equilibrium, the return on bank equity is also equated to the marginal cost of raising it. Consider a change in the capital requirement in Home that attracts capital. There are two potential sources for this adjustment: the quantity of bank equity supplied globally can increase, or capital can flow into Home from Foreign, therefore generating a spillover. The extent to which these two margins are used depends on the relative elasticity of the associated supply curves. At one extreme, if the global supply for *new* equity capital is perfectly inelastic (i.e., there is a fixed supply of global capital), all capital flowing into Home must flow out from Foreign; we have a 100% spillover. Conversely, if the global supply is perfectly elastic, all capital flowing to Home will be newly raised capital; and there is no spillover.

Having characterised the market equilibrium for a given set of capital requirements, we then turn to a policy game in which we endogenise the requirements. We compare the collaborative outcome with the Nash equilibrium where regulators seek to maximise net output subject to deadweight losses from financial instability. Bank equity capital alleviates these deadweight losses and hence is socially valuable. This gives rise to the competition across countries for bank equity capital: whether national regulators have an incentive to deviate upwards or downwards from the collaborative outcome depends on the sign of the capital flows the deviation would generate.

As we have explained, the sign of the capital flow depends on whether the initial requirement is higher or lower than the return maximising requirement. As an important aside: maximising returns is different from maximising welfare or even bank profits (as the return does not account for the banks' cost of funds).[2] Still, the return maximising requirement is a useful threshold for the direction of capital flows.

We assess incentives for regulators to deviate from the collaborative outcome. We provide a closed form solution for the optimal collaborative capital requirement, and an associated closed form condition for whether this requirement is tighter or not than the return maximising requirement. Together with a numerical solution for the Nash equilibrium, this allows us to formulate empirical predictions. In particular, the following factors make it more likely that, ceteris paribus, capital requirements will be set too low by competing regulators: i) the supply of bank equity capital is particularly tight; ii) bank risk-shifting incentives are acute; iii) the aggregate loan demand is relatively elastic, or iv) deadweight losses are severe. And vice versa: competitive regulators will tend to set capital requirements too high under the opposite conditions; e.g., if equity capital is relatively abundant and bank risk-shifting incentives are mild.

Current international standards for capital regulation can be approximated as a common minimum requirement plus a time varying add-on known as the counter-cyclical capital buffer (CCyB). The CCyB is the headline macroprudential capital requirement and the key margin via which policy is adjusted. In many jurisdictions, the buffer is to financial policy committees what the short-term interest rate is to monetary policy committees. The buffer is set in each jurisdiction and must be reciprocated (within limits).[3]

Our analysis suggests that competing regulators will raise the CCyB too high in normal times (when bank capital is not too scarce).[4] In this case, there are

[2]Since banks are perfectly competitive in our model, changes in capital requirements have no effect on equilibrium profits. However, we show that if banks have some market power, tighter regulation hurts bank profitability as one would expect.

[3]In some jurisdictions (such as within the EU) other macroprudential capital requirements, such as sectoral capital requirements, are reciprocated but on a voluntary basis.

[4]As we discuss in Section 6, the empirical literature is generally consistent with the notion that banks respond, most of the time, to increases in capital requirements by partially raising

gains from coordinating on more modest raises. However, if bank capital is very scarce (think of bad or troubled times, for instance after a big negative shock to bank equity capital), then competing regulators will have an incentive to cut the CCyB by more than what collaboration requires.

The reference paper for the non-reciprocal regime is Dell'Ariccia and Marquez (2006). To illustrate how, in such a regime, regulators' strategic interactions fundamentally differ from those in the one we study, it is best to highlight a key mechanism in their paper. They have a representative bank based in each of two countries, but both banks operate in both countries. Each bank has a fixed amount of equity capital and faces the capital requirement imposed by their country of origin. A key point is that a decrease in capital requirement by the Home regulator decreases the cost of capital for the Home-based bank, which gives it a competitive advantage in both markets and allows it to grab market share from its Foreign competitor. This is an externality that naturally gives incentives for countries to undercut one another. Adopting a reciprocity regime kills such a market-share externality.[5]

In a similar international context, a series of papers study the interaction between capital regulation and other policy levers. Acharya (2003) looks at how discretion in resolution regimes can undermine the benefit of coordination in capital regulation. Morrison and White (2009) examine the link between banking regulation and supervisory quality. In their set up, capital requirements are a substitute to the regulator's ability to distinguish sound banks from weak ones. Competition among regulators creates a selection effect: high quality banks prefer to be chartered by high ability regulators, which also set lower capital requirements than low ability regulators.[6]

In addition, a sequence of papers have focused on international coordination

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more equity (as well as adjusting assets). In our model, this happens if and only if higher capital requirements generate capital inflows. This supports our interpretation of normal times being those where capital is not too scarce and where the level of lending is larger than the level that maximises investor revenue.

[5]The Dell'Ariccia and Marquez (2006) model is more involved and also embeds a financial stability externality, which reinforces the market share externality. We also allow for additional externalities but only discuss them in Section 6 since they are not the focus of our analysis.

[6]Other examples include, Buck and Schliephake (2013) and Gersbach et al. (2020), which respectively focus on capital regulation interactions with supervision intensity and fiscal policy.

of bank supervision, rather than capital requirements. Carletti et al. (2016) and Colliard (2019) both consider the role of central and local supervision when local supervisors have informational advantages but neglect cross-border externalities. Similarly, Calzolari and Loranth (2011) and Calzolari et al. (2018) consider how the presence of multinational banks alter supervisory incentives.

At a more general level, Korinek (2016) identifies conditions under which there is scope for international policy collaboration. The relevant one in our paper is the violation of the Tinbergen Principle: Regulators have a single tool (the capital requirement) and face a policy trade off (e.g. between economic activity and financial stability). If regulators could, for instance, directly and costlessly subsidise the allocation of bank equity to domestic lending, then the trade off could disappear, and so could the gains from collaboration.

In practice, fiscal policy is mostly separated from macro-prudential policy. How these policies should be coordinated within and between countries is a complex, multifaceted question. Government guarantees generate implicit subsidies that can distort bank behaviour and have direct fiscal implications that can spillover across borders when banks fail. Faia and Weder (2016), Bolton and Oehmke (2018) and Segura and Vicente (2019) study how the resolution of banks should be coordinated between countries. Moreover, monetary policy can directly affect bank profitability, which may also call for coordination across borders.[7] Modelling all these different aspects of policy is beyond the scope of this paper, we focus on a prudential policymaker that only controls the capital requirement.

Finally, even though our main focus is on strategic interactions between national regulators, other dimensions of our analysis directly relate to previous literature on capital requirements. Commonalities include moral hazard due to government guarantees (Kareken and Wallace (1978)), incentives for banks to specialise (e.g., Martinez-Miera and Suarez (2014), Harris et al. (2020), Bahaj and Malherbe (2020) and Malherbe and McMahon (2022)), and the study of optimal capital regulation in the face of policy trade offs (e.g., Begenau (2020), Malherbe (2020) and Elenev et al. (2021)).

[7]From that angle, our paper relates to the wider literature on monetary policy coordination and currency wars (e.g., Hamada (1976), Corsetti and Pesenti (2001), Caballero et al. (2021) and Blanchard (2021)).

2 The model

The model has two dates: 0 and 1. Decisions are made at date 0. At date 1, all stochastic variables are realised, and production and consumption take place.

We consider two sovereign countries: Home and Foreign. There is a single, tradeable good which can be consumed or used as physical capital in production, in which case the goods depreciate fully. This good is also the numeraire.

In each country, there is a representative firm, a representative household, a representative investor, and a regulator. There is also a mass of banks that can operate in both countries. We describe here the details of the environment in the Home country. The Foreign country has the same environment (although we do not necessarily impose symmetry in parameter values); foreign variables are marked with a $'$.

Agents and preferences Private agents only value date-1 consumption, are risk neutral, and act competitively. We define and discuss regulator preferences starting in Section 4.

Firms and technology The representative firm operates a Cobb-Douglas production technology: $Ak^{\alpha}l^{1-\alpha}$, where k is capital, l is labour, $0 < \alpha < 1$, and $A \geq 0$ is a random variable that captures TFP. The firm invests in capital at date 0. At date 1, A realises and the firm hires labour and produces.

We normalise $\mathbb{E}[A] = 1$ and assume that A is distributed over $[0, A^H]$, with a corresponding density function $g(A)$, which is smooth, unless otherwise specified. Our analysis does not require to impose any specific structure on the dependence between A and A' but, for simplicity, we assume that the joint distribution has full support over $\left[0, A^H\right] \times \left[0, A'^H\right]$.

The firm is penniless and borrows from the bank to invest in capital. In equilibrium, it makes zero profits in all states. We therefore abstract from firm ownership.

All agents have access to a riskless storage technology with a zero rate of return.

Banks Banks start penniless, issue equity (protected by limited liability), take deposits insured at no cost, and lend to firms subject to a capital requirement constraint that we define below. The banks can potentially lend in both countries. There is free entry and equity and deposits can be raised globally (i.e. from investors and households in either country). Banks can choose their country of incorporation, which determines which taxpayer insures its deposits. Deposit insurance is funded by ex-post lump-sum taxes on households.

Investors and the supply of bank equity capital That bank equity capital is scarce is a key ingredient of our analysis. For tractability reasons, many papers in the literature (e.g., Dell'Ariccia and Marquez (2006)) assume that the supply is simply fixed. However, that bank equity scarcity depends on the state of the economy seems the premise for the need of time varying capital requirements (Kashyap and Stein (2004), Kashyap et al. (2008), Malherbe (2020)). So, we adopt a more flexible approach and, following Hellmann et al. (2000), simply assume a generally upward sloping supply curve. We formalise it as follows.

Only investors can invest in bank equity. They are endowed with some initial wealth and can generate additional date-0 wealth, at a disutility cost. Specifically, to generate m units of wealth, an investor has to incur a disutility cost $m(1+z)$, with

$$z \equiv \frac{\kappa}{2} M^2, \tag{1}$$

and where $\kappa \geq 0$ is a parameter and $M \geq 0$ is the global additional wealth generated by investors. Investors take the unit disutility cost as given. Unless $\kappa = 0$, generating additional wealth is costly and investors only potentially do so for the purpose of investing in bank equity, accordingly, we have:

$$M \equiv \begin{cases} 0 & N + N' \leq \omega \\ N + N' - \omega & N + N' > \omega \end{cases},$$

where $N + N'$ is the aggregate amount invested in bank equity globally and ω is the initial global endowment of investor wealth.

Investors supply equity competitively. Therefore, function (1) constitutes the bank equity inverse supply curve. Most of our analysis focuses on the case where $\kappa > 0$ and $N + N' > \omega$. However, having the option to set $\kappa = 0$ or $\kappa \to \infty$ allows us to study the extreme cases where the supply of bank equity is perfectly elastic or perfectly inelastic. Comparative statics over κ and ω allow us to study how incentives change under differing economic conditions.

Our baseline assumption is that excess cost of equity, z, is private and is not internalised by regulators. Whether bank capital is socially costly is a subject of debate in the banking literature (Admati et al. (2013)). In our context, assuming it is not helps with tractability but the assumption has no major role beyond that.

Households The representative household is endowed with one unit of labour, which it supplies inelastically (and, for simplicity, without disutility) at date 1. It also has a large endowment of goods at date 0, which it initially allocates between insured bank deposits and the storage technology. We assume that this endowment is sufficiently large that the storage technology is always used in equilibrium. This pins down a households' opportunity cost of funds of unity.

Capital requirements: the reciprocity regime Current capital standards specify a common, time-invariant, minimum capital requirement (made up of several components) that all regulators adhere to. In addition, there is a time varying requirement that varies across countries, known as the countercyclical capital buffer. As we explained in the introduction, the principle of reciprocity applies to this time varying buffer. Since the time-invariant requirement is common across countries and the marginal instrument is reciprocated, the whole regime can be seen as reciprocal.[8] We embed this principle of reciprocity in bank capital regulation: in our model, capital requirements are set by the regulator of the country where the lending takes place.

Consider a given bank i, with equity capital n_i, and denote x_i and x'_i the quantity it lends in Home and Foreign respectively. Irrespective of its country of incor-

[8] This abstracts from some other areas where national regulators have discretion over capital requirements; we discuss these in Section 6.

poration, this bank faces a capital requirement that takes the form:

$$n_i \geq \gamma x_i + \gamma' x_i', \tag{2}$$

where $\gamma \in (0,1)$ and $\gamma' \in (0,1)$ are parameters set by the Home and Foreign regulators, respectively. In our model, there is only one type of regulatory capital for banks: equity. To avoid confusion with physical capital, we henceforth refer to it as bank *equity capital*.

In reality banks are under the regulatory jurisdiction of the country where they are incorporated, and banks have three ways to lend across borders: directly, through branches, or through subsidiaries incorporated in the country of the borrower. Direct lending and lending made through branches fall under the jurisdiction of the country where the bank is incorporated and, *de jure*, is not subject to the capital requirement imposed in the jurisdiction where the lending takes place. So, in principle, banks from different countries may face different capital requirements when lending to the same firm. However, reciprocity levels the playing field. Concretely, any capital requirement set by the Home regulator is also imposed, by the Foreign regulator, on Home lending *by banks that fall under the Foreign regulator's jurisdiction* (and vice versa). So, *de facto*, branches, subsidiaries, and direct cross-border loans all face the same capital requirement set by the country where the lending takes place. This is what we are capturing in Equation (2).

In Appendix A, we discuss in more detail how our assumptions regarding the capital requirement can be mapped into real world regulation.

Equilibrium In an equilibrium: given capital requirements γ and γ', banks and firms maximise expected pure profits (i.e., revenue minus the total cost of inputs); households and investors maximise utility (i.e. date-1 consumption less any disutility of labour in date 0); and markets clear.

Preliminaries The problems of the firms, the households, and the investors are trivial. Price taking behaviour implies that, in equilibrium:

- Deposits promise a zero net rate of return.
- The wage is given by: $A(1-\alpha)K^{\alpha}$, where K is aggregate capital. Given labour supply is normalised to 1, this corresponds to the aggregate wage bill.
- The loan gross interest rate is $A\alpha X^{\alpha-1}$, where X is aggregate lending.[9]
- Investors break even in expectation. So, in equilibrium, M is such that the expected return on bank equity equals its marginal cost, i.e., the unit disutility of generating additonal wealth $(1+z)$.

Market clearing requires:

- $K = X$

The banks' problem is more involved and is the focus of the next section. However, parameter restrictions $\gamma, \gamma' < 1$ ensure that banks will never be 100% safe. This allows us to focus attention on equilibria where capital requirements have interesting effects.

3 Positive analysis: equity capital flows for given capital requirements

In this Section, we focus on the equilibrium behaviour of banks for a given pair of capital requirements. We treat γ and γ' as parameters, and study how a small change in γ affects the equilibrium allocation. We endogenise capital requirements in Section 4.

3.1 The banks' problem and the market equilibrium

Lemma 1. *(i) Banks default with strictly positive probability in equilibrium; (ii) capital requirements are binding; and (iii) each individual bank perfectly specialises as either a lender in Home or Foreign.*

[9]For simplicity, we consider an interest rate contingent on the realisation of TFP. Since firm defaults are costless, the realised repayment is exactly identical to what it would be in an equilibrium under a standard debt contract with face value $A^{H}\alpha X^{\alpha-1}$ per unit of debt.

Proof. All proofs are in Appendix B. □

Government guarantees generate an implicit subsidy for banks, which is maximised when the bank operates with maximum leverage. This is a well known result. In practise, capital requirements are not, strictly speaking, binding, as banks hold voluntary buffers to forestall violations in the event of small shocks. If these buffers are stationary, banks revert to target buffers after shocks and ultimately meet a change in requirement with an equivalent change in the capital ratio. Then, capital requirements are *essentially* binding, which is sufficent as a premise for our analysis.[10] Additionally, guarantees induce banks, ceteris paribus, to minimise diversification. To maximise the option value given by limited liability, banks prefer to operate with separate balance sheets in each country (i.e. subsidiaries) rather than branches (or engage in direct cross-border lending). Moreover, the market for bank equity capital is global, deposits promise a zero return in both countries, capital requirements follow a host country rule, and there are no corporate taxes. Hence, banks are indifferent regarding their country of incorporation and it plays no role for their behaviour. Where banks are incorporated (and so where deposits are insured) is, however, relevant for welfare and can affect the policy game. We return to this issue in Section 4.

