Four Essays on Capital Regulation of Banks

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The Essays

This collection of essays analyzes optimal capital requirement regulation and its effects on the incentives of stakeholders.

The first essay, written together with my supervisor Roland Kirstein was recently published in the Journal of Money Credit and Banking. It analyzes under which conditions a binding capital requirement reduces the incentives of banks to undercut in prices. Based on the strategic capacity commitment model of Kreps and Scheinkman (1983) we show that if the immediate recapitalization insufficiently costly, capital requirement regulation induces banks that compete in Bertrand competition to behave like Cournot competitors. Formally, the binding capital regulation changes the strategic price setting Bertrand game into a two stage game, where banks first have to commit to a loan supply capacity before they compete for loan interest rates. This decreases the loan supply and increases loan interest rates, resulting in higher profits for banks compared to the unregulated case. In this thesis, I add the online appendix to the published version that provides all the proofs of the propositions. This appendix was not part of the publication due to capacity limits within the journal.

The second essay builds on the results of the first essay and analyzes the impact of reduced competition on the efficiency of capital requirement regulation in establishing financial stability. It is shown that if the markets are concentrated, i.e., there are only few banks, the possibility to commit for capacities and the resulting gain of price setting power can increase the efficiency of capital regulation compared to the efficiency under perfect competition.

The third essay is an equally shared work with Florian Buck from the LMU München, which is accepted for publication in the Journal of Banking and Finance. In this paper we analyze the efficient mix of capital regulation and banking supervision. We show that both instruments are substitutes within a feasible set. If we allow for regulatory competition our model shows that the implementation of the optimal policy is not feasible. An agreement on international minimum capital standards may reduce the inefficiencies of international competition among regulators. However, a harmonized capital regulation may reduce the average supervisory effort.

The fourth essay concentrates on the regulator's incentives to implement optimal risk weighted capital requirements for risky and safe assets, i.e., government bonds. I show that a regulator that simultaneously regulates the banking sector while also borrowing from the sector is confronted with a conflict of interest. As a result a regulator with fiscal interest may set the risk weight for risky assets to high compared to the weight for government bonds. By doing so the banks' demand for government bonds is increased. This eases government spending. Therefore, the government regulator can indirectly influence his refunding conditions and increase government spending.

Essay I

Strategic Effects of Regulatory Capital Requirements in Imperfect Banking Competition

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Strategic Effects of Regulatory Capital Requirements in Imperfect Banking Competition

This paper analyzes the competitive effects of regulatory minimum capital requirements on an oligopolistic loan market. Before competing in loan rates banks choose their capital structure, thereby making an imperfect commitment to a loan capacity. It is shown that due to this imperfect commitment, regulatory requirements not only increase the marginal cost of loan supply, but can also have a collusive effect resulting in increased profits. This paper derives the threshold value from which capital requirements can turn one round Bertrand competition into a two-stage interaction with capacity commitment, leading to Cournot outcomes. Therefore, it provides theoretical support for the applicability of the Cournot approach when modeling imperfect loan competition.

JEL codes: G21, K23, L13
Keywords: capital regulation, oligopoly, capacity constraint.

We examine the likely anticompetitive effect of capital requirement regulation, as introduced by the international banking regulation under the Basel accords, which has not been examined in the previous literature. A sound banking system is essential for ensuring economic wealth and stability. Since the banking sector is particularly vulnerable to inefficient bank runs and contagion resulting in

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bank panics, the overall aim of banking regulation is to secure financial stability by minimizing the likelihood of bank runs *ex ante*, and reducing *ex post* contagion when banks fail. To achieve this goal, most countries have introduced a governmental safety net, which includes deposit insurances, and lender of the last resort practice as well as bailout policies. The undesirable secondary effect of such a safety net is the destruction of market discipline, thereby providing strong moral-hazard incentives to exploit the option value of the safety net. Greenbaum and Thakor summarize this idea as follows:

> The moral hazard engendered by one form of regulation, namely deposit insurance, creates the need for other forms of regulation such as capital requirements. (Greenbaum and Thakor 1995, p. 103)

The intuition is that well-capitalized banks have fewer incentives to increase asset risks. A bank endowed with more capital is less likely to exploit the option value of the deposit insurance, thereby reducing the probability of banking default. However, if a binding equity regulation is introduced (or tightened), then banks have to either reduce their assets or increase their capital. In the short run, an immediate increase in capital in order to match the regulatory requirement may prove costly or even impossible. Therefore, the immediate effect of increasing the capital requirements is likely to cause a reduction in the total supply of loans and, accordingly, an increase in the loan interest rate.

Our paper demonstrates that a binding regulatory capital requirement may alter the sequence in which strategic decisions are made since it constrains a bank's lending activities in the short run. This is in line with Brander and Lewis (1986), who analyzed the strategic impact of leverage decisions on output decisions. They argued that increases in a firm's leverage enhance the output level of the firm in a Cournot oligopoly with random demand. In contrast, we concentrate on the effects of a strategic capital choice in a deterministic Bertrand competition and examine the impact of a capital commitment on the fierceness of the loan rate competition. In the first stage, the capital regulated banks decide on their refunding structure, which consists of equity and deposits. In the second stage, loan rate competition takes place while the bank's ability to satisfy the demand resulting from the loan rate decision is conditioned by the amount of capital raised and the capital requirement regulation. If recapitalization is costly, then the capital decision in the first stage is an imperfect commitment to capacity for bank loans. Applying the model developed by Maggi (1996) to a bank loan market, we analyze the effects of a capital requirement regulation on the strategic behavior of oligopolistic banks. We show that if the cost of recapitalization is above an identified threshold, banks would no longer have an incentive to undercut each other in the second-stage loan rate competition. Due to the binding precommitment to a loan capacity, the Bertrand loan rate competition results in Cournot–Nash equilibrium outcomes. Our comparative static analysis shows that an increase in the regulatory capital requirement decreases the threshold that makes a first-stage capacity decision binding. In other words, if the capital requirement is higher, the commitment to a loan capacity is more binding.

Just as this collusive effect,[1] the increase in banks' marginal cost caused by capital regulation would reduce total lending. However, in contrast to such a cost effect, the collusive effect is likely to enhance bank profits.

This paper is organized as follows. Section 1 gives a short overview of the existing theoretical literature, which analyzes the impact of capital regulation and the strand of literature in industrial organization that is concerned with strategic commitment to a certain capacity in oligopolies. Section 2 introduces the basic model setup and discusses the conventional model of Cournot quantity competition that is often used in the IO banking literature to analyze imperfect competition among banks. Section 3 introduces our adaptation of the two-stage capacity loan rate competition for the banking market, and also shows how we derive the main results. In Section 4, we discuss the implications of our results and show that the main results of our analysis remain valid in a dynamic context where we allow for entry into the banking market.

1. LITERATURE REVIEW

The actual impact of a regulatory capital requirement on the individual behavior of banks and the individual incentives to take excessive risk is not undisputed in the banking literature. Berger, Herring, and Szegö (1995), Santos (2001), and Van Hoose (2007) provide comprehensive reviews of the theoretical literature regarding the impact of capital requirement regulation. Irrespective of the ambiguous theoretical predictions, there is a general consensus in the literature that higher capital has a positive direct effect on the balance sheet structure, as discussed by Van Hoose (2008). This bank default reducing effect is most often analyzed in a perfect competitive environment, but is also valid in a Bertrand oligopoly. Carletti (2008) points out that the majority of papers on banking regulation merely compare the equilibria of the two extreme market structures: a monopoly case and perfect competition. These models therefore lack the consideration of strategic interaction between financial intermediaries.

However, the empirical evidence suggests that imperfect competition is an important feature of most banking sectors: Berger et al. (2000) find empirical evidence that banks in the United States made consistent profits between 1970 and 1997. Barajas et al. (2010) apply the Rosse–Panzar (1987) H-test to the data of the holding companies of large banks and reject the two extreme hypotheses of competitive and monopolistic behavior in the banking industry.

A few theoretical papers that actually consider strategic interaction among banks model imperfect competition as oligopolistic, quantity-setting models in the Cournot fashion. VanHoose (1985) analyzes the effects of increased bank competition on the ability of a central bank to pursue monetary policy. Pecchenino (1983) models

1. We call this effect "collusive" in the sense of spontaneous tacit collusion that results from a noncooperative Nash equilibrium and that does not expressive any actual coordination among the competitors.

heterogenous banks that differ in risk tolerance and make decisions concerning both the size and risk level of their portfolios, while their individual actions have spillover effects on the actions of other banks. Boyd and De Nicolo (2005) model imperfect competition for loans à la Cournot in order to analyze the impact of competition on the risk that a bank takes when borrowers are able to influence the risk level of the bank's assets. Rime (2005) models Cournot loan market competition to analyze the coexistence of the very risk-sensitive capital regulation under the internal ratings-based approach in Basel II and the more risk-insensitive requirements under the standard approach. He shows that sophisticated banks will specialize in low-risk customers, whereas unsophisticated banks specialize in high-risk loan customers. The application of oligopolistic quantity competition to loan supply in which banks offer a certain amount of loans to the market and then demand for loans determines the equilibrium loan rates, appears counterintuitive. In fact, one expects banks to offer loan contracts that specify the loan rates, while prospective borrowers look for the best loan contract conditions and demand the loan from the bank with the best conditions (lowest interest rates).

We argue that modeling competition between banks à la Cournot might be justified because of a two-stage game, where banks first commit to loan capacities and then compete in loan interest rates brings about the Cournot competition results. The basic idea goes back to Edgeworth (1925), who emphasizes that due to exogenous capacity constraints, Bertrand oligopolists may not be able to serve the whole market demand and therefore would not undercut each other in prices until a competitive equilibrium is reached. Kreps and Scheinkman (1983) generalize this idea for an endogenous capacity choice. In their two-stage model, the oligopolists first compete in capacities, followed by a competition in prices, which is strictly constrained by the prior capacity decision. Kreps and Scheinkman conclude that when firms commit to a certain capacity of production before price competition takes place, the capacity and prices chosen in equilibrium are identical to the Cournot equilibrium. The question that arises is whether such a rigid capacity constraint can be applied in the case of lending competition among banks. Freixas and Rochet (1997) even state that a capacity constraint may not be feasible as a starting point for a theoretical analysis in the context of banking.

However, Freixas and Rochet (1997) may have overlooked that binding regulatory capital requirements can indeed affect the nature of strategic competition among banks. Following Berger, Herring, and Szegö (1995), we define capital requirements to be binding if the capital ratio in the presence of regulatory capital requirements is greater than the bank's market capital requirement. In particular, as mentioned by Gehrig (1995), if short-term recapitalization is costly, then capital requirements temporarily limit a bank's lending activities and thereby soften loan interest rate competition.

Empirical observations suggest that many banks do hold a capital ratio that is above the minimum capital requirement. For example, Berger, Herring, and Szegö (1995) show that the observed capital to asset ratios varied considerably over time. Flannery and Rangan (2008) report that banks' capital-to-asset ratios increased significantly during the 1990s. Bolton and Freixas (2006), as well as Chami and Cosimano (2010), offer a theoretical explanation based on dynamic considerations for the excess capital. It is optimal for banks to hold a certain buffer above the regulatory minimum capital requirement in order to avoid violating the regulatory constraint. Taking this into account, a binding capital constraint can also be interpreted as a bank-specific optimal capital ratio, which is the sum of the regulatory capital requirement and the optimal buffer. For a detailed comparison of regulatory and actual capital ratio, see Elizalde and Repullo (2007).

Empirical support of such a view on optimal capital ratios is provided by Barajas et al. (2010). Analyzing bank lending behavior during the 2007–09 financial crisis, they find strong evidence that banks optimally choose their capital structure in the anticipation of future loan demand. Further, they find support that the lending decisions during the crisis were constrained by capital rather than liquidity. Moreover, the recent quantitative impact study (QIS) by the Basel Committee (2010) concludes that banks are usually endowed with too little capital to fulfill the regulatory capital requirement, which suggests that the regulatory capital requirement is indeed binding.

In our static model, we focus on the endogenous choice of capital that, with binding capital constraints, may limit the lending capacity. We analyze the assumptions that contribute to a strategic choice of capital through which the Bertrand competition results in a sequential game with Cournot outcome. With regard to our main result, which is the potentially anticompetitive effect of capital regulation, it does not matter whether banks comply with the actual regulatory capital requirement or consider it optimal to add a constant buffer.

We deviate from the model of Kreps and Scheinkman (1983) and allow the oligopolistic banks in our framework to extend their capacities through urgent recapitalization measures, but this can only be done at higher cost. This assumption reflects the idea that a sudden need to increase capital may turn out to be costly. Empirical evidence for this idea can be found in the recent financial crisis: it was observed that some banks faced difficulties in replacing lost capital in a timely fashion. Calomiris and Herring (2012) discuss the problems that Citigroup and other financial institutions faced in 2008 when they had to raise additional capital in order to comply with capital requirements. Despite the urgent need to replace lost capital in 2008, institutions preferred to wait. They mention that stock prices were so low that issuing significant amounts of stocks in order to cover the large losses incurred would have implied substantial dilution of stockholders including existing management. These observations support our assumption that bank managers try to avoid an immediate increase of capital in order to satisfy market demand and rather prefer to reduce the demand for loans by increasing the loan rate.

The distinction between short run and long run, or as more specifically shown in our model, between the strategic long-term decisions made in the first stage and the short-term decisions in the second stage reflects exactly the cost of raising capital. On the one hand, the first-stage decision regarding the refunding structure is a strategic decision, which is made over a long-term horizon; that is, raising capital is not costly. On the other hand, it can be rather costly if there is an urgent need to raise additional equity as illustrated by the Citigroup example. The time horizon in which management tries to avoid modifications of the refunding structure is defined in our paper as "short term."

In the industrial organization literature, the impact of a flexible capacity constraint on Bertrand competition has been discussed by Gueth (1995) and Maggi (1996) for differentiated product markets. Both studies argue that capacity constrained Bertrand competition yields a Cournot outcome for sufficiently high additional costs of the capacity extension in the second stage. In the case of capital regulated banks, the decision-making process of banks cannot be reduced to the buildup and extension of production capacities. Rather, we have to derive the banks' optimal financial structure. We show that the best response functions of capital regulated banks are far more complex in our model than those of capacity constrained firms in the context of Gueth (1995), Maggi (1996), and Kreps and Scheinkman (1983). However, our analysis shows that the response functions in the neighborhood of a unique subgame perfect equilibrium are functionally similar to the capacity constraint response functions derived by Gueth and Maggi. We thereby show that a constraint on the financial structure of loans in Bertrand competition can lead to the Cournot outcomes in a way that is similar to a classical production capacity constraint.

By allowing for product differentiation, our model avoids one of the main shortcomings for which the Kreps and Scheinkman (1983) model has been criticized. In their model, they assume that firms compete in a homogeneous product market, which makes it inevitable to define a rationing rule that determines the specific demand addressed to each supplier. The shortcoming is that the derived results are not robust with regard to changes in the specific rationing rule as proven by Davidson and Deneckere (1986). Assuming product differentiation is not only reasonable in the relationship bank lending context, but also provides the means for accurately defining the demand of each bank in the second stage for any loan rate pair, the results do not depend on a specific rationing rule. Yet, in order to generalize our results, we allow the degree of heterogeneity between banks to be close to zero and show that our results still hold.

The theoretical setup closest to our research was modeled by Chami and Cosimano (2010). They use a dynamic model to analyze the impact of monetary policy on imperfect loan rate competition under capital regulation. The impact of capital regulation on the strategic interaction among banks setting loan rates is captured in a cooperative supergame of oligopolistic behavior in the fashion of Abreu, Pearce, and Stacchetti (1990). The authors conclude that the threat of a constraint on lending capacity also restricts the achievable profit from reneging on the coordinated loan rate policy. Hence, capital requirements reinforce the existing collusive behavior among banks in the dynamic cooperative supergame. Since the analysis carried out by Chami and Cosimano concentrates on the impact of the monetary policy on loan rate competition, the existence of collusive behavior is simply assumed but not endogenously derived. In contrast, our paper provides an argument of how collusive behavior may occur in the first place, that is, as a result of the capital requirement regulation.

2. MODEL SETUP

2.1 Basic Definitions

Consider a loan market with two identical banks. These banks try to maximize their profits by investing in loans that they refund with insured deposits and own resources, that is, capital. We assume that all parties are risk neutral and the bank management is acting in the best interest of the owner(s). Banks can only invest in loans (L) demanded by the representative borrowers of one risk class. The investment in assets is financed by deposits (D) and equity capital (e). This implies the balance sheet constraint:

$$L \leq e + D. \tag{1}$$

The constraint is binding if banks maximize profits and cash yields no returns.

We assume that banks compete in imperfect loan rate competition. For simplicity, we concentrate on the case of two banks that are labeled with the indices $i, j = 1, 2$; $i \neq j$, even though the results could be generalized to the case where there is an arbitrary number of banks. Boccard and Wauthy (2000), for instance, develop a generalization of Kreps and Scheinkman (1983) with regard to the oligopoly case with $n \geq 2$ competitors.

Like in the Maggi (1996) model, we use a standard linear representative consumer model with product differentiation to describe the borrowers' demand for loans. Adapting the model developed by Matutes and Vives (2000), we assume that there is a continuum of borrowers of the same type whose utility can be described by a representative utility function.[2] The following lemma summarizes the demand structure.

LEMMA 1. *If there exists a continuum of homogenous borrowers whose utility can be described with a representative utility function of the form $U(L_1, L_2) = m + a(L_1 + L_2) - \frac{b}{2}(L_1^2 + L_2^2) - dL_1L_2$, one can derive a generalized inverse demand function:*

$$r_i(L_i, L_j) = a - bL_i - dL_j, \tag{2}$$

provided that both banks do not ration their customers and make nonnegative profits, the direct demand function is defined as

$$L_i(r_i, r_j) = \frac{a}{(b+d)} - \frac{br_i}{(b^2 - d^2)} + \frac{dr_j}{(b^2 - d^2)}. \tag{3}$$

2. To keep our results tractable, we abstract from different risk types of borrowers. In this respect, our model describes the rather risk insensitive capital requirement regulation under Basel I and the Standard Approach in Basel II (III); for example, our model describes a commercial bank lending to small- and medium-sized enterprises. An explicit modeling of different risk classes as in the IRB Approach of Basel II and III is beyond the scope of this paper.

PROOF. An appendix containing the derivation of the linear differentiation model from a representative consumer's utility function is provided online and by the authors upon request.[3] □

In (2), r_i represents the loan interest rate of bank i, and L_i represents the total lending of bank i to borrowers. It is assumed that $a > b > d \geq 1$.[4] If d were negative, the loans offered by the competing banks would be complements and if $d = 0$, the two loans would be independent in demand. If $d \to b$, the loans become perfect substitutes. In our analysis, we concentrate on the more general case of a heterogeneous market; therefore, we do not have to invoke a specific customer rationing rule. The heterogeneity could emerge from the reputation of the bank, the specific service offered to the borrower or relationship banking combined with a switching cost for borrowers. Yet, one can argue that bank loans are rather homogeneous goods. Therefore, we will also consider the particular case $d \to b$ in our analysis.

It is further assumed that banks only choose loan rates that result in nonnegative profits. This assumption is taken into account by introducing nonnegativity constraints into the profit maximization problem: $br_i - dr_j \leq a(b - d)$ and $dL_j \leq a - bL_i$. Provided that these constraints are not violated, the inverse demand function can be inverted[5] to obtain the direct demand function.

Like Dixit and Norman (1985), we assume in our analysis that a firm is willing to meet any level of demand beyond its installed capacity provided that the loan rate is above the additional cost of extending the capacity. Thus, rationing is excluded from our analysis.

2.2 *The Cournot Duopoly*

Later, we want to show the conditions under which the equilibrium of the two-stage Bertrand game with capacity choice (presented in Section 3) is identical to the outcome of a Cournot game. In order to be able to compare the results of the two-stage game, we derive the general Cournot equilibrium outcome in the following. If banks compete in quantities and the marginal cost of providing loans is x, bank i's profit function is

$$\Pi_i = (r_i(L_i, L_j) - x)L_i. \tag{4}$$

Inserting (2) into (4) leads to the first-order condition

$$2bL_i + dL_j = a - x. \tag{5}$$

3. The stable url is: http://rolandkirstein.de/jmcb/appendix.pdf.

4. Under the assumption of symmetric marginal cost and linear demand, the symmetry of second derivatives (Young's theorem) requires that the parameter d is equal for both banks. This can only be true if parameters a and b are also equal for both banks.

5. The inversion is allowed under the assumption that both firms always satisfy their demand, otherwise the quantity demanded of one firm is a function of the residual demand left by the rationing opponent. See Boccard and Wauthy (2000) for an analysis of the robustness of the Gueth Maggi results when firms are allowed to ration their customers. Furthermore, these equations are only valid for $b \neq d$.

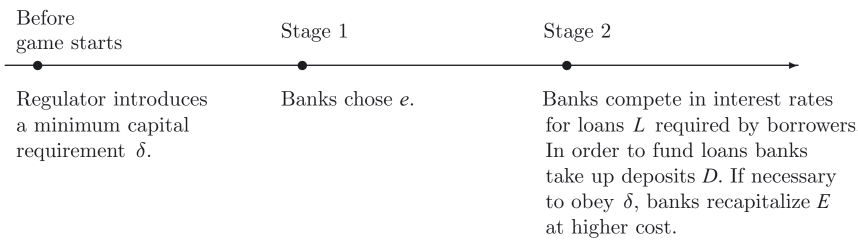

FIG. 1. The Timeline of the Decisions Taken.

This gives the best response function in quantities

$$R_i^C(L_j) = \frac{(a-x) - dL_j}{2b}, \tag{6}$$

which results in the symmetric Cournot equilibrium outputs

$$L^C(x) = \frac{(a-x)(2b-d)}{(2b)^2 - d^2} = \frac{a-x}{2b+d}. \tag{7}$$

The corresponding symmetric Cournot equilibrium interest rates are

$$r^C(x) = \frac{ab + (b+d)(x)}{2b+d} = x + \frac{b(a-x)}{2b+d}. \tag{8}$$

The resulting Cournot equilibrium payoff for each bank is

$$\Pi^c(x) = \frac{b(a-x)^2}{(2b+d)^2}. \tag{9}$$

3. THE TWO-STAGE MODEL

In order to analyze which parameter constellations of the minimum capital requirement regulation allow for Cournot equilibrium outcomes under loan rate competition, we model the loan rate competition as a two-stage game in which banks raise capital in the first stage and compete by setting loan rates in the second stage.

The timeline of our model is illustrated in Figure 1. In stage 0, the regulator sets up a certain minimum capital requirement rate. Knowing this rate, the banks raise capital in stage 1 in order to take part in the loan rate competition in stage 2. Based on the minimum capital requirement regulation, the amount of capital then determines a capacity for providing loans to borrowers of a certain risk class.[6] In the second

6. To keep the model simple, we neglect the default probabilities of assets. However, the basic results derived from our model will hold as long as banks invest in a fixed loan portfolio composition.

stage, the banks compete in rates that turn into loan quantities demanded by the borrowers.

As Tirole (1988) mentions, the Bertrand and Cournot model should not be seen as two different models, which predict contradictory outcomes of imperfect competition. The models rather describe the same markets with different cost structures. A change in the cost structure can transform a Bertrand competition into a two-stage game with Cournot outcomes. In order to understand how capital requirement regulation influences loan rate competition among banks, we now focus on the cost structure that results from a minimum capital requirement regulation under the basic assumptions of our model.

3.1 Equity Regulation and Capacity

The investment in assets in our two-stage model is financed by deposits raised in the second stage (D), as well as capital raised in the first stage (e) and capital raised in the second stage (E) at a higher cost. This implies the extended balance sheet constraint:

$$L \leq e + E + D. \tag{10}$$

We assume that depositors are fully insured against default at a premium normalized to zero. This assumption, which is often made in the literature (e.g., Boot and Marinc 2006, Wagner 2010) allows us to neglect competition on the deposits market because insured depositors are insensitive to the bank's exposure to risk and are ready to supply any amount of deposits at a deposit rate r_D. We assume that the expected rate of return on capital is higher than the return on insured deposits. This is a common assumption in the literature (e.g., Holmström and Tirole 1993, Diamond and Rajan 2000, Hellmann, Murdock, and Stiglitz 2000, Repullo 2004, Hakenes and Schnabel 2007). However, this assumption is not undisputed. We take a closer look at the discussion regarding the cost of capital, since the assumptions we make on the refunding cost structure of bank loans are essential for the outcome of our model.

In our model, the cost of capital represents the average return per unit of capital that the bank has to credibly promise to capital holders so as to induce them to provide equity. This average payment has to exceed the riskless rate on deposit funding.

Admati et al. (2010) refute the assumption that bank capital is costly to society. They examine the macroeconomic perspective of capital cost, whereas we take a business economics view in assuming that capital financing is more costly than deposit funding to a specific bank. From the perspective of a single bank, factors like tax disadvantages, agency conflicts, and the incentive effects of the banking safety net implicate that the Modigliani–Miller theorem may not hold, which means that capital financing is more expensive than debt financing per unit, irrespective of the time horizon. Empirical evidence that the cost of capital is indeed above the cost of debt financing can be found in Kashyap, Stein, and Hanson (2010) and Cosimano and Hakura (2011).

If capital financing were not expensive, banks would be indifferent with respect to whether they fund their loan investments with deposits or capital. They would therefore be willing to finance loans even with 100% capital, and there would be no need for a minimum capital requirement regulation. By assuming the marginal cost of capital to be $r_e = r_D + c$, where $c > 0$ reflects the expected premium of capital investors, we exclude this case.