Accordingly, one interpretation of our setup is that banks set up holding companies that operate across borders through separate subsidiaries in each country. Alternatively, we can think of individual banks as stand-alone specialised lenders in each country. The former is closer to how banks operate in reality. However, for ease of exposition, and to save on notation, we will present our analysis using the interpretation of banks as stand-alone specialised lenders in each country.

The key object: Equity capital *allocated* to lending The key object in our analysis will be N, the aggregate quantity of bank equity capital *allocated* to banks specialising in lending at Home. A change in γ causes a reallocation of equity capital between Home (N) and Foreign (N'): effectively a bank equity capital

[10] There is substantial empirical evidence that capital regulation influences bank decisions both at the bank-level (Gropp et al. (2019)) and within bank portfolios (Behn et al. (2016)). See Bahaj et al. (2016) for direct evidence supporting the essentially binding requirement hypothesis.

flow. It turns out that the direction of this capital flow will be key in governing the strategic interactions between regulators. We will come on to this later. In this section we first look at the economic mechanisms that pin down the direction of the capital flow in the market equilibrium.

The bank's problem We consider a representative bank specialising in lending to Home firms. We denote this bank's equity n. Since capital requirements bind, the bank's lending is $x = \frac{n}{\gamma}$, and the proceeds from lending are given by $\frac{n}{\gamma}\left(A\alpha X^{\alpha-1}\right)$ where the bank takes X as given. To lend an amount $\frac{n}{\gamma}$, the bank raises a total of $(1-\gamma)\frac{n}{\gamma}$ of deposits on which it pays zero interest. Aggregating across banks we have $X = \frac{N}{\gamma}$.

Define A^0 as the realisation of A such that the bank just has sufficient proceeds from its loans to make depositors whole. That is:

$$A^0(N,\gamma) = \frac{(1-\gamma)}{\alpha\left(\frac{N}{\gamma}\right)^{\alpha-1}}.$$

The revenue available for shareholder payouts is, in expectation:

$$\frac{n}{\gamma}\int_{A^0(N,\gamma)}^{A^H}\left(\alpha A\left(\frac{N}{\gamma}\right)^{\alpha-1} - (1-\gamma)\right)g(A)dA.$$

Shareholders receive zero in the event of default. $A\alpha\left(\frac{N}{\gamma}\right)^{\alpha-1}$ is the unit proceeds from lending and $(1-\gamma)$ is the unit the cost of deposits. Shareholders have collectively invested equity capital n, hence, their expected return on equity is:

$$R(N,\gamma) \equiv \frac{\int_{A^0(N,\gamma)}^{A^H}\left(\alpha A\left(\frac{N}{\gamma}\right)^{\alpha-1} - (1-\gamma)\right)g(A)dA}{\gamma}. \tag{3}$$

The shareholders are the investors and since their required return is $1+z$, the bank's optimisation problem can be written as:

$$\max_{n\geq 0} nR(N,\gamma) - n(1+z). \tag{4}$$

Market equilibrium Let N^* denote an equilibrium level of Home capital. We have the following result:

Proposition 1. *For all $\gamma, \gamma' \in (0, 1)$, there exists a unique pair $\{N^*, N'^*\}$ such that returns on equity in both countries are equal to the investors' required return. This pair is implicitly defined by:*

$$R(N^*, \gamma) = R'(N'^*, \gamma') = (1 + z(N^*, N'^*)), \tag{5}$$

For intuition, note that, for a given γ, an increase in N implies more lending and therefore more aggregate physical capital. From diminishing returns, it directly follows that both $R(N, \gamma)$ is decreasing in N (and $R'(N', \gamma')$ in N'). This leads to the result since $z(N, N')$ is weakly increasing, and strictly from $N + N' = \omega$.[11]

In our interpretation that banks are stand-alone entities that specialise in lending in either country, international capital mobility means that they can raise equity capital from investors in either countries. In the alternative bank holding company interpretation, one can think of the holding company raising equity (mainly or even exclusively) where it is incorporated, and then allocating it to its subsidiaries via its internal capital markets. Either way, (5) is the relevant indifference condition. That deposits are mobile internationally plays no role in our analysis. All results would, for instance, go through if deposits could only be raised in the country where a bank is incorporated.

3.2 International spillovers

We now turn to how capital requirements alter banks' allocation of capital to either Home or Foreign.

Starting from equilibrium, we now consider the effect of marginal changes in the Home capital requirement γ. The no-arbitrage condition in Proposition 1 implicitly defines a function $N^*(\gamma, \gamma')$. From now on, functions denoted with a * are evaluated at the market equilibrium arising from γ, γ' and hence have the two capital requirements as their arguments. For compactness, we sometimes drop

[11] While the pair $\{N^*, N'^*\}$ is unique, the proportion of bank equity capital sourced from investors in Home or Foreign is indeterminate as investors are indifferent in equilibrium.

function dependencies below. We represent partial derivatives with a subscript, and we write total derivatives in full.

We first characterise how N^* adjusts following a change in γ.

Lemma 2. *For all* $\gamma, \gamma' \in (0,1)$,

$$\frac{dN^*}{d\gamma} = R_\gamma(N^*, \gamma)\xi^*(\gamma, \gamma'), \tag{6}$$

where $\xi^*(\gamma,\gamma') \equiv \left(\frac{\kappa M - R'_{N'}}{R_N R'_{N'} - \kappa M \left(R'_{N'} + R_N\right)} \right)\Bigg|_{N^*(\gamma,\gamma'), N'^*(\gamma,\gamma')} > 0.$
Therefore it is the case that

$$\frac{dN^*}{d\gamma} \gtreqless 0 \Leftrightarrow R_\gamma(N^*, \gamma) \gtreqless 0.$$

Equation (6) states that the response of N^* to γ depends on κ and on R_N and $R'_{N'}$, the sensitivity of returns to the equity capital invested in the respective countries. We will elaborate below on the role of these objects.

The second part of the lemma establishes that $\frac{dN^*}{d\gamma}$ and $R_\gamma(N^*, \gamma)$ have the same sign. The intuition is simple: a change in capital requirements will trigger an increase (decrease) in bank equity capital in Home if, and only if, this change increases (decreases), ceteris paribus, the Home bank return on equity.

By construction, new capital can only be raised by Home banks from two different sources: (i) investors can generate additional wealth so as to increase the global stock of bank equity capital; (ii) there can be a flow of capital from Foreign banks to Home banks. In general, we get a combination of the two.

The function $R'(N', \gamma')$ is the inverse demand curve for N' and, hence, can be thought of as an inverse supply curve for N arising from capitals flows. Likewise, $z(N, N')$ is the inverse supply curve from investors generating additional wealth. These two curves have respective slopes $R'_{N'}$ and κM. With this in mind, the proposition that expresses the capital flow naturally follows:

Proposition 2. *For all* $\gamma, \gamma' \in (0,1)$,

$$\frac{dN^{*\prime}}{d\gamma} = -\underbrace{\left(\frac{\kappa M^*}{\kappa M^* - R'_{N'}(N'^*, \gamma^*)}\right)}_{\equiv \boldsymbol{SP}^*(\gamma,\gamma')\in[0,1]} \frac{dN^*}{d\gamma}. \tag{7}$$

That $\frac{dN^{*\prime}}{d\gamma}$ has the opposite sign to $\frac{dN^*}{d\gamma}$ indicates that any change in capital in Home is met by a change of opposite sign in Foreign. The term which we denote SP* (for spillover), determines the relative proportion of these changes. Intuitively, SP* is pinned down by the relative slopes of the implicit supply curves we mentioned above.

Now, there are two special cases. First, if $\kappa = 0$, a change in capital requirements at Home does not affect the equilibrium cost of bank capital: supply adjusts entirely through raising fresh equity capital, and there is no spillover.[12] Second, $\kappa \to \infty$ implies a spillover of 100%. This corresponds to the extreme case where investors' wealth is fixed. In this case, unless their endowment is sufficiently large, it is obvious that any change in equity capital at Home should be met by an exactly opposite change in Foreign.

Remark. Strictly speaking, non-zero spillovers require that $\kappa M^* > 0$, and not necessarily that $z^* > 0$: What is needed to generate a spillover is not that capital is costly per se but that the equilibrium cost of capital is affected by a change in capital requirements. In a modified version of the model where $z^* > 0$ (say, due to a tax advantage of debt) but $\kappa M^* = 0$, there would be no spillover as a change in the capital requirement at Home would have no effect on the equilibrium cost of capital in Foreign.

3.3 The direction of international bank equity flows

Lemma 2 and Proposition 2 show that the direction of equity capital flows hinges on the sign of $R_\gamma(N^*, \gamma)$. We now discuss the economics of this sign and establish that it generally implies the following result: for any γ' there is a threshold value for γ that pins down the direction of the capital flow.

[12] Similarly, if $M^* = 0$, there is initially excess supply of bank capital at $z = 0$. So Home capital will adjust without affecting Foreign. In both cases, we have $\xi^*(\gamma, \gamma') = -1/R_N(N^*, \gamma)$, and $\frac{dN^*}{d\gamma} = -R_\gamma(N^*, \gamma)/R_N(N^*, \gamma)$.

3.3.1 An increase in γ can raise return on equity ($R_\gamma(N^*, \gamma) > 0$)

Given that R embeds a subsidy from a government guarantee, which is decreasing in the capital requirement, it is perhaps natural to assume that $R_\gamma(N^*, \gamma)$ is negative and higher capital requirements always generate capital outflows. However, there is another force via which increases in γ can raise bank return on equity. Raising γ decreases aggregate lending in Home, which can increase total revenues in the banking sector, much as if there had been a decrease in competition. Crucially, increased revenues translate to a higher return on equity. We first formalise this intuition with a simplified example and then come on to how things play out in our model.

A simplified problem Consider our environment, but without uncertainty (set $A = 1$) and consider a monopolist bank, with predetermined capital N, that maximises pure profits. The monopolist's optimal level of lending, $\mathring{X}$, is given by:

$$\mathring{X} \equiv \arg\max_X \alpha X^\alpha - X - zN. \tag{8}$$

The objective is hump-shaped in X, which reflects monopoly rents: starting from low levels, it increases up to $\mathring{X}$ where it peaks and then decreases. Pure profits are hump-shaped in X, and so is the return on equity (for given N):

$$\frac{1}{N}\left(\alpha X^\alpha - (X - N)\right),$$

and they are both maximised at the same level of lending, $\mathring{X}$. Now, substituting $N = \gamma X$, the return on equity can be written:

$$R(N, \gamma) = N^{\alpha-1}\alpha\left(\frac{1}{\gamma}\right)^\alpha - \frac{1}{\gamma} + 1, \tag{9}$$

which is also hump-shaped in γ, reflecting that X is monotonic in γ, for a given N. So, R_γ is positive when $\gamma < N/\mathring{X}$ and turns negative past that threshold. The intuition being that unless the level of lending is already lower than what a monopolist would choose (taking N as given), an increase in γ contracts credit (since $X = N/\gamma$).

Adding back uncertainty to Equation (9), we return to the definition of the return on equity in our model (Equation (3)):

$$R(N,\gamma) = \int_{A^0(N,\gamma)}^{A^H} \left(AN^{\alpha-1}\alpha \left(\frac{1}{\gamma}\right)^{\alpha} - \frac{1}{\gamma} + 1 \right) g(A)dA. \tag{10}$$

The risk of bank failure is important for our analysis as it is a source of moral hazard (bank return on equity embeds the subsidy from government guarantees) and motivates the use of capital requirements as policy tools . The presence of uncertainty does not affect the fact that restraining aggregate quantities can increase total revenue in the banking sector. However, the introduction of uncertainty creates a technical challenge linked to the truncation in Equation (10). To deal with this, we introduce the following condition.

Condition 1. (Regularity - single crossing) For all $\gamma, \gamma' \in (0,1)$, $R_{\gamma\gamma}(N,\gamma) < 0$ when $R_\gamma(N^*,\gamma) = 0$.

The fundamental drivers of a hump-shaped return on equity in our simple example is that: i) the production function is concave, which generates a downward sloping and convex loan demand curve; ii) capital requirements bind. The regularity condition allows us to streamline the analysis by ignoring knife-edge cases where $R_{\gamma\gamma}$ could be locally positive.[13]

[13]Due to the truncation in $R(N,\gamma)$, its second derivative with respect to γ may be locally badly behaved. This can happen if there is a local bump in the probability density function $g(A)$ in the direct vicinity of A_0. Then, a small change in γ can (relatively speaking) dramatically affect the probability of default and generate effects that *locally* dominate the more general forces that make the function hump-shaped in γ. In that case, the condition $R_{\gamma\gamma} < 0$ is not necessarily satisfied when $R_\gamma = 0$. Such issue is, e.g., ruled out if the equilibrium elasticity of the bank probability of survival with respect to the capital requirement is smaller than 1 (which, generally speaking, is not a very demanding condition: consider a bank with an initial probability of survival of 90%; An elasticity less than one means that, for instance, an increase in capital requirement from $\gamma = 10\%$ to $\gamma = 11\%$ does not raise the probability of survival above 99%). Accordingly, a simple way to ensure that the Condition 1 is always satisfied is to restrict A to a binary distribution over $\{0, A^H\}$, which implies a zero elasticity. This is what we do to derive closed form results in Section 5.

3.3.2 There is a threshold for γ that pins down the sign of the capital flows

The simplified example treats N as exogenous. However, with N endogenous, $R^*(\gamma,\gamma') \equiv R(N^*(\gamma,\gamma'),\gamma)$ is still generally hump shaped in γ, which allows us to link the sign of $\frac{dN^*}{d\gamma}$ to the level of the capital requirement.

Theorem 1. *Assume Regularity Condition 1 holds in the considered equilibrium. Then,* $\forall\, \gamma' \in (0,1)$*, there exists a* $\widehat{\gamma}\,(\gamma') > 0$ *such that,* $\forall \gamma \in (0,1)$

$$\begin{cases} \frac{dN^*}{d\gamma} > 0 & ; \gamma < \widehat{\gamma}\,(\gamma') \\ \frac{dN^*}{d\gamma} = 0 & ; \gamma = \widehat{\gamma}\,(\gamma') \\ \frac{dN^*}{d\gamma} < 0 & ; \gamma > \widehat{\gamma}\,(\gamma') \end{cases}$$

To understand how endogenising N alters the relationship between γ and the equilibrium return on equity, first imagine that $R_\gamma(N^*,\gamma) > 0$. This means an increase in γ increases N^*. This inflow increases lending and reduces returns. However, the expansion never fully offsets the partial effect represented by $R_\gamma(N^*,\gamma)$ (otherwise we would have an outflow, contradicting Lemma 2). This means $R_\gamma(N^*,\gamma)$ and $\frac{dR^*}{d\gamma}$ share the same sign. However, total derivative is smaller in absolute terms than the partial due to the offset from the capital flow. Formally, using Equation (6), we have

$$\begin{aligned} \frac{dR^*(\gamma,\gamma')}{d\gamma} &= R_\gamma(N^*,\gamma) + \frac{dN^*}{d\gamma} R_N(N^*,\gamma) \\ &= R_\gamma(N^*,\gamma) \underbrace{\left(1 + \xi^*(\gamma,\gamma') R_N(N^*,\gamma)\right)}_{\in[0,1]}, \end{aligned} \tag{11}$$

where $(1 + \xi^* R_N(N^*,\gamma)) \in [0,1]$ captures the offsetting effect of the equity capital flows (The proof of Theorem *1* establishes the bounds).

Regularity condition 1 ensures that $R^*(\gamma,\gamma')$ is a well-behaved hump shape in γ.[14] This means $\hat{\gamma}(\gamma')$ is the capital requirement that maximises $R^*(\gamma,\gamma')$ given

[14]To see this, note that deriving Equation (11) a second time with respect to γ, we obtain $R_{\gamma\gamma}(N^*,\gamma)(1 - \xi^* R_N(N^*,\gamma))$ at $\frac{dR^*}{d\gamma} = 0$. Hence the second order condition for a maximum is satisfied given regularity Condition 1.

γ'; that is, it is the requirement at which $\frac{dR^*}{d\gamma} = 0$. This can only be true when $R_\gamma(N^*, \gamma)$ and, hence, $\frac{dN^*}{d\gamma}$ are equal to zero.[15]

In equilibrium banks cannot benefit from an increase in γ. Note that $\frac{dR^*}{d\gamma}$, $\frac{dN^*}{d\gamma}$ and $R_\gamma(N^*, \gamma)$ are all zero at the same value, $\widehat{\gamma}(\gamma')$. An implication is that $\widehat{\gamma}(\gamma')$ is the value of the capital requirement that maximises not only R^*, but also investor revenues, R^*N^*, and the shareholder payout net of the capital invested $(R^* - 1)N^*$. However, what $\widehat{\gamma}(\gamma')$ does not maximise is bank pure-profits $(R^* - (1 + z^*))\, N^*$, simply because the latter includes the cost of bank equity capital. In our model, perfect competition implies that pure profits are always zero in equilibrium, so the cost increase just offsets the increase in revenue.