Moreover, we assume that it is more costly to acquire additional capital in stage 2. As Kashyap, Stein, and Hanson (2010) point out, raising capital might create flow costs. This cost may consist of the rate difference of urgently issued shares, as argued by Berger, Herring, and Szegö (1995), or the cost of organizing an additional general assembly. The cost can also be interpreted as a time constraint, highlighting the fact that an immediate increase of capital would be impossible, while loan rates could be adapted immediately.

In contrast to gradually accumulating capital by retaining earnings, an immediate issue of new public capital may create significant costs because it might be interpreted as a negative signal. This was first pointed out by Myers and Majluf (1984). We adopt this assumption in our framework by defining $r_E = r_e + \theta$ with $\theta > 0$. If short-run recapitalization is impossible, then $\theta \rightarrow \infty$. However, to secure strictly positive profits, we assume that the reservation loan interest rate is higher than the cost of equity: $a > r_E$.

We consider two stages of decision making. These stages are defined by the nature of the cost of capital. The first-stage decision-making process captures the long-term planning horizon of a bank.[7] In this stage, decisions on retained earnings can be made. Hence, the flow cost of capital is low and the bank faces only the cost of holding capital on the balance sheet. After these long-term decisions have been irrevocably made, we consider a second stage in which increasing capital requires additional cost. This assumption is justified if banks can raise additional capital during the second stage only by issuing new equity, which creates higher flow costs.

Under capital regulation, banks are forced to refund a percentage of their assets with capital. We denote this percentage as the minimum capital requirement $\delta \in [0, 1]$. Hence, regulation requires in the second stage $e + E \geq \delta L$. At the beginning of the second stage, holding capital e results in a capacity commitment to the maximum amount of loans the bank is allowed to invest in loans $L = \frac{e}{\delta}$. This capacity commitment defines a constraint above which additional recapitalization costs have to be paid. If a bank plans to give out loans $L > \frac{e}{\delta}$, the bank has to raise additional capital E at an expected rate r_E. However, the bank is forced to cover only a share δ of the additional loans $(L - \frac{e}{\delta})$ with capital and the remainder with deposits. Hence, E is determined by

$$E = \delta \max\left\{L - \frac{e}{\delta}; 0\right\} = \max\{\delta L - e; 0\}. \tag{11}$$

7. Like in standard macroeconomic theory we refer to "long term" not in a temporal meaning, but in the sense that all factors of production can be freely chosen, while the "short term" is defined as the planning horizon where at least one factor of production is fixed.

Note that with infinite recapitalization cost θ the bank is unable to raise additional capital in the second stage. Such a setting reflects a rigid capacity constraint as presented in Kreps and Scheinkman (1983). In our model, we generalize the idea to an imperfect capacity constraint with finite recapitalization cost $\theta > 0$. In the next section, we solve the two-stage game by backward induction.

3.2 *The Second-Stage Bertrand Competition*

Marginal cost of a bank under equity regulation. In the second stage, the capacity $\frac{e}{\delta}$, defined by the first-stage capital decision, is an exogenous condition of the loan rate decision. We first determine the cost and marginal cost function of a bank that provides loans L.

LEMMA 2. *A capital regulated bank that has raised capital in the first stage faces the following piecewise-defined cost function at the beginning of the second stage:*

$$C(L) = \begin{cases} r_e e & \text{if} \quad L \le e \\ r_D L + ce & \text{if} \quad e < L \le \dfrac{e}{\delta} \\ (r_D + c\delta)L + \theta(\delta L - e) & \text{if} \quad L > \dfrac{e}{\delta}. \end{cases} \tag{12}$$

PROOF. For brievity, the proof is included in an appendix that is available online.[8] □

From Lemma 2, we can easily derive the marginal cost by differentiation (note that $C(L)$ is not differentiable at $L = e$ and $L = \frac{e}{\delta}$).

COROLLARY 1. *In the second stage, the bank faces the following piecewise-defined marginal cost function*

$$MC(L) = \begin{cases} 0 & \text{for} \quad L < e \\ r_D & \text{for} \quad e < L < \dfrac{e}{\delta} \\ r_D + (c + \theta)\delta & \text{for} \quad L > \dfrac{e}{\delta}. \end{cases} \tag{13}$$

If the loan demand is low ($L \le e$), no marginal cost arises since the cost of capital is sunk in the second stage. If $e < L \le \frac{e}{\delta}$, the marginal cost equal the cost of deposits. Lending above the loan capacity requires banks to increase their capital. Thus, the marginal cost of providing additional loans is a combination of the marginal cost of additional capital $(c + \theta)$ plus the deposit interest rate.

Denoted as $r_i^{e_i}(r_j)$ and $r_i^{e_i/\delta}(r_j)$, the loan rate of bank i is implicitly defined by $L_i(r_i^{e_i}(r_j), r_j) = e_i$ and $L_i(r_i^{e_i/\delta}(r_j), r_j) = e_i/\delta$. At these critical loan rates, the residual loan demand for bank i for a given loan rate of the opponent r_j equals the

8. The stable url is: http://rolandkirstein.de/jmcb/appendix.pdf.

fixed capital e_i and the loan capacity e_i/δ, respectively. The closed-form expressions for the critical loan rates are:

$$r_i^{e_i}(r_j) := \frac{(b-d)a - (b^2 - d^2)e_i + dr_j}{b} \tag{14}$$

$$r_i^{e_i/\delta}(r_j) := \frac{(b-d)a - (b^2 - d^2)\frac{e_i}{\delta} + dr_j}{b}. \tag{15}$$

Note that for a given r_j and e_i, it must hold that $r_i^{e_i}(r_j) > r_i^{e_i/\delta}(r_j)$ for any $\delta \in [0, 1]$. These capital and capacity clearing rates are increasing in the opponent's rate, as well as in the exogenous parameter a that captures the potential loan demand. If the opponent's loan rate r_j and/or the potential market demand is higher, the residual demand addressed to bank i is also higher. In order to clear the given capacity, the clearing rates must increase. Choosing a loan rate $r_i \geq r_i^{e_i}(r_j)$ will result in a residual demand that is lower or equal to the capital the bank has raised in the first stage. Hence, the marginal cost for providing loans in the second stage is zero. A loan rate $r_i^{e_i}(r_j) > r_i \geq r_i^{e_i/\delta}(r_j)$ results in a residual demand that is greater than the first-stage capital, but lower or equal to the loan capacity. The marginal cost of supplying loans at such a rate would therefore be given by the second piece of (13). A loan rate chosen below the capacity clearing rate $r_i^{e_i/\delta}(r_j) > r_i$ results in residual demand above the loan capacity of the capital requirement regulation. In order to satisfy the demand above capacity, bank i needs to raise additional capital in stage 2 and marginal cost of providing loans at such a low loan rate are defined by the third piece of (13).

Best response functions. Assuming that banks will try to maximize their overall profits, we can state the objective function of bank i in the second stage as

$$\Pi_i(r_i, r_j) = \begin{cases} r_i L_i - r_e e_i & \text{if} \quad r_i \geq r_i^{e_i}(r_j) \\ (r_i - r_D)L_i - ce_i & \text{if} \quad r_i^{e_i}(r_j) > r_i \geq r_i^{e_i/\delta}(r_j) \\ (r_i - r_D - \delta(c+\theta))L_i + \theta e_i & \text{if} \quad r_i^{e_i/\delta}(r_j) > r_i. \end{cases} \tag{16}$$

The positive last term in the third piece of the profit function reflects the saved cost from raising capital in the first stage. Note that the profit function is not differentiable at the points $L_i = e_i$ and $L_i = \frac{e_i}{\delta}$. Choosing moderate levels of capital in the first stage will result in binding capacity constraints of the second-stage loan rate competition. These imperfect constraints result in the discussed discontinuities of the profit function (i.e., cost function). To ascertain the best response regarding the loan rate choice of bank i to any loan rate chosen by bank j, we, therefore, have to distinguish the different cases that can arise, depending on the capital levels raised by both banks in the first stage and the parameters of the model. A loan rate pair (r_i, r_j) results in a certain quantity demanded from each bank. For a given level of e_i, we determine the best response loan rate choice, depending on the relation of the realized demand to the loan capacity of bank i. We call bank i's best loan rate response function "consistent" if, for a specified value of r_j and the given e_i, this bank's demand L_i is indeed included in the specified interval for which the chosen loan rate is the best response in terms of the profit maximization program. Lemma 3 derives the consistent best response function of bank i for each possible case.

LEMMA 3.

(a) For given values of e_i, e_j, δ under the assumed demand system, a best response function $R_i(r_j)$ is represented as

$$R_i(r_j) = \begin{cases} \dfrac{(b-d)a + dr_j}{2b} & =: \; R^I \\ \dfrac{(b-d)a - (b^2-d^2)e_i + dr_j}{b} & =: \; R^{II} \\ \dfrac{(b-d)a + dr_j + br_D}{2b} & =: \; R^{III} \\ \dfrac{(b-d)a - (b^2-d^2)\dfrac{e_i}{\delta} + dr_j}{b} & =: \; R^{IV} \\ \dfrac{(b-d)a + dr_j + b(r_D + \delta(c+\theta))}{2b} & =: \; R^{V} \\ \dfrac{br_j - (b-d)a}{d} & =: \; R^{VI} \\ \dfrac{1}{2}(a + r_d + \delta(c+\theta)) & =: \; R^{VII} \end{cases},$$

which is consistent if the following holds

$$\begin{array}{lllll} R^I & \Longleftrightarrow & [0 \le L_i(R_i(r_j), r_j) < e_i & \text{and} & r_j < r_j^l(e_i)] \\ R^{II} & \Longleftrightarrow & [L_i(R_i(r_j), r_j) = e_i & \text{and} & r_j^l(e_i) \le r_j \le r_j^h(e_i)] \\ R^{III} & \Longleftrightarrow & [e_i < L_i(R_i(r_j), r_j) < e_i/\delta & \text{and} & r_j^h(e_i) < r_j < r_j^L(e_i)] \\ R^{IV} & \Longleftrightarrow & [L_i(R_i(r_j)_i, r_j) = e_i/\delta & \text{and} & r_j^L(e_i) \le r_j \le r_j^H(e_i)] \\ R^{V} & \Longleftrightarrow & [e_i/\delta < L_i(R_i(r_j), r_j) & \text{and} & r_j^H(e_i) < r_j \le r_j^{L=0}(e_i)] \\ R^{VI} & \Longleftrightarrow & [L_j(R_i(r_j), r_j) = 0 & \text{and} & r_j^{L=0} < r_j < r_j^{L^M}] \\ R^{VII} & \Longleftrightarrow & [L_i(R_i(r_j)_i, r_j) \ge L_i^M & \text{and} & r_j^{L^M} \le r_j]. \end{array}$$

(b) Depending on the parameters of the model and the chosen capital in the first stage, a maximum of seven cases can occur, which are indicated above.

PROOF. An appendix containing the detailed proof as well as the derivation of the critical values of r_j is available online.[9] □

$\mathbf{R}^{\mathrm{I}}$ to $\mathbf{R}^{\mathrm{VII}}$ capture the possible branches that can be a part of the best response function of the capital regulated bank, where the superscripts I to VII refer to the specific function. L_i^M denotes the loan amount demanded at the monopoly loan rate. The right

9. The stable url is: http://rolandkirstein.de/jmcb/appendix.pdf.

column defines intervals for the opponent's loan rate. Together with the capital choice of the first stage, each interval defines a residual demand, which then determines the best reaction of the bank. The interval $r_j^l(e_i) \leq r_j \leq r_j^h(e_i)$ corresponds to a fairly low loan interest choice of the opponent (superscripts l and h correspond to moderately low and moderately high) such that the resulting residual demand for bank i can be financed with the capital raised in the first stage. The interval $r_j^L(e_i) \leq r_j \leq r_j^H(e_i)$ (superscripts L and H correspond to the lower and upper bound of an opponent's fairly high loan interest rate) corresponds to a fairly high loan interest rate chosen by the opponent, which results in a residual demand that can be satisfied with first-stage capital and deposits, but without raising additional capital. The superscript $L = 0$ corresponds to a loan interest rate of the opponent that results in zero demand for the opponent (where the Kuhn Tucker condition on nonnegative loan demand becomes binding) and $r_j^{L^M}$ refers to an interest rate of the opponent that results in a residual demand that is greater or equal to the monopoly demand.

The intuition of Lemma 3 is that bank i chooses the optimal loan rate r_i according to its residual demand function for a given r_j. As r_j increases, the optimal loan rate reaction is thereby given by the identified response functions. The intersections of the respective response functions determine the individual threshold values for r_j. For a very low loan rate of bank j, the residual demand for bank i is very low and smaller than the capacity. Therefore, the optimal response r_i^* is the Bertrand loan rate for producing below the capacity constraint. The branches of the best response function then follow the logic that as bank j increases its loan rate, the residual demand for bank i also increases. If the opponent chooses a loan rate, such that the residual demand for loans from bank i increases above the capacity due to the jump in marginal cost, the capacity clearing loan rate is still below the Bertrand loan rate of expanding capacity. Hence, the optimal response is not to expand capacity, but to ask for the capacity clearing loan rate until the residual demand is so high that the best response Bertrand loan rate that takes the recapitalization cost θ into account is above the capacity clearing loan rate. If the opponent increases the loan rate even more until it reaches $L_j(R_i(r_j), r_j) = 0$, then bank i's best response is to increase its loan rate further until the best reaction loan rate equals the monopoly loan rate. However, bank i would only increase its loan rate up to the monopoly loan rate. It would not be optimal to further increase the loan rate as a response to increases in the opponent's loan rate. The best response function becomes horizontal.

Figure 2 illustrates the findings of Lemma 3. For a given parameter constellation, the chosen capital levels of the first stage specify how many branches the best response function consists of. The actual best response function is given by the bold line, while the narrow lines are the respective branches. The labels I to VII capture the branches $\mathbf{R}^{\mathrm{I}}$ to $\mathbf{R}^{\mathrm{VII}}$ that are part of the best response function.

For relatively low levels of capital ($e_i \to 0$), the best response function consists solely of branches $\mathbf{R}^{\mathrm{V}}$, $\mathbf{R}^{\mathrm{VI}}$, and $\mathbf{R}^{\mathrm{VII}}$. Without any capital raised in the first stage, bank i has to raise capital in the second stage to be able to supply loans. This case is illustrated in Figure 3. □

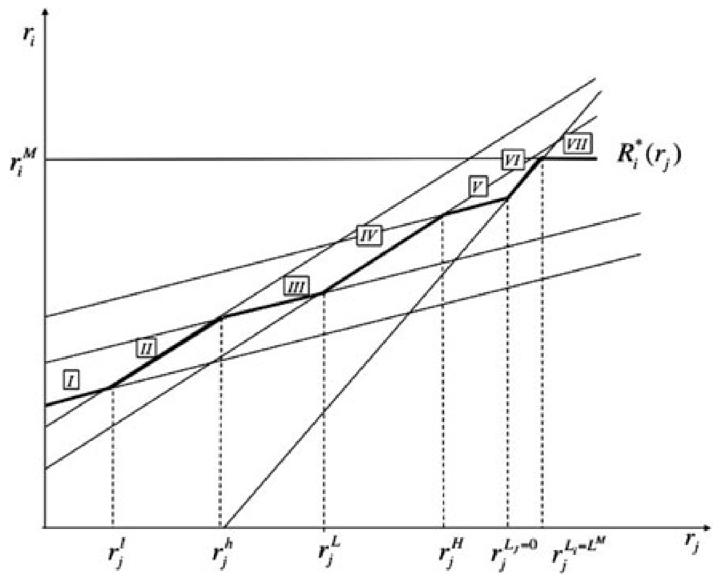

FIG. 2. The Best Response Function with Seven Branches.

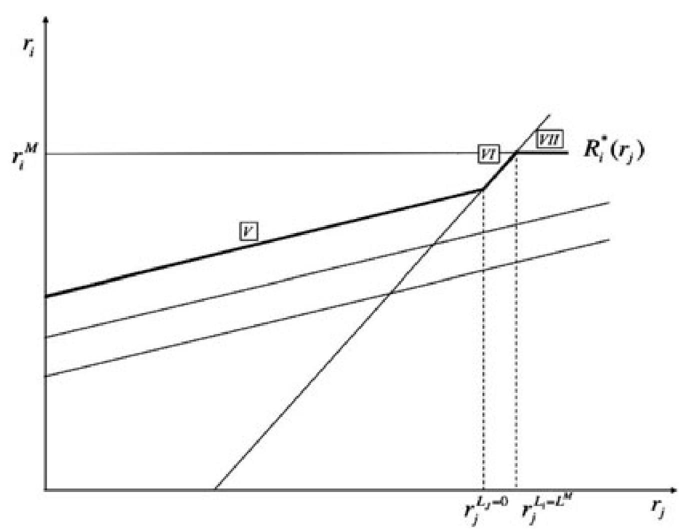

FIG. 3. The Best Response Function with No Capital Raised in the First Stage.

Subgame perfect loan rates. If the capital amount in the first stage translates into a capacity that allows the entire market to be served (monopoly supply), bank i will never need to raise additional capital in the second stage. Hence, branch $\mathbf{R}^{\mathrm{V}}$ is not a part of the best response function as illustrated in Figure 4.

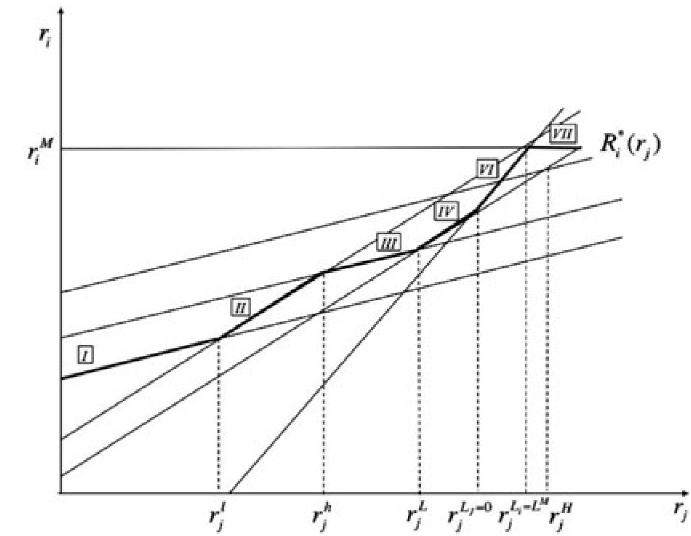

FIG. 4. The Best Response Function with High Capital.

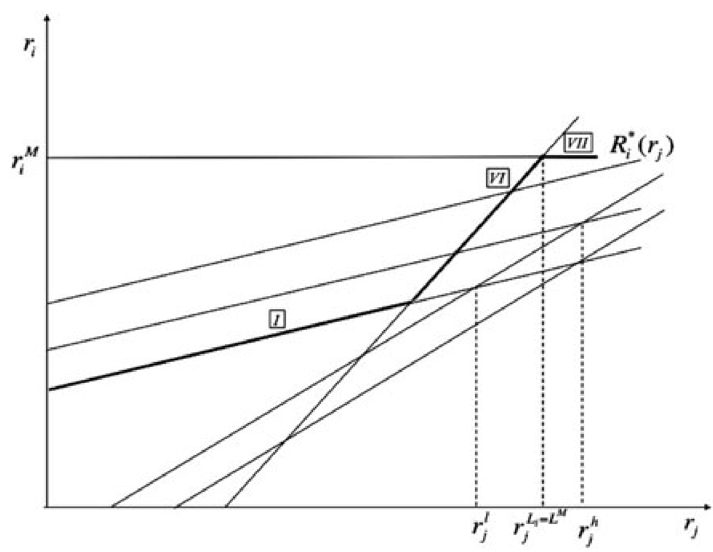

FIG. 5. The Best Response Function Very High Capital.

If bank i has raised very high levels of capital such that it can refund the whole market demand for loans by its capital raised in the first stage, the best response function only consists of branches $\mathbf{R}^{\mathrm{I}}$, $\mathbf{R}^{\mathrm{VI}}$, and $\mathbf{R}^{\mathrm{VII}}$ as illustrated in Figure 5.

There are other cases in addition to these extreme cases; however, an analysis of them would be redundant. In the interest of brevity, we only discuss the extreme cases here, since a detailed discussion of the different cases is unnecessary for the derivation of a subgame perfect equilibrium as Lemma 4 shows.

LEMMA 4. *The branches* $\mathbf{R}^{\mathrm{I}}$, $\mathbf{R}^{\mathrm{II}}$, $\mathbf{R}^{\mathrm{VI}}$, *and* $\mathbf{R}^{\mathrm{VII}}$ *of the best response function cannot be part of a subgame perfect Nash equilibrium.*

PROOF. Branches $\mathbf{R}^{\mathrm{VI}}$ and $\mathbf{R}^{\mathrm{VII}}$ cannot form a Nash equilibrium since firm j faces zero demand and earns zero profits. Lowering r_j could strictly increase profits; thus, bank j would be strictly better off by deviating from the high loan rate decision. Branches $\mathbf{R}^{\mathrm{I}}$ and $\mathbf{R}^{\mathrm{II}}$ can also be excluded from the set of candidates for a subgame perfect equilibrium. If bank i anticipates limiting its loan supply to $L_i \leq e_i$ in the second stage, it would save cost (i.e., profit maximizing) to choose a lower level of capital in the first stage. □

PROPOSITION 1. *For any pair of capital levels* e_i, e_j *chosen in the first stage, the subgame perfect equilibrium choice of loan rates in the second stage is unique if* $d \neq b$.

PROOF. From Lemma 4 we know that only branches $\mathbf{R}^{\mathrm{III}}$, $\mathbf{R}^{\mathrm{IV}}$, and $\mathbf{R}^{\mathrm{V}}$ are feasible candidates for a subgame perfect equilibrium. The best reaction function is kinked; however, it is continuous and monotone increasing. From Lemma 3 we can derive the slopes of branches $\mathbf{R}^{\mathrm{III}}$ and $\mathbf{R}^{\mathrm{V}}$ that equal $\frac{d}{2b}$, respectively, and the slope of branch $\mathbf{R}^{\mathrm{IV}}$ that is equal to $\frac{d}{b}$. With $b > d > 0$, all branches have a slope between 0 and 1. Hence, the intersect between the two banks' best response function is unique.[10] □

3.3 The First-Stage Capital Choice

Knowing the feasible intersects of the best response functions in the second stage, it is possible to determine the first-stage payoffs as a function of the respective capacity choices. Anticipating the best response equilibria of the second stage, bank i chooses an optimal level of capital that results in a capacity equal to the equilibrium demand of the second stage. It would not be profit enhancing to deviate from a capacity choice that equals demand in the second stage since capital is expensive in our model. A profit-maximizing bank therefore takes no more capital than is required by regulation to satisfy the loans demanded in the second stage. Reducing the capital to the required level for satisfying loan demand in the second stage would not affect the demand and loan rates; however, it saves cost. Similarly, a capacity below the anticipated equilibrium demand would not be optimal because raising additional capital in the first stage

10. The proposition holds for the slightest degree of differentiation. Yet, the particular case of perfectly homogeneous loans is not covered in our model. In this case, where $b = d$, the slope of branch $\mathbf{R}^{\mathrm{IV}}$ equals $\frac{\partial R_i(r_j)}{\partial r_j} = 1$, such that an intersection of the reaction functions at these branches give a continuum of equilibria and a unique pure strategy equilibrium fails to exist. However, Kreps and Scheinkman (1983) show that in a perfectly homogeneous loan rate competition with efficient rationing, a unique subgame perfect equilibrium can also exist.

would save on the costs associated with recapitalization in the second stage without influencing the equilibrium loan rates or demand in the second stage. Hence, in the first-stage equilibrium, a profit-maximizing bank will raise the exact amount of capital required for satisfying the equilibrium demand in the second stage $e_i = \delta L_i(r^*)$.

Applying this argument to both agents, it becomes clear that only the intersect of $\mathbf{R}^{\mathrm{IV}}$ of the best reaction function qualifies for a subgame perfect Nash equilibrium of the whole game. This intersect defines a capacity clearing equilibrium where the loan rates chosen in the second stage guarantee a demand that just clears the capacity defined by the capital raised in the first stage.

In general, the optimal loan rate choice is implicitly defined at the point where the marginal benefit from loan rate cutting, reflected by an increased demand resulting from lowering the loan rate, equals the marginal cost of expanding the supply of loans. In an unconstrained Bertrand competition, the Cournot loan rates can never be sustained in equilibrium, since the marginal benefit from loan rate undercutting outweighs the marginal costs of supply until the loan rate equals the marginal costs.

Now suppose the banks raise the exact capital required for supplying the Cournot loan quantities in the second stage. The capacity clearing loan rate of the second stage would then be the Cournot loan rates. Undercutting this loan rate would only be beneficial if the marginal benefit of increased demand outweighs the marginal costs of expanding the loan capacity. Let θ^H denote the critical level of the recapitalization cost during the second stage, that is, the level that exactly outweighs the marginal benefits of expanding capacity.