Although an increase in γ only makes the banks of our model *weakly* worse off, it would make them *strictly* worse off if they had market power (which is the case in reality). The reason is that the increase in cost (due to a higher γ) would always more than offset the possible increase in revenue. We show this in Appendix C.1.

4 A framework for welfare analysis

We now treat γ and γ' as the choice variables of national regulators who take as given that, in equilibrium: (i) capital requirement are binding;[16] and (ii) market forces will equate bank return on equity across countries (per Proposition 1). To maintain tractability, we assume ex-ante symmetry for the remainder of the paper (i.e., the environments in Home and Foreign are initially identical, and global investor endowment (ω) is split equally across the two countries), and we will impose regularity conditions on objective functions when needed. As a tie-breaking rule, we now assume banks have a vanishingly slight preference to incorporate

[15]Note that the theorem does not restrict $\widehat{\gamma}$ to be smaller than 1. If $\widehat{\gamma}(\gamma') > 1$, then it is simply the case that $\frac{dN^*}{d\gamma} > 0$ for all admissible γ. Hence, there always exists values for γ that are low enough (i.e., in between 0 and $\widehat{\gamma}$) for a marginal increase in γ to raise the Home bank's return on equity and, therefore, trigger capital inflows to Home.

[16]Strictly speaking, the capital requirements may be only *weakly* binding. In cases where the capital structure is undetermined we break the tie by assuming it is pinned down by the requirement.

in the country where they specialise (i.e., where they do their lending); so it is the tax payer of this country who insures their deposits.

4.1 Setting up the framework

We first derive results for a general welfare function subject to regularity conditions. This allows us to pinpoint the role of a novel externality that operates through capital flows.

Definition 1. Given N and γ, the value of the Home regulator's objective is $\pi(N, \gamma)$. For any pair of capital requirements $\{\gamma, \gamma'\}$, the equilibrium value of the objective is given by $\pi^*(\gamma, \gamma') \equiv \pi(N^*(\gamma, \gamma'), \gamma)$. The objective in Foreign $\pi'(N', \gamma')$ is defined in the same way.

While this functional form is general, our chosen specification implies that welfare in a country is affected by policy choices abroad only through flows of bank equity (γ' only enters π^* through the dependencies in N^*). This choice is deliberate as these flows are our focus. In Section 6, we consider other channels via which capital regulation spills over across borders.

We consider both competition and collaboration between regulators. When they compete, we consider a symmetric Nash equilibrium of the game in which they maximise $\pi^*(\gamma, \gamma')$ and $\pi'^*(\gamma', \gamma)$ separately, setting their capital requirement taking the other's as given. When they collaborate, the regulators jointly set $\gamma = \gamma' = \gamma^{\text{col}}$ such that

$$\gamma^{\text{col}} \equiv \arg\max_{\gamma=\gamma'} \Pi^*(\gamma, \gamma'), \tag{12}$$

where $\Pi^*(\gamma, \gamma') \equiv \pi(N^*(\gamma, \gamma'), \gamma) + \pi'(N'^*(\gamma', \gamma), \gamma')$.

The following conditions ensures that both problems (the competitive and the collaborative ones) are convex maximisation problems with interior solutions, and that the Nash equilibrium of the competitive regulator game is unique.

Condition 2. (Regularity: existence and uniqueness). For all $\gamma, \gamma' \in [0, 1]$: $\pi^*_\gamma(0, \gamma') > 0$, $\pi^*_\gamma(1, \gamma') < 0$, $\pi^*_{\gamma\gamma}(\gamma, \gamma') < 0$, $\pi^*_{\gamma\gamma'}(\gamma, \gamma') < 0$; and similarly for $\Pi^*(\gamma, \gamma')$.

Henceforth, functions with superscripts $^{\text{nash}}$ are evaluated at the Nash equilibrium of the competitive regulator game.[17] For example, $N^{\text{nash}} \equiv N^*\left(\gamma^{\text{nash}}, \gamma^{\text{nash}}\right)$. Likewise, functions with superscripts $^{\text{col}}$ are evaluated at the market equilibrium where both capital requirements are set at γ^{col}.

4.2 The nature of the inefficiency and incentives to deviate

The first order condition (with respect to γ) for the collaborative problem (12) is

$$\Pi^*_\gamma(\gamma, \gamma') = \pi^*_\gamma(\gamma, \gamma') + \pi'^*_\gamma(\gamma', \gamma) = 0.$$

The term $\pi^*_\gamma(\gamma, \gamma')$ captures the marginal benefit for Home of an increase in γ. The other term, $\pi'^*_\gamma(\gamma', \gamma)$, captures the welfare effect on Foreign. The latter term is internalised by a collaborative regulator but it is ignored by the competitive regulator when setting γ. Hence, $\pi'^*_\gamma(\gamma', \gamma)$ captures the externality on foreign from home capital regulation.

Proposition 3. *Unless $\pi'^{nash}_\gamma = 0$, the Nash equilibrium is inefficient. That is: $\Pi^{nash} < \Pi^{col}$. The direction of the mutually beneficial deviation is pinned down by the sign of the externality. In particular, $\pi'^{nash}_\gamma \gtreqless 0 \Leftrightarrow \pi'^{col}_\gamma \gtreqless 0 \Leftrightarrow \gamma^{nash} \lesseqgtr \gamma^{col}$.*

The inefficiency result is straightforward and the intuition for the direction of the deviation goes as follows. Take the case in which $\pi'^{\text{nash}}_\gamma > 0$. Then, at $\gamma = \gamma' = \gamma^{\text{nash}}$, a small increase in γ does not affect Home's objective, and strictly benefits Foreign. By symmetry, an increase in γ' benefits Home without affecting Foreign, and this leads to $\gamma^{\text{nash}} < \gamma^{\text{col}}$. Vice versa, $\gamma^{\text{nash}} > \gamma^{\text{col}}$ if $\pi'^{\text{nash}}_\gamma < 0$.

Capital flows and the nature of the inefficiency The externality can be expressed as:

$$\pi'^*_\gamma(\gamma', \gamma) = \frac{dN'^*}{d\gamma} \pi'_{N'}(N'^*, \gamma'). \tag{13}$$

[17]Formally, the unique Nash equilibrium is defined as the fixed point $\gamma^{\text{nash}} = \arg\max_\gamma \pi\left(N^*(\gamma, \gamma^{\text{nash}}), \gamma\right)$.

Imagine that $\pi'_{N'}(N'^{*},\gamma') > 0$. This means that bank capital is socially valuable to Foreign in equilibrium. As we have seen in Section 3, $\frac{dN'^{*}}{d\gamma}$ can have either sign. If it is negative, an increase in γ imposes a negative externality on Foreign, because it siphons off valuable bank capital from it. Vice versa, the externality is positive if an increase in γ implies an inflow of bank capital to Foreign.

The framework we have developed in this section allows us to highlight the welfare implications of bank capital flows associated with changes in capital requirements and to study the associated strategic interactions. To go further, however, we need to impose structure on the objective functions (beyond the regularity conditions stated above).

Since capital requirements are binding, an increase in N, holding γ fixed, implies an increase in X. In models where there is for instance a trade off between economic activity and financial stability, this can be either a good or a bad thing. Hence, it would not be sensible to directly restrict the sign of $\pi_N(N,\gamma)$.

This is why we introduce a change of variable and consider the class of objective functions in which *holding the level of lending X fixed*, an increase in bank capital (or, equivalently, a decline in bank leverage) improves welfare. Formally, denoting functions of (X,N) with a tilde, we have: $\widetilde{\pi}\left(X,N\right) \equiv \pi\left(N,\gamma = N/X\right)$;[18] and we impose:

$$\widetilde{\pi}_N(X,N) > 0, \forall N < X.$$

As we discuss below, such a restriction is economically meaningful and implies that, for any γ', the regulators would never choose a capital requirement at which $\pi_N(N^{*},\gamma) < 0$.[19] As a result:

[18] Taking further dependencies on γ and γ', we have:

$$\widetilde{\pi}\left(X^{*}(\gamma,\gamma'),N^{*}(\gamma,\gamma')\right) \equiv \pi\left(N^{*}(\gamma,\gamma'),\frac{N^{*}(\gamma,\gamma')}{X^{*}(\gamma,\gamma')}\right) = \pi\left(N^{*}(\gamma,\gamma'),\gamma\right).$$

[19] From the change of variable, we have: $\pi_N = \widetilde{\pi}_N + \frac{\widetilde{\pi}_X}{\gamma}$. If $\widetilde{\pi}^{*}_N > 0$, then for $\pi^{*}_N < 0$, it must be the case that $\pi^{*}_X < 0$. But then, increasing γ would unambiguously improve the objective. This is because increasing γ: i) necessarily decreases X^{*}, which would be beneficial since π^{*}_X would be negative; and ii) increases N^{*}, keeping X^{*} constant (since capital requirements are binding), which is also beneficial. Hence, irrespective of γ', it is never optimal to pick γ so low that $\pi^{*}_N < 0$. To fix ideas, one can for instance think of a case where the regulator would set capital requirements so low that banks would finance negative NPV lending. In that case, raising γ would both improve financial stability (by assumption) and economic surplus since it would

Proposition 4. *If* $\widetilde{\pi}_N(X, N) > 0$, $\forall N < X$, *then* $\pi_N(N^{nash}, \gamma^{nash}), \pi_N(N^{col}, \gamma^{col}) > 0$.

This proposition simply implies that, both at the Nash and collaborative outcomes, a country is hurt if a policy change abroad siphons off capital from it.

This intuition is valid for all objective functions where $\widetilde{\pi}_N(X, N) > 0$. In our model, the level of economic activity (both output and economic surplus) is pinned down by the level of lending, X. So, an objective function in (X, N) suggests that regulators care not only about the level of economic activity, but also about how lending is funded. A natural interpretation of $\widetilde{\pi}_N(X, N) > 0$ is for instance that in which a more leveraged banking system could generate financial instability, which is costly for welfare. Higher N for a given X means lower leverage, and therefore improves financial stability. This is the logic that motivates the concrete objective function we use in our policy game in the next section.

We discuss other classes of objective functions, including some used in previous literature, and also highlight how our capital flow externality relates and differs from previously highlighted mechanisms in Section 6. However, the following remark is already in order: With objective functions where $\widetilde{\pi}_N(X, N) = 0$, bank capital can only affect welfare through its impact on the level of lending. But if capital requirements are binding in equilibrium (like in our model), a regulator who wants to achieve a specific level of X (among the feasible set)[20] will choose $\gamma = N^*(\gamma, \gamma')/X$ to do so. In that case, bank capital inflows or outflows following a policy change abroad do not affect welfare, as the domestic regulator can always just offset their effect. In that sense, there is no trade off between economic activity and financial stability.

Likewise, if we would endow the regulators with as many instruments as policy goals (two in our case), then the trade off could vanish (Tinbergen (1952)). For instance, if a regulator could subsidise the allocation of bank capital to their country, it could both reduce leverage (via the capital requirement) and avoid the associated contraction in economic activity (via the subsidy). Provided that κ is finite, and the associated taxes are not distortionary, this policy mix could lead

reduce negative NPV investment.

[20]Recall that regulators take the market equilibrium as given. So, they cannot for instance implement extremely low or extremely high levels of X^* and X'^*. However, given regularity Condition 2, the feasibility constraint is not binding at either the Nash or the collaborative outcomes.

to $\pi_N^{\text{nash}} = 0$. Then, there would be no gains from international collaboration. This assumption that the subsidy can be implemented costlessly is however rather extreme, and unlikely to be satisfied in practice.[21] More generally, this feature of our model relates to Korinek (2016), which shows that violations of the Tinbergen principle can create scope for collaboration.[22]

5 The policy game

Consider the following example objective function that captures a trade off between economic activity and financial stability (which directly takes into account that $X = K$ in equilibrium):

$$\widetilde{\pi}(X, N) = \underbrace{(X^\alpha - X)}_{\equiv \widetilde{\text{NDP}}(X)} - \underbrace{\lambda \int_0^{\widetilde{A}^0} \left(\underbrace{X - N}_{\text{tot. deposits}} - \underbrace{\alpha A X^\alpha}_{\text{lending proceeds}} \right) f(A) dA}_{\equiv \widetilde{L}(X,N)}, \tag{14}$$

where λ is a positive parameter.

The first term $(X^\alpha - X)$ captures expected Net Domestic Product (NDP) in Home (recall the normalisation $\mathbb{E}[A] = 1$).[23] Maximising this term alone would yield a natural result for a frictionless version of our economy: the marginal product of capital would equate the return to storage (which could be interpreted as the Modigliani-Miller outcome).

From this, we deduct a loss function, denoted $\widetilde{L}(X, N)$, that is proportional to the expected shortfall in bank assets relative to its liabilities. So, $\widetilde{L}(X, N)$ can be

[21] Such a subsidy is costless in our model with deep-pocketed households and inelastic labour supply. In general, however, the required subsidy and associated taxes may generate distortions or be infeasible due to limits on fiscal capacity or political economy considerations.

[22] Korinek (2016) identifies three conditions under which there are no gains from international policy cooperation: i) Regulators are price takers; ii) the Tinbergen Principle is satisfied (for external instruments); and iii) International Markets are frictionless. The third condition is satisfied in our model. The second is not, as we have discussed. Neither is the first, but the existence of gains from collaboration does not hinge on this violation. In fact, gains from cooperation increase when regulators are price takers (see the next section).

[23] Gross output by firms in Home is AX^α, production involves investing X in capital goods which fully depreciate, hence X is deducted to obtain net output.

interpreted as capturing deadweight losses that arise from bank defaults (as, e.g., in Acharya et al. (2017) and Malherbe (2020)).[24] Such deadweight losses could for instance arise through bankruptcy costs (Townsend (1979)), distortionary taxation (Acharya et al. (2011)) or financial contagion (Capponi et al. (2022)).

Remark 1. By definition, NDP is a measure of domestic production rather than income or consumption (which, are more standard starting points for welfare functions). We use it in $\widetilde{\pi}(X, N)$ because this approach yields insights (some based on closed form solutions) that nicely complement the more general approach of Section 4. In equilibrium, investors are indifferent between investing in any bank equity, and banks are indifferent with respect to country of incorporation, which generates indeterminacy. It is worth noting that if we resolve indeterminacy with a home-bias tie-breaking rule, $\widetilde{\pi}(X, N)$ will equal domestic income in a symmetric equilibrium (either Nash or collaborative).[25] Objective (14) also relies on our baseline assumption that bank-equity capital is not socially costly. This assumption is great for tractability, but our main insights do not hinge on it.[26]

With objective (14), holding X constant, an increase in N reduces both the likelihood of default (it reduces $\widetilde{A}^0(X, N)$) and the extent of default when it happens. Therefore, specifying deadweight losses in this manner satisfies the condition $\widetilde{\pi}_N(X, N) > 0$, $\forall N < X$.[27] Hence, per Proposition 4, the social shadow value of bank equity capital is positive at the collaborative optimum. The externality now has a natural, more concrete interpretation: a policy change that siphons off cap-

[24]Recall that home households are responsible for insuring deposits used to fund home lending. This means the deposit insurance payment itself is a pure transfer and is already embedded within NDP. With $\lambda > 0$, $\widetilde{L}(X, N)$ captures any excess costs associated with bank failures.

[25]Specifically, this is the case if domestic investors only invest in domestic bank equity and if banks incorporate in the country where they do their lending. Given that lending is specialised anyway, the latter is a mild assumption as this just rules out the case where a bank would incorporate in a country where it does not lend at all. Given symmetry, that domestic investors exclusively invest domestically in equilibrium only requires a vanishingly small home bias. More drastic assumptions are required for this to hold off-equilibrium. More generally, a welfare function directly based on domestic income requires arbitrary assumptions on how cross-border indeterminacies play out. Using $\widetilde{\pi}(X, N)$ allows for a more transparent analysis.

[26]We analyse the case where capital is socially costly in Section 6.1 (briefly) and in more detail in Appendix C.2.