LEMMA 5. *The critical recapitalization cost value θ^H is unique and given by $\theta^H = \frac{d^2(a-r_D-c\delta)}{(2b-d)b\delta}$.*

PROOF. Let $r_B(\theta) := \frac{((b-d)a+b(r_D+(c+\theta)\delta))}{(2b-d)}$ denote the symmetric Bertrand loan rate with costly recapitalization in the second stage $(L(r_B(\theta)) \geq e/\delta)$, that is, the intersection of the branches $\mathbf{R}^{\mathrm{V}}$ of both banks.[11] From (8) we have $r^C(r_D - c\delta) := \frac{ab+(b+d)(r_D-c\delta)}{2b+d}$ as the Cournot loan rate for the marginal cost of supplying the Cournot quantity without recapitalization, which is represented as $(L(r^C(r_D - c\delta)) = L^C = \frac{a-r_D-c\delta}{2b+d})$. Without loss of generality, we assume that both banks raised $e = \delta L(r^C(r_D - c\delta))$ in stage 1. Note that even with a differentiated, but linear demand, the Bertrand equilibrium loan rate is always below the Cournot equilibrium loan rate for the equal marginal cost, that is, $r_B(x) < r^C(x)$. Vives (1985) shows that with linear demand, the Cournot loan rate is always greater than the Bertrand loan rate in differentiated duopolies. Hence, at least for an arbitrarily small recapitalization cost $(\theta \to 0)$ it must hold that $r_B(\theta) < r^C(r_D - c\delta)$. In this case, both banks announce $r_B(\theta)$, undercut Cournot loan rates, recapitalize and supply $L(r_B(\theta)) > L(r^C(r_D - c\delta)$; therefore,

11. Formally, $r_i^B(\theta) = \text{argmax}(r_i - r_D - \delta(c+\theta))L_i - \theta e_i$ gives the first-order condition $R_i(r_j) = \frac{(b-d)a+dr_j+b(r_D+\mathrm{d}(c+\mathrm{j}))}{2b}$. A symmetric equilibrium requires $\frac{dr+(b-d)a+b(r_D+\mathrm{d}(c+\mathrm{j}))}{2b} = \frac{2br+(b-d)a+b(r_D+\mathrm{d}(c+\mathrm{j}))}{d}$. Solving for r gives $\frac{((b-d)a+b(r_D+(c+\theta)\delta))}{(2b-d)}$.

the Cournot equilibrium does not sustain loan rate competition; that is, the the first-stage capacity choice is not binding. Increasing the recapitalization cost θ increases $r_B(\theta)$, but leaves $r^C(r_D - c\delta)$ unchanged. Therefore, there must be a positive value of θ^H such that $r_B(\theta) > r^C(r_D - c\delta)\ \forall\theta > \theta^H$. This critical value is implicitly defined by $r_B(\theta) = r^C(r_D - c\delta)$ or $\frac{((b-d)a+b(r_D+(c+\theta)\delta))}{(2b-d)} = \frac{ab+(b+d)(r_D-c\delta)}{2b+d}$. Solving for θ gives $\theta^H = \frac{d^2(a-r_D-c\delta)}{(2b-d)b\delta}$. □

PROPOSITION 2. *The symmetric two-stage game has a unique subgame perfect equilibrium consisting of*

$$e^* = \begin{cases} \delta L(r_B(\theta)) & \text{iff} \quad \theta < \theta^H \\ \delta L^C(r_D - c\delta) & \text{iff} \quad \theta \geq \theta^H \end{cases}$$

$$r^* = \begin{cases} r_B(\theta) & \text{iff} \quad \theta < \theta^H \\ r^C(r_D - c\delta) & \text{iff} \quad \theta \geq \theta^H. \end{cases}$$

PROOF. In the deterministic environment of our model, each bank anticipates the second stage-loan rate equilibrium. Therefore, optimal capacity choice is the capital that satisfies $e_i(e_j) = \delta L(r_i(e_i), r_j(e_j)$, where $r_i(e_i), r_j(e_j)$ is the second-stage loan rate pair that satisfies $max(r_i - r_D + c\delta)D(r_i, r_j)$ subject to $r_j = R_j(r_i, \frac{e_i}{\delta})$ and $r_i^{III} \leq r_i^* \leq r_i^V$. From Lemma 5, we know that for $\theta < \theta^H$ the second-stage symmetric loan rate choice is the Bertrand loan rate with the marginal cost of expending capacity (i.e., recapitalization in the second stage) $r_B(\theta)$. Since $r_B(\theta) < r^C(r_D - c\delta)$ for $\theta < \theta^H$, the Cournot loan rates do not sustain the loan rate competition. Anticipating $L(r_B(\theta)r_B(\theta))$ as the demand resulting from the second-stage loan rate choices, the optimal capital amount raised by each bank is $e^* = \delta L(r_B(\theta), r_B(\theta))$.

Now consider the case where the recapitalization costs are $\theta \geq \theta^H$ and hence, $r_B(\theta) \geq r^C(r_D - c\delta)$. For high recapitalization costs, the banks anticipate that once Cournot capacities are installed, undercutting in loan rates is not beneficial. Hence, the symmetric Cournot loan rate pair is included in the subset characterized by the two constraints of the maximization problem. The optimal capacity (capital) choice is therefore equal to the optimal quantity choice. Formally, the optimal capacity decision has to equal the anticipated demand. Hence, firms know that the optimal loan rate in the second stage will be the intersect of branch $\mathbf{R}^{\mathrm{IV}}$ of both agents. The first-stage optimal capacity choice can therefore also be written as

$$r_i(e_i, e_j) = a - b\frac{e_i}{\delta} - d\frac{e_j}{\delta}. \tag{17}$$

Both banks maximize the objective function with respect to the constraint of the optimal capital level simultaneously, which is represented as

$$\max_{e_i}\ \Pi_i = (r_i(e_i, e_j) - r_D)\frac{e_i}{\delta} - ce_i. \tag{18}$$

The first-order condition is

$$(a - r_D - \delta c) - 2b\frac{e_i}{\delta} - d\frac{e_j}{\delta} = 0. \tag{19}$$

A symmetric capital choice can then be derived, which is represented as

$$e^* = \delta\frac{a - (r_D + \delta c)}{(2b + d)}. \tag{20}$$

The following symmetric loan rate choice in the second stage is then

$$r^* = \frac{(ab + (b + d)(r_D + \delta c))}{2b + d}. \tag{21}$$

We characterized the general Cournot equilibrium outcomes as functions of a marginal cost x in (7), (8), and (9).

Substituting the first-stage cost of supplying loans $x = r_D + \delta c$, we obtain

$$L^C(r_D + \delta c) = \frac{a - (r_D + \delta c)}{2b + d} = e^*/\delta$$

and

$$r^C(r_D + \delta c) = \frac{ab + (b + d)((r_D + \delta c))}{2b + d} = r^*. \qquad \square$$

The optimal symmetric capacity and the loan rates associated with it result in the following symmetric profits:

$$\Pi^c(r_D + \delta c) = \frac{b(a - (r_D + \delta c))^2}{(2b + d)^2} = \Pi^*. \tag{22}$$

If short-term recapitalization is costly, the unique symmetric subgame perfect equilibrium of the two-stage capital loan rate choice competition is to issue capital in the first stage that supports the Cournot equilibrium quantities. As a consequence, the symmetric banks are able to realize Cournot profits. The intuition is that if short-term capitalization is sufficiently costly, the imperfect precommitment to capacities becomes perfect. If the extension of the capacity in the second stage is (marginally) too costly, the bank has an incentive to undercut its opponent in loan rates since the marginal cost of serving the demand above capacity exceeds the marginal benefit of attracting additional loans. That is why banks only want to meet the demand up to their capacity. Anticipating the credible precommitment, the Cournot capacity choice is the unique equilibrium of the first stage. Note that in the symmetric equilibrium, the optimal loan rates chosen generate a demand that exactly clears the capacity. Without excess demand above capacity, the bank does not incur any recapitalization costs. Thus, for imperfect capacity commitment ($\theta < \theta^H$), banks in the symmetric equilibrium also set loan rates higher than the Bertrand loan rate for the actual marginal costs incurred by the bank $r_B(\theta) > r_B(r_D + \delta c)$. Thus, even an imperfect commitment to capital raised in the first stage enhances profits.

3.4 The Impact of Capital Regulation

The analysis has shown that a binding regulatory capital requirement may reduce the incentives of banks to undercut each other in loan rates. This collusive effect results from the strategic complementarity of loan rates. Anticipating the best response function in the second stage, the banks have an incentive to strategically underinvest into capital during the first stage, thereby reducing the incentives to undercut in loan interest rates in the second stage. For any cost equal to or above the critical threshold, it would be optimal to precommit in the first stage to a financial structure that exactly allows for Cournot capacities and resulting in Cournot loan rates in the second stage, which maximizes the noncooperative equilibrium profits. From Lemma 5, we know that the critical recapitalization cost value is a function of the capital requirement rate δ. Capital regulation, therefore, influences the subgame perfect equilibrium outcome that was characterized in Proposition 2. The impact of capital regulation on the equilibrium is summarized in the following proposition.

PROPOSITION 3.

(a) The critical recapitalization cost value is decreasing in the capital requirement rate δ.

(b) A critical value of the minimum capital requirement δ^H exists where whenever the regulator sets a minimum capital requirement above this threshold, ceteris paribus*, the Cournot outcomes define the unique subgame perfect equilibrium.*

PROOF.

(a) Partial differentiation yields $\frac{\partial \theta^H}{\partial \delta} = -\frac{d^2(a-r_D)}{(2b-d)b\delta^2}$. Since by assumption $a > r_D$ and $b > d$ it is clear that $\frac{\partial \theta^H}{\partial \delta} < 0$. As d approaches b (the loans are nearly homogeneous), this value approaches $\left(-\frac{(a-r_D)}{\delta^2}\right)$, which is clearly negative. The critical value of recapitalization cost that allows a Cournot equilibrium to be sustained in Bertrand competition is decreasing in the minimum capital requirement rate.

(b) Because the recapitalization cost threshold is decreasing in the capital requirement, there must exist a capital requirement $\delta^H(\theta)$ for which it must hold that the critical recapitalization cost threshold is below the actual cost $\theta \geq \theta^H(\delta^H)$. This critical capital requirement is implicitly defined by Lemma 5 and its explicit expression is $\delta^H = \frac{d^2(a-r_D)}{\theta(2b-d)b+cd^2}$. From Proposition 2, we know that a recapitalization cost above the critical threshold results in the Cournot outcomes as a unique subgame perfect equilibrium. □

COROLLARY 2. *For $\delta < \delta^H$,* ceteris paribus*, the symmetric equilibrium loan supply resulting from $r_i^* = r_B(\theta)$ is $L_i^* = L(r_B(\theta))$, which is greater than the Cournot quantity L^C, since $r_B(\theta) < r^C$. However, with $0 < \theta < \theta^H$ the equilibrium loan supply is greater than the one-stage Bertrand equilibrium $L_i^* < L(r_B(r_D + \delta c))$ because $r_B(\theta) > r_B(r_D + \delta c)$.*

Corollary 2 demonstrates that if $\delta < \delta^H$, the loan rate competition under capital regulation does not entail Cournot outcomes; however, the equilibrium loan rates are still higher than in the unregulated loan rate competition. Similarly, the equilibrium quantities are also lower and the profits are higher with regulation.

4. DISCUSSION

4.1 Dynamic Context, Potential Entry

The analysis presented in the previous sections is based on a static perspective of the market. The main result is that banks in Bertrand competition can use equity regulation to generate higher profits. However, these positive profits could attract new entrants if barriers to entry are low. Additional competitors would thereby erode the Cournot profits. In modern banking, the barriers to market entry seem to be low, which would challenge the practical relevance of our results in a dynamic setting. However, Rhoades (1997) points out that despite the growing importance of electronic banking and improvements in information processing, the lack of customer information, switching costs, and sunk costs create significant barriers to entry in modern banking. Furthermore, several empirical studies provide strong evidence on the existence of significant entry barriers in banking. In a data set of Italian banks before and after deregulation, Gobbi and Lotti (2004) find that credit market incumbents in credit markets have an informational advantage over new entrants. More recently, Berger and Dick (2007) identify an early mover entry advantage in the data of 10,000 U.S. banks in local retail markets. Similarly, Adams and Amel (2007) find that moderate changes in market conditions do not increase the likelihood of entry in retail banking. Despite these barriers to entry, the banking sector in many countries is strictly regulated, and often obtaining a license is prerequisite for operating as a bank. If licenses are restricted and scarce, new competitors are not allowed to enter the banking sector, which creates a significant barrier to entry for outside competitors.

When discussing repeated interaction and potential entry, it therefore seems to be justified to assume that entry costs in modern banking are nonnegligible. Let $F > 0$ denote the fixed cost of entry. Further, let $\Pi(N)$ denote the individual profit of each bank in a symmetric Cournot Nash equilibrium with N competitors that is strictly decreasing in N. Observing the profit level $\Pi(n) > F > 0$ in a loan market with n incumbents, a potential entrant will enter if, and only if $\Pi(n+1) \geq F$. If F is low, potential entrants will enter the loan market and decrease future profits. However, as long as $F > 0$, a number m of incumbent banks exists, such that $\Pi(m) > F$ but $\Pi(m+1) < F$, implying that a potential entrant would face negative profits and will therefore abstain from entry. Since $F > 0$, it must hold that $\Pi(m) > 0$. Hence, with a certain fixed cost of entry, banks competing in Cournot fashion make strictly positive profits even in a dynamic framework where we allow for free entry.

We therefore conclude that as long as positive fixed cost of entry exists, capital requirements can reduce competitive forces and therefore be an explanation for strictly positive profits in the banking industry.

4.2 Conclusion

We have shown that banks that are competing in Bertrand competition can use minimum capital requirements to credibly commit to Cournot capacities and, thereby, achieve Cournot profits. By showing that binding capital requirement regulation can establish collusive behavior among banks we come to similar conclusions as Chami and Cosimano (2010) in a collusive setting, even though our starting point is the noncooperative strategic behavior of banks.

The main prerequisite for our results is that the recapitalization cost in the second stage are high, that is, above the threshold described in Lemma 5. The intuition is that banks, which are facing a binding capital requirement, prefer to cut back lending opposed to raising additional equity capital. This appears to be in line with recent empirical observations we discussed in the literature review.

Contrary to that part of the banking literature that argues that regulatory capital requirements reduce the profits of banks because they increase the cost of offering loans, this paper shows that regulation can also enhance the bank's profits, and thus the charter value of the bank in excess of the increased cost of capital. Therefore, our theoretical results help to explain the occurrence of substantial profits in Bertrand banking markets. Furthermore, they provide a justification for the usage of the Cournot model in theoretical banking models of imperfect competition even if banks actually compete in loan interest rates.

The potential welfare effects remain ambiguous. On the one hand, increased profits may stabilize the banking sector by reducing risk-taking incentives of banks due to an increase in the banks' charter value. On the other hand, the reduction in competition reduces borrower rents and may lead to inefficiencies in the loan market. Assuming that the regulator aims at an optimal trade-off between incentives for the competitiveness of bank services and stability in the banking sector, the collusive effect should be considered in the design of prudential regulation, especially in the discussion of an increase in capital requirements.

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Online-Appendix to the Article Strategic Effects of Regulatory Capital Requirements in Imperfect Banking Competition

(not published in the Journal of Money, Credit and Banking)

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Appendix

Lemma 1. *If there exists a continuum of homogenous borrowers whose utility can be described with a representative utility function of the form* $U(L_1, L_2) = m + a(L_1 + L_2) - \frac{b}{2}(L_1^2 + L_2^2) - dL_1L_2$ *, one can derive a generalized inverse demand function:*

$$r_i(L_i, L_j) = a - bL_i - dL_j. \tag{1}$$

Provided that both both banks do not ration their customers and make non-negative profits, the direct demand function is defined as:

$$L_i(r_i, r_j) = \frac{a}{(b+d)} - \frac{br_i}{(b^2 - d^2)} + \frac{dr_j}{(b^2 - d^2)}. \tag{2}$$

Proof. We adopt the model of Matutes and Vives (2000) by assuming there is a continuum of borrowers of the same type with the following representative utility function, which is represented as:

$$U(L_1, L_2) = m + a(L_1 + L_2) - \frac{b}{2}(L_1^2 + L_2^2) - dL_1L_2$$

Where m represents all other goods and $p_m = 1$ is the normalized loan rate for all other goods. The representative borrower tries to maximize his utility subject to the budget constraint $Y \geq m + r_1L_1 + r_2L_2$ where Y is the income of the borrower. The Lagrangian function to describe the optimization problem is as follows:

$$\max \mathcal{L}(L_1, L_2) =$$
$$m + a(L_1 + L_2) - \tfrac{b}{2}(L_1^2 + L_2^2) - dL_1L_2 + \lambda(Y - m - r_1L_1 - r_2L_2)$$

The Kuhn–Tucker conditions are:

$$a - bL_1 - dL_2 - \lambda r_1 \leq 0 \quad L_1 \geq 0 \quad L_1(a - bL_1 - dL_2 - \lambda r_1) = 0 \tag{3}$$

$$a - bL_2 - dL_1 - \lambda r_2 \leq 0 \quad L_2 \geq 0 \quad L_2(a - bL_2 - dL_1 - \lambda r_2) = 0 \tag{4}$$

$$1 - \lambda \leq 0 \quad m \geq 0 \quad m(1 - \lambda) = 0 \tag{5}$$

$$Y - m - r_1 L_1 - r_2 L_2 \leq 0 \quad \lambda \geq 0 \quad \lambda(Y - m - r_1 L_1 - r_2 L_2) = 0 \tag{6}$$

If the borrower's income Y is sufficiently large, such that $m > 0$, from 5 we obtain that:

$$\lambda = 1 \tag{7}$$

which implies the equation below with (6):

$$Y = m + r_1 L_1 + r_2 L_2 \tag{8}$$

Substituting (7) in (3) and (4), we obtain the following:

$$a - bL_1 - dL_2 - r_1 \leq 0 \quad L_1 \geq 0 \quad L_1(a - bL_1 - dL_2 - r_1) = 0 \tag{9}$$

$$a - bL_2 - dL_1 - r_2 \leq 0 \quad L_2 \geq 0 \quad L_2(a - bL_2 - dL_1 - r_2) = 0 \tag{10}$$

With positive demand for loans from both banks $L_1 > 0$ and $L_2 > 0$ we obtain the inverse demand curves below:

$$r_1(L_1, L_2) = a - bL_1 - dL_2 \tag{11}$$

$$r_2(L_1, L_2) = a - bL_2 - dL_1 \tag{12}$$

Since demand for loans of both banks is positive, we can invert the inverse demand curves in order to obtain the direct demand curves (note that $\frac{a(b-d)}{(b^2-d^2)} = \frac{a}{(b+d)}$), as follows:

$$L_1(r_1, r_2) = \frac{a}{(b+d)} - \frac{br_1}{(b^2-d^2)} + \frac{dr_2}{(b^2-d^2)} \tag{13}$$

$$L_2(r_1, r_2) = \frac{a}{(b+d)} - \frac{br_2}{(b^2-d^2)} + \frac{dr_1}{(b^2-d^2)} \tag{14}$$

If the demand for one bank is zero (i.e., $L_j = 0$) while the demand for the competitor is positive (i.e., $L_i > 0$), (9) and(10) imply that the inverse demand for loans from bank i is:

$$r_i(L_i) = a - bL_i$$

and the direct demand function that bank i faces is:

$$L_i(r_i) = \frac{a - r_i}{b}$$

At the same time, the Kuhn–Tucker conditions for the demand for loans j with the binding constraint $L_j = 0$ imply that:

$$r_j > a - dL_i.$$

□

Lemma 2. *A capital regulated bank that has raised capital in the first stage faces the following piecewise–defined cost function at the beginning of the second stage:*

$$C(L) = \begin{cases} r_e e & \text{if } L \leq e \\ r_D L + ce & \text{if } e < L \leq e/\delta \\ (r_D + c\delta)L + \theta(\delta L - e) & \text{if } L > e/\delta \end{cases} \tag{15}$$

Proof. Since the balance sheet constraint is binding, we can write D as a function of loans and capital $D = L - E - e$. If the bank invests in loans $L \leq e$, it can refund its assets solely out of the capital raised in the first stage at cost r_e. Hence, $D = 0$ and $E = 0$.

Intending to provide loans $L > e$, the bank needs to raise additional funds. Since refunding with deposits is cheaper (by assumption) than raising additional capital, the bank will refund the assets with deposits. No additional capital is required by regulation, in which $E = 0$ in the second stage. The cost of providing a loan amount $e < L < {}^{e}\!/\!_{\delta}$ is given by $r_e e + r_D(L - e)$. Since $r_e - r_D = c$, the cost of funding consists of the deposit rate times the total loan amount plus the risk premium for the capital raised in the first stage.

If the asset investment exceeds the first–stage loan capacity $L > {}^{e}\!/\!_{\delta}$, the bank is forced to raise additional capital in the second stage in order to comply with the minimum capital requirement. The additional capital is expressed as $E = \delta L - e$. Refunding cost can therefore be summarized as $r_D D + r_e e + r_E E$. Using the balance constraint leads to $r_D(L - \delta L) + (r_D + c)\, e + (r_D + c + \theta)\, \delta\, (L - {}^{e}\!/\!_{\delta})$, which can be simplified to the third piece of the cost function. $\square$

Lemma 3. a) For given values of e_i, e_j, δ under the assumed demand system, a best response function $R_i(r_j)$ is represented as:

$$R_i(r_j) = \begin{cases} \frac{(b-d)a+dr_j}{2b} & =: R^{I} \\ \frac{(b-d)a-(b^2-d^2)e_i+dr_j}{b} & =: R^{II} \\ \frac{(b-d)a+dr_j+br_D}{2b} & =: R^{III} \\ \frac{(b-d)a-(b^2-d^2)\frac{e_i}{\delta}+dr_j}{b} & =: R^{IV} \\ \frac{(b-d)a+dr_j+b(r_D+\delta(c+\theta))}{2b} & =: R^{V} \\ \frac{br_j-(b-d)a}{d} & =: R^{VI} \\ \frac{1}{2}(a + r_d + \delta(c+\theta)) & =: R^{VII} \end{cases},$$

which is consistent if the following holds:

$$
\begin{array}{cccccc}
R^I & \Longleftrightarrow & [0 \leq L_i(R_i(r_j), r_j) < e_i & \wedge & r_j < r_j^l(e_i)] \\
R^{II} & \Longleftrightarrow & [L_i(R_i(r_j), r_j) = e_i & \wedge & r_j^l(e_i) \leq r_j \leq r_j^h(e_i)] \\
R^{III} & \Longleftrightarrow & [e_i < L_i(R_i(r_j), r_j) < e_i/\delta & \wedge & r_j^h(e_i) < r_j < r_j^L(e_i)] \\
R^{IV} & \Longleftrightarrow & [L_i(R_i(r_j)_i, r_j) = e_i/\delta & \wedge & r_j^L(e_i) \leq r_j \leq r_j^H(e_i)] \\
R^V & \Longleftrightarrow & [e_i/\delta < L_i(R_i(r_j), r_j) & \wedge & r_j^H(e_i) < r_j \leq r_j^{L=0}(e_i)] \\
R^{VI} & \Longleftrightarrow & [L_j(R_i(r_j), r_j) = 0 & \wedge & r_j^{L=0} < r_j < r_j^{L^M}] \\
R^{VII} & \Longleftrightarrow & [L_i(R_i(r_j)_i, r_j) \geq L_i^M & \wedge & r_j^{L^M} \leq r_j].
\end{array}
$$

b) Depending on the parameters of the model and the chosen capital in the first stage, a maximum of seven cases can occur, which are indicated above.

Proof. To prove part a) of Lemma 3, we proceed as follows. We first derive the first order condition for each piece of the profit function that implicitly defines the best loan rate response (i.e., R^I, R^{III}, R^V) for each of the cases discussed. Then we consider the points of discontinuity ($R^{II}, : R^{IV}$). We then discuss the remaining possible cases (R^{VI}, R^{VII}). Finally, we show that part b) of Lemma 3 must hold.

From Lemma 2 we obtain bank i's piecewise–defined objective function $max_{r_i} \Pi_i(r_i, r_j)$. A best response function $R_i(r_j)$ is implicitly defined by $\Pi_i'(R_i(r_j), r_j) = 0$. The first order conditions for the three pieces of bank i's objective function can be summarized as $(r_i - MC(L))L_i' + L_i = 0$ with $L_i' = -\frac{b}{b^2-d^2}$. Substituting L_i' and solving for r_i gives:

$$r_i = \frac{(b-d)a + dr_j + b(MC)}{2b} \tag{16}$$

Inserting the pieewise defined marginal cost into the best response function gives R^I, R^{III}, R^V:

$\mathbf{R^I}$: If the best response to r_j results in a residual demand $0 \leq L(R_i(r_j), r_j) < e_i$, the marginal costs in the second stage are $MC(L(p)) = 0$. Substituting and solving for r_i gives $R_i(r_j) = \frac{(b-d)a+dr_j}{2b}$. We now have to show that $L_i(R_i(r_j), r_j) < e_i \, \forall \, r_j < r_j^l(e_i) := \frac{2(b^2-d^2)e_i-(b-d)a}{d}$. In closed form this can be rewritten as $e_i > \frac{a}{(b+d)} - \frac{b}{(b^2-d^2)} \frac{(b-d)a+dr_j}{2b} +$

$\frac{dr_j}{(b^2-d^2)}$. This can be simplified to $2e_i(b^2-d^2) > a(b-d)+dr_j$, or $\frac{2(b^2-d^2)e_i-(b-d)a}{d} > r_j$, which holds $\forall\, r_j < r_j^l(e_i)$.

$\mathbf{R^{III}}$: If the best response to r_j results in a residual demand $e_i < L_i(R_i(r_j), r_j) < \frac{e_i}{\delta}$, the second–stage marginal cost are $MC(L(p)) = r_D$, which results in the best reaction $R_i(r_j) = \frac{(b-d)a+dr_j+br_D}{2b}$. We first show that $e_i < L_i(R_i(r_j), r_j)$ holds $\forall\, r_j^h(e_i) := \frac{2(b^2-d^2)e_i-(b-d)a+br_D}{d} < r_j < r_j^L(e_i) := \frac{2(b^2-d^2)e_i/\delta-(b-d)a}{d}$. The closed form is $e_i < \frac{a}{(b+d)} - \frac{b}{(b^2-d^2)}\frac{(b-d)a+dr_j+br_D}{2b} + \frac{dr_j}{(b^2-d^2)}$, which can be simplified to $2e_i(b^2-d^2) < a(b-d) - br_D + dr_j$, or $\frac{2(b^2-d^2)e_i-(b-d)a+br_D}{d} < r_j$, which holds $\forall\, r_j > r_j^h(e_i)$.

Similarly, it can be shown that $L_i(R_i(r_j), r_j) < e_i/\delta$, with $\frac{a}{(b+d)} - \frac{b}{(b^2-d^2)}\frac{(b-d)a+dr_j+br_D}{2b} + \frac{dr_j}{(b^2-d^2)} < e_i/\delta$ is true for $\forall r_j < r_j^L(e_i)$

$\mathbf{R^{V}}$: If the best response to r_j results in a residual demand, represented as

$L_i(R_i(r_j), r_j) > \frac{e_i}{\delta}$, the optimal loan rate response is $R_i(r_j) = \frac{(b-d)a+dr_j+b(r_D+\delta(c+\vartheta))}{2b}$. This is the best loan rate response if $\frac{a}{(b+d)} - \frac{b}{(b^2-d^2)}\frac{(b-d)a+dr_j+b(r_D+\delta(c+\vartheta))}{2b} + \frac{dr_j}{(b^2-d^2)} > \frac{e_i}{\delta}$

or

$\frac{2(b^2-d^2)e_i-(b-d)a+b(r_D+\delta(c+\vartheta)}{d} < r_j$ which is obviously true for all

$r_j > r_j^H(e_i) := \frac{2(b^2-d^2)e_i/\delta-(b-d)a+b(r_D+\delta(c+\theta)}{d}$ as long as the non–negativity constraints of the maximization program are not binding.

$\mathbf{R^{II}}$ and $\mathbf{R^{IV}}$ result from the discontinuous jumps in the marginal cost function at the points where $L_i(R_i(r_j), r_j) = e_i$ and $L_i(R_i(r_j), r_j) = \frac{e_i}{\delta}$. These equalities define the capital and capacity clearing loan rate pairs (r_i, r_j). Since $\forall\, r_j < r_j^l(e_i)$, the best loan rate response is $L_i(R_i(r_j), r_j) < e_i$ and $\forall\, r_j^h(e_i) < r_j < r_j^L(e_i)$ the best loan rate respond is $e_i < L_i(R_i(r_j), r_j)$ for $r_j^l(e_i) \leq r_j \leq r_j^h(e_i)$. Therefore, it must hold that $L_i(R_i(r_j), r_j) = e_i$ similar, for $r_j^L(e_i) \leq r_j \leq r_j^H(e_i)$ it must hold that $L_i(R_i(r_j), r_j) = \frac{e_i}{\delta}$.

$\mathbf{R^{VI}}$: This branch of the best response function results from the assumptions of our model, i.e., the non–negativity constraints on demand in the optimization problem: $0 \leq L_j = \frac{a}{b+d} + \frac{br_j}{b^2-d^2} + \frac{dr_i}{b^2-d^2}$. A loan rate pair $(R_i(r_j), r_j)$ that result in a negative demand for the opponent j makes the non–negativity constraint binding. Solving the constraint for r_i yields $R_i(r_j) = \frac{br_j-(b-d)a}{d}$. Inserting $L_j(R_i(r_j), r_j) = \frac{a}{(b+d)} - \frac{b}{(b^2-d^2)}r_j + \frac{d}{(b^2-d^2)}\frac{br_j-(b-d)a}{d}$ gives $L_j(R_i(r_j), r_j) = 0$.

$\mathbf{R^{VII}}$: If $r_j > r_j^{L=0}$, bank i's best response loan rate is only increasing in r_j as long as the "residual demand" (note that bank i covers the entire market since $L_j(R_i(r_j^{L=0}), r_j^{L=0}) = 0$) is smaller than the monopoly output $L_i(R_i(r_j), r_j) < L_i^M$. Hence, it is only optimal to respond to a further increase of bank r_j with increasing r_i as long as $R_i(r_j) > r_i^M$ with r_i^M being the monopoly loan rate that solves the maximization problem:

$r_i^M = argmax(r_i - r_D - \delta(c+\theta))L_i r_i + \theta e_i$ implicitly defined by the first order condition. Solving for the loan rate gives $r_i^M = \frac{1}{2}(a + r_d + \delta(c+\theta))$.

Since r_i^M is unique and independent of r_j (depending solely on the exogenous model parameters), the best response loan rate function becomes vertical. It would never be beneficial to deviate from the monopoly loan rate for $L_i(R_i(r_j), r_j) < L_i^M$. Hence, no further best response branches can exist, which means that part b) must hold. □

The critical values of the opponent's loan rate are implicitly defined by the intercept of the different best response branches. Equating the different branches and solving for r_j we derive the critical values:

$r_j^l(e_i) : (R^I = R^{II})$ solving $\frac{(b-d)a+dr_j}{2b} = \frac{(b-d)a-(b^2-d^2)e_i+dr_j}{b}$ for r_j yields

$$r_j^l(e_i) := \frac{2(b^2-d^2)e_i - (b-d)a}{d}$$

$r_j^h(e_i) : (R^{II} = R^{III})$ solving $\frac{(b-d)a-(b^2-d^2)e_i+dr_j}{b} = \frac{(b-d)a+dr_j+br_D}{2b}$ for r_j yields

$$r_j^h(e_i) := \frac{2(b^2-d^2)e_i - (b-d)a + br_D}{d}$$

$r_j^L(e_i) : (R^{III} = R^{IV})$ solving : $\frac{(b-d)a+dr_j+br_D}{2b} = \frac{(b-d)a-(b^2-d^2)\frac{e_i}{\delta}+dr_j}{b}$ for r_j yields

$$r_j^L(e_i) := \frac{2(b^2-d^2)e_i/\delta - (b-d)a + br_D}{d}$$

$r_j^H(e_i) : (R^{IV} = R^V)$ solving $\frac{(b-d)a-(b^2-d^2)e_i+dr_j}{b} = \frac{(b-d)a+dr_j+b(r_D+\delta(c+\theta))}{2b}$ for r_j yields

$$r_j^H(e_i) := \frac{2(b^2-d^2)e_i/\delta - (b-d)a + b(r_D+\delta(c+\theta))}{d}$$

$r_j^{L=0}(e_i) : (R^V = R^{VI})$ solving $\frac{(b-d)a+dr_j+b(r_D+\delta(c+\theta))}{2b} = \frac{br_j-(b-d)a}{d}$ for r_j yields

$$r_j^{L=0}(e_i) := a - \frac{bd(a-(r_D+\delta(c+\theta)))}{2b^2-d^2}$$

$r_j^{L^M}(e_i) : (R^V = R^{VI})$ solving $\frac{br_j-(b-d)a}{d} = \frac{1}{2}(a+r_d+\delta(c+\theta))$ for r_j yields

$$r_j^{L^M}(e_i) := \frac{a(2b-d)+d(r_D+\delta(c+\theta))}{2b}$$

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Essay II

When Banks Strategically React to Regulation: Market Concentration as a Moderator for Stability

When Banks Strategically React to Regulation: Market Concentration as a Moderator for Stability

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Abstract

Minimum capital requirement regulation forces banks to refund a substantial amount of their investments with equity. This creates a buffer against losses, but also increases the cost of funding. If higher refunding costs translate into higher loan interest rates, then borrowers are likely to become more risky, which may destabilize the lending bank. This paper argues that, in addition to the buffer and cost effect of capital regulation, there is a strategic effect. A binding capital requirement regulation restricts the lending capacity of banks, and therefore reduces the intensity of loan interest rate competition and increases the banks' price setting power as shown in Schliephake and Kirstein (2013). This paper discusses the impact of this indirect effect from capital regulation on the stability of the banking sector. It is shown that the enhanced price setting power can reverse the net effect that capital requirements have under perfect competition.

Keywords: Capital Requirement Regulation; Competition; Financial Stability
JEL: G21, K23, L13

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1. Introduction

This paper analyses the effect of capital requirement regulation on the stability of banks in a loan market where few oligopolistic banks compete in loan interest rates and decide on optimal loan capacities by their refunding structure.

Because bank loans are likely to be homogenous, the unregulated loan interest rate competition is fierce, and banks undercut each other in loan rates until the interest payments equal the marginal refunding cost of the asset investment - the classical Bertrand result.

However, regulating the capital structure also changes the competitive behavior of the banks, i.e., the timing of strategic decisions. Due to higher costs, banks may prefer to adapt lending rather than the capital structure when they are confronted with a binding capital requirement. In this case the introduction of a capital requirement regulation can change Bertrand competition into a two stage game. In the first stage banks choose optimal loan capacities, and then, in the second stage, the banks choose loan interest rates to clear capacities. This idea that capital regulation creates a credible precommitment to loan interest rates, and thereby reduces the intensity of interest rate competition, was first discussed in Schliephake and Kirstein (2013).[1] They develop a detailed analysis of the conditions under which capital requirement regulation changes the strategic interaction among oligopolistic banks from strategic complementarity in price setting to strategic substitutes in capacity choices. They show that higher capital requirements reduce the incentives of banks to undercut in

[1]For technical reasons Schliephake and Kirstein (2013) assume that borrowers have preferences for a specific banks. This assumption allows the transformation from indirect to direct demand without the explicit definition of a certain rationing rule. However, they show that their results also hold when borrowers become close to indifference between loans such that loans are perfect substitutes.

interest rates but their model neglects any uncertainty and risk effects.

In contrast, this paper focuses on the impact of increased price setting power on the stability of the banking sector. In this paper I will call the effect of enhanced price setting power “Cournotization” effect. It creates an indirect effect of capital requirement regulation on the stability of the banking sector. In particular, it influences the ability of banks to consider the risk shifting behavior of their borrowers, and thus the effect changes the optimal reaction of banks when they face increased capital requirements. This effect adds to various direct and indirect effects of capital requirement regulation and competition on the stability of the banking system that are discussed in the literature overview and summarized in Figure 1 and Table 1.

This paper shows that the cost of recapitalization and the resulting Cournotization effect may play a role in determining the net effect of capital requirement on banking stability. In particular, the results indicate that the number of oligopolistic competitors, the correlation of loan defaults, and the intensity of borrower risk shifting simultaneously determine whether capital requirement regulation of oligopolistic bank markets enhances or erodes the stability of the sector.

In order to analyze the effect of Cournotization on bank stability, it is necessary to establish the "missing link" between the literature on competition and stability on one hand, and the literature on capital regulation and stability, on the other hand. This is done in section 2. In section 3, the basic model of oligopolistic loan interest rate competition and capital regulation is set up. A simplified version of the model in Schliephake and Kirstein (2013) is introduced and the results derived to illustrate the Cournotization effect. In section 4, the effect of the increased price setting power on the optimal decisions and resulting effects on stability are analyzed under perfect correlation. In section 5, the results are generalized for imperfectly correlated borrower defaults. Section 6 discusses the policy implications and concludes.

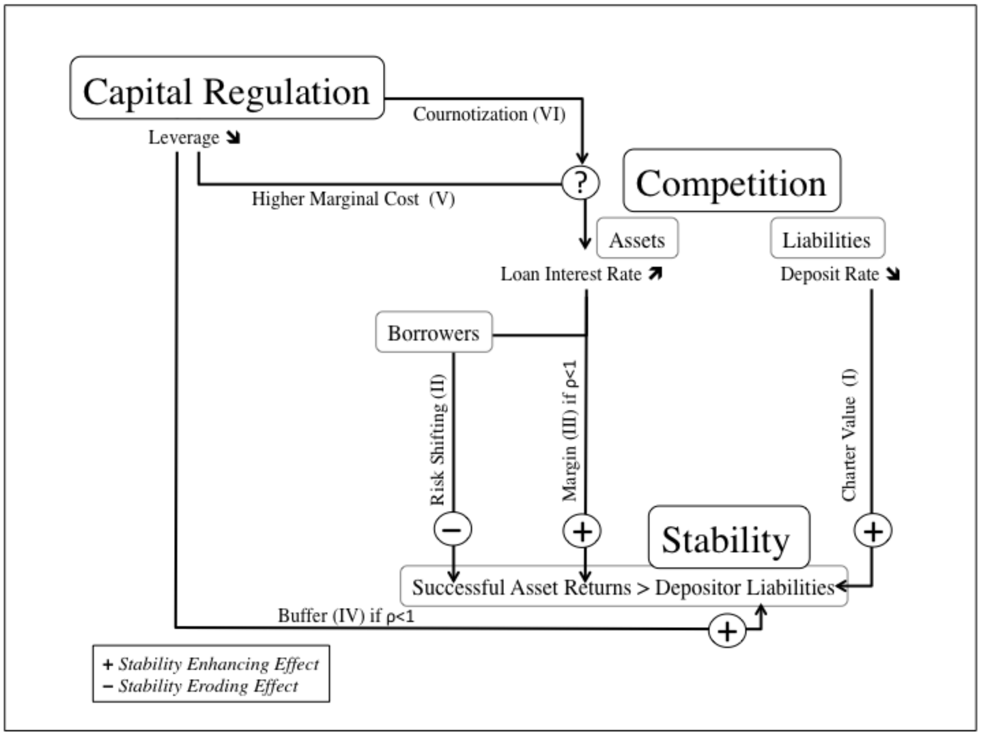
2. Literature Review

The literature on competition and stability and the literature on capital regulation and stability respectively is extensive. However, only few theoretical papers exist that analyze the simultaneous effects. Figure 1 provides an overview of the main effects that capital regulation and competition have on the stability of banks. The term banking stability thereby means the probability of an individual bank to default. In particular, consider a bank that invests its equity and deposits in risky loans. The term stability then reflects the probability that the return of non-defaulting loan assets is greater or equal the bank's liabilities to its depositors. A lower probability of an individual bank default thereby reflects higher banking stability.[2]

The literature on the relationship between competition and stability can be roughly divided in two streams. Representatives of the competition-instability hypothesis argue that more competition erodes stability because it reduces the charter value of the bank and, therefore, increases the incentives to take more risk. This charter value effect is the effect numbered (I) in Figure 1 and has been discussed, for example, by Matutes and Vives (2000), Hellmann et al. (2000), Repullo (2004) and Allen and Gale (2000). Moreover, Allen and Gale (2004) argue that a reduction in the charter value of banks also decreases incentives to spend effort on monitoring, thereby further increasing the riskiness of the bank. In general, the models on the stability enhancing charter value effect of competition focus on competition on the liability side of the bank and take the investment risk of banks as exogenous. In other words the charter value effect argues that if banks fully control their riskiness, they

[2]This idiosyncratic definition of banking stability does not reflect systemic risk. An analysis of the impact of competition on the systemic risk of the banking sector is beyond the scope of this paper and left for future research.

Figure 1: The Effects of Capital Regulation and Competition on Banking Stability



The charter value effect (I) enhances stability by reducing the deposit rates to be paid on liabilities. The risk shifting effect (II) reflects the aggregate probability of asset default that is influenced by the loan interest rate. The margin effect (III) occurs when defaults are imperfectly correlated ($\rho < 1$) and enhances stability through higher returns on non-defaulting assets. The buffer effect (IV) reflects lower liabilities to depositors if assets are financed with more equity. Higher equity funding increases the marginal cost (V) and thereby the loan interest rate, which reinforces borrower risk shifting. The Cournotization effect (VI) may introduce price setting power of banks if recapitalization is sufficiently costly and, therefore, influences the bank's reavtion to higher regulation.

have more incentives to decrease their risk of default the more profits they expect to make in future. If higher regulation constraints the ability of banks to invest in assets, banks demand less deposits resulting in lower deposit rates and higher marginal profits. Since this effect is straightforward and unambiguous, it will be neglected in the below analysis.

Boyd and De Nicolò (2005) challenge the charter value hypothesis by allowing not only banks but also borrowers to control the riskiness of the bank and its investments. In their model they consider the competition for loan assets and allow borrowers to react to higher loan interest rates. Building on the seminal work of Stiglitz and Weiss (1981), they argue that it is not only the limited liability of banks, which gives rise to risk shifting, but also that the risk of loan assets increases in the loan interest rate. Assuming perfect correlation of loan defaults, this extension actually the "conventional wisdom" that higher competition leading to instability. If risk shifting takes place in the loan asset market, increased competition can actually reduce the probability of bank failure, since lower loan rates reduce loan asset risk. This borrower risk shifting effect is labeled effect (II) in Figure 1.

Martinez-Miera and Repullo (2010) extend the Boyd and De Nicolò (2005) model and allow for imperfect correlation among the investment projects. They argue, that higher loan interest rates from lower competition increase borrower risk shifting on the one hand but also increase the margin on non-defaulting loans, labeled effect (III). The higher margins on non-defaulting loans can outweigh the borrower risk shifting. The relative strength of the margin effect thereby depends on the correlation of defaults in the bank's asset portfolio. Their findings indicate that if all loans do not default at the same time then the impact of competition on banking stability is generally non-monotonous.

Similar to the theoretical predictions of the literature on the impact of competition on stability, the literature on the net effect of minimum capital regulation on stability is contradictory, as well. Higher equity funding of investment, ceteris paribus, increases the stability of banks, since equity provides a buffer against unexpected losses and reduces the moral hazard of banks similar to the charter value effect of low competition. In other words, forcing banks to refund a fixed amount of assets with higher equity decreases leverage and makes banks more stable, which is labeled effect (IV). If banks internalize all costs and benefits of bank equity, the private optimal capital structure would coincide with the socially optimal capital structure as discussed by Gale (2003). However, banks do not fully internalize the benefits of equity since they are shielded at least partly against the downside risk of their investments by the banking safety net. Setting minimum capital requirements is a regulatory instrument that shifts the risks borne by the depositors, or insured by the safety net, back to the shareholders. Hence, moral hazard and the incentive of excessive risk taking is reduced as shown by Hellmann et al. (2000), Repullo (2004), and Allen et al. (2011). Furthermore, higher capital requirements reduce the risk of contagion among banks as pointed out by Allen and Carletti (2011).

However, regulating the refunding structure of banks also changes their optimal investment decisions. Generally, when equity funding is costly to the bank, an increase in capital requirement regulation has multiple effects that stabilize and destabilize the banking sector.

Firstly, higher equity funding decreases the amount of deposit funding and, therefore, reduces the states of nature in which a bank can fail, which is the above discussed buffer effect (IV).

Secondly, it increases the marginal cost of financing investments. The higher cost of funding decreases the banks profitability, which decreases the banks charter value, and thereby gives rise to higher risk taking, which destabilizes the bank. At the same time, the higher cost of funding decreases the activity of the banks. Less activity means less lending, which results in increased loan interest rates. Higher loan interest rates lead to higher earnings on non-defaulting loans, which can offset losses from defaulting loans (II), on the one hand. On the other hand, higher loan rates reduce the earnings of borrowers, which induces risk shifting of borrowers (III). The net effect of capital requirement regulation on banking stability depends on which of the described effects prevails.

Empirical evidence on the relationship of capital requirements, competition, and financial stability is equally ambiguous. Carletti and Hartmann (2003) provide a good overview of the mixed empirical findings on the relationship between competition and stability. Keeley (1990) finds that the erosion in the US banks' market power, which resulted from deregulation, caused an increase in the bank failure rates during the 1980's. Similarly, Beck et al. (2006) provide evidence that more concentrated banking systems are less vulnerable to systemic risk because more concentrated banks tend to diversify their risks more. Schaeck et al. (2009) also come to the result that a more concentrated banking system is less fragile to systemic risk. In contrast, Berger et al. (2009) find that, though more competitive banking systems tend to take more risk, they also compensate the higher risk with higher equity to asset ratios and are, thus, less fragile to systemic risk. Schaeck and Cihak (2011) find empirical evidence that a bank's capital structure is one of the channels through which competition may have an impact on the stability of the banking sector. However, there is little empirical evidence that suggests that more stringent capital regulation actually improves the stability of a particular banking sector as pointed out by Barth et al. (2005).

Building on the rather mixed theoretical prediction and empirical evidence, recent empirical work focuses on the role that the market and institutional environment plays in the determination of the relationship between competition and the stability of the banking sector. Beck et al. (2011) seize the theoretical suggestions on non-monotone relationships among competition and stability, and try to identify the most prominent factors that determine the amplitude and direction of the relationship. Based on cross-country data, they find that the relation between competition and stability is likely to be negative the stricter the capital regulation is, the more restricted banking activities are, and the more homogenous the banking sector is as a whole. In particular, they find that more binding capital regulation tends to have an amplifying effect on the competition-stability relationship, regardless of the sign of the particular relationship.

To the author's knowledge, only two theoretical papers exist that try to simultaneously analyze the effect that competition and capital regulation have on bank stability: Hakenes and Schnabel (2011) show that the ambiguous effect of competition on banks' risk taking translates into ambiguous effects of capital requirement on the stability of the banking sector. Though their model tries to capture the influence of correlation among loan defaults, the simplification they use in their model still implies that either all loans default at the same time or no defaults occur. Banks themselves can only influence the probability with which these defaults occur. Hence, there is no positive marginal effect of higher profits from non-defaulting loans, which could buffer losses from defaulting loans.

Martinez-Miera (2009) analyzes the impact of capital requirement regulation on the probability of bank failure under different exogenous market structures when loan defaults are imperfectly correlated. He argues that if the asset risk of the bank's loan portfolio is not perfectly correlated, capital requirements have ambiguous effects on the stability of a bank, which is labeled effect (V). He shows that in highly concentrated loan markets the increase in price setting power resulting from

Table 1: Overview of the Main Literature and the Discussed Effects

<table>
<tr><th></th><th colspan="2">Literature</th><th>Low Competition:</th><th>High Competition:</th><th>Assumptions</th><th>Basic Effects</th></tr>
<tr><td rowspan="4">**No Capital Regulation**</td><td colspan="2">Among others:
Matutes and Vives (2000),
Hellmann et al. (2000),
Allen and Gale (2000)</td><td>Stabilizes Banking</td><td>Destabilizes Banking</td><td>Exogenous Competition for Deposits, Bank Risk Shifting</td><td>Charter Value (I)</td></tr>
<tr><td colspan="2">Boyd and De Nicolò (2005)</td><td>Destabilizes Banking</td><td>Stabilizes Banking</td><td>Exogenous Competition for Loan Assets, Borrower Risk Shifting</td><td>Risk Shifting (II)</td></tr>
<tr><td rowspan="2">Martinez-Miera and Repullo (2010)</td><td>Perfect Correlation</td><td>Destabilizes Banking</td><td>Stabilizes Banking</td><td rowspan="2">Exogenous Competition for Loan Assets, Borrower Risk Shifting, Imperfect Correlation</td><td rowspan="2">Risk Shifting (II),
Margin (III),
Buffer (IV)</td></tr>
<tr><td>Imperfect Correlation</td><td colspan="2">U-shaped Relationship:
Competition-Instability</td></tr>
<tr><td rowspan="3">**Capital Regulation**</td><td colspan="2">Hakenes and Schnabel (2011)</td><td>Regulation Destabilizes if Competition Stabilizes</td><td>Regulation Stabilizes if Competition Destabilizes</td><td>Exogenous Competition for Deposits and Assets, Bank controls „correlation“ (probability of perfectly correlated Default)</td><td>Risk Shifting (II)</td></tr>
<tr><td colspan="2">Martinez-Miera (2009)</td><td colspan="2">Net Effect of Capital Requirement Depends on Exogenous Competition and Correlation</td><td>Exogenous Competition for Loan Assets, Borrower Risk Shifting, Imperfect Correlation</td><td>Risk Shifting (II),
Margin (III),
Buffer (IV)</td></tr>
<tr><td colspan="2">This Paper</td><td colspan="2">Net Effect of Capital Requirement Depends on Cost of Recapitalization, Bank Concentration, and Correlation</td><td>Endogenous Competition, Schliephake and Kirstein (2013)</td><td>Risk Shifting (II),
Margin (III),
Buffer (IV),
Cournotization (VI)</td></tr>
</table>

higher capital requirements can reestablish the stability enhancing effect of capital requirements even with borrower risk shifting, provided that the risk shifting effect is strong enough. The intuition is that a monopolist who anticipates the risk shifting of borrowers may find it profitable to internalize the increased marginal costs of higher capital requirement regulation.

In contrast to Martinez-Miera (2009), this paper does not take the competitive environment as given but explicitly considers changes in the competitive structure due to the strategic reaction of banks on the regulation. The Cournotization effect (VI) of capital requirement regulation reduces the incentives to undercut competitors in loan interest rates. This leads to increased price setting power, which again reinforces the two effects of increased loan interest rates: the margin effect (III), if loan defaults are not perfectly correlated, and the risk shifting effect (II) by borrowers.

This paper shows that the net effect of fiercer regulation on banking stability depends on how much market power is gained by the Cournotization effect. Intuitively, the increase in price setting power is higher, the more concentrated the market structure is, i.e., the less banks compete for loans.

Using a model framework adapted from Martinez-Miera (2009) the analysis suggests that in an economy, where a monopolist finds it optimal to internalize the increased marginal cost of capital regulation, there exists a critical market concentration for which the Cournot oligopolists internalize the increased costs. In this case the cost of default decreases due to lower liabilities to depositors, as well as the probability of default shrinks, because the banks anticipate profit reducing risk shifting behavior of their customers. The paper therefore extends the analysis of Martinez-Miera (2009) for endogenous competition and adds an important policy implication: a regulator that wants to foster bank stability does not only have to consider the number of competitors but also the cost of recapitalization in the banking sector.

The main finding of this paper is that if low competition has a stability enhancing effect, higher capital regulation should not be accompanied by a support of recapitalization of banks. A summary of the main literature, their crucial assumptions and differences in results is provided in Table 1.

The next section introduces the basic model assumptions and presents a simplified and generalized version of the Cournotization effect as discussed in Schliephake and Kirstein (2013).