[27]Note that $\widetilde{\pi}_N > 0$ would be satisfied for any arbitrary deadweight loss function $\widetilde{L}(X, N)$ where $\widetilde{L}_N < 0$. In particular, deadweight losses could occur for other reasons than bank failure.

ital from abroad imposes a negative externality on other countries *because* bank capital alleviates deadweight losses from bank default (and imposes a positive externality if the change generates flows to the other country).

From Theorem 1, we know that $\frac{dN^*}{d\gamma} \Leftrightarrow \gamma \gtreqless \hat{\gamma}(\gamma')$, so that the sign of the externality at the collaborative optimum depends on whether $\gamma^{\text{col}} \gtreqless \hat{\gamma}(\gamma^{\text{col}})$. This is a condition in terms of endogenous objects, so it does not tells us which cases can actually occur and, if so, in which circumstances. We will study an example in which we can map the outcome to the primitives of the model. This example will allow us to develop empirical predictions and policy implications.

5.1 Results in closed form

We derive closed-form results for the special case where i) $\kappa \to \infty$ (the global supply of bank equity capital is, in effect, perfectly inelastic);[28] and ii) A follows a binary distribution: $A \in \{0, \frac{1}{q}\}$ with $Pr(A = \frac{1}{q}) = q$.[29]

The closed form solution allows us to show how deadweight losses, the loan demand elasticity, and moral hazard affect the properties of the collaborative optimum. In particular, we get insights on how they affect whether the externality is positive or negative and, therefore, on whether $\gamma^{\text{nash}} \gtreqless \gamma^{\text{col}}$.

Since $A = 0$ (in which case the bank necessarily defaults) occurs with probability $1 - q$, we have:

$$\pi^*(\gamma, \gamma') = X^{*\alpha} - X^* - \underbrace{\lambda(1-q)\left(X^* - N^*\right)}_{=\widetilde{L}(N,X)}.$$

It is apparent that holding X^* fixed, π^* is increasing in N^* (NDP is unaffected, and deadweight losses decrease with N). Specifically, $\widetilde{\pi}_N(N, X) = \lambda(1-q) > 0$.

The collaborative optimum Given that total bank capital is essentially fixed at ω, it is clear that, from symmetry, $N^{\text{col}} = \omega/2$. But then, picking γ^{col} is the same as picking $X^{\text{col}} = \omega/(2\gamma^{\text{col}})$. So, the relevant first order condition for the collaborative

[28]This implies that $\xi^* \to (R'_{N'}(N'^*, \gamma') + R_N(N^*, \gamma))^{-1}$ and SP$^* \to 1$.
[29]We depart here from the smooth distribution assumption imposed elsewhere.

optimum is:

$$\underbrace{\alpha\left(X^{\text{col}}\right)^{\alpha-1}}_{\text{MPK}} = 1 + \underbrace{(1-q)\,\lambda}_{\widetilde{\pi}_N(N,X)}. \tag{15}$$

Collaborative regulators equate the marginal social benefit of lending (the marginal product of capital) to the marginal social cost (one plus the marginal increase in deadweight losses that the lending generates). From Equation (15), one can solve for γ^{col} in closed form. However, for reasons that will soon become clear, it is more convenient to keep the optimality condition above in terms of X, rather than γ.

Is $\gamma^{\text{col}} \gtreqless \gamma^{\text{nash}}$? We cannot solve for γ^{nash} in closed form. However, we can characterise the sign of the externality at γ^{col}.[30] To do so, we solve for $\hat{\gamma}(\gamma')$. Recall this is the value for γ at which $R_\gamma\left(N^*(\gamma,\gamma'),\gamma\right) = 0$. We have

$$R\left(N^*,\gamma\right) = \frac{q}{N^*}\left(\frac{1}{q}\alpha\left(\frac{N^*}{\gamma}\right)^{\alpha} - \frac{N^*}{\gamma} + N^*\right).$$

Hence, $R_\gamma(N^*,\gamma') = 0$ if and only if

$$\frac{q}{N^*}\left(\frac{-N^*}{\gamma^2}\right)\left(\frac{\alpha^2}{q}\left(\frac{N^*}{\gamma}\right)^{\alpha-1} - 1\right) = 0,$$

Or, equivalently:

$$\frac{\alpha^2}{q}\left(X^*\right)^{\alpha-1} = 1.$$

So, the value of X^* at which $R_\gamma(N^*,\gamma') = 0$ is

$$\hat{X} \equiv \frac{N^*\left(\hat{\gamma}(\gamma'),\gamma'\right)}{\hat{\gamma}(\gamma')} = \left(\frac{q}{\alpha^2}\right)^{\frac{1}{1-\alpha}}. \tag{16}$$

[30]Our assumptions ensure that regularity Condition 1 is satisfied and Condition 2 holds for $\Pi^*(\gamma,\gamma')$.

$\hat{X}$ is the same for any value of γ', including γ^{col}. Hence, we can directly compare $\hat{X}$ to X^{col}. We have

$$X^{\text{col}} \gtreqless \hat{X} \Leftrightarrow \frac{q-\alpha}{(1-q)\,\alpha} \gtreqless \lambda.$$

Even though N^* may increase with γ, this never more than offsets the direct effect on aggregate lending of higher capital requirements. Hence, we have $dX^*/d\gamma < 0$ (see the proof of Proposition 4). This implies

$$\hat{\gamma}(\gamma^{\text{col}}) \gtreqless \gamma^{\text{col}} \Leftrightarrow \frac{q-\alpha}{(1-q)\,\alpha} \gtreqless \lambda,$$

and provides closed form conditions for the sign of the externality at the collaborative optimum.

Proposition 5. *Under Objective (14), if $\kappa \to \infty$, and $A \in \left\{0, \frac{1}{q}\right\}$, with $0 < q < 1$ and $\Pr(A = \frac{1}{q}) = q$, then*

$$\lambda \gtreqless \frac{q-\alpha}{(1-q)\,\alpha} \Leftrightarrow \gamma^{col} \gtreqless \hat{\gamma}(\gamma^{col}) \Leftrightarrow \pi_{\gamma}^{\prime col} \gtreqless 0.$$

If $\pi_{\gamma}^{\prime\text{col}} < 0$, the (competitive) Home regulator has an incentive to deviate upward from the collaborative equilibrium, which suggest that $\gamma^{\text{nash}} > \gamma^{\text{col}}$, and vice versa for $\pi_{\gamma}^{\prime\text{col}} > 0$.[31] We confirm this intuition in numerical examples below. But before doing so, we use our closed form results to build intuition on how the model parameters affect the sign of $\pi_{\gamma}^{\prime\text{col}}$.

Deadweight losses: the role of λ Recall equation (15), the condition for the collaborative optimum:

$$\alpha \left(X^{\text{col}}\right)^{\alpha-1} = 1 + (1-q)\,\lambda. \tag{17}$$

The higher λ, the higher are deadweight losses at the margin. Hence, a higher λ must be associated with a more constrained level of equilibrium lending, which

[31]Note that we cannot directly apply the results of Section 4 because, for similar reasons to those stated in Section 3, the second order condition can be locally violated (or, at least, we cannot rule out violations). In this situation, setting the first order condition to zero may not be necessary and sufficient to pin down a maximum. Simply assuming the second order condition is satisfied, then it is trivial to show that indeed $\gamma^{\text{nash}} > \gamma^{\text{col}}$ when $\pi_{\gamma}^{\prime\text{col}} < 0$, and vice versa.

translates to a higher γ^{col}. So, if λ is high enough, we have $\gamma^{\text{col}} > \hat{\gamma}(\gamma^{\text{col}})$: it is optimal to set regulation at a tighter level than that at which returns are maximised. Now, as γ^{col} is monotonically increasing in λ, there exists a threshold value for this parameter below which the externality at the collaborative outcome is negative, and positive otherwise. This threshold is given by the first inequality in Proposition 5.

Moral hazard and marginal ROE: the role of q and α Let us rewrite equation (16) as

$$\frac{1}{q} \times \alpha \left(\hat{X}\right)^{\alpha-1} = \frac{1}{\alpha} \tag{18}$$

and recall that $\hat{X}$ is the level of aggregate lending that maximises return on bank equity. Compared to equation (17), equation (18) has an additional factor $\frac{1}{q}$ on the marginal benefit side (left) and a factor $\frac{1}{\alpha}$ on the marginal cost side (right), where, by definition, deadweight losses (the term $(1-q)\lambda$) are ignored.

The parameter α pins down the elasticity of aggregate loan demand. Return maximisation requires maximising revenues for the banking sector. So, the term $1/\alpha$ simply reflects the revenue maximising markup (over the relevant opportunity cost of funds).[32] The lower α, the higher the markup and the more likely $\hat{X} < X^{\text{col}}$.

The factor $1/q$ reflects that, with deposit insurance and limited liability, the return on equity only depends on the upside. The realised return on equity is always nil when the bank goes bust. Therefore, the X that maximises the return on equity only depends on the value of A when the bank survives (rather than its expectation): namely $1/q$. Holding $\mathbb{E}[A] = 1$, the better the upside (i.e., the lower q) the higher $\hat{X}$. On the other hand, regulators do care about the downside and they also care about deadweight losses. From the right-hand-side of Equation (17), we can see that the lower q the more deadweight losses lending generates at the margin, hence the lower X^{col}. Together, it is clear that the higher q the more likely $\hat{X} < X^{\text{col}}$, and vice versa.

[32] Recall that $\hat{X}$ is defined given N. So the relevant opportunity cost of funds is the return to storage, which is 1. Put differently, the excess cost of capital should here be considered sunk.

The role of ω Parameter ω, the initial supply of capital, does not appear in the condition of Proposition 5. Its absence is due to the assumed binary distribution function, so that the probability of default is fixed at $1-q$. In the general case, ceteris paribus, a higher ω allows the planner to achieve a lower probability of default (a higher q) for a given level of economic activity. This suggests a higher X^{col} and a lower $\hat{X}$. And hence, that changing ω can flip the sign of the externality. We confirm this numerically in the next subsection.

5.2 Numerical results

So far, we have focused on incentives to deviate from the collaborative optimum. We now proceed numerically to i) solve for the Nash Equilibrium; ii) study the role of ω by relaxing the fixed probability of default assumption; and iii) extend the model to the case of more than two countries.

Collaborative optimum versus Nash equilibrium We first look at the same environment as in the closed-form example above (i.e., $\kappa \to \infty$ with regulators' objectives as in equation (14)), with the exception that we return to a continuous distribution function to allow for endogenous probability of default.[33]

Figure 1 presents the numerical results. The left panel presents an example for a given value of ω. It displays γ^{col}, $\hat{\gamma}(\gamma^{\text{col}})$ and γ^{nash}, which is at the intersection of the best response curves. In addition, it presents the solution for γ^{nash} when, rather than two countries, there is a mass of atomistic countries. We will comment on this latter case later.

The example we provide is one where $\gamma^{\text{col}} < \hat{\gamma}(\gamma^{\text{col}})$. Hence, for both regulators, starting from γ^{col}, raising the capital requirement would generate an inflow of valuable bank equity capital from the other country. Hence, the best response to γ^{col} would be to pick a higher capital requirement (which reflects the negative externality). Therefore, as expected, the result is $\gamma^{\text{nash}} > \gamma^{\text{col}}$; competitive regulators

[33]Note that we use a log-normal distributions for A and A'. This is technically in violation of 0 being part of their support. However, in the parameter space (including the range of capital requirements we look at) we consider, banks always default with positive probability in equilibrium, which is what matters.

set overly tight requirements compared to collaboration.

The right panel illustrates that the sign of the externality can reverse if ω is low enough. Intuitively, the lower ω, the smaller both γ^{nash} and γ^{col} (bank capital is intrinsically scarcer, and high capital requirements would contract NDP too much). But again, the sign of the externality depends on their ordering. The graph shows how the sign and magnitude of the difference between γ^{nash} and γ^{col} varies with ω. For high values of ω this difference is positive but when ω is relatively low it becomes negative.

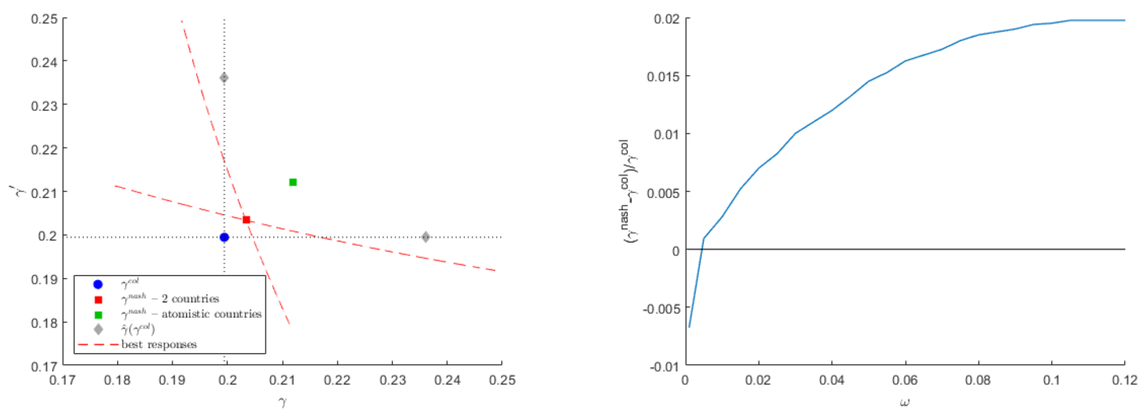
As above, collaborative regulators set γ^{col} trading off that more lending boosts NDP but also generates more deadweight losses. When ω is large, the regulator can achieve, with a relatively high γ^{col}, a combination of low marginal deadweight losses and high levels of lending, so that $\gamma^{\text{col}} < \hat{\gamma}\left(\gamma^{\text{col}}\right)$. This is what happens in the left panel. However, when ω is relatively low, reflecting that bank equity capital is intrinsically quite scarce, high levels of lending are too costly in terms of deadweight losses. Accordingly, if ω is low enough, collaborative regulators pick a γ^{col} high enough such that $X^{\text{col}} < \hat{X}$ (recall that deadweight losses do not affect $\hat{X}$). In this case, the sign of the externality reverses. Starting from γ^{col}, *lower* requirements are needed to siphon capital from abroad. Hence, competing regulators have an incentive to undercut one another and $\gamma^{\text{nash}} < \gamma^{\text{col}}$.

The case with more than two countries Our model can be extended to more than two countries. Take for instance the case $\kappa \to \infty$ and consider a number of ex-ante identical countries, each with an initial investor endowment of $\omega/2$. The collaborative optimum would be the same as in the corresponding two-country case (i.e., γ^{col} and N^{col} would be unchanged). In addition, the direction in which regulators have an incentive to deviate would still depend on whether increases in capital requirement raise return on equity at home.

However, the more countries the greater the incentive to deviate and the further the Nash equilibrium from the collaborative optimum (as indicated by the atomistic case in Panel A of Figure 1). The reason is that countries become effectively "smaller" on a global scale and, therefore, face a more elastic inverse supply curve of bank capital. Take the case where an increase in γ in a coun-

Figure 1: Policy choices under different levels of ω

Panel A: Best Response Curves ($\omega = 0.1$) Panel B: $\frac{\gamma^{\text{nash}} - \gamma^{\text{col}}}{\gamma^{\text{col}}}$ against ω



Notes - Parameter choices: $log(A) \sim N(0, \sigma^2)$, $\sigma^2 = 0.02$, $\lambda = 5$, $\alpha = 0.75$. NB: This violates $\mathbb{E}(A) = 1$ but amounts to a simple rescaling of the return function. Panel A: γ^{col} is denoted by the blue circle; γ^{nash} (for the two-country case) is denoted by the red square at the intersection of the best response curves (i.e. the red dashed lines); γ^{nash} (for the atomistic-countries case) is denoted by the green square further away from γ^{col}; and $\hat{\gamma}(\gamma^{\text{col}})$, and its Foreign counterpart, are denoted by the grey diamonds. Panel B: Plots γ^{nash} relative to γ^{col} as a function of ω.

try siphons off capital from abroad. Capital flows will ensue so as to restore the no-arbitrage condition in international capital markets. As the capital outflow is spread across more and more countries, the total inflow into the deviating country (for an identical deviation) becomes greater. As a result, the deviating country can achieve an identical financial stability benefit at the cost of a lower and lower decrease in economic activity.

From a collaborative point of view, each country attempts to *overuse* capital in the Nash equilibrium. Not unlike in the tragedy of the commons, this gets worse as the number of users becomes large. Such an interpretation applies to the case where $\gamma^{\text{col}} < \gamma^{\text{nash}}$, which we just discussed and can be interpreted as a race to the top. But it also applies to $\gamma^{\text{nash}} < \gamma^{\text{col}}$. In this case, competition among regulators leads to a race to the bottom instead. However, this occurs precisely because cutting capital requirements attracts capital from abroad.

This case highlights that our results do not hinge on regulators not being price takers in international markets, and that the inefficiency does not arise from regulators exploiting market power.

5.3 Empirical predictions and policy implications

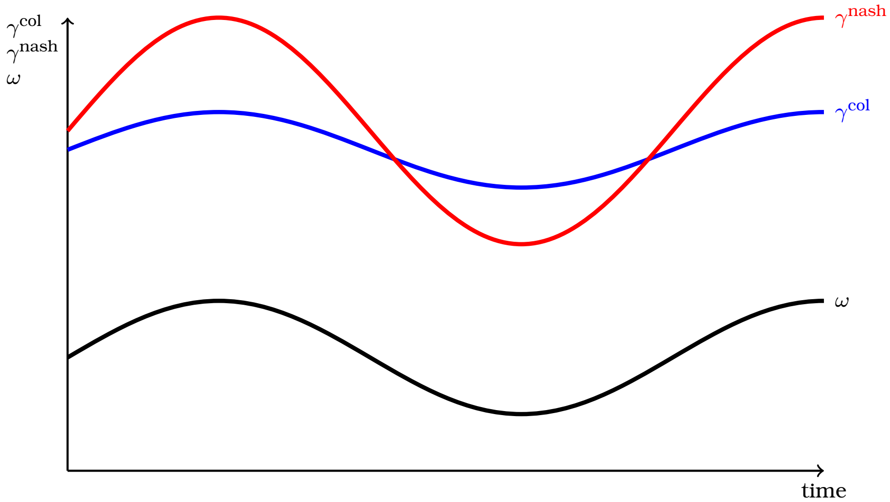
The discussion above makes clear that the direction of the capital flows depends on the structure of the lending market (for instance through parameter α, which affects loan-demand elasticity) and the state of the economy (for instance through ω, which affects the intrinsic scarcity of bank capital). The key condition is whether $\gamma^{\text{col}} \gtreqless \hat{\gamma}(\gamma^{\text{col}})$. Our empirical predictions are based on how parameters affect these two objects *on a relative basis*. In particular, we can state that the following factors will raise γ^{col} relative to $\hat{\gamma}(\gamma^{\text{col}})$ and, hence, increase the equity capital outflow from Home following a unilateral capital requirement increase: (i) Substantial market power in the banking sector or, more generally, high elasticity of loan demand (i.e. a high α in our closed-form example); (ii) Strong regulatory preferences for financial stability mandate and the avoidance of deadweight losses (i.e. a high λ, or more generally a high intensity of deadweight losses); (iii) Strong incentives to shift-risks or make one-sided bets (i.e. a low q); (iv) Scarce bank capital (i.e. low ω or high κ), as would occur, for instance, following a crisis. The combination of these factors can be such that Home regulators have an incentive to deviate towards lower regulation than under collaboration.

This reasoning can be used to formulate implications for the setting of the countercyclical capital buffer (CCyB). This buffer is the headline macroprudential capital requirement and the Basel III accords mandate that signatories reciprocate changes in the CCyB in other jurisdictions. In normal times, when the banking sector is healthy (bank capital is relatively abundant, risk-shifting incentives are contained, etc.) we are more likely to be in a situation where national regulators have an incentive to deviate upward. Doing so would attract capital from abroad and impose a negative externality onto other countries. So national regulators have an incentive to tighten requirements too much in good times. Hence, there are gains from coordinating on smaller raises. Conversely, after a negative shock, when ω is low and risk-shifting incentives are more important, national regulators have incentives to cut the CCyB too aggressively. Hence, there are gains from coordinating on smaller cuts.

There seems to be a consensus in the literature and among policymakers that the CCyB should be set higher in good times than in bad times. A key reason is that bank capital is scarcer in bad times (see, e.g., Kashyap and Stein (2004), and Malherbe (2020)). Building on this insight, we could think of a version of our model where the unique period would be repeated over time, with exogenous changes in ω. As mentioned above, the lower ω, the smaller both γ^{nash} and γ^{col}. But, more importantly, the lower ω the more likely $\gamma^{\text{nash}} < \gamma^{\text{col}}$. So, the prediction is that changes in γ^{nash} will follow changes in γ^{col} but with a greater amplitude. We illustrate this in Figure 2.

The Basel III accords also specify limits to the CCyB. In particular: (i) reciprocation is only mandatory up to a 2.5% buffer, and (ii) the buffer cannot be set at a negative level. Interestingly, through the lens of our model, these limits could mitigate strategic behaviour. In bad times, the effective lower bound on the CCyB limits the scope for regulators to undercut one another. Whereas in good times,

Figure 2: Illustration of $\gamma^{\text{nash}} \lesseqgtr \gamma^{\text{col}}$ over the cycle



if a national regulator sets the buffer above 2.5%, other regulators will not be obliged to reciprocate. Of course, whether 0% and 2.5% are appropriate bounds is an involved question; considerations range from what is the collaborative outcome in practice to how much discretion individual countries need to respond to asymmetric shocks. A full analysis of these is beyond the scope of this paper.

Finally, a potential implication of our discussion above of country size is that it is smaller countries that should be most active in using the CCyB.[34] These countries have the greatest incentive to deviate upwards during good times and to cut during bad times as from their perspective, the supply of bank equity capital is more elastic. While other forces may be at work, this is what we have seen in reality. The most active users of the CCyB have been small economies in Scandinavia, Hong Kong and the smaller members of the Eurozone. At the time of writing, the U.S., China and Japan have not used the buffer while Germany has varied the buffer by 25bp since its introduction.

[34]We have not formally considered asymmetries in country size (or along other dimensions) within our framework. Differences in country size can generate interesting predictions for the coordination of policies in other contexts (e.g. see Opp (2010) for an analysis of tariffs). We postpone such an analysis to future research.

6 Discussion

6.1 Generalising the bank capital flow externality

We now put our results in a broader perspective by considering how regulatory incentives change in our model when the objective function allows for changes in γ to affect π' in other ways than through its effect on N'^{*}. To capture this, we rewrite the objective as $\pi(N^{*}, \gamma, \gamma')$ where the final argument captures all mechanisms via which the capital requirements in foreign directly affect welfare in Home (that is, beyond its impact on N^{*}). Some examples of potentially relevant mechanisms include the following:

- If bank equity capital is socially costly, then the excess cost of equity (z) would enter the regulator's objective. This cost is affected by demand for equity in the other country and, hence, the other country's capital requirement.

- If some of the banks incorporated in Home did lend in Foreign (against our tie-breaking rule), then Home taxpayers would be liable for the deposits used to fund Foreign loans. The probability of such a default and its scale would depend on the Foreign capital requirement.

- More generally, if deadweight losses in Home depended on economic outcomes in Foreign (e.g., the defaults of Foreign banks) again the Foreign capital requirement would affect home welfare.

In these cases, and many more, the generalised externality takes the form:

$$\pi'^{*}_{\gamma}(\gamma', \gamma) = \frac{dN'^{*}}{d\gamma}\pi'_{N'}(N^{*\prime}, \gamma', \gamma) + \pi'_{\gamma}(N^{*\prime}, \gamma', \gamma). \tag{19}$$

Three points are in order. First, generalising the objective function does not affect the existence of the capital flow externality: the first term in the right hand side of the above equation is essentially identical to that in our model. Furthermore, the sign of $\frac{dN'^{*}}{d\gamma}$ still hinges here on whether $\gamma \gtreqless \hat{\gamma}(\gamma')$: if $R_{\gamma}(N^{*}, \gamma)$ is positive, an increase in γ siphons off capital from Foreign. As long as $\pi'_{N'}(N^{*\prime}, \gamma', \gamma)$ is positive this constitutes a negative externality.

Second, that an increase in bank capital, holding lending fixed, increases welfare (i.e., the counterpart to our condition $\widetilde{\pi}_N(X,N) > 0$ in Proposition 4) would no longer be a sufficient condition for $\pi_N^{\mathrm{col}} > 0$. Without putting additional restrictions on π'_γ, we cannot fully rule out cases where the social value of capital is negative at the collaborative optimum. In that case, bank equity capital becomes a sort of hot potato that regulators would prefer to pass onto their neighbours. The empirical relevance of such a case seems, however, limited.

Third, there also is a "direct" capital requirement externality $\pi'_\gamma(N^{*\prime}, \gamma', \gamma)$. For instance this could capture that a decrease in Home bank's probability of default has a positive impact on welfare in Foreign. Obviously, in the presence of this additional term, the sign of the total externality no longer hinges on that of $\frac{dN'^*}{d\gamma}$. The additional externality may either reinforce, mitigate, or even offset the bank equity capital flow externality.

In Appendix A, we analyse in greater detail the case where capital is socially costly (the first example mentioned above). This gives a concrete example of the generalised externality given by Equation (19) and confirms that the key insights of our analysis do not hinge on the excess cost of capital being a purely private cost.

6.2 Is there empirical evidence for the sign of the externality?

When setting capital requirements, do regulators have incentives to undercut one another or, to the contrary, to engage in a race to the top? The mere fact that international standards are formulated in terms of minima suggests the former. However, such standards were initially set when requirements were not reciprocated. A formal empirical analysis of the new regime is beyond the scope of this paper (and, to our knowledge, such a study does not exist in the literature). The short time frame since reciprocity was introduced and relatively infrequent changes in the CCyB are significant hurdles. However, we argue that one can still draw some inference on the sign of the capital flows based on existing literature.

There is a substantial literature identifying the effect of capital requirements at the bank level by exploiting the heterogeneous impact of regulatory reforms, stress tests, or supervisory interventions (Francis and Osborne (2012); Bahaj et al. (2016); Gropp et al. (2019); Imbierowicz et al. (2018); Juelsrud and Wold (2020); De Jonghe et al. (2020)). The message from these papers is that banks facing an increase in capital requirement increase their equity.[35] In some cases, the response is not significantly different than zero, but there is no evidence that banks reduce their levels of capital in response to higher requirements.

In our model, this bank-level relationship corresponds to $\frac{dn}{d\gamma} \geq 0$. Extrapolating at the aggregate level, this suggests $\frac{dN}{d\gamma} \geq 0$ and, therefore, corresponds to the condition under which regulators have an incentive to deviate upwards.[36] Now, if $\frac{dN}{d\gamma} > 0$, unless bank equity capital is supplied perfectly elastically (which would correspond to $\kappa = 0$ in our model), it must be that $\frac{dN'}{d\gamma} < 0$.

Consistent with this prediction, there is also bank-level evidence that tighter capital requirements at home causes domestic banks to cut lending abroad (see Aiyar et al. (2014); Forbes et al. (2017)), which would also correspond to $\frac{dn'}{d\gamma} < 0$ in our model. From a broader perspective, Buch and Goldberg (2017) provide a meta analysis showing that, in general, the tightening of prudential policies (including capital requirements) spillover to generate less lending abroad.

More empirical research is required to determine the direction of aggregate equity capital flows following sector-wide changes in requirements. However, the existing empirical evidence does suggest that the direction of equity capital flows is such that higher capital requirements at Home do, *on average*, generate a negative externality on Foreign.

6.3 Frictionless cross-border banking and equity capital mobility

Our environment assumes that both banks and investors can frictionlessly allocate their activities and equity capital across borders. These are two tractable

[35] See also Bahaj and Malherbe (2020) for a theoretical analysis.

[36] Interpreting bank-level estimates at the aggregate level may draw a biased picture (Berg et al. (2021)). However, one would typically expect competitive pressures to result in a single bank raising proportionally less capital following an idiosyncratic requirement increase than the entire banking sector would do following a sector-wide increase.

assumptions that allow us to illustrate the economic forces we have in mind but they are realistic. Relaxing them does not alter the fundamental logic behind the capital flow externality we identify.

First consider a situation where banks were not able (due to some informational frictions for instance) or even allowed (for regulatory reasons) to operate across borders. Maintaining the assumption of free capital mobility for investors, the equilibrium would be identical except specialisation would be hard-wired in, rather than an endogenous outcome. However, since banks cannot engage in regulatory arbitrage, reciprocity is simply irrelevant. We study a reciprocal regime to match current reality. Our environment also has the advantage that specialisation emerges endogenously. Still, the logic of our results extends beyond the setting. In particular, competition for bank capital will also emerge as an important consideration for setting capital requirements if banks cannot freely operate across borders: Regulators have an incentive to tweak capital requirements to reallocate capital to banks that have a comparative advantage in lending in their economy.

Second, imagine that not only banks do not operate accross borders, but also investors face barriers to reallocating their wealth to banks in different jurisdictions.[37] Now the return on equity may not always be perfectly equalised across countries. However, a change in the home capital requirement that alters the return on equity in Home will still generate an externality so long as some capital reallocation occurs (e.g., so long as the relevant reallocation cost does not exceed the return differential).

6.4 Other externalities and other regulatory tools

The market share externality and other externalities As we mentioned in the introduction, a key mechanism in Dell'Ariccia and Marquez (2006) illustrates how regulators' strategic interactions fundamentally differ in a non-reciprocal regime. In their model, there is a representative bank based in each country,

[37]When investors face barriers but banks can operate freely across borders, the barriers become irrelevant as the banks can still allocate their capital to the country of their choice leading to an equalisation of returns.

but both banks freely operate in both countries. Each bank has a fixed amount of equity capital and faces the capital requirement imposed by the regulator of their country of origin. A key point is that a decrease in capital requirement by the Home regulator decreases the cost of capital for the Home-based bank, which gives it a competitive advantage in both markets and allows it to grab market share from its Foreign competitor. This is a negative externality that naturally leads to a race to the bottom. Adopting a reciprocity regime kills such a market-share externality.

In contrast to our paper, a change in the Home capital requirement cannot change the allocation of the Home bank's capital across borders since, for a given bank, the same requirement applies to both Home and Foreign lending. Necessarily, $dN^*/d\gamma$ is nil: we have a case of a non-reciprocal regime where the capital flow externality does not operate. However, as we discussed just above, if banks can only operate locally, the capital flow externality will arises whether the regime is reciprocal or not.[38]

Now, the market share externality is not the whole story in Dell'Ariccia and Marquez (2006). There is another, subtle mechanism which reinforces the market share-externality. The probability that a bank defaults is affected by its monitoring activity. Increasing capital requirements effectively restricts competition and increases profitability, which improves banks' incentive to monitor. Because reduced competition raises profitability for all banks, an increase in capital requirements by one country improves monitoring incentives for both banks in the other country. National regulators do not internalise such effect, which contributes to them setting requirements too low. This effect is not present in our model, but could be captured with a different deadweight loss function.

Other sources of spillovers can run through asset prices. The failure of regulators to internalise foreign fire-sale externalities (Jeanne and Korinek (2010), Kara (2016)), regulators exerting market power (Caballero and Simsek (2020), Bengui (2014)), or contagion from changes in the value of cross-holdings (Niepmann and Schmidt-Eisenlohr (2013)) can also generate scope for policy collaboration. This

[38]In the intermediate case, where banks can operate across borders but subject to frictions, the natural conjecture is that both externalities would operate.

is different from what happens in our model, where the inefficiency does not emanate from changes in equilibrium prices. Since, in equilibrium, equity capital costs just offset changes in the return on equity, we have that holding equity capital fixed in a country, its welfare does not depend on the equilibrium price of bank capital (z^*). Changes in the equilibrium price of bank capital are purely redistributive. Instead, the externality arises through the failure to internalise the role capital has in alleviating deadweight losses abroad. With an alternative objective, regulators could directly care about equilibrium prices. However, fundamentally, what drives the changes in foreign returns is the capital flow. Reasoning in the terms of these flows, therefore, nests a wide range of potential channels.

Finally, Haufler and Maier (2019) study another type of additional externality: if goods markets are integrated across countries regulators may have an incentive to deviate upwards. The logic follows from a form of terms-of-trade externality common in the international taxation literature (Devereux (1991)): policies that constrain a country's output, like capital requirements, impose a negative externality on trading partners leading to overly tight policy.

Other regulatory tools Our model focuses on capital requirements and abstracts from other regulatory tools. Previous literature has for instance looked at strategic interactions when regulators choose capital requirements as well as supervisory intensity (Buck and Schliephake (2013)) and at how unified capital requirements affects forbearance in resolution (Acharya (2003)).