3. The Model Setup

Consider a single-period model of n banking firms.The banks compete for risky loans L in loan interest rates r. Loans default with probability p in which case the bank receives nothing. In case of success, i.e., with probability $1-p$ the bank receives the contracted repayment from the borrower. In the basic setting, I assume that loan defaults are perfectly correlated such that all projects default at the same time. In the beginning of the period, each bank has access to deposit finance (D) at a constant cost ($r_D \geq 0$). The deposits are insured at a flat insurance premium, normalized to zero without loss of generality.[3] Therefore, the supply of deposits to a bank is independent of the riskiness of the bank's asset investment.

Each bank is run by a bank owner manager, who can acquire equity k_i from shareholders, which have an alternative and equally risky investment opportunity with return $r_K = r_D + c$. This fixed opportunity cost reflects the higher cost of equity compared to the insured deposit funding.

The assumption that equity funding is costly is not undisputed in the literature. In particular, Admati et al. (2010) elaborate the weaknesses of the assumption that bank equity funding is costly to society. However, in this simple model, the cost of equity is not seen from a welfare perspective, but it is rather assumed that equity funding is relatively more costly to the specific bank than deposit funding. This is a direct consequence of the deposit insurance system. The insured depositors do not expect a risk premium, while the liable equity investors do. Another interpretation is that higher opportunity cost compared to deposit funding reflects the additional benefits that deposits create to the depositors. The role of the bank as a financial intermediary is, therefore, welfare enhancing. Unnecessarily high capital requirement regulation would erode the bank's role as a financial intermediary offering depositing services, i.e. a equity to asset ratio of 1 would not allow for financial intermediation in the sense of providing deposit services. Hence, equity is assumed to be costly to

[3] In alliance with the current regulatory system, this paper takes the existence of the fixed-rate deposit insurance as given, whereas the insurance can be explicit by an ex ante financed deposit insurance or implicit by a guaranteed ex-post bail out policy.

the bank, and pure equity funding in our simple model setup would be inefficient in the absence of bank Moral Hazard.

A minimum capital requirement is defined as the requirement to refund a specific proportion of assets (of a specific risk type) with equity $\beta l_i \leq k_i$. In line with the theoretical and empirical findings, it is assumed that bank managers rather avoid increasing equity, but adapt their asset portfolios when facing a regulatory equity shortage.[4] The assumption that there are prohibitive costs of recapitalizing immediately changes the sequence of decisions made, and influences the competitive environment. The Bertrand competition among banks becomes a two stage decision making process, where in the first stage, the bank has to define the capital structure, and in the second stage, competition in loan interest rates takes place.

t=1 According to minimum capital requirement regulation, banks choose optimal k_i , $i = 1...n$, $i \neq j$ with $K = \sum_i^n k_i$.

t=2 After observing the opponents k_{-i}, bank i chooses optimal $r_i(r_{-i}, K)$

For simplicity, I assume that equity can only be raised in $t = 1$, i.e., the cost of immediate recapitalization is prohibitively high.[5] The capital decision is sunk in stage 2. Hence, the marginal cost of equity in stage two is zero. Instead of influencing the

[4] Anecdotal evidence that equity constrained banks adapt assets rather than liabilities could be found during the recent financial crisis, where many banks faced difficulties in replacing lost equity in a timely fashion. Calomiris and Herring (2012) discuss that despite banks being undercapitalized as a result of the need to write off asset losses in 2008, the financial institutions preferred to wait instead of immediately raising new equity. They argue that stock prices were so low that the issuance of significant amounts of equity, in order to cover the large losses incurred, "would have implied substantial dilution of stockholders – including existing management." These observations suggest that bank managers try to avoid an immediate increase in equity in order to satisfy market demand, and prefer to reduce the demand for loans by increasing the loan rate.

[5] Schliephake and Kirstein (2013) allow for recapitalization in stage two and show that if recapitalization is costly enough, the equity raised in the first stage becomes a binding constraint in the second stage.

marginal cost of investing in loan assets in the second stage, the regulatory minimum capital requirement sets an upper bound on the individual bank's ability to supply loans l_i:

$$l_i(r_i(r_{-i}), r_{-i}) \leq \frac{k_i}{\beta} \tag{1}$$

Let $r(\cdot)$ be the inverse demand function that is decreasing and concave in the loan quantities supplied, i.e., $r(0) > r_D$, $r'(\cdot) < 0$ and $r''(\cdot) \leq 0$. The optimal prices chosen in the second stage, therefore, depend on the amount of equity raised by each bank in the first stage. Therefore, the capacity constraint for loan supply puts a lower bound to equilibrium loan interest rates:

$$r_i(r_{-i}, K) \geq r^{min}\left(\frac{k_i}{\beta}\right) \tag{2}$$

For given amount of equity, it would never be profitable to undercut r^{min}, because this would imply a demand above the capacity, i.e. a demand that cannot be served due to the regulatory restrictions; implying lower profits.

3.1. The Optimal Second Stage Behavior

Consider first the trivial case where all banks have raised sufficient equity to serve the loan market demand at the Bertrand price with externalized downside risk. Formally, this means that the aggregate equity on the balance sheet of all banks exceeds

$$K > \beta L(r_D). \tag{3}$$

The second stage pricing decision would be the same as in the unregulated case. The fierce price competition is not constrained by the first stage capital decision. Because the equity decision is sunk at the second stage, the marginal cost equal the deposit funding cost and the non-profit condition would be:

$$r = r_D. \tag{4}$$

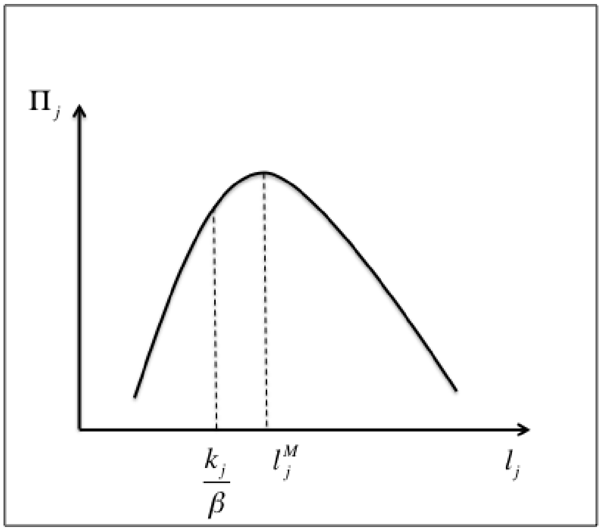
Consider now the case where the raised amount of equity is "sufficiently small". The first stage amount of equity is sufficiently small if, firstly, the capacity to provide loans to borrowers from the first stage capital decision bindingly constrains the price competition $K < \beta L(r_D)$. Secondly, sufficiently small assumes that the capacities are so low that, under any rationing rule, the remaining demand whenever $r_i < r_{-i}^{min}$, is below the monopoly loan output $\beta l_i^M(K) > k_i$ for i, j, where $l_i^M(K)$ is the monopoly loan amount in the residual market.

Lemma 1. *(From Tirole (1988)) For "sufficiently small" capacities to lend that are set in the first stage, the second stage loan rate competition yields a unique Nash Equilibrium that is independent of any rationing rule, namely a loan interest rate that just clears capacities:* $r\left(\frac{K}{\beta}\right)$

Proof. If the infimum of the loan interest rates set by the competitors equals the capacity clearing interest rate, undercutting the opponent's price can never be profitable. Consider contrariwise the case where $r_i < r(K)$. Since recapitalization is assumed not to be possible in stage two, price undercutting would only lead to excess demand for loans, which cannot be served due to the binding minimum capital requirement. Undercutting in loan rates is not profitable, because each bank lends already the maximum capacity to its borrowers.

Furthermore, a price increase is not profitable, since profits are assumed to be strictly convex in loan quantities and the capacity is assumed to be smaller than the residual demand monopoly quantity. For any $r(K) < r_i$, bank i receives the residual demand, after the m other banks served the loan applicants up to their own capacity. The assumption $l_i^M(K) > \frac{k_i}{\beta}$ implies by definition $\Pi(l_i^M) > \Pi(\frac{k_j}{\beta})$. The inverse demand function implies $r(L_j^M(k_i, k_j)) < r\left(\frac{K_j}{\beta}\right)$. Since the resulting profit maximizing loan quantity in the residual market is higher than the small capacity, the respective profit maximizing loan rate must be lower than the constrained optimal loan rate that clears capacity. Hence, overbidding can never be profitable. Figure 2 illustrates this point. $\square$

Figure 2: The Overbidding at Competitor's Profit with Sufficiently Low Capacities



The underlying assumption that capacities are chosen to be sufficiently small in the first stage seems to be quite restrictive. One sufficient condition for the choice of low capacities would be very high cost of equity. However, the seminal work of Kreps and Scheinkman (1983) shows that, for a concave inverse demand function, and efficient rationing of the residual demand, installing sufficiently low capacities is the unique sub-game perfect equilibrium of the two stage game, regardless of the investment cost of capacity, which is the private cost of equity in this model.[6] Since this model focuses on the effects of a change in the competitive structure induced by capital requirement regulation on the riskiness of banks, it is assumed for simplicity that borrowers are rationed according to the efficient rationing rule, and accordingly

[6]Davidson and Deneckere (1986) show that this result is not robust against different rationing rules. With alternative rationing rules, competitors find it optimal to build up capacities that are not sufficiently low, but below the demand for selling the product at marginal cost. For capacities that are not sufficiently small, sub-game perfect strategies only exist in mixed strategies. However, regardless of the specific rationing rule, the separation of decisions into capacity buildup and price competition leads to reduced incentives to undercut in prices and, therefore, positive profits.

that the result of Kreps and Scheinkman (1983) can be applied.

3.2. The Optimal First Stage Capacity Choice

Anticipating that it is the optimal behavior in the second stage to clear any capacity, banks choose the individual amount of equity in the first stage that maximizes the first stage objective function:

$$k_i^* = argmax\left(\frac{k_i}{\beta}\cdot\left[(1-p)\cdot\left(r\left(\frac{K}{\beta}\right)-r_D(1-\beta)\right)-r_K\beta\right]\right) \tag{5}$$

This is the classical Cournot competition objective function, where r_K -the cost of equity - can be interpreted as the marginal cost of investing into loan capacity. A symmetric equilibrium then consists of a vector $\mathbf{k_i}$ which simultaneously satisfy the system of first order conditions for all banks $i = 1...n$.

For symmetric banks, which have identical characteristics and face the identical demand and cost functions, the Cournot equilibrium is symmetric.[7] In such a symmetric equilibrium it must hold that $k_i = k_j = k$. Therefore, it must also hold that $K = \sum k_i = nk$. The first order condition for a symmetric Cournot equilibrium can thus be simplified to:

$$r'(K)\cdot\frac{K}{n}+\left((r(K)-(1-\beta)r_D-\frac{\beta r_K}{(1-p)}\right)=0 \tag{6}$$

The first term reflects "market power rents" that result from the strategic commitment to Cournot capacities in the first stage. The term captures the effect of a decreasing demand that is taken into consideration when capacities are built up in the first stage. The second term reflects each bank's expected payoff per unit of loans.

[7]See Tirole (1988), pp. 220 for a discussion of symmetry, existence and uniqueness of a Cournot equilibrium.

The Cournotization effect then describes a situation where, because of sufficiently high recapitalization costs, the actual Bertrand competition for loans is constrained by a strategic loan capacity choice. Therefore, the Bertrand competition for loans can be described by Cournot competition. If the recapitalization costs are low, such that the capacity constraint is not binding, the existing Bertrand competition can still be described in the quantity space by Cournot competition with an infinite number of competitors.

Lemma 2. *If there is no Cournotization effect, because recapitalization costs are low, the unconstrained Bertrand competition can be described in the quantity space by the Cournot equilibrium with an infinite number of competitors.*

Proof. If the number of competitors approaches infinity, then the market power term vanishes and the sub-game perfect outcome approaches the one stage Bertrand equilibrium outcome

$$\lim_{n \to \infty} \left(r(K) = (1-\beta) r_D + \frac{\beta r_K}{(1-p)} \right). \tag{7}$$

□

When discussing the impact of the Cournotization effect on stability of banks, I will therefore compare the situation where $n \to \infty$ with a situation where $n < \infty$. This also implies that a low number of banks in the oligopolistic market leads to a relatively high increase of price setting power in the two stage game, compared to unconstrained Bertrand competition. Therefore, a high market concentration is likely to be reflected in a capacity constrained loan market competition with higher marginal profits compared to the Bertrand equilibrium.

Because in equilibrium the capital requirement will be binding, I can substitute $\frac{k_i}{\beta} = l_i$ such that each bank chooses its individual optimal loan amount. The capacity constrained objective function then reflects the Cournot decision problem in loan quantities.[8]

$$l_i^* = argmax\left(l_i\left[(1-p)(r\left(L\right) - r_D(1-\beta)) - r_K\beta\right]\right) \tag{8}$$

Denoting $h(L) := (1-p)(r\left(L\right)-r_D(1-\beta))$ as the extended indirect demand function I can write the first order condition as the general Cournot equilibrium condition: $h'(L) \cdot \frac{L}{n} + (h(L) - r_K\beta) = 0$. Analogous to equation (6) the first term reflects the gained market power, which approaches zero in the unconstrained Bertrand competition, i.e., if recapitalization is costless. Lemma 2 implies that such an unconstrained competition can be described in the quantity space as hypothetical increase of n to infinity.

In the following section, I will discuss how the increase of capital requirement regulation β influences this equilibrium condition and the according default risk of a bank, given there is a Cournotization effect. Moreover, I will compare the results to the net effects in Bertrand competition and will discuss if a regulator should control for the Cournotization effect or not.

4. Constrained Competition with Risk Shifting and Perfect Correlation

The previous discussion concentrated on the changes in competitive behavior of banks when capital requirement regulation is tightened, while the risk taking behavior of borrowers was assumed to be exogenous. However, not only banks, but also borrowers are limitedly liable, and thus protected against the downside risk of investments. Higher loan interest rates reduce the profitability of borrowers investment projects, which gives incentives to search for higher yields at the cost

[8] Keeping equity as the decision variable does not change the qualitative results but unnecessarily complicates the notation in the following, because the capital requirement rate *beta* influences not only the marginal equity cost but also acts as a scaling factor for the equity decision. However, this function as a scaling factor has no impact on the risk choice of the bank and is, therefore, neglected in the following.

of a higher risk of the project. The model is, therefore, extended to the optimal responses of borrowers' to differing loan rates resulting from the tightening of capital requirement regulation.

The intuition is that the individual default probabilities of projects is partly controlled by the borrowers decision to control for risk. This could either reflect a certain costly effort that borrowers spend to enhance the success of their projects, or by the unobservable choice of the particular project the borrower invests in. The less profitable projects become that are financed by bank loans, the less effort borrowers are willing to spend, and the lower are the success rates of their projects. To model the borrower risk shifting I follow the model set up of Martinez-Miera and Repullo (2010).

A continuum of penniless entrepreneurs captured with i, who have access to risky projects of fixed size, normalized to 1. The entrepreneurs can spend effort on an individual alternative (e.g. employment) to obtain a utility level $b[0, B]$. The reservation utility is continuously distributed on $[0, B]$ with the cumulative distribution function $G(b)$. Let $G(u)$ denote the measure of entrepreneurs that can obtain an alternative utility less than or equal to u.

In case of success, projects yield a risky return $\alpha(p_j)$ and zero otherwise. The component p_i is the endogenously chosen probability of default, and reflects the costly effort an entrepreneur spends on the project to enhance expected output.[9]

[9]Boyd et al. (2009) explicitly model the optimal effort choice of entrepreneurs. The projects yield an output of $\tilde{y} + z$. The total return component y is random and distributed with the density function $f(y)$ and the cumulative density $F(y)$ on the closed interval $[0, A]$, which is known by the bank and the borrowers. The component z is endogenous and reflects the costly effort the borrower is willing to spend on the project to enhance output. The effort cost is $c(z)$ a strictly increasing, twice differentiable, convex cost function. For a given contracted loan rate, a borrower defaults whenever $y \leq \underline{y} \equiv r - z$. Knowing the loan rate offered, the entrepreneur chooses his optimal effort in order to maximize his expected profit: $\underset{z}{max} \int_{\underline{y}}^{A} (y + z - r) f(y) dy - c(z)$. Integrating by parts

As in Martinez-Miera and Repullo (2010), I assume that $\alpha(0) < \alpha'(0)$ in order to get interior solutions. The bank offers a standard debt contract with limited liability of borrowers: In case of project success with probability $(1 - p_i)$, the bank receives the contracted loan interest r, and in case of default with probability p_i, the bank receives nothing, since the project's liquidation value is assumed to be zero.

Lemma 3. *Because of the limited liability of a standard debt contract the default risk of a single loan increases in the equilibrium loan interest rate* $\frac{dp}{dr} > 0$.

Proof. The proof is provided in Appendix A. □

It is further assumed that entrepreneurs are homogenous in their objective function, except for the exogenous reservation utilities u_j. Hence, all entrepreneurs will choose the identical optimal default probability $p_j(r(L)) = p(r(L))$, $\{j \mid u_j \leq u(r)\}$ or opt for their outside option and do not borrow from banks. A bank that is lending to $L_i(r)$ borrowers, faces individual loan defaults of $p(r(L))$ in the portfolio.

If all projects are perfectly correlated, i.e., $\rho = 1$, and thus default at the same time, the bank's portfolio risk of default is also equal to $p(r(L))$. Under perfect correlation, there is no margin effect, because all projects either default or not. Similarly, there is no buffer effect for a leveraged bank. A lower leverage allows the bank to absorb a higher share of defaults in the portfolio. However, with perfect correlation the share of defaults is either zero or 1. In section 5 the influence of imperfect correlation and in particular the impact of the margin and buffer effects is discussed. As before, the Cournot equilibrium is defined by the optimal choices of

yields the objective function: $A + z - r - \int_{\underline{y}}^{A} F(y)dy - c(z)$, resulting in the first order condition: $1 - F(r - z) = c^{'}(z)$. Total differentiation yields $z_{R^L}(r) = \frac{F^{'}(r-z)}{F^{'}(r-z)-c^{''}(z)} < 0$. Higher loan rates imply less optimal effort, which translates into higher risk. Therefore, a riskier project (less costly effort) yields a higher success return to the borrower, i.e. $\alpha(p_i)$ is assumed to be positive, concave and increasing in p_i.

individual loan quantities:

$$l_i^* = argmax\left(\left[(1 - p(r(L)))(r(L) - r_D(1-\beta)) - r_K\beta\right]\right) \tag{9}$$

For the sake of notational simplification, the extended indirect demand function is defined as: $h(L, \beta) := (1 - p(r(L)))(r(L) - r_D(1-\beta))$. Even with linear indirect demand and indirect risk shifting, the extended indirect demand function is not any more linear. However, with linear demand and risk shifting functions, $h(L)$ has the characteristics that guarantee a unique Cournot equilibrium, i.e.: $h'(L) < 0$ and $h''(L) < 0$.[10] To make sure that the reaction functions intersect, I assume that $h(0) > \beta \cdot r_K$. In other words, it is assumed that investing in risky projects is socially desirable. The first order condition, that defines a symmetric pure strategy Cournot equilibrium is then defined by:

$$h'(L, \beta) \cdot \frac{L}{n} + (h(L, \beta) - r_K\beta) = 0 \tag{10}$$

As this paper is concerned with the stability of the banking sector in Bertrand and two stage capacity constrained competition that yields Cournot results, the question to be answered is how the probability of default of each bank is effected by changes in the exogenous parameters. Define q as the probability of default of a single bank. For the very simplified case of perfect correlation, the probability of default of a bank is reflected by the probability of default of the borrowers $q = p(r(L))$. In particular, the probability of bank default increases whenever the loan interest increases, implying that a decrease in equilibrium loan supply increases the probability of a bank default.

Lemma 4. *A decrease in aggregate equilibrium loan supply of perfectly correlated*

[10]For the existence of a pure strategy Cournot equilibrium with the linear cost function, it is sufficient that the extended demand function is concave $h'(L) = -p'(L)(r(L) - r_D(1-\beta)) + (1 - p(r(L)))r'(L) < 0$ because $p'(r) > 0$ and $r'(L) < 0$ and $h''(L) = p'(r(L))r'(L) < 0$.

risky loans increases the probability of default of the investing banks and thus destabilizes the banking sector.

Proof. Using Lemma 3 and the assumption of decreasing loan demand it is straightforward that $\frac{dq}{dL} = p'(r(L))r'(L) < 0$. □

Consider first the direct effect of a change in the competition level due to an exogenous change in the market concentration. As in the traditional Cournot equilibrium, a change in the competition that is reflected by an exogenous change of the number of competitors n has a positive effect on the supply of loans.

Lemma 5. Ceteris paribus*, the aggregate loan supply L in equilibrium is lower in more concentrated markets, i.e.,* $\frac{dL}{dn} > 0$.

Proof. Applying the implicit function theorem to equation (10) I show that

$$\frac{dL}{dn} = -\frac{h(L, \beta) - \beta \cdot r_K}{h''(L)L + (1+n)h'(L)} > 0 \tag{11}$$

The denominator is negative whenever the second order condition of the bank's objective function holds, i.e., it is clearly negative for a concave extended demand function. The numerator is positive, as long as the assumption that $h(0) > \beta \cdot r_K$ holds. □

This is the result of Boyd and De Nicolò (2005). Due to the risk shifting effect, a reduction in competition that increases loan interest rates destabilizes the banking sector.

However, this paper is not concerned with the direct effect of competition on the stability of banks, but instead with the indirect effect that capital requirement has on the price setting power and its impact on banking stability. In order to analyze this impact, it is necessary to understand first the direct impact of an increase in capital requirements on banking stability, and then compare the results for Bertrand competition and two stage capacity loan interest rate competition. Applying the implicit function theorem to equation (10) I obtain:

$$\frac{dL}{d\beta} = -\frac{\frac{\partial^2 \Pi(L,\beta)}{\partial L \partial \beta}}{\frac{\partial^2 \Pi(L,\beta)}{\partial L^2}} = -\frac{\left(\frac{\partial h(L,\beta)}{\partial \beta} - r_K\right) + \frac{\partial^2 h(L,\beta)}{\partial \beta \partial L}\frac{L}{n}}{h''(L)L + (1+n)h'(L)} \tag{12}$$

The denominator is negative if the second order condition holds, which is in particular true for linear demand and linear risk shifting functions. Therefore, the sign of the right hand side of equation (12) is determined by the sign of the numerator. In particular, if $\left(\frac{\partial h(L,\beta)}{\partial \beta} - r_K\right) + \frac{\partial^2 h(L,\beta)}{\partial \beta \partial L}\frac{L}{n} < 0$, an increase in capital requirements results in lower aggregate supply of loans in equilibrium, and vice versa. For perfectly correlated loan defaults, the partial derivative of the extended demand function is simply:

$$\frac{\partial h(L,\beta)}{\partial \beta} = (1 - p(r(L)) \cdot r_D > 0 \tag{13}$$

If equity funding is costly ($r_K \geq r_D$) then it must clearly hold that $(1-p(r(L)))\cdot r_D < r_K$ because $p(r(L)) \in [0,1]$ because it is a probability.[11] Therefore, the first term in brackets is negative and reflects the decreasing profitability of each unit of loan when equity funding is more expensive than deposit funding.

Applying Young's theorem to equation (13) one obtains:

$$\frac{\partial^2 h(L,\beta)}{\partial L \partial \beta} = -p'(r(L))) \cdot r'(L) \cdot r_D > 0 \tag{14}$$

The impact of an increase in capital requirement on each bank's profit is thus ambiguous:

[11] Even if the opportunity cost of equity funding would equal r_D, the limited liability to depositors already implies higher expected marginal cost of equity.

$$\frac{\partial^2 \Pi(L,\beta)}{\partial L \partial \beta} = \underbrace{\left(\frac{\partial h(L,\beta)}{\partial \beta} - r_K\right)}_{<0} + \underbrace{\frac{\partial^2 h(L,\beta)}{\partial L \partial \beta} \cdot \frac{L}{n}}_{>0} \tag{15}$$

Proposition 1. *If the cost of recapitalization is sufficiently low, such that there is no binding capacity constraint on Bertrand competition, an increase in capital requirements will unambiguously decrease the stability of banks under perfect correlation.*

Proof. Recall from Lemma 2 that unconstrained Bertrand competition translates in the quantity space into $n \to \infty$ such that equation (15) becomes unambiguously negative: an increase in β decreases the supply of loans in equilibrium. The decrease in loan supply increases the equilibrium loan interest rate and through risk shifting as the only effect this decreases the banks' probability of default as shown in Lemma 4. □

This result is similar to the argumentation of Boyd and De Nicolò (2005). Without any price setting power the only effect of the increase in capital requirements and the resulting higher marginal funding costs is an increase in loan interest rates. The higher loan interest rate then unambiguously translates into borrower risk shifting and decreases the bank stability.

Moreover, it becomes clear that the sign of right hand side of equation (15) depends critically on n.