Capital requirements have, in practice, several layers called buffers. Conceptually, one can think of the Counter-Cyclical Capital Buffers (CCyB) as the marginal buffer. It is the one that is supposed to vary over-time and is subject to reciprocity. However, national regulators have discretion over other aspects of capital regulation that are not reciprocated (e.g., the definition of regulatory capital, the calculation of risk weights, and bank-specific capital requirements). Hence, strategic interactions are more complex in practice than they are in our model.

By combining the insights from Dell'Ariccia and Marquez (2006) and ours, one can formulate the following hypothesis. Consider a regulator who wants to achieve a given level of capital requirement stringency. It may be tempted to achieve it by an excessively tight CCyB (as part of the costs of CCyBs are borne by other countries through our bank capital flow externality) and overly loose regulation on non-reciprocated aspects. For instance, the regulator may impose overly low buffers for their systemically important banks. This is because these buffers are bank specific and therefore apply irrespective of where the bank operates. As per Dell'Ariccia and Marquez (2006), this could help domestically incorporated banks grab market share from foreign competitors, in all markets. Such a prediction is of course speculative and a formal model is beyond the scope of the paper. However, this thought experiment serves to illustrate the complexity of the situation and stresses the need for further research in the area.

7 Conclusion

We have shown how the principle of reciprocity fundamentally affects strategic interactions between national regulators. In a non-reciprocal regime, regulators have an incentive to undercut one another's capital requirements to allow their own banks to steal market shares from international competitors. Reciprocity neutralises such incentives. The relevant strategic interaction becomes competition for scarce bank equity capital. Depending on economic conditions, a rise in a given country's capital requirement can generate capital flows of either sign. Outflows from that country are associated with a positive externality on other countries, inflows with a negative one. We argue that this capital flow externality is likely to make individual regulators raise requirements too much (compared to full collaboration) in normal and good times and cut them too much in bad times. Other forces can however mitigate or offset this externality.

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A Reciprocity in practice

In this appendix we discuss how reciprocity fits into the regulatory framework outlined in Basel III and how to map, in greater detail, the regulatory environment seen in our model into real world regulation.

At the outset, note that the 27 jurisdictions that form the Basel Committee cover most of the world's major economic and financial centres (including the US, EU and China). These jurisdictions are compliant with Basel III regulations including those on reciprocity. For the rest of the world, Basel compliance varies. However, our model should be seen as capturing competition between regulators in developed, integrated economies where capital can flow freely and so the Committee members are the best real world analogue.

Basel III prescribes a series of additive capital requirements, often also called buffers. For simplicity, we express capital requirements in terms of ratio of Tier 1 capital to risk weighted assets.[39] Basel III specifies that all banks must adhere to a minimum 6% capital requirement at all times, plus an additional 2.5% capital conservation buffer that the bank can use temporarily to absorb a loss but will face dividend restrictions as a result. The minimum requirement and conservation buffer are homogeneous across jurisdictions and lending location and are not time varying.

These static requirements are supplemented by the countercyclical capital buffer (CCyB). The CCyB is time varying and set at the discretion of regulators in a particular jurisdiction for macroprudential purposes. The CCyB is set on lending (or other bank exposures) to agents within the regulator's jurisdiction. The regulator can always impose the requirement on banks within its jurisdiction (domestic banks and the subsidiaries of foreign banks). For banks outside the regulator's jurisdiction that may lend within it, the regulator relies on reciprocity:

[39]Tier 1 capital includes some contingent capital instruments beyond common equity that can enable the bank can absorb losses on a going concern basis. The minimum capital requirement for common equity is 1.5 percentage points lower. The Basel III framework also contains an additional 2 percentage point requirement for Tier 2 capital which can be thought of as gone-concern loss absorbing liabilities such as subordinated debt. Our model makes no distinction between common equity and other forms of contingent liabilities so we abstract from different definitions of capital.

that foreign regulators will impose the equivalent CCyB on the banks they regulate. Per the Basel III framework, reciprocation is mandatory up to a CCyB of 2.5% and voluntary thereafter (we will come back to the distinction between the two below). For members of the Basel committee the requirement to reciprocate is encoded in the law governing capital regulation.

In essence, we can interpret this framework through rewriting our baseline capital requirement expressed in equation (2) as:

$$n_i \geq (\bar{\gamma} + \text{CCyB})x_i + (\bar{\gamma} + \text{CCyB}')x_i',$$

where $\bar{\gamma}$ is a static common capital requirement representing the minimum requirement and conservation buffer, and the CCyB reflects the marginal requirement where the regulators have discretion. Note that since $\bar{\gamma}$ is common across jurisdictions whether or not it is reciprocated is irrelevant. If we take $\bar{\gamma}$ as a fixed primitive and CCyB as the marginal instrument whether the regulator has discretion, this ends up being equivalent to the regulator choosing $\gamma \equiv \bar{\gamma} + \text{CCyB}$. This however abstracts from the CCyB being bounded below by zero and that mandatory reciprocation ends at 2.5%. As we discuss in Section 5.3, these bounds could help with strategic pressures towards overly tight or loose policy.

We are also abstracting from the fact that regulators have scope to also set bank specific capital requirements. These could be due to the bank having raised a supervisory flag (e.g. failing a stress test) or because the bank is viewed as systemic (leading to so-called systemic institution buffers). Regulators have some discretion over these requirements. However, as they address risks at the bank-level rather than the exposure (e.g. loan) level there is no conceptual role for reciprocity. This means that regulators could be tempted to be too lenient on average when setting bank specific requirements if they are concerned about banks' market share. In practice, this has led to coordination on bank specific capital requirements. For instance, the most systemic banks within the EU have their systemic institution buffers set by the union-wide regulator rather than national regulators. The implementation of Basel III also has that the buffers for globally systemically important banks are set in a formulaic manner limiting regulators" discretion. In our model, all banks are ex-ante identical and we have no role for bank specific requirements.

Last, regulators have scope to set additional capital requirements on specific types of lending for macroprudential purposes. These are known as sectoral capital requirements. So for example, a regulator could raise the capital requirement on a particular type of mortgage lending within its jurisdiction (or alternatively, it could impose restrictions on the risk weight on that lending). There is no mandatory reciprocation of sectoral requirements. However, some jurisdictions or groups of jurisdictions have set up voluntary reciprocation regimes. The ESRB is a particular example of this: see here for a description of their regime. Voluntary reciprocation is not codified in the same way as the mandatory reciprocation of the CCyB. Nonetheless, moral suasion, reputational costs from and repeated game aspects appear to sustain equilibria where regulators do agree to reciprocate sectoral requirements in practice.

To summarise, the Basel III regime can be approximated as a capital requirement that has a fixed, common component and a time-varying one set by the country where the lending takes place. Since the time varying requirement is what matters at the margin, this maps to the setting we consider in our model.

B Proofs

Remark. When proofs are identical for Home and Foreign, we only provide the former.

Lemma. 1. *(i) Banks default with strictly positive probability in equilibrium; (ii) capital requirements are binding; and (iii) each individual bank perfectly specialises as either a lender in Home or Foreign.*

Proof. Consider a bank i with equity capital n_i and for which x_i and x' denotes lending in Home and Foreign respectively. The bank defaults if

$$\alpha A X^{\alpha-1} x_i + \alpha A' \left(X'\right)^{\alpha-1} x_i' < x_i' + x_i - n_i,$$

This means we can define two functions that both represent the default boundary: points in the state space where the Bank just has sufficient resources to make depositors whole.[40]

$$a_i^0(A') = \frac{x_i' + x_i - n_i - \alpha A' \left(X'\right)^{\alpha-1} x_i'}{\alpha X^{\alpha-1} x_i},$$

$$a_i'^0(A) = \frac{x_i' + x_i - n_i - \alpha A X^{\alpha-1} x_i}{\alpha \left(X'\right)^{\alpha-1} x_i'}.$$

Given this, we can write the bank's problem as the following Lagrangian (ignoring non-negativity constraints, and noting that $\mathbb{E}[A] = \mathbb{E}[A'] = 1$)

$$\begin{aligned} \max_{n_i, x_i, x_i'} \left(\alpha X^{\alpha-1} x_i + \alpha \left(X'\right)^{\alpha-1} x_i' - x_i - x_i' \right) + \\ \int_0^{a_i^0(0)} \int_0^{a_i'^0(A)} \left(x_i' + x_i - n_i - \alpha A X^{\alpha-1} x_i - \alpha A' \left(X'\right)^{\alpha-1} x_i' \right) h(A, A') dA' dA + \\ \psi \left(n_i - \gamma x_i - \gamma' x_i' \right) - n_i z(N, N'), \end{aligned}$$

where $h(A, A')$ is the joint density of A and A'. The first row corresponds to the economic surplus generated by the bank's lending. The second row is strictly positive when the bank defaults with strictly positive probability (zero otherwise) and captures the implicit subsidy to the bank arising from the government's guarantee. The third row captures constraints arising from the capital requirements, with corresponding multiplier ψ, and the excess cost to the bank of the capital raised.

We first prove by contradiction that capital requirements must be binding in equilibrium. Imagine they are not and the multiplier is nil. Then the bank can reduce n_i holding x_i and x_i' fixed. Since x_i and x_i' are fixed, the surplus from lending (the first line) is unaffected. However, the implicit subsidy can be increased by decreasing n_i. When the subsidy is positive a marginal increase in n_i both reduces the integrand and shifts the default boundary inwards. If the subsidy is initially nil, a sufficiently large decrease in n_i will render it positive. So, the deviation is profitable. Hence, capital requirements must bind in equilibrium (*ii*).

We do not consider $\gamma, \gamma' = 1$, coupled with binding capital requirements this implies in equilibrium $n_i < x_i + x_i'$. This means $a_i^0(0)$ and $a_i'^0(0)$ are strictly positive in equilibrium. Since A and A' can both be nil, banks default with strictly positive probability in equilibrium (*i*).

[40]Note that if A' is such that $a^0(A') < 0$, the bank simply cannot default for this value of A'.

We also prove part (*iii*) by contradiction. Consider a hypothetical equilibrium where banks do not perfectly specialise; that is, there is an interior solution at the bank level for both x_i and x'_i. Define the following function

$$\mathrm{rc}(A,\gamma) = \alpha A X^{\alpha-1} - (1-\gamma).$$

For given A and γ, the term rc is the residual cash flows available to the banks shareholders from lending in Home. It corresponds to bank revenue, net of repayments to depositors, per unit of lending in home. We can write the return, for this bank, of a unit of equity being allocated to a loan in Home as:

$$\frac{\mathrm{rc}(1,\gamma)}{\gamma} - \int_0^{a_i^0(0)} \int_0^{a_i'^0(A)} \left(\frac{\mathrm{rc}(A,\gamma)}{\gamma}\right) h(A,A')dAdA';$$

and similarly for a loan in Foreign.

If both x_i and x'_i are strictly positive in equilibrium, the bank must be indifferent at the margin. Then,

$$\begin{aligned}&\tfrac{\mathrm{rc}(1,\gamma)}{\gamma} - \textstyle\int_0^{a_i^0(0)} \int_0^{a_i'^0(A)} \left(\tfrac{\mathrm{rc}(A,\gamma)}{\gamma}\right) h(A,A')dA' = \\ &\tfrac{\mathrm{rc}'(1,\gamma)}{\gamma} - \textstyle\int_0^{a_i^0(0)} \int_0^{a_i'^0(A)} \left(\tfrac{\mathrm{rc}'(A,\gamma')}{\gamma'}\right) h(A,A')dA'.\end{aligned}$$

We now show that an individual bank can profitably deviate by lending entirely in the Home country. To see this first note that the after-deviation revenues of such a bank is:

$$n_i \left(\frac{\mathrm{rc}(1,\gamma)}{\gamma} - \int_0^{A^0} \left(\frac{\mathrm{rc}(A,\gamma)}{\gamma}\right) g(A)dA\right),$$

where, as in the text, A^0 is the default boundary for a bank that specialises in lending at Home. Making use of the fact that returns are equalised across countries allows us to compute the benefit from deviating as

$$n_i \left(\int_0^{a_i^0(0)} \int_0^{a_i'^0(A)} \left(\frac{\mathrm{rc}(A,\gamma)}{\gamma}\right) h(A,A')dA' - \int_0^{A^0} \left(\frac{\mathrm{rc}(A,\gamma)}{\gamma}\right) g(A)dA\right).$$

By definition, $\mathrm{rc}(A,\gamma) < 0$ for all $A \in [0, A^0]$. Hence, this benefit is strictly positive so long as there exists $A \in [0, a_i^0(0)]$ such that $\mathrm{rc}(A,\gamma) > 0$. This is guaranteed by $h(A, A')$ having full support over $[0, A^H] \times [0, A'^H]$. Since a profitable deviation exists, an individual bank will never choose for both x_i and x_i' to be interior at the same time. Hence, the only possible equilibrium is one where individual banks perfectly specialise in either country and aggregate returns are equated by the aggregate amount of equity capital allocated to each country. □

For further reference, we prove the following two Lemmas.

Lemma A1. *For all $\gamma, \gamma' \in (0,1)$, and all $N, N' > 0$, the partial derivatives $R_N(N,\gamma)$ and $R'_{N'}(N',\gamma')$ exist and are continuous in their arguments.*

Proof. First note that from the smoothness of $g(A)$ we have that $R(N,\gamma)$ is continuous in N. The derivative reads:

$$R_N(N,\gamma) = \begin{cases} \frac{1}{\gamma^2} \int_{A^0(N,\gamma)}^{A^H} \left(\alpha(\alpha-1) A \left(\frac{N}{\gamma}\right)^{\alpha-2} \right) g(A) dA & A^0(N,\gamma) \leq A^H \\ 0 & A^H \leq A^0(N,\gamma) \end{cases}.$$

Continuity directly follows as the integral is continuous, and the two possible values coincide at $A^0(N,\gamma) = A^H$. (Note that $\gamma > 0$ ensures $A^0(N,\gamma) > 0$ so we don't need to consider the lower bound for A). □

Lemma A2. *For all $\gamma, \gamma' \in (0,1)$, and all $N, N' > 0$, the partial derivatives $R_\gamma(N,\gamma)$ and $R'_{\gamma'}(N',\gamma')$ exist and are continuous in γ and γ', respectively.*

Proof. First note that from the smoothness of $g(A)$ we have that $R(N,\gamma)$ is continuous in γ. The derivative reads:

$$R_\gamma(N,\gamma) = \begin{cases} \frac{-1}{\gamma^2} \int_{A^0(N,\gamma)}^{A^H} \left(\alpha^2 A \left(\frac{N}{\gamma}\right)^{\alpha-1} - 1 \right) g\left(A\right) dA & A^0(N,\gamma) \leq A^H \\ 0 & A^H \leq A^0(N,\gamma) \end{cases}.$$

Continuity directly follows as the integral is continuous, and the two possible values coincide at $A^0(N,\gamma) = A^H$. □

Proposition. 1. *For all* $\gamma, \gamma' \in (0,1)$, *there exists a unique pair* $\{N^*, N'^*\}$ *such that returns on equity in both countries are equal to the investors' required return. This pair is implicitly defined by:*

$$R(N^*, \gamma) = R'(N'^*, \gamma') = (1 + z(N^*, N'^*)).$$

Proof. First, let us establish that the double equality necessarily holds in equilibrium. If $R(N^*, \gamma) > (1 + z(N^*, N'^*))$, the representative bank will scale up infinitely but this cannot be the case since $z \geq 0$, $lim_{N\to\infty} R(N, \gamma) = 0$ and, in equilibrium, $n = N$. Likewise, If $R(N^*, \gamma) < (1 + z(N^*, N'^*))$ banks will choose $n = 0$, which is inconsistent with $n = N$ and $lim_{N\to 0} R(N^*, \gamma) = \infty$. Hence, in equilibrium we must have that $R(N^*, \gamma) = 1 + z(N^*, N'^*)$ and, with the same logic, $R'(N'^*, \gamma') = 1 + z(N^*, N'^*)$.

It is straightforward to show that, for a given z, there is a single, interior N that solves $R(N, \gamma) = 1 + z$. But z depends on the global demand for bank equity capital: $z = \frac{\kappa}{2} \left(\max\{N + N' - \omega, 0\}\right)^2$. So, the question is whether there is a unique pair (N, N') that solves the system:

$$\begin{cases} R(N, \gamma) = 1 + z(N, N') \\ R'(N', \gamma') = 1 + z(N, N') \end{cases}. \tag{20}$$

By construction, $z \geq 0$. So, if the left-hand-side functions in system (20) are invertible for N and N' for values of $R, R' \geq 1$ (which we prove later), we can write the bank capital demand functions for Home and Foreign implicitly (and for a given pair $\{\gamma, \gamma'\}$) as:

$$\begin{cases} N(z) = R^{-1}(1 + z) \\ N'(z) = R'^{-1}(1 + z) \end{cases}. \tag{21}$$

And we can aggregate them to write an implicit global demand function for bank capital: $N^D(z) = R^{-1}(1 + z) + R'^{-1}(1 + z)$.

From $z = \frac{\kappa}{2}(\max\{N + N' - \omega, 0\})^2$, we have an explicit global supply function:

$$N^S(z) \equiv \begin{cases} \frac{\sqrt{2z}}{\kappa} + \omega & , z \geq 0 \\ \omega & , z = 0 \end{cases}.$$

If $N^D(0) \leq \omega$, there is excess supply,[41] and we simply have $z^* = 0$ and N^* and N'^* pinned down by their respective demand functions (21).

To complete the proof, we first show that (*i*) $R(N, \gamma)$ and $R'(N', \gamma')$ are respectively invertible for N and N' for values of $R, R' \geq 1$; and that (*ii*) $N^D(z)$ and $N^S(z)$ always cross exactly once when $N^D(0) > \omega$, with $z^* > 0$. Then, unique corresponding values of N and N'^* arise from Equations (20).

(*i*) From Lemma A1, we have

$$R_N(N, \gamma) = \begin{cases} \frac{1}{\gamma^2}\int_{A^0(N,\gamma)}^{A^H} \left(\alpha(\alpha-1)A\left(\frac{N}{\gamma}\right)^{\alpha-2}\right) g(A)dA & 0 \leq A^0(N,\gamma) < A^H \\ 0 & A^H \leq A^0(N,\gamma) \end{cases}.$$

Since $R_N < 0$ when $A^0(N, \gamma) < A^H$, $R(N, \gamma)$ is invertible for N over the corresponding range of values such that $A^0(N, \gamma) < A^H$. The function is therefore invertible for the relevant range of values where $R \geq 1$. (Note that $R < 1$ cannot be an equilibrium as shareholders would always prefer to invest their wealth in the storage technology.)

(*ii*) $N^S(z)$ is strictly increasing starting from the point $N^S(0) = \omega$. Given (*i*), we know that R^{-1} and R'^{-1} are decreasing in z. Hence, $N^D(z)$ is decreasing too. If $N^D(0) > \omega$, this ensures single crossing at a point $z^* > 0$. $\square$

For further reference, we can now state:

Corollary A1. *For all* $\gamma, \gamma' \in (0, 1)$ *and associated* $\{N^*(\gamma, \gamma'), N'^*(\gamma, \gamma')\}$*, we have* $R_N(N^*, \gamma) < 0$ *and* $R'_{N'}(N'^*, \gamma') < 0$*.*

[41] Strictly speaking, it is investors' wealth which is in excess of the demand for bank equity. Since they can use a storage technology with unit gross return, their supply is actually perfectly elastic in this region.

Lemma. 2. *For all* $\gamma, \gamma' \in (0,1)$,

$$\frac{dN^*}{d\gamma} = R_\gamma(N^*, \gamma)\xi^*(\gamma, \gamma'), \tag{22}$$

where $\xi^*(\gamma,\gamma') \equiv \left(\frac{\kappa M - R'_{N'}}{R_N R'_{N'} - \kappa M\left(R'_{N'} + R_N\right)}\right)\Bigg|_{N^*(\gamma,\gamma'), N'^*(\gamma,\gamma')} > 0.$
Therefore, it is the case that

$$\frac{dN^*}{d\gamma} \gtreqless 0 \Leftrightarrow R_\gamma(N^*, \gamma) \gtreqless 0.$$

Proof. From the no-arbitrage condition

$$R(N^*(\gamma,\gamma'),\gamma) - R'(N'^*, \gamma') = 0.$$

So, given Lemmas A1, A2, and Corollary A1, we can apply the implicit function theorem to obtain

$$\frac{dN'^*}{d\gamma} = \frac{R_\gamma(N^*,\gamma) + R_N(N^*,\gamma)\frac{dN^*}{d\gamma}}{R'_{N'}(N'^*,\gamma')}. \tag{23}$$

Consider the case when $z^* > 0$. We have

$$R'\left(N'^*, \gamma'\right) - \frac{\kappa}{2}(N^*(\gamma,\gamma') + N^{*\prime} - \omega)^2 - 1 = 0.$$

So, given Lemma A1, and Corollary A1, we obtain

$$\frac{dN'^*}{d\gamma} = \frac{\kappa M^* \frac{dN^*}{d\gamma}}{R'_{N'}(N'^*,\gamma') - \kappa M^*}. \tag{24}$$

Combining equations (23) and (24) yields

$$\frac{dN^*}{d\gamma} = R_\gamma(N^*,\gamma)\underbrace{\left(\frac{\kappa M^* - R'_{N'}(N'^*,\gamma')}{R_N(N^*,\gamma)R'_{N'}(N'^*,\gamma') - \kappa M^*\left(R'_{N'}(N'^*,\gamma') + R_N(N^*,\gamma)\right)}\right)}_{\equiv \xi^*(\gamma,\gamma')}.$$

which is well defined and continuous for all $\gamma, \gamma' \in (0,1)$ and associated $\{N^*(\gamma,\gamma'), N'^*(\gamma,\gamma')\}$. Since $R_N(N^*,\gamma), R'_{N'}(N'^*,\gamma') < 0$ (Corollary A1), and $\kappa M^* \geq 0$, this means $\xi^*(\gamma,\gamma') >$

0.

In the case where $z^* = 0$, we have $R\left(N^*, \gamma\right) - 1 = 0$, hence

$$\frac{dN^*}{d\gamma} = -\frac{R_\gamma(N^*, \gamma)}{R_N(N^*, \gamma)}.$$

The left hand side is equivalent to $R_\gamma(N^*, \gamma)\xi^*(\gamma, \gamma')$ when $M^* = 0$ (which is an implication of $z^* = 0$). Since $R_N(N^*, \gamma) < 0$ (Corollary A1), $\xi^*(\gamma, \gamma') > 0$ when $M^* = 0$. Therefore the result holds for all $z^* \geq 0$.

To conclude, since $\xi^*(\gamma, \gamma') > 0$ is always positive, the sign of $\frac{dN^*}{d\gamma}$ is the same as the sign of $R_\gamma(N^*, \gamma)$. □

Proposition. 2. *For all* $\gamma, \gamma' \in (0, 1)$,

$$\frac{dN^{*\prime}}{d\gamma} = -\underbrace{\left(\frac{\kappa M^*}{\kappa M^* - R'_{N'}\left(N'^*, \gamma^*\right)}\right)}_{\equiv \boldsymbol{SP}^*(\gamma,\gamma')\in[0,1]} \frac{dN^*}{d\gamma}. \tag{25}$$

Proof. The result directly follows from Equation (24) in the proof above, together with $R'_{N'}(N'^*, \gamma') < 0$ (Corollary A1). If $z^* = 0$, then $M^* = 0$, and $\frac{dN^{*\prime}}{d\gamma} = 0$. □

Theorem. 1. *Assume Regularity Condition 1 holds in the considered equilibrium. Then,* $\forall\ \gamma' \in (0, 1)$, *there exists a* $\widehat{\gamma}\left(\gamma'\right) > 0$ *such that,* $\forall \gamma \in (0, 1)$

$$\begin{cases} \frac{dN^*}{d\gamma} > 0 & ; \gamma < \widehat{\gamma}\left(\gamma'\right) \\ \frac{dN^*}{d\gamma} = 0 & ; \gamma = \widehat{\gamma}\left(\gamma'\right) \\ \frac{dN^*}{d\gamma} < 0 & ; \gamma > \widehat{\gamma}\left(\gamma'\right) \end{cases}.$$

Proof. From Lemma 2 we know that the sign of $\frac{dN^*}{d\gamma}$ is the same as that of $R_\gamma\left(N^*(\gamma, \gamma'), \gamma\right)$. Based on this, the proof proceeds in steps to show the following:

i) $\frac{dR^*(\gamma,\gamma')}{d\gamma}$ exists and is continuous in γ, for all $\gamma, \gamma' \in (0, 1)$.

ii) The sign of $R_\gamma\left(N^*(\gamma, \gamma'), \gamma\right)$ is the same as that of $\frac{dR^*(\gamma,\gamma')}{d\gamma}$ (and they are nil at the same γ).

iii) At low values of γ, $R_\gamma\left(N^*(\gamma, \gamma'), \gamma\right)$ is positive.

Then, given regularity Condition 1, for each γ', either $R_\gamma\left(N^*, \gamma\right)$ is positive for all $\gamma \in (0,1)$, in which case we can simply set $\hat{\gamma}(\gamma') = 1$, or there exists a $\bar{\gamma}(\gamma') < 1$, for which $R_\gamma\left(N^*(\bar{\gamma}(\gamma'),\gamma'),\bar{\gamma}(\gamma')\right) = 0$. But then, since regularity Condition 1 implies single crossing, it must be that $R_\gamma\left(N^*(\gamma,\gamma'),\gamma\right) < 0$, for all $\gamma > \bar{\gamma}(\gamma')$. In these cases, setting $\widehat{\gamma}\left(\gamma'\right) = \bar{\gamma}(\gamma')$, guarantees that the Theorem holds.

We now proceed we the details of the three steps.

Step i) Note that

$$\frac{dR^*(\gamma,\gamma')}{d\gamma} = R_\gamma(N^*,\gamma) + \frac{dN^*}{d\gamma}R_N(N^*,\gamma). \tag{26}$$

From Lemmas A1, A2, and *2* we know that all three elements of the right hand side exist and are continuous in γ.

Step ii) From Lemma *2, we have*

$$\frac{dN^*}{d\gamma} = R_\gamma(N^*,\gamma)\xi^*(\gamma,\gamma').$$

Substituting in Equation (26) gives:

$$\frac{dR^*(\gamma,\gamma')}{d\gamma} = R_\gamma(N^*,\gamma)\left(1 + \xi^*(\gamma,\gamma')R_N(N^*,\gamma)\right).$$

But, we have

$$1 + \xi^*(\gamma,\gamma')R_N(N^*,\gamma) = \left.\left(1 + \frac{\kappa M R_N - R'_{N'}R_N}{R_N R'_{N'} - \kappa M\left(R'_{N'} + R_N\right)}\right)\right|_{N^*(\gamma,\gamma'),N'^*(\gamma,\gamma'))}.$$

Hence

$$1 + \xi^*(\gamma,\gamma')R_N(N^*,\gamma) = \left.\left(\frac{-\kappa M R'_{N'}}{-\kappa M R'_{N'} + R_N R'_{N'} - \kappa M R_N}\right)\right|_{N^*(\gamma,\gamma'),N'^*(\gamma,\gamma')},$$

and, given that $\kappa M^* \geq 0$, and that $R_N(N^*,\gamma) < 0$, $R'_{N'}(N'^*,\gamma') < 0$ (corollary A1), it is the case that

$$1 + \xi^*(\gamma,\gamma')R_N(N^*,\gamma) \in [0,1],$$

and, therefore, that

$$\operatorname{sgn}\left(\frac{dR^{*}(\gamma,\gamma')}{d\gamma}\right)=\operatorname{sgn}\left(R_{\gamma}(N^{*},\gamma)\right).$$

Step iii) We start from

$$R_{\gamma}\left(N,\gamma\right)=\frac{-1}{\gamma^{2}}\int_{A^{0}(N,\gamma)}^{A^{H}}\left(\alpha^{2}A\left(\frac{N}{\gamma}\right)^{\alpha-1}-1\right)g\left(A\right)dA.$$

and consider the limit as γ tends to 0 from above. It is positive if

$$\lim_{\gamma\longrightarrow0^{+}}\int_{A^{0}}^{A^{H}}\left(\alpha^{2}A\left(\frac{N}{\gamma}\right)^{\alpha-1}-1\right)g\left(A\right)dA<0.$$

It turns out that it must be the case in equilibrium. To see why, consider X such that $\alpha\left(X\right)^{\alpha-1}=1$. At such X, as γ tends to 0, banks make strictly positive profits (lending just breaks even in expectation, but banks have no equity, so they only pick the upside, i.e., $A^{0}>0$). This cannot be true in equilibrium. Instead, it must be the case that $\alpha\left(X^{*}\right)^{\alpha-1}<1$. Since $\alpha<1$, this is also true for $\alpha^{2}\left(X^{*}\right)^{\alpha-1}<1$. So, $R_{\gamma}\left(N^{*},\gamma\right)$ is positive at low enough values of γ. □

Proposition. 3. *Unless $\pi_{\gamma}^{\prime nash}=0$, the Nash equilibrium is inefficient. That is: $\Pi^{nash}<\Pi^{col}$. The direction of the mutually beneficial deviation is pinned down by the sign of the externality. In particular, $\pi_{\gamma}^{\prime nash}\gtreqless 0\Leftrightarrow\pi_{\gamma}^{\prime col}\gtreqless 0\Leftrightarrow\gamma^{nash}\lesseqgtr\gamma^{col}$.*

Proof. Consider $\gamma=\gamma'=\gamma^{\text{nash}}$. Condition 2 guarantees that $\pi_{\gamma}^{\text{nash}}=0$. So, at this point, a marginal change in γ has no impact on Home's own objective. The impact of the change on Foreign is $\pi_{\gamma}^{\prime\text{nash}}$. If it is nil, regularity Condition 2 ensures that $\gamma^{\text{nash}}=\gamma^{\text{col}}$, and the Nash equilibrium is efficient, that is, it correspond to the collaborative outcome. If $\pi_{\gamma}^{\prime\text{nash}}\neq0$, there exists a mutually beneficial deviation. Consider $\pi_{\gamma}^{\prime\text{nash}}>0$. By symmetry, it must be that $\pi_{\gamma'}^{\text{nash}}>0$. So, a coordinated marginal increase in γ and γ' makes both countries strictly better off. Regularity Condition 2 then ensures that $\gamma^{\text{nash}}<\gamma^{\text{col}}$. And vice versa if $\pi_{\gamma'}^{\text{nash}}<0$. Hence, $\pi_{\gamma}^{\prime\text{nash}}\gtreqless 0\Leftrightarrow\gamma^{\text{nash}}\lesseqgtr\gamma^{\text{col}}$.

To show that $\pi_{\gamma}^{\prime\text{nash}}\gtreqless 0\Leftrightarrow\pi_{\gamma}^{\prime\text{col}}\gtreqless 0$, first, note that condition 2 guarantees that $\pi_{\gamma}^{\text{col}}+\pi_{\gamma}^{\prime\text{col}}=0$. Now consider $\pi_{\gamma}^{\prime\text{nash}}>0$. As $\gamma^{\text{nash}}<\gamma^{\text{col}}$ and $\pi_{\gamma}^{\text{nash}}=0$, 2 ensures

$\pi_\gamma^{\text{col}} < 0$; hence $\pi_\gamma'^{\text{col}} > 0$. And vice versa, if $\pi_{\gamma'}^{\text{nash}} < 0$. From the reasoning above, $\pi_\gamma'^{\text{nash}} = 0 \Leftrightarrow \pi_\gamma'^{\text{col}} = 0$. □

Lemma A3. $\frac{dN^*}{d\gamma} < X^*$

Proof. We have $N^* = \gamma X^*$. So, $\frac{dN^*}{d\gamma} \equiv X^* + \gamma\frac{dX^*}{d\gamma}$. We show that $\frac{dX^*}{d\gamma} < 0$, which establishes the result.

Using a change of variable, we have

$$\check{R}(X^*, \gamma) - (1 + \check{z}\,(X^*, \gamma, \gamma')) = 0.$$

From which we get

$$\frac{dX^*}{d\gamma} = -\frac{\check{R}_\gamma - \check{z}_\gamma}{\check{R}_X - \check{z}_X}. \tag{27}$$

Because of the diminishing marginal product of physical capital, we have $\check{R}_X < 0$. Furthermore, even though R_γ can be positive (as we show in Section 3), $\check{R}_\gamma$ cannot: an increase in γ keeping X constant can only decrease the return on bank capital, as this decreases the value of the implicit subsidy from the government guarantee without altering the gross revenues through changes in aggregate lending.