Lemma 6. *A higher market concentration, i.e., a lower n, increases the cross partial derivative $\frac{\partial^2 \Pi(L,\beta)}{\partial L \partial \beta}$.*

Proof. Using equations (13), (14) and (15) I obtain:

$$-\left(\frac{r_K}{r_D} - (1 - p(r(L)))\right) - p'(r(L)) \cdot r'(L) \cdot \frac{L}{n} \tag{16}$$

Differentiation with respect to n yields:

$$-p'(r(L))) \cdot r'(L) \cdot \left[\frac{dL}{dn} + \frac{\frac{dL}{dn}}{n} - \frac{L}{n^2}\right] \gtrless 0 \tag{17}$$

Because $-p'(r(L))) \cdot r'(L) > 0$, the sign of the derivative depends on the terms in brackets. A lower n increases equation (15) whenever $\left[\frac{dL}{dn} + \frac{\frac{dL}{dn}}{n} - \frac{L}{n^2}\right] < 0$. Intuitively, this condition means that an increase in the number of competitors increases the aggregate loan supply more than it reduces the individual loan supply as conjectured in Martinez-Miera (2009) based on simulations. Because n, the number of competitors, is strictly positive, this condition can be reduced to:

$$\frac{dL}{dn} < \frac{L}{n \cdot (n+1)} \tag{18}$$

Recalling Lemma 5, i.e., using equation (11) I obtain:

$$-\frac{h(L, \beta) - \beta \cdot r_K}{h''(L)L + (1+n)h'(L)} < \frac{L}{n \cdot (n+1)} \tag{19}$$

This can be simplified to:[12]

$$h(L, \beta) - \beta \cdot r_K < -\frac{h''(L)L^2}{n \cdot (n+1)} - h'(L) \cdot \frac{L}{n} \tag{20}$$

Moreover, the first order condition for the Cournot equilibrium that is given in equation (10) can be rewritten as:[13]

$$(h(L, \beta) - \beta \cdot r_K) = -h'(L, \beta) \cdot \frac{L}{n} \tag{21}$$

Substituting the right hand side in the left side of the inequality yields:

$$-\frac{h''(L)L^2}{n \cdot (n+1)} > 0 \tag{22}$$

This condition holds for $h''(L) < 0$ as provided in our model.[14] □

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[12] The second order condition requires that $-(h''(L)L + (1+n)h'(L)) > 0$.

[13] Further modification would lead to the standard Cournot equilibrium condition - $\frac{(h(L,\beta)-\beta \cdot r_K)}{(h(L,\beta)} = \frac{\frac{1}{n}}{e}$ - the Lerner Index in equilibrium equals the market share over the point price elasticity at the equilibrium price.

[14] In the standard Cournot oligopoly model with linear indirect demand, this term is zero. Implying that, with a linear extended demand function, the market concentration plays no role on the impact of capital requirement regulation on the stability of banks because an increase in the number of competitors increases the aggregate output exactly in the same amount as the individual

Lemma 6 shows that there exists an n for which it is not optimal for the competing banks to shift the cost of higher capital requirements to their borrowers. Anticipating the risk shifting reaction to higher loan interest rates, a bank with high price setting power prefers to keep the loan interest rate constant or even lowers it, when capital requirements are increased. Denoting L^M as the optimal monopoly output and assuming that the risk shifting effect is high enough, i.e., $-p'(r(L^M))) \cdot r'(L^M)L^M > \left(\frac{r_K}{r_D} - (1 - p(r(L^M)))\right)$, the following proposition can be derived.

Proposition 2. *If risk shifting is high, the impact of the capital requirement on the equilibrium loan interest rate is not monotone but may depend on the number of competitors:*

$$\begin{array}{llll} if\ n > \hat{n} & \rightarrow \frac{\partial^2 \Pi(L,\beta)}{\partial L \partial \beta} < 0 & \rightarrow \frac{dr}{d\beta} > 0 \\ if\ n < \hat{n} & \rightarrow \frac{\partial^2 \Pi(L,\beta)}{\partial L \partial \beta} > 0 & \rightarrow \frac{dr}{d\beta} < 0 \end{array}$$

Proof. If risk shifting is high, i.e. $\left(-p'r'(L^M) \cdot L^M > \frac{r_K}{r_D} - (1 - p(r(L^M)))\right)$, a monopolist finds it optimal to increase the loan interest rate, i.e., to reduce the loan supply, when he faces higher marginal cost from capital requirement regulation $(\frac{dr(L)}{d\beta} < 0)$. If $n \rightarrow \infty$, the cross partial derivative is unambiguously negative such that the default probability increases with higher capital requirements $\frac{dr(L)}{d\beta} > 0$. From Lemma 6, it becomes clear that there must exist a critical number of competitors $\hat{n}$ for which the cross partial derivative is zero. □

If banks gain price setting power through higher capital requirements, the loan interest rate is not monotonically increasing in capital requirements. If the Cournotization effect is high compared to risk shifting (due to high market concentration), a capital requirement increase will increase aggregate lending. The intuition is that banks consider the risk shifting effect when setting optimal capacities. If they gain enough price setting power, they can internalize the increased marginal cost and thereby avoid the risk shifting of their borrowers.

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output is reduced.

Proposition 3. *A binding capacity constraint on Bertrand competition, resulting from increased capital requirements, may stabilize the banking sector if the market is highly concentrated.*

Proof. Recall from Lemma 2 that unconstrained Bertrand competition translates in $n \to \infty$ such that equation (15) becomes unambiguously negative: an increase in β decreases the supply of loans in equilibrium. The decrease in loan supply increases the banks' probability of default as shown in Lemma 4. $\square$

Note, however, that the increase in capital requirements decreases the leverage of the potentially defaulting banks. Considering that a high proportion of the social cost of a bank default is driven by the size of outstanding debt, and not only by the fact of the default, a lower debt level may mean lower cost in case of default. Therefore, an increase in capital requirements in this setting makes a bank default ex ante more likely, but may decrease the ex post cost of the default.

5. Generalization to Imperfect Correlation

If not all loan investments default at the same time, the bank can survive a certain aggregate share of loan defaults in the investment portfolio, due to the equity it invested, which is the so called buffer effect (IV), and the profit it makes on non-defaulting loans in the portfolio, which is called the margin effect (II) accordingly to Martinez-Miera and Repullo (2010) . As illustrated in Figure 1, an individual bank goes bankrupt whenever the revenue from non-defaulting loans cannot compensate the liabilities r_D to its depositors $D = (1 - \beta)L$. Using the introduced variables, this aggregate share of defaults that a bank can survive is implicitly defined by the following equation:

$$(1 - x) \cdot r(L)L < r_D \cdot D \tag{23}$$

Define $\hat{x}(L)$ as the critical aggregate loan failure rate that makes the non-defaulting condition binding:

$$\hat{x}(L) = \frac{r(L) - (1-\beta)r_D}{r(L)} \tag{24}$$

The bank's probability of default is then the probability to observe an aggregate portfolio default rate above this critical value.

The probability of observing such an aggregate default rate in the portfolio is analyzed using a one-factor Gaussian copula model of time to default.[15] The basic assumption is that a bank invests in a highly granulated portfolio of assets with individual probabilities of default $p(r(L))$. It is assumed that the copula correlation between each pair of homogenous borrowers is $\rho < 1$. The single risk factor model then assumes that the default of each individual loan investment is triggered by the random project value falling below a critical value. The random project return of a project can be described as:

$$B_j = \sqrt{\rho} \cdot Z + \sqrt{1-\rho} \cdot \varepsilon_j \tag{25}$$

where Z is a common systematic risk factor that effects all projects and ε_j is an idiosyncratic risk factor that is independent among the projects. Assume that both random variables are independently standard normally distributed. The constant ρ, hence, measures the correlation between project returns, i.e., defines the proportion of systematic and idiosyncratic risk that triggers the project value. For each state of nature, which reflects a certain realization of the systemic factor, I can define a

[15] The IRB approach in Basel II and III is based on this model that is also known as the Vasicek model (Vasicek, 2002).

conditional probability of default:

$$p_j(z) = P\left[B_j < c_j | Z = z\right] \tag{26}$$

where c_j reflects a certain threshold value, which the project return has to outweigh. In this paper's model framework this threshold value is the borrower's liability to the bank.

Because the project return is the sum of two independent standard normally distributed variables the return itself is also $B_j \sim N(0,1)$, such that $p_j(z) = \phi(c_j)$ or $c_j = \phi^{-1}(p_j)$. The threshold value is the quantile for the default probability that the borrowers choose when confronted with the standard debt contract. Conditional on the realization of $Z = z$, there is only one random variable left, the idiosyncratic risk that determines the conditional probability of default of a representative project:

$$q_j(z) = P\left[\sqrt{\rho} \cdot z + \sqrt{1-\rho} \cdot \varepsilon_j \leq \phi^{-1}(p_j) \,|\, Z = z\right] \tag{27}$$

Since $\varepsilon_j \sim N(0,1)$, the conditional probability of default in a certain state of nature is:

$$q_j(z) = \phi\left(\frac{\phi^{-1}(p_j) - \sqrt{\rho} \cdot z}{\sqrt{1-\rho}}\right) \tag{28}$$

For the derivation of the cumulative distribution of the failure rate the assumption that the states of nature are also standard normally distributed, $z \sim N(0,1)$, is used:

$$F(x,p) = P\left[\phi\left(\tfrac{\phi^{-1}(p) - \sqrt{\rho} \cdot z}{\sqrt{1-\rho}}\right) \leq x\right]$$

$$= P\left[-z \leq \frac{\sqrt{1-\rho} \cdot \phi^{-1}(x) - \phi^{-1}(p)}{\sqrt{\rho}}\right] = \phi\left(\frac{\sqrt{1-\rho} \cdot \phi^{-1}(x) - \phi^{-1}(p)}{\sqrt{\rho}}\right) \tag{29}$$

This gives the probability to observe an aggregate failure rate smaller or equal to $x \in [0,1]$.

A certain bank's stability can therefore be described as the probability of observing an aggregate failure rate, which a bank is able to survive $P[x < \hat{x}]$:

$$F(\hat{x}(\beta, r(L)), p(r(L)) = \phi\left(\frac{\sqrt{1-\rho}\cdot\phi^{-1}(\hat{x}) - \phi^{-1}(p)}{\sqrt{\rho}}\right) \tag{30}$$

The above equation illustrates that the correlation ρ among individual loan defaults determines the existence and strength of the the buffer and margin effects, which are effects on the critical default rate $\hat{x}$. If the correlation is imperfect $\rho < 1$, the bank's stability depends on the individual loan default probabilities $p(r(L))$ and the value of the aggregate failure rate the bank can survive $\hat{x}(\beta, r(L))$ weighted with $\sqrt{1-\rho}$. If correlation is perfect, i.e., $\rho = 1$, the weight becomes zero and bank stability is defined solely by $\phi(\phi^{-1}(p)) = p$ the default probability of a single loan is equal to the default probability of the bank as it was analyzed in the section above.

Bank stability with $\rho < 1$ directly depends on the capital requirement rate, because with higher equity a bank can absorb higher losses. This is reflected in the fact that the critical default rate is increasing in the capital requirement $\frac{\partial\hat{x}}{\partial\beta} > 0$.[16] Moreover, the bank's stability depends on the effect the capital requirement has on the equilibrium loan interest rate. On the one hand, an increase in the loan interest rate leads to higher profits per non-defaulting loan. This again increases the bank's stability because with higher profits, more defaults can be absorbed. On the other hand, as discussed above, a higher loan interest rate results in the discussed risk shifting effect: the limitedly liable borrowers choose higher individual risks, which increases the bank's probability of default.

Lemma 7. *Under imperfect correlation, an increase of capital requirement affects the stability of a bank in three ways. Which effect prevails is influenced by the strength*

[16]For notational simplicity I neglect in the following the indirect functional relationships and where suitable, I write e.g. only $F(\hat{x}, p)$ when referring to $F(\hat{x}(\beta, r(L)), p(r(L))$.

of the Cournotization effect.

$$\frac{dF\left(\hat{x},p\right)}{d\beta}=\underbrace{\frac{\partial F(\hat{x})}{\partial\hat{x}}\cdot\frac{\partial\hat{x}}{\partial\beta}}_{Buffer(+)}+\left(\underbrace{\frac{\partial F(\hat{x})}{\partial\hat{x}}\cdot\frac{\partial\hat{x}}{\partial r}}_{Margin(+)}+\underbrace{\frac{\partial F(p)}{\partial p}\cdot\frac{\partial p}{\partial r}}_{Risk\,Shifting(-)}\right)\cdot\underbrace{\frac{dr}{d\beta}}_{Cournotization(\pm)}\gtrless 0 \qquad (31)$$

Proof. For the formal proof see Appendix B. Intuitively, *Buffer* effect (IV) is positive, because $F(\hat{x},p(r(L)))$ is a cumulative distribution function such that increasing $\hat{x}$ has a positive effect on bank stability $\frac{\partial F(\hat{x},p(r(L)))}{\partial\hat{x}}>0$ and $\frac{\partial\hat{x}}{\partial\beta}=\frac{r_D}{r(L)}$ is positive for strictly positive loan and deposit rates. Similarly, the *Margin* effect (III) is positive because higher loan interest rates increase the critical default threshold level $\frac{\partial\hat{x}}{\partial r}=\frac{(1-\beta)(r_D)}{(r(L))^2}>0$. The *Risk Shifting* effect (II) is negative due to the negative first order stochastic dominance effect of an increased borrower default probability $\frac{\partial F(\hat{x},p(r(L)))}{\partial p}<0$ and the positive effect of an increased loan rate on the borrowers' default probabilities. □

Depending on the exogenous parameters, three possible scenarios exist that determine the effect that the gained market power has on the impact of an increase in regulation on stability.

Case 1: $|Buffer|>|(Margin+Risk\ Shifting)\cdot\frac{dr}{d\beta}|$, the buffer effect outweighs the risk shifting and margin effect. In this case, the gained price setting power of banks does not influence the total effect that is fully driven by the buffer effect. An increase in capital requirement regulation unambiguously increases the stability of banks regardless of the competitive market structure. This situation reflects the traditional view on capital regulation and is not analyzed any further.

Case 2: $|Buffer|<|(Margin+Risk\ Shifting)\cdot\frac{dr}{d\beta}|$ and $|Margin|<|Risk\ Shifting|$: the buffer effect is low and the risk shifting outweighs the margin effect. This is a more general case of the perfect correlation analysis above: Risk shifting is the dominant effect and an increase in capital requirements translates into higher risk. If banks have no price setting power, an increase in capital requirements unambiguously decreases the banks' stability. The Cournotization effect may enhance stability because the gain of price setting power allows banks to internalize the increase in the marginal cost of equity funding. In highly concentrated markets banks are thus reluctant to increase the loan interest because they anticipate risk shifting of borrowers. Analogous to the discussion of perfect correlation an increase in capital requirements then can lead to lower loan interest rates if the risk shifting effect is high enough as discussed above.

Case 3: $|Buffer|<|(Margin+Risk\ Shifting)\cdot\frac{dr}{d\beta}|$ and $|Margin|>|Risk\ Shifting|$: The buffer effect is small and the margin effect outweighs the risk shifting effect. In this case, a gain in price setting power that would lead to a decrease in the equilibrium loan interest rate would destroy the stability enhancing effect of an increase in equity funding. However, such a situation is not feasible in equilibrium because whenever the margin effects outweighs the Risk Shifting effect, an increase in capital requirements always increases the equilibrium loan rate, i.e., reduces the equilibrium loan supply, regardless of the number of competitors.

The following argumentation shows that the Cournotization can only influence the net effect of capital requirement regulation on stability in **Case 2** but not in **Case 3**.

From equation (12) it is clear that an increased capital requirement decreases the equilibrium loan interest rate, whenever the equilibrium loan supply increases, i.e., whenever the cross partial derivative of the objective function with respect to L and β is positive.

The necessary conditions for the cross partial derivative to be positive is a low number of competitors n, as well as a positive cross-derivative of the extended demand function $\frac{\partial^2 h(L,\beta)}{\partial L \partial \beta} > 0$.[17] However, in contrast to the perfect correlation analysis, the cross partial derivative of the indirect extended demand function is not unambiguously positive. The indirect demand function of a limitedly liable bank may now be written as:

$$h(L,\beta) := \int_0^{\hat{x}} ((1-\hat{x}) \cdot r(L) - r_D \cdot (1-\beta))\, dF(x, p(r(L)) \tag{32}$$

Partial integration yields:

$$h(L,\beta) := \int_0^{\hat{x}} F(x, p(r(L))) \cdot r(L) dx. \tag{33}$$

$$\frac{\partial h(L,\beta)}{\partial \beta} = F(\hat{x}, p(r(L))) \cdot r(L) \cdot \frac{\partial \hat{x}}{\partial \beta} > 0 \tag{34}$$

Substituting $\frac{\partial \hat{x}}{\partial \beta} = \frac{r_D}{r(L)}$ this reduces to:

$$\frac{\partial h(L,\beta)}{\partial \beta} = F(\hat{x}, p(r(L))) \cdot r_D > 0. \tag{35}$$

Applying Young's theorem, the cross partial is obtained:

$$\frac{\partial^2 h(L,\beta)}{\partial L \partial \beta} = r_D \left(\underbrace{\frac{\partial F(\hat{x})}{\partial \hat{x}} \cdot \frac{\partial \hat{x}}{\partial r}}_{(+)} + \underbrace{\frac{\partial F(p)}{\partial p} \cdot \frac{\partial p}{\partial r}}_{(-)} \right) \cdot \frac{dr(L)}{dL} \tag{36}$$

The first term in brackets is the *Margin* effect and the second term is the *Risk Shifting* effect, as defined above. With decreasing indirect demand for loans, i.e., $\frac{dr(L)}{dL} < 0$,

[17] As before, the cross partial derivative of the objective function is: $\frac{\partial^2 \Pi(L,\beta)}{\partial L \partial \beta} = \left(\frac{\partial h(L,\beta)}{\partial \beta} - r_K \right) + \frac{\partial^2 h(L,\beta)}{\partial L \partial \beta} \cdot \frac{L}{n}$. As under perfect correlation, the first term is negative, due to the limited liability of the banks. However, the sign of the second term is not any more unambiguously positive.

the equation (36) is positive if |*Margin*|<|*Risk Shifting*| and negative otherwise.

Proposition 4. *If the* Buffer *effect is small and the* Risk Shifting *effect outweighs the* Margin *effect* ***(Case 2)****, an increased price setting power of banks may reestablish the stabilizing impact of capital regulation.*

Proof. If |*Margin*|<|*Risk Shifting*|, it follows from equation (36) that $\frac{\partial^2 h(L,\beta)}{\partial L \partial \beta} > 0$ and thus

$$\frac{\partial^2 \Pi(L,\beta)}{\partial L \partial \beta} = \underbrace{\left(\frac{\partial h(L,\beta)}{\partial \beta} - r_K\right)}_{(-)} + \underbrace{\frac{\partial^2 h(L,\beta)}{\partial L \partial \beta} \cdot \frac{L}{n}}_{(+)}. \tag{37}$$

As this is equal to equation (15), the Proposition 2 and Proposition 3 from the special case of perfect correlation also hold as long as the assumptions of **Case 2** hold. □

However, for **Case 3**, where it is assumed that the *Margin* effect outweighs the *Risk Shifting* effect, equation (36) becomes negative. With a negative cross partial derivative of the indirect extended demand function, the cross partial derivative of the objective function is also negative, regardless of the number of competitors.

Proposition 5. *If the* Buffer *effect is small and the* Margin *effect outweighs the* Risk Shifting *effect* ***(Case 3)*** *an increased capital requirement unambiguously increases the stability of the banking sector regardless of the market structure.*

Proof. If |*Margin*|>|*Risk Shifting*|, the right hand side of (36) is unambiguously negative, such that

$$\frac{\partial^2 \Pi(L,\beta)}{\partial L \partial \beta} = \underbrace{\left(\frac{\partial h(L,\beta)}{\partial \beta} - r_K\right)}_{(-)} + \underbrace{\frac{\partial^2 h(L,\beta)}{\partial L \partial \beta} \cdot \frac{L}{n}}_{(-)} < 0. \tag{38}$$

Therefore:

$$\frac{dL}{d\beta} = -\frac{\frac{\partial^2 \Pi(L,\beta)}{\partial L \partial \beta}}{\frac{\partial^2 \Pi(L,\beta)}{\partial L^2}} < 0 \tag{39}$$

Increased capital requirements result in a reduced equilibrium loan supply such that $\frac{dr}{d\beta} > 0$ regardless of the number of competitors. Using Lemma 7 it is straightforward that $\frac{dF(\hat{x},p)}{d\beta} > 0 \; \forall n \in \mathbb{Z}^+$ □

Table 2: Overview of the Results

	Buffer (IV)	Margin (III)	Risk Shifting (II)	**Effect of Cournotization (VI) on Stability**		
Case 1	+++	+	−	None		
Case 2	+	++	−−−	Banking Concentration :	**Low** (if $n > \hat{n}$)	**High** (if $n < \hat{n}$)
				High Cost of Recapitalization	Regulation Reduces Stability	Regulation Increases Stability
Perfect Correlation	0	0	−−	Low Cost of Recapitalization	None	None
Case 3	+	+++	−−	None		

The + and − signs indicate the direction of the effect, the frequency indicates the relative strength of each effect.

If stricter equity regulation allows competing banks to strategically commit on loan capacities, the gained price setting power has only limited implications on the stability of the banking sector. In **Case 1** and **Case 3**, a stricter regulation fosters stability regardless of the competitive mode in the banking sector. However, in **Case 2** where stricter regulation harms the stability under perfect competition, the anti-competitive effect of stricter regulation can outweigh the risk shifting and reestablish banking stability. Because of the gained price setting power from stricter regulation, the banks consider the risk shifting effect in their optimal choices if the market concentration is low. The results are summarized in Table 2.

6. Conclusion

Higher capital requirements may increase the price setting power of banks that compete for risky borrowers. If increased capital requirements stabilize the banking sector under perfect competition this increased price setting power does not have any impact on stability. However, if under perfect competition higher capital requirements result in a significant increase in the default probabilities of borrowers, i.e., *Risk Shifting* is high, the increased price setting power can revers this destabilizing effect. Intuitively, the Cournotization of the market enhances the ability of banks to internalize the increased costs of equity funding. With many competitors, the price setting power increase is not enough to offset the higher marginal cost of capital funding. The impact of the capital requirement with Cournotization is the same as under Bertrand competition. However, if the increase in price setting power is high enough, the banks internalize the increased marginal cost and the net effect of higher capital requirements becomes stability enhancing.

The analysis implies that an increase in capital requirement regulation should be accompanied by policies that regulate competition and the recapitalizations of banks if correlation among loans is high and the borrowers' risk taking is very sensitive to loan interest changes. The optimal policy mix depends on the structure of the banking sector and the risk characteristics of the borrowers that banks invest in. If and only if the risk shifting of borrowers is high, such that **Case 2** is likely to describe the real economy, an increase in capital requirements should be accompanied by a restriction of competition and by no means with a support of recapitalization. With the gained price setting power, the banks can consider the price sensitivity of their borrowers. Therefore, the banks will be reluctant to burden their customers with the cost of higher capital requirements but will absorb the higher marginal cost with their profits from increased price setting power. If reality can be described by **Case 1** or **Case 3**, the market structure has no impact on the effectiveness of capital requirement regulation. In this case, the traditional view that a regulator has to trade off stability and bank market efficiency does not hold. In this case, equity regulation and efficiency are separable goals such that a regulator can increase capital requirements and foster competition among banks at the same time.

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Appendix A. Proof of Lemma 3

For any given loan rate, the entrepreneur maximizes his payoff:

$$\begin{aligned} \max_{p_j} u(r) &= (1-p_j)(\alpha(p_j)-r) \\ \text{s.t. } & u(r) \geq u_i \end{aligned} \tag{A.1}$$

The first order condition is characterized with:

$$(1-p_j)\cdot\alpha'(p_j)-\alpha(p_j)+r=0 \tag{A.2}$$

Which implicitly defines a unique default choice $p_j^*(r)$. The assumption $\alpha(0) > \alpha'(0)$ secure a unique interior solution for any loan interest rate in the interval $\alpha(0)-\alpha'(0) < r < \alpha(1)$. Using the envelop theorem, it can be shown that $\frac{\partial u(r)}{\partial r} = -(1-p^*(r)) < 0$. For any optimal effort choice, an increase in the loan rate decreases borrowers utility. Let $L(r)$ denote the total loan demand, which exactly equals $L(r) = G(u(r))$. For any given loan rate r, a measure of $G(u(r))$ obtains an alternative utility less or equal to $u(r)$ and, therefore, demands a loan. Since $G' > 0$, it is straightforward that the total demand for loans is decreasing in the loan interest rate. Total differentiation of the first order condition gives

$$\frac{dp}{dr} = -\frac{1}{(1-p)\cdot \alpha''(p) - 2\alpha'(p)} > 0 \tag{A.3}$$

An increase in loan interest rates increases the probability of default of the loan.