If $z^* = 0$, we have $\check{z}_\gamma, \check{z}_X = 0$. So both the numerator and the denominator in equation (27) are strictly negative and, therefore, $\frac{dX^*}{d\gamma} < 0$.

If $z^* > 0$, we have that $\check{z}\,(X^*, \gamma, \gamma') = \frac{\kappa}{2}(X^*\gamma + N'^*(\gamma, \gamma') - \omega)^2$, so $\check{z}_X > 0$: keeping γ constant, an increase in X^* other variable increases N^* and therefore the equilibrium cost of bank capital. So the denominator in equation (27) is still negative.

Now

$$\check{z}_\gamma = \kappa(X^*\gamma + N'^*(\gamma, \gamma') - \omega)\left(X^* + \frac{dN'^*}{d\gamma}\right).$$

Appealing to Proposition 2, we know that

$$\frac{dN'^*}{d\gamma} = -\text{SP}^*\frac{dN^*}{d\gamma} = -\text{SP}^*\left(X^* + \frac{dX^*}{d\gamma}\right).$$

Hence, we can write

$$\check{z}_\gamma = \kappa(X^*\gamma + N'^*(\gamma, \gamma') - \omega)\left((1 - \text{SP}^*)X^* - \gamma\text{SP}^*\frac{dX^*}{d\gamma}\right).$$

Substituting this expression into Equation (27) and rearranging, we have, when $z^* > 0$, the following expression:

$$\frac{dX^*}{d\gamma} = -\left(\frac{\check{R}_\gamma - \kappa(X^*\gamma + N'^*(\gamma, \gamma') - \omega)(1 - \text{SP}^*)X^*}{\check{R}_X - \check{z}_X}\right)\left(1 - \frac{\gamma\text{SP}^*}{\check{R}_X - \check{z}_X}\right)^{-1}. \tag{28}$$

It is the case that $\kappa(X^*\gamma + N'^*(\gamma, \gamma') - \omega)(1 - \text{SP}^*)X^*$ is strictly positive when $z^* > 0$. Since $\left(\check{R}_X - \check{z}_X\right)$ and $\check{R}_\gamma$ are both negative, the first parenthesis is strictly positive. And $\left(\check{R}_X - \check{z}_X\right) < 0$ also implies that the second parenthesis is positive. Hence, $\frac{dX^*}{d\gamma} < 0$. □

Proposition. *4If $\widetilde{\pi}_N(X, N) > 0$, $\forall N < X$, then $\pi_N(N^{nash}, \gamma^{nash}), \pi_N(N^{col}, \gamma^{col}) > 0$.*

Proof. First, we prove $\pi_N^{\text{nash}} > 0$. Given γ' , the competitive regulator's first order condition is:

$$\pi^*_\gamma(\gamma, \gamma') = \pi_\gamma(N^*, \gamma) + \frac{dN^*}{d\gamma}\pi_N(N^*, \gamma) = 0. \tag{29}$$

With a change of variable, we obtain:

$$\widetilde{\pi}_N(X^*, N^*) \equiv \frac{\pi_\gamma(N^*, \gamma)}{X^*} + \pi_N(N^*, \gamma).$$

Substituting $\pi_N(N^*, \gamma)$ in the first order condition gives:

$$\pi_\gamma(N^*, \gamma) + \frac{dN^*}{d\gamma}\left(\widetilde{\pi}_N(X^*, N^*) - \frac{\pi_\gamma(N^*, \gamma)}{X^*}\right) = 0$$

or

$$\frac{dN^*}{d\gamma}\widetilde{\pi}_N(X^*, N^*) = \pi_\gamma(N^*, \gamma)\left(\frac{1}{X^*}\frac{dN^*}{d\gamma} - 1\right).$$

From Lemma A3, we know that $\left(\frac{1}{X^*}\frac{dN^*}{d\gamma} - 1\right) < 0$. So, we have that $\widetilde{\pi}_N(X^*, N^*) > 0$ implies that $\pi_\gamma(N^*, \gamma)$ and $\frac{dN^*}{d\gamma}$ have opposite signs along the best response function. But then, from the first order condition (29), it must be that $\pi_N(N^*, \gamma) > 0$. If this is true along the best response function, it is true at the Nash equilibrium: $\pi_N^{\text{nash}} > 0$.

We now turn to proving $\pi_N^{\text{col}} > 0$. Given γ' , the collaborative regulator first order condition for γ is:

$$\pi_\gamma^*(\gamma,\gamma') = \pi_\gamma(N^*,\gamma) + (1-\text{SP}^*)\frac{dN^*}{d\gamma}\pi_N(N^*,\gamma) = 0. \tag{30}$$

Following the same steps as above, we get

$$\frac{dN^*}{d\gamma}\widetilde{\pi}_N(X^*,N^*) = \pi_\gamma(N^*,\gamma)\left((1-\text{SP}^*)\frac{1}{X^*}\frac{dN^*}{d\gamma} - 1\right).$$

And noting that $\text{SP}^* \in [0,1]$ yields to the result: $\pi_N^{\text{col}} > 0$. □

Proposition. 5. *Under objective (14), if* $\kappa \to \infty$*, and* $A \in \left\{0, \frac{1}{q}\right\}$*, with* $0 < q < 1$ *and* $\Pr(A = \frac{1}{q}) = q$*. Then*

$$\lambda \gtreqless \frac{q-\alpha}{(1-q)\,\alpha} \Leftrightarrow \gamma^{col} \gtreqless \hat{\gamma}(\gamma^{col}) \Leftrightarrow \pi_\gamma'^{col} \gtreqless 0.$$

Proof. The result is established in the main text. □

C Additional theoretical results

C.1 Higher capital requirements make banks strictly worse off

Here we relax the perfect competition assumption and extend the model in Section 3 to allow banks to have market power in the loan market. In particular, we assume that there are ν identical banks specialising in lending each country and compete a la Cournot to supply loans to penniless firms.[42] Banks still act as price takers in the markets for deposits and equity capital. We focus on banks specialising in Home lending and abstract from the Foreign country (function dependencies on γ' are omitted). Our goal is to show that a rise in capital requirements strictly decreases the pure profits of banks in equilibrium.

[42] From Schliephake and Kirstein (2013) this is equivalent to banks first raising equity to generate lending capacity and then, holding fixed the liability side of the balance sheet, competing a la Bertrand (see also Kreps and Scheinkman (1983)).

To briefly summarise the environment: as before, banks fund their lending by raising a mix of deposits and equity. Deposits are insured and are raised elastically from households that have an opportunity cost of funds of one. For the purposes of this extension we assume each bank has a vanishingly small endowment of inside equity. The bank can raise new outside equity from the global capital market. As in the main text, outside equity must return in expectation, $1 + z = 1 + \frac{\kappa}{2}M^2$ per unit raised, where M is the total amount of new outside raised both in Home and Foreign. Banks take z as given. The regulator sets the minimum share of equity financing (inside and outside) in the form of the capital requirement, γ. This requirement always binds in equilibrium and is taken as a parameter in the spirit of Section 3.

As in the baseline model, firms borrow from banks to invest in physical capital that is used to produce consumption goods using an aggregate Cobb-Douglas technology with curvature parameter $0 < \alpha < 1$. For simplicity, we assume that aggregate TFP is binary: it is zero with probability $(1 - q)$ and equal to $\frac{1}{q}$ with probability q.

Consider bank i that makes loans $x_i = \frac{n_i}{\gamma}$, where n_i is the value of the firms equity. Since firms are penniless all the returns on physical capital are captured by the bank. Hence, bank expected revenues are given by $\alpha \left(x_i + \sum_{j \neq i} x_j \right)^{\alpha - 1} x_i$. Imposing binding capital requirements, the bank's problem can be framed as a choice of how much equity to raise in order to maximise pure profits or, equivalently, the cash flows that accrue to inside equity:

$$\max_{n_i} \frac{n_i}{\gamma} \left(\alpha \left(\frac{n_i + \sum_{j \neq i} n_j}{\gamma} \right)^{\alpha - 1} - q(1 - \gamma) \right) - n_i(1 + z).$$

The first order condition is given by

$$\frac{1}{\gamma} \left(\alpha \left(\frac{n_i + \sum_{j \neq i} n_j}{\gamma} \right)^{\alpha - 1} - q(1 - \gamma) \right) + \frac{n_i}{\gamma} \left(\alpha \frac{1}{\gamma} (\alpha - 1) \left(\frac{n_i + \sum_{j \neq i} n_j}{\gamma} \right)^{\alpha - 2} \right) = (1 + z).$$

In equilibrium banks are symmetric so $n_i = n_j = n^*(\gamma)$. Hence, we obtain the standard result that banks demand a return on loans that is a fixed markup over a term that can be interpreted as a marginal cost:

$$\underbrace{\alpha\left(\frac{\nu n^*(\gamma)}{\gamma}\right)^{\alpha-1}}_{\text{return on loans}} = \left(1+\underbrace{\frac{1-\alpha}{\alpha+(\nu-1)}}_{\text{markup}\equiv\mu}\right)\underbrace{(\gamma(1+z^*(\gamma))+(1-\gamma)q)}_{\text{marginal cost}\equiv\text{MC}^*(\gamma)} \tag{31}$$

In equation 31, $1+z^*(\gamma)$ is the equilibrium cost of outside equity. At the same time, deposits are only repaid by the bank with probability q at a gross rate of unity. Given γ is the portion of equity (versus deposit) finance, this leads to the intuitive expression for marginal cost of funds: $\text{MC}^*(\gamma) = \gamma(1+z^*(\gamma))+(1-\gamma)q$.

Given this markup, pure profits for an individual bank are

$$\pi^*(\gamma) = \mu\text{MC}^*(\gamma)x^*(\gamma),$$

where $x^*(\gamma)$ is the equilibrium level of lending. We can now show that π^* decreases with γ. We have that

$$\frac{d\pi^*}{d\gamma} = \mu\left(\frac{dx^*}{d\gamma}\text{MC}^*(\gamma)+\frac{d\text{MC}^*}{d\gamma}x^*(\gamma)\right).$$

Noting $x^*(\gamma) = \frac{n^*(\gamma)}{\gamma}$ and applying the implicit function theorem to equation (31) we obtain

$$\frac{dx^*}{d\gamma} = \frac{\frac{d\text{MC}^*}{d\gamma}x^*(\gamma)}{(\alpha-1)\text{MC}^*(\gamma)}.$$

Hence

$$\frac{d\pi^*}{d\gamma} = \mu\frac{d\text{MC}^*}{d\gamma}x^*(\gamma)\underbrace{\left(\frac{\alpha}{\alpha-1}\right)}_{<0}.$$

So, it is sufficient to show that $\frac{d\text{MC}^*}{d\gamma}$ is always positive. Now,

$$\frac{d\text{MC}^*}{d\gamma} = 1+z^*(\gamma)-q+\kappa\gamma M^*(\gamma)\frac{dM^*}{d\gamma}.$$

Using Proposition 2 and noting that $N^*(\gamma) = \nu\gamma x^*$, we have

$$\frac{dM^*}{d\gamma} = \frac{dN^*}{d\gamma} + \frac{dN'^*}{d\gamma} = \nu\left(1 - \mathrm{SP}^*\right)\left(x^*(\gamma) + \gamma\frac{dx^*}{d\gamma}\right).$$

Note that to appeal to Proposition 2, we just require that investors in outside equity equate the return on outside equity to $1 + z$ in both countries. We do not need to specify the competitive environment in Foreign.

As a result, we have that

$$\frac{d\mathrm{MC}^*}{d\gamma} = 1 + z^*(\gamma) - q + \kappa\gamma\nu M^*\left(1 - \mathrm{SP}^*\right)\left(x^* + \gamma\frac{dx^*}{d\gamma}\right),$$

or

$$\frac{d\mathrm{MC}^*}{d\gamma} = \left(1 + \frac{\kappa\gamma^2\nu M^*\left(1 - \mathrm{SP}^*\right)}{(1-\alpha)\mathrm{MC}^*(\gamma)}\right)^{-1}\left(1 + z^*(\gamma) - q + \kappa\gamma\nu M^*\left(1 - \mathrm{SP}^*\right)x^*\right).$$

Inspecting terms it is straightforward to verify that MC^* is always increasing in γ.

To give the intuition for this result, note that an increase in γ affects MC^* through two channels. First, it causes a switch in the composition of liabilities from deposits to capital. As the latter is a more expensive form of finance from the Bank's point of view this raises marginal cost. Second, the change in the capital requirement generates a change in the demand for equity capital. When the increase in requirements causes banks to raise more equity, this simply causes a further increase in marginal cost. When the increase in requirements causes banks to raise less equity, this mitigates the increase in MC^* associated with the composition effect, but cannot overturn it, otherwise we would get a contradiction: there would be higher capital requirements, higher lending, yet less equity in equilibrium (this also follows from the proof of Lemma A3).

In turn, this implies Bank pure profits are strictly decreasing in the capital requirement. The markup means that while higher costs can be offset by higher revenues, the offset can never be complete. Moreover, the decline in profits is increasing in the markup hence a less competitive banking sector would be more averse to an increase in capital requirements.

C.2 The externality when regulators treat equity capital as socially costly

In our example objective function (equation (14)), the regulators treated the cost of raising equity capital as a private cost. Hence, from the regulator's perspective, the economic surplus from domestic lending was $X^\alpha - X$.

If, on the other hand, equity capital is considered socially costly, then the excess cost of the equity capital used to fund the lending (i.e. $z^* N^*$ in the case of home) should also be deducted from the objective. Putting this together leads to an alternative objective in the same family as those discussed in Section 6.1:

$$\pi(N^*, \gamma, \gamma') = \widetilde{\text{NDP}}(N^*/\gamma) - \widetilde{L}(N^*/\gamma, N^*) - z(N^*, \gamma, \gamma')N^*,$$

where $z(N^*, \gamma, \gamma') = \frac{\kappa}{2}\left(\max\left\{N^* + N'(\gamma, \gamma') - \omega, 0\right\}\right)^2$. The externality is then given by

$$\pi_\gamma'^*(\gamma', \gamma) = \frac{dN'^*}{d\gamma}\pi'_{N'}(N^{*\prime}, \gamma', \gamma) - \frac{dN^*}{d\gamma} z_N^* N'^*, \tag{32}$$

the second term captures that a change in γ alters Home demand for equity which raises the cost of capital in Foreign. This imposes an additional cost on Foreign unrelated to the direction of the capital flow.

However, we can go further to obtain a better understanding of how internalising the cost of equity changes regulators' strategic incentives relative to objective (14). First, we can develop $\pi'_{N'}(N^{*\prime}, \gamma', \gamma)$ to obtain:

$$\pi'_{N'}(N^{*\prime}, \gamma', \gamma) = \frac{\widetilde{\text{NDP}}_X^* - \widetilde{L}_X^*}{\gamma} - \widetilde{L}_N - z_{N'}^* N'^* - z(N^*, \gamma, \gamma').$$

Second, from Proposition 2, we know that $\frac{dN^*}{d\gamma} = -\frac{1}{\text{SP}^*}\frac{dN'^*}{d\gamma}$. Third, we have that $z_N = z_{N'}$. Substituting these expressions into equation (32) with we obtain:

$$\pi_\gamma'^*(\gamma', \gamma) = \frac{dN'^*}{d\gamma}\left(\frac{\widetilde{\text{NDP}}_X^* - \widetilde{L}_X^*}{\gamma} - \widetilde{L}_N\right) - \frac{dN'^*}{d\gamma}\left(z^* - \frac{1 - \text{SP}^*}{\text{SP}^*} z_{N'}^* N'^*\right). \tag{33}$$

Now we see that $\frac{dN'^*}{d\gamma}$ multiplies two terms in brackets in equation (33). The first term corresponds precisely to how socially valuable a unit of capital would be to the Foreign regulator if it operated with an objective given by equation (14). We have argued this is typically positive.

The second term in brackets captures all additional effects running through the cost of equity. The term reflects both that a marginal unit of new equity has an excess cost z^*; so if $\frac{dN'^*}{d\gamma}$ is positive there is a direct negative consequence on Foreign. And that, in equilibrium, investing a marginal unit in Foreign in response to a change in γ would require global demand for new equity to fall by a factor $\frac{1-\mathrm{SP}^*}{\mathrm{SP}^*}$; this lowers z^*, benefiting Foreign. On balance then, the second term is ambiguous in sign.

Overall, the key point that emerges from this analysis is that the mechanisms described in Section 5 under objective (14) are still present even when the regulator internalises the cost of equity. In this case, what we see are additional forces that may mitigate or reinforce the externality arising from capital flows identified in the main text.