Appendix B. The Effects of Capital Requirement on the Stability of the Banking Sector

The probability that a bank does not fail as a measure for the banking sector stability is:

$$F\left(\hat{x}(\beta, r(L)), p(r(L)\right) = \phi\left(\frac{\sqrt{1-\rho}\cdot \phi^{-1}(x) - \phi^{-1}(p)}{\sqrt{\rho}}\right) \tag{B.1}$$

The direct effect of capital on the bank's probability of failure is the capital buffer effect, i.e., higher equity funding increases the failure threshold:

$$\underbrace{\frac{\partial F(\hat{x})}{\partial \hat{x}} \cdot \frac{\partial \hat{x}}{\partial \beta}}_{Buffer} = \left(\frac{\sqrt{1-\rho}}{\sqrt{\rho}}\right)\phi\left(\frac{\phi^{-1}(p) - \sqrt{1-\rho}\cdot\phi^{-1}(\hat{x})}{\sqrt{\rho}}\right)\left(\frac{d\phi^{-1}(\hat{x})}{d\hat{x}}\right)\frac{r_D}{r(L)}0 \tag{B.2}$$

The indirect effect of capital requirements: through higher cost and the Cournotization effect, less loans are supplied, but at a higher loan interest rate. This leads to the risk shifting effect. When banks charge higher loan interest rates, the borrowers react with investing in riskier loans.

$$\underbrace{\frac{\partial F(p)}{\partial p} \cdot \frac{\partial p}{\partial r}}_{Risk\ Shifting} = \left(-\frac{1}{\sqrt{\rho}}\right)\phi\left(\frac{\phi^{-1}(p) - \sqrt{1-\rho}\cdot\phi^{-1}(\hat{x})}{\sqrt{\rho}}\right)\left(\frac{d\phi^{-1}(p)}{dp}\right) < 0 \tag{B.3}$$

When all projects do not default at the same time, higher loan rates also imply higher margins of non-defaulting loans which enhances bank stability.

$$\underbrace{\frac{\partial F(\hat{x})}{\partial \hat{x}} \cdot \frac{\partial \hat{x}}{\partial r}}_{Margin} = \left(\frac{\sqrt{1-\rho}}{\sqrt{\rho}}\right) \phi \left(\frac{\phi^{-1}(p) - \sqrt{1-\rho} \cdot \phi^{-1}(\hat{x})}{\sqrt{\rho}}\right) \left(\frac{d\phi^{-1}(\hat{x})}{d\hat{x}}\right) \frac{(1-\beta) r_D}{r(L)^2} > 0 \tag{B.4}$$

The total impact can be summarized as:

$$\begin{aligned} \tfrac{dF(\hat{x},p)}{d\beta} = & \underbrace{\left(\frac{\sqrt{1-\rho}}{\sqrt{\rho}}\right) \phi \left(\frac{\phi^{-1}(p) - \sqrt{1-\rho} \cdot \phi^{-1}(\hat{x})}{\sqrt{\rho}}\right) \left(\frac{d\phi^{-1}(\hat{x})}{d\hat{x}}\right) \frac{r_D}{r(L)}}_{Buffer\ (+)} \\ & - \underbrace{\left(\frac{1}{\sqrt{\rho}}\right) \phi \left(\frac{\phi^{-1}(p) - \sqrt{1-\rho} \cdot \phi^{-1}(\hat{x})}{\sqrt{\rho}}\right) \left(\frac{d\phi^{-1}(p)}{dp}\right) \cdot p'(r) \cdot \tfrac{dr}{d\beta}}_{Risk\ Shifting(-)} \\ & + \underbrace{\left(\frac{\sqrt{1-\rho}}{\sqrt{\rho}}\right) \phi \left(\frac{\phi^{-1}(p) - \sqrt{1-\rho} \cdot \phi^{-1}(\hat{x})}{\sqrt{\rho}}\right) \left(\frac{d\phi^{-1}(\hat{x})}{d\hat{x}}\right) \frac{(1-\beta)(r_D)}{(r(L))^2} \cdot \tfrac{dr}{d\beta}}_{Margin(+)} \end{aligned} \tag{B.5}$$

It is easy to see that the correlation between bank failures determines which effect prevails. For imperfect correlation, the result is generally ambiguous and depends on which effect prevails. The more the individual project failures are correlated (the higher the systematic risk), the more likely it is that the bank destabilizing risk shifting effect outweighs the stabilizing margin effect and the buffer effect. With perfect correlation, the margin effect and the buffer effect disappear, and the only effect of an increased loan interest rate is the borrower risk shifting.

Essay III

The Regulator's Trade-off: Bank Supervsion vs. Minimum Capital

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The regulator's trade-off: Bank supervision vs. minimum capital

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ABSTRACT

We develop a simple model of banking regulation with two policy instruments: minimum capital requirements and the supervision of domestic banks. The regulator faces a trade-off: high capital requirements cause a drop in the banks' profitability, whereas strict supervision reduces the scope of intermediation and is costly for taxpayers. We show that a mix of both instruments minimises the costs of preventing the collapse of financial intermediation. Once we allow for cross-border banking, the optimal policy is not feasible. If domestic supervisory effort is not observable, our model predicts a race to the bottom in capital requirement regulation. Therefore, countries are better off by harmonising regulation on an international standard.

1. Introduction

As demonstrated by the recent financial crisis, asymmetric information between depositors and banks may cause a breakdown of financial markets. Empirical studies suggest that the probability of such a confidence crisis, i.e., the stability of the banking sector, responds to two factors: changes in the minimum capital requirement regulation (Barth et al., 2006; Laeven and Levine, 2009) and changes in domestic supervision (Buch and DeLong, 2008). However, supranational reforms focus on the design of capital regulation, whereas the specific standards of supervision remain left in the hands of national authorities.[1]

This paper disentangles the trade-off between higher capital requirements and more supervision by explicitly considering both policy instruments to secure the stability of a domestic banking sector. Due to the coexistence of moral hazard and adverse selection, we show that the regulator needs both instruments to ensure financial intermediation. Intuitively, both problems result from asymmetric information regarding the actual riskiness of banks. Capital regulation solves an individual bank's moral hazard, reducing the cost of a market breakdown, whereas supervision reduces the adverse selection problem and the probability of a collapse. Therefore, a regulator minimises the expected cost of a collapse via a neo-classical production function with both input factors. However, the cost burden of intervention differs: the cost of increasing capital is borne by the banks, and the cost of supervising and improving the banking sector is borne by the regulator and thus by taxpayers.[2]

We distinguish between household income and bank profits to include financial market frictions into our model. In a frictionless world where households have unrestricted access to perfect financial markets there is no role for banks, capital regulation, and supervision. Because we are interested in the interplay of both instruments, we exclude the direct access of households to the financial sector. Interestingly, this highly stylised model yields a rich set of results when we allow for a certain degree of biased preferences of the regulator.

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[1] Even after two substantial revision processes, the main focus of the Basel Accords remains the regulation of capital and liquidity standards. Although the regulatory framework encourages convergence towards common supervisory standards, the rather general implementation guidelines are by far less detailed and matured than the regulation of capital requirements, which leaves national authorities room to incorporate supervisory practices that are best-suited to their own national systems. As a result, there exist considerable variations in supervisory standards in jurisdictions that are adopting the Basel framework. Regulation differs, for example, with respect to definitions of the requested reporting items, time-tables, or technical details.

[2] This assumption is consistent with recent empirical findings, such as those by Masciandaro et al. (2007), who analyse the financial governance of banking supervision in a sample of 90 countries. The authors conclude that full public financing is the most common budgetary arrangement. However, some supervisory systems are financed by both taxpayers and supervised institutions, e.g. Germany where the banking sector pays half of the costs.

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First, we examine the optimal regulation of a banking sector in a closed economy that consists of banks, which differ with respect to their ability to control the risk of their investment projects. If depositors cannot observe the actual ability of each bank, they will deposit less money in banks compared to fully informed depositors. To reduce the inefficiency stemming from asymmetric information, the regulator selects an optimal combination of a minimum capital requirement level, which incentivises banks to control their risk, and supervisory effort, which influences the quality of the banking sector (i.e., the proportion of banks that are able to control their risky investments). The regulator's optimal choice depends on both the cost of supervisory effort in influencing the quality of the average bank and the weight she places on the rent or the size of the domestic banking sector. This political economic approach represents a rather broad view of regulation compared to the prudential framework found in most of the existing literature.

Second, we show that with institutional competition among regulators, the optimal combination of policy instruments crucially depends on the moving costs and observability of differences in national regulation in the banking sector. If depositors are able to fully observe country-specific regulatory regimes and to differentiate via adjusted interest rates, jurisdictions evolve into a "club" supplying a regulatory framework for banks. In such a situation, the regulatory costs of preventing the breakdown of financial markets increase with the mobility of banks. Moreover, if depositors cannot distinguish between different national regulatory regimes, incentives to underbid the other country's capital ratios appear, resulting in an even higher probability of a collapse. This finding implies that competition among regulators causes a rent-shifting between banks and taxpayers compared to the optimal policy mix in autarky, which always reduces domestic welfare.

Our results are related to the small but growing theoretical literature on the political economy of regulatory competition in banking. In a globalised world, regulators must consider that banks seek to go abroad, and thus must address externalities created by mobile banks. Empirical studies document increased foreign bank entry in many economies. Barth et al. (2006) show in a sample of 91 countries that on average 45% of banking assets were owned by banks that are more than 50% foreign owned. A recent study by Ongena et al. (2013) provides an analysis of spillover effects of national capital requirement regulation and supervision on the lending behaviour of cross-border banks. The authors find empirical evidence that stricter regulation and supervision reduces risk-taking among banks in the home country but increases risk-taking in lending in foreign countries. Their findings suggest that national capital regulation and supervision may have important spillover effects. Instead of enhancing bank stability, stricter capital regulation and supervision may simply reallocate the risk-taking behaviour to other countries.

Kilinc and Neyapti (2012) develop a general dynamic equilibrium model to analyse the joint welfare implications of stricter capital regulation and supervision. In their model banking regulation and supervision have the same impact on the economy: they reduce transaction costs and thus increase the efficiency of financial intermediation. Because more efficient financial intermediation facilitates economic growth, the authors show that an increase in regulation and supervision unambiguously increases welfare. Our paper makes a similar argument; however, we are interested in the particular adverse effects of each policy instrument on the efficiency and size of the banking sector. With a partial equilibrium analysis we derive the optimal input mix of both instruments to establish financial intermediation at minimum cost. In other words, we address the Coasian question of an optimal selection of regulatory policies in the banking sector – but we incorporate market frictions such as restricted access to markets and asymmetric information, which standard general equilibrium models not consider. Analysing the regulator's incentives to use each specific instrument then allows us to discuss the welfare implications of an international harmonisation of capital requirement regulation among heterogeneous countries.

For this purpose Dell'Arricia and Marquez (2006) develop in their seminal paper a two-country model with structural spillovers between two national banking systems. Without a supranational regulator, externalities induce nations to select sub-optimally low standards of minimum capital requirements. Trading off the benefits and costs of centralisation Dell'Arricia and Marquez show that nations with relatively homogenous banking systems have a stronger incentive to form a regulatory union. However, they do not allow for supervisory interventions. Complementary to their findings, Acharya (2003) discusses the desirability of uniform capital requirements among countries with divergent closure policies. He illustrates that ex post policies may have an incremental effect on the optimality of ex ante regulation. Therefore, the regulator has to consider these policies when designing prudential ex ante policies. He concludes that, with heterogeneous closure policies, level playing fields can result in a welfare-declining race to the bottom.

The main findings of Morrison and White (2009), however, suggest the opposite phenomenon. In their model, a less competent jurisdiction suffers from international financial integration, as good banks flee to the better jurisdiction, which is able to cherry-pick the best banks applying for licenses. Therefore, less competent jurisdictions benefit from the international harmonisation of regulation, although international capital requirements alone cannot prevent the exit of sound banks. One may conclude that the catching-up of the weakest regulator over the best-regulated economy takes place when capital is mobile. Therefore, in their view, level playing fields are desirable for weaker regulators.

Our model incorporates both of these ideas and analyses if competition among regulators leads to a race to the bottom in capital ratios or to an outcome where the more efficient regulator expects higher volumes of deposits. In contrast to Acharya (2003), who concentrates on the interlinkage of capital requirement and closure policies, our baseline model focuses on the link between optimal harmonised capital requirements and ex ante supervisory efforts that will change the pool quality, and thereby affect the stability of the banking sector within a jurisdiction. Moreover, we combine our results with the political-economic literature showing the distributional effects of regulatory competition between taxpayers and the banking sector which create incentives for lobbying activity. Finally, our analysis of cost-efficient regulatory intervention provides a rationale for the international harmonisation of minimum capital standards à la Basel when banks shop for their regulator. We show that the equilibrium outcome of regulatory competition is welfare-inferior compared to a world with closed economies. Consequently, there are two driving forces for the international harmonisation of capital requirements: (1) independently of the information structure, harmonised capital regulation counters a regulatory race that increases the overall cost of intervention and (2) the network benefits of harmonisation make optimal regulation cheaper for national supervisors.

This paper proceeds as follows: In Section 2, we introduce our basic model setup in a closed economy showing the conditions under which an unregulated banking sector may be characterised as a lemons market where no financial intermediation is possible. To prevent such a domestic market breakdown the regulator can now use capital standards and supervision. In Section 3, we allow for the free movement of banks and introduce regulatory competition to analyse the changes in the optimal policy mix. Section 4 discusses our main findings and Section 5 concludes.

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2. Optimal regulation in closed economies

2.1. Lemons equilibrium in an unregulated banking sector

We develop our arguments in a partial equilibrium model with three types of risk-neutral agents: regulators, banks and depositors.[3]

Consider a continuum of banks normalised to 1. Banks simply collect funds from depositors and equity investors to finance risky projects. Unmonitored projects return R in the case of success with probability p_L and zero in case the of failure with probability $(1-p_L)$. Suppose that a fraction $\theta \in [0,1)$ of banks has access to a monitoring technology, which allows them to increase the probability of project success to $p_H = p_L + \triangle p > p_L$ at a cost m. We call these banks efficient. The remaining banks in the national banking sector $(1-\theta)$ are said to be goofy.

We assume that equity funding has high opportunity cost and is thus scarce, i.e., the opportunity cost of equity ρ is greater than the efficient investment, $\rho > R \cdot p_H$.[4] Therefore, banks never invest equity in an unregulated world, but prefer to be financed by deposits.

A large pool of depositors, each endowed with 1, may either invest in a risk-less storage technology yielding a certain return of $\gamma \geqslant 1$ or lend it to a bank without any form of depositor insurance. Therefore, banks may raise deposits as long as the offered expected return on deposits exceeds the depositors' outside option $r_D \geqslant \gamma$. Let $R \cdot p_H > \gamma > R \cdot p_L$ such that non-monitored projects have a negative expected value. This relationship implies that a depositor is unwilling to deposit with a bank that does not monitor. However, due to a single banks' opaqueness, we suppose that her type is private information and cannot be credibly communicated to depositors. Therefore, the decision to deposit depends on the average quality of banks in the economy provided that efficient banks have enough "skin in the game" in the form of equity to monitor their projects. Our unobservability assumption reflects information asymmetries between depositors and banks and is in line with traditional banking models as well as recent empirical findings.[5] The opacity of the banking sector implies that depositors cannot distinguish between banks based on their individual balance sheets. In particular, a single bank is not able to signal its quality by any choice variable such as additional equity, profits or the leverage ratio. Depositors may only observe the minimum capital requirement standard implemented by the national regulator.[6] Because inside equity funding is costly and cannot be used by banks to signal their quality due to balance sheet opaqueness, any bank will intuitively minimise costly equity capital such that capital requirements are always binding. Note that binding minimum capital requirement regulation also implies that there is no competition among banks for deposits.[7]

In the spirit of this literature we model the breakdown of financial intermediation as a confidence crisis where depositors are unwilling to give their money to a bank which they select at random. We may now construct two conditions for the existence of financial intermediation, i.e., depositing: first, monitoring must be incentive-compatible for efficient banks. The fraction θ of banks will choose to monitor projects only if the return from monitoring exceeds the return from not doing so, i.e., $(R - r_D)(p_L + \triangle p) - m \geqslant (R - r_D)p_L$. Therefore, banks must receive a sufficiently high rent to be incentivised to monitor. In other words, the monitoring incentive compatibility constraint for efficient banks provides an upper bound on the deposit rate:

$$r_D \leqslant r_D^{MIC} := R - \frac{m}{\triangle p}. \tag{1}$$

This upper bound on the refinancing cost is increasing in the value added of monitoring $\frac{\partial r_D^{MIC}}{\partial \triangle p} > 0$ and decreasing in the cost of monitoring $\frac{\partial r_D^{MIC}}{\partial m} < 0$. Any deposit rate $r_D > r_D^{MIC}$ will destroy the efficient bank's incentives to monitor, and will result in a homogenous banking sector where the probability that the project succeeds equals p_L. If $r_D \leqslant r_D^{MIC}$, depositors anticipate that the fraction θ of banks engage in monitoring. Knowing the overall fraction of banks with monitoring technology allows for the deduction of an expected unconditional probability of project success of $(p_L + \theta\triangle p)$.

Note that the monitoring incentive constraint also excludes the possibility that efficient banks signal their quality through higher deposit rates. Any bank that would offer a deposit rate $r_D \leqslant r_D^{MIC}$ cannot credibly commit to monitor and cannot signal its efficiency due to higher deposit rates in equilibrium.[8]

Anticipating this average probability, depositors are willing to deposit their endowments at the bank if the expected return from depositing exceeds their outside option $r_D \cdot (p_L + \theta\triangle p) \geqslant \gamma$. The participation constraint from depositors thus gives the second condition for depositing, which defines a lower bound on the deposit rate. Depositors require at least a deposit rate that is equal to, or greater than

$$r_D^{PCD} := \begin{cases} \frac{\gamma}{p_L} & \text{iff } r_D > r_D^{MIC}, \\[2ex] \frac{\gamma}{p_L + \theta\triangle p} & \text{iff } r_D \leqslant r_D^{MIC}. \end{cases} \tag{2}$$

Because of the perfectly elastic supply of deposits, i.e., no competition among banks for deposits, the depositor's rent declines, resulting in a binding participation constraint denoted by $r_D[\theta] := \frac{\gamma}{p_L + \theta\triangle p}$ if θ efficient banks monitor.

However, financial intermediation is only possible in an opaque banking sector when the depositors require an interest rate that deposit rate that is required by depositors does not violate the bank's monitoring condition. If the natural fraction of efficient banks is high enough, financial intermediation may exist without any regulatory intervention. However, throughout this paper, we will assume that the "natural" proportion of banks that have access

[3] The basic set-up follows Holmström and Tirole (1997) and Morrison and White (2009) with perfect correlation of risk for each type of bank. Alternatively, we may assume that depositors are fully insured, but the deposit insurance risk premium to be paid by the banks depends on the average risk in the banking sector. We will discuss this case in Section 2.5.

[4] The assumption that bankers prefer to economise on equity is a regular assumption and is commonly justified by the scarcity of bankers' wealth, e.g. Morrison and White (2011), by the existence of agency problems, e.g. Holmström and Tirole (1997), or simply by the special tax treatment or an underpriced safety net, e.g. Admati et al. (2011).

[5] Morgan (2002) supports empirically the assumption of significant opacity in the banking sector by comparing the frequency of disagreements among bond-rating agencies regarding the values of firms across sectors of activity. The disagreements are higher for financial institutions than for other economic sectors. In addition, Flannery et al. (2013) find significant bank balance sheet opacity during times of financial crisis. They also find evidence that capital and policy actions increase transparency and are substitutes.

[6] This assumption is in line with the empirical observations of Jordan et al. (2000) who show that market prices react to supervisory announcements supporting the claim that investors do not have full information.

[7] Following Acharya (2003) and Morrison and White (2011) we remain with the assumption that competition for deposits is absent.

[8] The efficient banks would be able to credibly signal their type by offering a higher deposit rate only if they make higher profits than goofy banks. To see that such a case is not feasible, note that no bank is able to attract depositors by offering an interest rate that is higher than the monitoring incentive constraint r_D^{MIC}, because depositors would foresee that efficient banks lack the incentive to monitor. They would require a deposit rate $r_D = \frac{\gamma}{p_L} > R$, which is strictly higher than the return a bank makes from investing the deposits. Therefore, the maximum interest rate that unregulated banks can credibly offer is r_D^{MIC} (or with binding capital regulation r_D^{MICk}). By definition, this deposit rate is the rate that equals the profit of monitoring efficient and goofy banks.

to a monitoring technology is too small so that unregulated depositing is not feasible without any regulation.[9]

Definition 1 (*Lemons Equilibrium*). If $\theta < \hat{\theta} := \frac{\gamma}{\triangle p R - m} - \frac{p_L}{\triangle p}$, financial intermediation is on average less productive than investments in the storage technology and the banking market disappears.

Proof. If $\theta < \hat{\theta}$, it follows that $\frac{\gamma}{p_L + \theta \triangle p} > R - \frac{m}{\triangle p}$. Depositors correctly foresee that no banks are monitoring. From (2), it follows that depositors require $r_D = \frac{\gamma}{p_L}$ to participate. However, for $\gamma > R \cdot p_L$, no bank would be able to pay such a deposit rate without experiencing losses, i.e., the required return for the depositor's participation constraint to hold will violate the participation constraint of the non-monitoring banks. Although lending to efficient banks is socially valuable, depositors are unwilling to deposit, leading the banking market to break down; a lemons equilibrium à la Akerlof emerges. □

In a lemons equilibrium, even banks with efficient monitoring technology would not be able to raise funds and no investments would be made, even though monitored projects could create value. As a result, the financial market is unable to channel funds effectively to firms that have the most productive investment opportunities.

In the following sections we argue that the market inefficiency caused by asymmetric information may be alleviated by two alternative policy instruments: capital standards and supervision.

2.2. The effects of capital standards

The introduction of a minimum capital requirement changes the individual incentive constraints of banks. The first effect of capital concerns the monitoring condition of efficient banks. To see this, note that if a bank refunds each investment by a fraction of capital k, the incentive to monitor changes to $(R - r_D(1-k))(p_L + \triangle p) - m \geqslant (R - r_D(1-k))p_L$. It follows that the incentive constraint becomes

$$r_D \leqslant r_D^{MICk} := \frac{R - \frac{m}{\triangle p}}{(1-k)} > r_D^{MIC}. \tag{3}$$

This tells us that a capitalised bank, which refunds a proportion of its investments with equity, is able to pay higher deposit rates without violating its incentive constraint. Because $\frac{\partial r_D^{MICk}}{\partial k} > 0$, the incentive constraint (*MIC*) is upward sloping in a deposit rate-capital ratio space. Efficient banks wish to provide monitoring services only when the deposit rate is sufficiently low to compensate them for monitoring activities. A minimum capital requirement reduces the rent an efficient bank requires to be willing to monitor. Therefore, with more " skin in the game", efficient banks may accept higher deposit rates, while still credibly offering the assurance to monitor their projects ex post. Fig. 1 illustrates how the monitoring incentive constraint *MIC* is increasing in k. Without any regulation, depositing does not occur, as all depositors prefer to invest in the storage technology instead of lending money to banks. The equity funding rate k^* gives the minimum capital requirement rate that establishes financial intermediation by solving the moral hazard problem of efficient banks for a given required return of depositors $r_D[\theta]$.

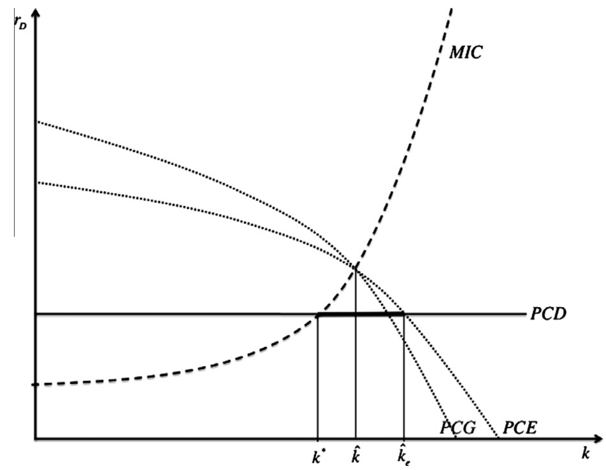

Fig. 1. The intermediation region for a high pool quality: The figure plots the constraints on deposit rates as functions of the capital regulation, i.e., the participation constraint of depositors, *PCD*, the participation constraint of efficient and goofy banks, *PCE* and *PCG*, and the monitoring incentive constraint of efficient banks, *MIC*. A market for financial intermediation is possible if the imposed capital regulation is set within the feasible range $k \in [k^*, \hat{k}^e]$, where k^* denotes the minimum capital standard necessary for monitoring investments at a given deposit rate r_D, and $\hat{k}^e$ represents the capital standard where intermediation allows zero profits for efficient banks.

However, because equity funding is costly, a higher capital requirement rate diminishes the rents of both bank types. Therefore, it also influences each bank type's incentive to participate, i.e., the break-even point which limits the range of feasible capital standards.

The participation constraint of a monitoring bank is given by the non-negative profits condition: $(R - r_D(1-k))p_H - m - \rho k \geqslant 0$. Solving for a maximum deposit interest rate, we obtain:

$$r_D[\theta] \leqslant r_D^{PCE} := \frac{R - \frac{m + \rho \cdot k}{p_H}}{(1-k)}. \tag{4}$$

Because we assume that $\rho > p_H \cdot R$, the minimum capital requirement must be small enough to sustain the continued operation of efficient banks: $k < \hat{k}_e[r_D] := \frac{p_H(R - r_D[\theta]) - m}{\rho - p_H \cdot r_D[\theta]}$.

Goofy banks, on the contrary, will make non-negative profits whenever $(R - r_D(1-k))p_L - \rho k > 0$, which is the case for every deposit rate

$$r_D[\theta] \leqslant r_D^{PCG} := \frac{R - \frac{\rho k}{p_L}}{(1-k)}, \tag{5}$$

implying a break-even capital standard that is equal to $\hat{k}_g[r_D] := \frac{p_L(R - r_D[\theta])}{\rho - p_L \cdot r_D[\theta]}$. Let $\hat{k}[r_D]$ denote the capital standard that solves *MIC* = *PCG* = *PCD*. With a sufficiently high cost of capital $\rho > \frac{p_L \cdot m}{\Delta p}$, we may derive the following Lemma:

Lemma 1. *For a sufficiently high proportion of efficient banks,* $r_D[\theta] < r_D[\hat{k}]$, *there exists a continuum of minimum capital requirement rates* $k \in [k^*, \hat{k}_e]$ *that solves the moral hazard problem.*

Otherwise, capital requirements alone cannot guarantee financial intermediation, $k \in [\emptyset]$.

Proof. With $\rho > \frac{p_L \cdot m}{\Delta p}$, it must hold that $0 < \hat{k} < 1$. Therefore, there exists a maximum interest rate $r_D[\hat{k}]$ that simultaneously makes the *MIC* (3) and the *PCs* of each bank type (4) and (5) binding. Any capital requirement above $\hat{k}_e$ would further decrease the required interest rate for monitoring incentives but violates (3).

[9] The condition of non-negative profits: $(R - r_D)p_H - m \geqslant 0$ gives the participation constraint of a monitoring bank and hence $r_D \leqslant r_D^{PCE} := R - \frac{m}{p_H}$. Note that the lower bound on the deposit rate of the efficient bank's participation is always above the *MIC*, as $p_H > \Delta p$ and the *MIC* will be violated first. By contrast, goofy banks will make non-negative profits whenever $(R - r_D)p_H > 0$, which is the case for any deposit rate $r_D \leqslant r_D^{PCG} := R$.

Therefore, there exists no capital requirement that guarantees that efficient banks monitor and are willing to participate. □

Lemma 1 tells us that observable and binding minimum capital requirements can only overcome a lemons equilibrium in the market if the fraction of efficient banks is sufficiently high. Then, by decreasing the moral hazard incentives in an opaque banking sector, efficient banks credibly commit to monitor. However, capital regulation cannot solve the adverse selection problem by crowding out goofy banks. On the one hand, it is true that for any $k > \hat{k}$, monitoring banks are more profitable than goofy banks, $r_D^{PCE} > r_D^{PCG}$. Consequently, setting a sufficiently high capital requirement $\hat{k}_e \geqslant k > \hat{k}_g$ will induce the exit of goofy banks first. On the other hand, depositors correctly anticipate that only efficient banks participate and monitor: The expected success of projects increases to p_H and the required return on deposit falls to $r_D = \frac{\gamma}{p_H}$. However, with lower deposit funding costs, goofy banks find it profitable to participate in banking – and re-enter the market. Therefore, crowding out goofy banks by setting a sufficiently high capital requirement cannot be an equilibrium unless the capital requirement is set such that $\hat{k}_e\left[\frac{\gamma}{p_L+\theta\triangle p}\right] > k > \hat{k}_g\left[\frac{\gamma}{p_H}\right]$. From these observations we can define the depositors' participation constraint as follows:

$$r_D^{PCD} := \begin{cases} \frac{\gamma}{p_L} & k < k^* \\ \frac{\gamma}{p_L+\theta\triangle p} & \hat{k}_g \geqslant k \geqslant k^* \\ \frac{\gamma}{p_H} & k > \hat{k}_g. \end{cases} \qquad (6)$$

The depositors' willingness to invest does not depend linearly on the capital requirement, because a bank's probability of success is affected not by the capital structure of the bank, but only by the monitoring incentives of banks and the incentives to enter the market.[10] Intuitively, depositors require a "goofy" risk premium for the average success probability in the banking sector.

Recall Fig. 1 where the *PCs* of depositors, efficient and goofy banks, as well as the monitoring incentive constraint are plotted. A capital standard k^*, as the intersection point of the *MIC*- and the *PCD*-curve labels the lowest capital ratio that must be implemented to guarantee the existence of a national banking sector. Capital requirements that exceed this threshold may solve the moral hazard problem induced by asymmetric information, but a prohibitive high requirement $\hat{k}_e$ will violate the bank's participation constraint of non-negative profits. It follows that effective regulation is only possible within the feasible set $k = \{k^*, \hat{k}_e\}$. Such a policy is welfare-superior compared to an unregulated economy: The expected output of the regulated banking sector is strictly higher. Because the transfer between the bank and the depositor is welfare-neutral, the level of the deposit rate is negligible from a regulator's point of view.

Definition 2 (*Welfare*). A policy is welfare-superior if the expected output of the banking sector exceeds the cost of implementation.

[10] The fact that higher equity funding does not directly influence the bank's success probability, is a result of the simplicity of our model where defaulting investment projects have perfect correlation. One major argument in favour of higher capital requirements is that equity provides a buffer against unexpected losses. Such a condition could be implemented in our model by a shock to risky investment returns, where a proportion of the projects do not succeed. When a bank has funded its investments with more equity, it will be able to absorb larger shocks; in other words, the actual return on investment covers at least the deposit liabilities. However, this additional stability enhancing buffer effect does not change our results, but would increase the complexity of our model. Therefore we neglect the effect of imperfect correlation in our model.

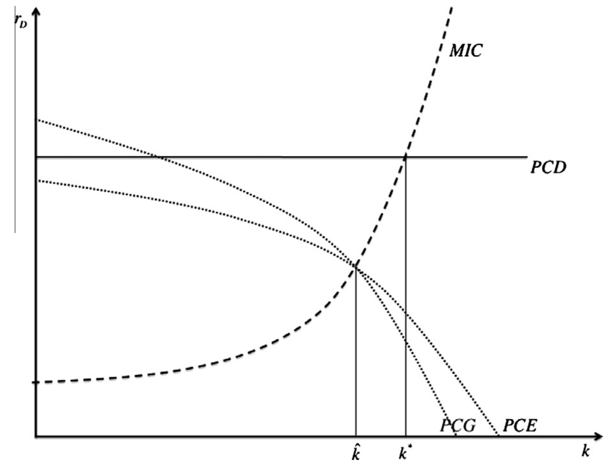

Fig. 2. The intermediation region for a low pool quality: The dashed monitoring incentive constraint, *MIC*, and the dotted participation constraints of each bank type, *PCE* and *PCG*, intersect below the depositors' participation constraint, *PCD*. Because the capital standard k^* that solves the efficient banks' moral hazard problem is prohibitively high, no bank is willing to remain in the market. For any capital requirement policy the intermediation region is empty.

One interesting corollary of the model setup is that we observe an implicit cross-subsidy for goofy banks. Efficient banks must pay higher refinancing costs in an opaque banking sector compared to a transparent one; by contrast, goofy banks face lower refinancing costs. In other words, goofy banks free-ride on the monitoring activity of their efficient competitors. This positive externality may be interpreted as a cross-subsidy equal to $\left[\frac{1}{p_L+\theta\triangle p} - \frac{1}{p_L+\triangle p} > 0\right]$. It is straightforward that this externality has consequences for the reluctance of capital standards: if banks maximise profits, $\Pi^i = p^i \cdot (R - r_D(1-k)) - \rho \cdot k - m$, we show that $\Pi^E > \Pi^G$ for any $k = \{k^*, \hat{k}_e\}$.

However, Fig. 2 illustrates the second case of Lemma 1 where the natural fraction of efficient banks is too low, and the feasible set of capital requirement regulation is empty $k = \{\emptyset\}$. Here, capital regulation alone cannot solve the lemons market; i.e., regulation cannot implement a situation where efficient banks will monitor and participate. In this case, non-relevant capital standards yield the same outcome and welfare as in an unregulated banking sector. Intuitively, depositors' confidence in the banking sector is so low that only a prohibitively high capital standard k^* satisfies the monitoring condition of efficient banks and the market breaks down.

From here on, we assume the "natural fraction" of efficient banks to be zero. As a consequence, the regulator must interfere and improve the quality of the banking sector. She must make use of a second policy tool. We call this tool supervisory effort.

2.3. The effects of supervision

We now introduce the alternative policy instrument used to ensure financial intermediation and foster depositors' confidence in the banking sector, which simultaneously influences the composition of efficient and goofy banks. The regulator has the possibility of spending resources on supervisory officers, watchdog institutions, and specialised equipment to prevent goofy banks from obtaining a licence. Therefore, the regulator may control the pool quality of the national banking sector in a direct way via screening and auditing domestic banks, via on- and offsite examinations, or via disclosure requirements in order to select out goofy banks.

In terms of our model, the fraction of efficient banks in our economy and thereby the absolute number of goofy banks G, is the output of the regulator's investment in a supervisory technology. In other words, for a given size of the banking sector, we endogenise $\theta = \frac{E}{E+G}$ reflecting the supervisory effort e of the national regulator with $\theta(e) = f[e]$, $\theta(0) = 0$ where f is a production function for the pool quality in our economy. Given f, a higher level of effort spent on running supervisory agencies and institutions to evaluate the soundness of national banks, facilitates the discovery of offenses and the identification of goofy banks.[11]

However, supervision is costly. According to Goodhart et al. (1998) the cost of banking supervision may be divided into three classes: the institutional cost of operating supervisory agencies, the costs of compliance and structural costs which include ways in which supervision affects markets such as the possible impairment of competition. All of these costs become excessively burdensome with the regulator's investment in supervision.

Therefore, let the cost of supervision be continuously increasing in effort, convex, and twice differentiable $c[0] = 0$, $c[e^{\max}] = \infty$, $c'[0] = 0$, $c'[e] > 0$, $c''[e] > 0$. Intuitively, a regulator has a certain capacity (manpower or time) that allows her to screen only a limited number of banks. It is straightforward that she may enhance the pool quality of the banking sector, if she supervises with great intensity. Although doing so would be easy and cheap for one bank, an increase in the number of supervised banks may increase the institutional cost. For too many banks, it might not even be at all possible "to keep an eye" on each bank. In addition, the excess burden of supervisory activities (structural costs) increases with the number of banks supervised. To keep our model simple and traceable, we parametrise θ as a linear increasing function of effort such that $e = \theta$ where the cost function is equal to $c[e] = \frac{c}{2} \cdot \theta^2$. We assume that the source of financing of banking supervision comes directly (budget assigned by government) or indirectly (seigniorage) from taxpayers via lump-sum taxes that do not change the investment choice of households.[12] Accordingly, a better screening ability of the regulator, reflected in a lower marginal cost of supervision c, implies less for taxpayers and fewer goofy banks in the banking sector for a given cost level. It follows that a regulator that faces high supervisory effort costs, may allow more goofy banks. She shows this behaviour not because her basic motivation differs but because her benefits and costs differ from a regulator that faces less effort cost. It follows that the efficiency of a supervisor's technology determines the ex-ante composition within the national banking sector.

The introduction of our supervisory technology does not affect the *MIC* of efficient banks, but does change the composition of the banking sector, and thus the *PCD* of depositors. The intuition is simple: depositors will encounter investment in supervision by adapting their beliefs of the overall market quality and thus the required deposit rate, given that efficient banks have an incentive to monitor. All banks benefit from the more effective screening provided by the regulator because of lower deposit rates. As a consequence, the profits of the remaining banks are greater in jurisdictions with better supervision ability, i.e., lower supervisory costs, $c[\theta]$. The highest rent per bank may be achieved only when efficient banks are left in the banking sector, such that $\theta = 1$ (though this would imply prohibitively high effort cost). However, even in this case the outside option of the depositor may exceed the value added from monitoring. Then the beneficial effect from supervision, i.e., cheaper refinancing, erodes and the banking market freezes regardless of the level of supervisory effort.

Lemma 2. *If $\gamma > p_H\left(R - \frac{m}{\triangle p}\right)$, supervision alone cannot solve the moral hazard problem.*

Proof. Consider the highest quality a banking sector may have, $\theta = 1$, where there are only efficient banks in the sector. The deposit rate required by depositors is $\frac{\gamma}{p_H}$, provided that the *MIC* is not violated. However, with $\frac{\gamma}{p_H} > R - \frac{m}{\triangle p}$, this is not the case. Depositors foresee that efficient banks have no incentive to monitor and thus require $\frac{\gamma}{p_L} > R$. Without any additional capital requirement, the market breaks down. □

Indeed, this finding implies that the expected value of the depositors' alternative investment is more profitable than the expected return of efficient bank investments, which may be an extreme case because banking is not at all desirable. However, even if supervision alone may solve the moral hazard problem $\theta = 1$, it might not be optimal, due to increasing supervision costs. If a country does not have the supervisory capabilities or simply the ability to raise taxes to oversee banks the regulator may be forced to take different actions. Moreover, an improved pool quality of the banking sector will cause the size of the sector to shrink. Keep in mind that an investment in supervision may be interpreted as a contractionary policy that limits the scope of financial intermediation by selecting out goofy banks.

After having introduced the two parameters of our model that govern the banking sector (directly to increase the number of efficient banks via supervision or indirectly via incentivising monitoring of efficient banks with capital standards), we now analyse the optimal policy mix.

2.4. The optimal policy mix

The concern of the regulator is to prevent the breakdown of financial intermediation at the lowest cost. To reach this goal, she must balance the cost and benefits of both policy instruments which are driven by the characteristics of the domestic economy. However, we allow for the possibility that the regulator has a certain preference for both instruments; in other words, she weighs the rent of domestic efficient banks and the rent of the taxpayers.[13] If one policy instrument will produce more output with the same inputs, this information will become a factor in choosing among supervision and capital standards. Therefore, the regulator's objective function may be expressed as

$$\max_{\theta,k} \; U = \phi \cdot \Pi^E[\theta,k] + (1-\phi) \cdot \left(\Pi^D[\theta,k] - \frac{c}{2} \cdot \theta^2\right),$$

constrained by the conditions for the monitoring of efficient banks (3), for the banks' participation (4) and (5) and for the depositors' participation (6). The terms $\Pi^E[\theta,k]$ and $\Pi^D[\theta,k]$ denote the rents of efficient banks and depositors respectively and the parameter $\phi \in [0,1]$ captures the weight that the regulator places on the rent of efficient banks. Because we assume perfect competition on the deposit market, the profit of depositors is zero $\Pi^D[\theta,k] = 0$. Inserting the profit function of efficient banks, we may rewrite the utility maximisation problem, which is in fact a cost minimisation problem:

$$\max_{\theta,k} \; U = \phi \cdot \{p_H \cdot (R - r_D[\theta] \cdot (1-k)) - m - \rho \cdot k\} - (1-\phi) \cdot \frac{c}{2} \cdot \theta^2 \quad (7)$$

[11] According to Barth et al. (2006) 80% of all countries impose basic requirements to screen entrants to better ensure that they are "fit and proper".

[12] See Masciandaro et al. (2007) for an in-depth analysis of the financing sources of banking supervision for 90 countries. The authors show that public financing is the most common budgetary arrangement for central banks as supervisors.

[13] We thus assume that the regulator cares only for the taxpayers' money and the expected value of financial intermediation. Because goofy banks are inefficient and reduce the value of the banking sector, their profits are ignored. Given a country's taste and economic structure, this condition implies that the regulator chooses efficient capital standards and bank supervisory actions in a Coasian manner.

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$$
\begin{aligned}
&s.t. \\
&r_D[\theta] = \frac{\gamma}{p_L + \theta \triangle p}, \\
&k \geqslant 1 - \frac{(R - \frac{m}{\Delta p})}{r_D}, \\
&k \leqslant \frac{p_H(R - r_D) - m}{\rho - p_H r_D} \\
&0 \leqslant k \leqslant 1,\ 0 \leqslant \theta \leqslant 1,
\end{aligned}
$$

where $r_D[\theta]$ labels the deposit refinancing cost. The regulator now maximises welfare U and decides how to ensure financial intermediation with the most cost-efficient usage of her two tools capital standards k and supervisory effort θ. Partial derivation yields:

$$
\begin{aligned}
\frac{\partial U}{\partial k} &= \left[\phi \cdot \{p_H \cdot r_D[\theta] - \rho\} \langle 0|\rho \rangle \frac{p_H}{p_L}\gamma\right], \\
\frac{\partial U}{\partial \theta} &= -\phi p_H \frac{\partial r_D[\theta]}{\partial \theta}(1-k) - (1-\phi)\cdot c \cdot \theta.
\end{aligned}
$$

The first derivative with respect to k is always negative for $\rho > \frac{p_H}{p_L}\gamma$: capital is comparatively costly for any feasible level of the deposit rate.

The regulator chooses the lowest feasible capital requirement and the *MIC* (3) becomes binding for any $\phi > 0$. Substituting (3) into $\frac{\partial U}{\partial \theta}$ yields

$$
\frac{\partial U}{\partial \theta} = \phi p_H \left(\frac{R \cdot \Delta p - m}{p_L + \theta \triangle p}\right) - (1-\phi)\cdot c \cdot \theta.
$$

Indeed, the chosen policy affects the rents of the two interest groups, the banking industry and the taxpayers, who are assumed to have opposite interests regarding the policy. Tighter capital standards in an opaque banking sector reduce the profitability of banks, for example, by restricting investment policy, stifling innovation, or preventing the expansion of investment activities. This limiting may be regarded as the banking sector's direct regulatory burden consisting of opportunity costs for the banking sector or, alternatively, as the forgone benefits from financial intermediation to depositors. Therefore, banks have an incentive to minimise the capital standard and lobby for supervisory effort, thereby implicitly shifting the cost burden of regulatory intervention to taxpayers. On the other hand, taxpayers have the interest to maintain financial intermediation via setting high capital requirements, as banks would ultimately bear the cost burden and cannot externalise it to society. Intuitively, the composition of both policy tools determines rent shifting between taxpayers and banks. Given the conflicts about the policy mix, resolution occurs in the political realm, based on distributional and economic efficiency criteria. The organisation of political systems may thus also play a prominent role in determining national banking regulation.

2.4.1. Jacksonian regulation ($\phi = 0$)

Consider first the case where the profitability of efficient banks receives no weight in the regulator's welfare function. The term Jacksonian regulation goes back to US President Andrew Jackson (1767–1845) who fundamentally opposed government-granted monopolies to banks ("The bank is trying to kill me, but I will kill it!").

Because $\frac{\partial U}{\partial k} = 0$, $\frac{\partial U}{\partial e} < 0$, we know that the *MIC* determines the necessary supervisory effort. If the participation constraint never becomes binding before the monitoring incentive constraint, i.e., $\rho < \frac{p_L \cdot m}{\Delta p}$ the regulator will simply set $k = 1$ and save any effort on supervision with $\theta = 0$. However, with $k = 1$, the bank would lose its function as a financial intermediary. Therefore, this trivial solution appears to be rather unconvincing. If equity capital is costly, i.e., $\rho > \frac{p_L \cdot m}{\Delta p}$, the regulator must spend a minimum supervisory effort to secure the existence of financial intermediation, i.e., the *MIC* and the *PCE* become binding. The regulator sets a capital requirement $\hat{k} = \frac{p_L}{\Delta p}\cdot\frac{m}{\rho}$ and exerts just enough supervisory effort to satisfy *PCD* = *MIC* = *PCE*. In particular, the regulator exerts effort to increase the average bank quality just up to the amount where the required deposit rate equals the break-even deposit rate: $\theta = \frac{\gamma\cdot(1-\hat{k})}{\triangle pR - m} - \frac{p_L}{\triangle p}$.

2.4.2. Captured regulation ($0 > \phi \geqslant 1$)

We now consider the more relevant case where the regulator also considers the profits of efficient banks.[14] A possible capture of the regulator by the banking industry is supported by a rich literature of empirical studies; e.g., Colburn and Hudgins (1996) provide evidence that the voting behaviour of the House of Representatives in the 1980s was influenced by the interests of the thrift industry. More recently, Igan et al. (2011) find that financial institutions that successfully lobby on mortgage lending and laxity in securitisation issues adopt riskier investment strategies.

If the profitability of banks influences the regulator's decision, then there arises a trade-off between spending more costly effort on supervision and allowing banks to yield higher profits. Intuitively, a policy-maker that places more weight on efficient bank margins will vote for lower capital ratios, and vice versa. Such a regulator would balance the weighted marginal cost of supervision with the weighted marginal cost of higher capital requirements for the banks.

The optimal mix of a captured regulator depends on her marginal rates of substitution to the corresponding relative prices, i.e., costs. Using (7) we may generally characterise her decision with the following proposition.

Proposition 1. *For $\phi \in \left[0, \frac{c_i}{R\Delta p - m + c_i}\right]$, there exists a unique optimal pair of k^* and $\theta^* \in [0,1]$ that maximises regulator's utility.*

Proof. If (4) and (5) are non-binding, and effort costs are sufficiently high, i.e., if $c > \frac{\phi}{(1-\phi)}(R\cdot\Delta p - m)$, there exists a unique interior solution. For a given level of effort cost, the first-order condition implicitly defines the optimal supervisory level θ^* and capital standard $k[\theta^*]$. The detailed analysis may be found in Appendix A. □

The intuition for Proposition 1 comes from the fact that bank supervision reduces the number of goofy banks in the market, and thus the required interest rate in the domestic deposit market. The bank's incentive to monitor projects increases, and capital requirements may be reduced; optimal regulatory capital standards decrease with the number of efficient banks in an economy. A higher fraction of efficient banks leads to a lower capital standard required to maintain depositing in a banking sector: $\frac{dk^*}{d\theta} = -\frac{1}{\gamma}(R\cdot\Delta p - m) < 0$ (see Fig. 3). A regulator balances the weighted profitability of efficient banks with the marginal costs of supervision and select an optimal level of enforcement e^* that translates into a specific θ. Therefore, if $k[\theta^*] < \hat{k}[\theta^*]$, then the regulator chooses an optimal supervisory effort that trades off the higher marginal effort cost with the lower marginal cost of capital requirements consistent with financial intermediation.

[14] A special case of the analysis, $\phi = 0.5$, will yield the social welfare function, where the regulator selects supervision and capital regulation in an economically efficient manner based on wealth maximisation but not Pareto optimality, see Acemoglu et al. (2005). This view is often called the "Coasian theorem of banking regulation" and may be reinterpreted as a condition where the banking sector "regulates" itself by credibly agreeing on minimum capital ratios and bears the cost for spending effort on peer monitoring.

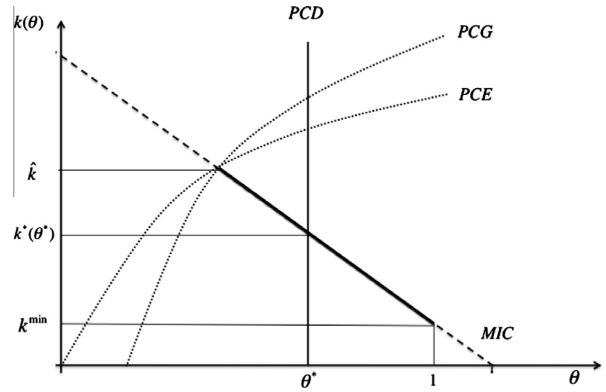

Fig. 3. The feasible regulatory set: The figure plots the monitoring incentive constraint *MIC* and the participation constraints of each bank type as well of depositors, *PCE*, *PCG*, and *PCD*, as functions of the supervisory effort θ. The optimal regulatory policy consists of both minimum capital requirements $k^*[\theta^*]$ and a supervisory effort θ^* considering the corresponding constraints. The feasible set of solutions is depicted as a bold line.

2.4.3. The feasible policy set

The appeal of capital requirements for supervision that will be optimally set by a captured regulator depends on the economic state. Within a feasible set of effective regulation, our model predicts how the regulator adjusts to certain features and shocks in the domestic economy.

Fig. 3 illustrates the decision problem of the regulator by plotting the optimal capital standard and supervisory effort in a k^*–θ-diagram. Whereas the downward sloping curve graphs the *MIC* function, the upward sloping lines capture the participation constraints of the banks, and the vertical line captures the participation constraint of depositors. The figure shows that there is a well-defined window for possible combinations of a capital standard and supervision that ensures financial intermediation ($\hat{k} > k > k^{\min}$).

From Lemma 2, we know that for a prohibitively high outside option of depositors/monitoring costs, the effort spent on supervision alone cannot solve the moral hazard problem. Therefore, the regulator must still set a capital requirement $k = k^{\min}$ to ensure that efficient banks monitor and financial intermediation actually occurs. On the other hand, Lemma 1 tells us that capital requirement regulation alone cannot also solve the adverse selection problem if the required capital requirement is above the capital requirement that ensures that banks break even, i.e., $k[\theta] > \hat{k}$. Therefore, the regulator must spend a minimum supervisory effort such that financial intermediation occurs in equilibrium. There is a natural limit for possible combinations of feasible capital standards and supervisory investments.

Specifically, for an interior solution, the point of intersection between the optimal supervisory effort and the *MIC* is the regulator's optimum. The first-best capital ratio that maximises the regulator's utility within the feasible policy set depends on her supervisory efficiency and on the parameters of the domestic banking industry. The following table shortly summarises the comparative statics.

	θ	c	ρ	m	$\triangle p$
k^*	–	+	–	+	–

First, it is worth noting that a jurisdiction that spends higher effort on supervisory enforcement may allow banks to operate with lower capital requirements. However, it is optimal to have stricter capital regulation when the regulator is less efficient in controlling the quality of the banking sector, whereby a regulator's ability to supervise efficiently is reflected by the marginal costs of supervision. Therefore, lower cost efficiency in supervisory effort leads to higher optimal capital requirements.

Lemma 3. *Within the feasible policy set, capital standards and supervision are substitutes.*

Second, when the economy is in good condition (the cost of equity ρ is sufficiently low), it is optimal to require banks to hold capital sufficient to contain moral hazard, i.e., to set higher capital standards, whereas in bad economic states (where equity costs are sufficiently high), it becomes optimal to decrease capital standards. Essentially, such a countercyclical policy of capital standards increases the regulator's welfare by lowering the impact of equity shocks on banks.

Lemma 4. *Within the feasible policy set, capital standards are set counter-cyclically.*

The intuition is straightforward. Whereas the benefits from monitoring are independent of the state of the world, the cost of inducing monitoring is higher in bad states, when capital is costly. Analogously, a higher monitoring cost decreases the profit of efficient banks which lowers the optimal effort level, thereby increasing the optimal capital requirement. Moreover, both the *MIC* and the participation constraint of efficient banks become more likely to be binding. For higher levels of value added by monitoring, there is a greater probability that the *MIC* holds. In terms of our model, higher profits justify lower capital requirements.

To summarise the main findings in this section, our model suggests that there are two ways to ensure financial intermediation. The first is the introduction of minimum capital requirements that reduce banks' margins. The second is to exert effort on sophisticated supervision to improve the efficiency of the average bank in the market, which reduces the size of the banking sector. We obtain a lower bound for the cost of banking regulation based on the minimal rents necessary to implement both cost-efficiency and the existence of the intermediation. Our analysis shows that the cost minimisation problem of the regulator requires two actions: making monitoring profitable via capital standards (this ensures the existence of the pie we call a banking sector that is to be divided among depositors and banks) and ensuring that no participation constraint is violated (minimising the costs, and thereby maximising the size of the pie). We show that for any domestic regulator, the optimal combination of both instruments that maximises domestic utility under the constraint that financial intermediation occurs, depends on her marginal rates of substitution to the corresponding relative costs where the first term is related to the weight the regulator places on the rent of each interest group. Therefore, the regulator implicitly creates rents by selecting a policy mix of capital regulation and supervisory effort that deviates from the weighting of a benevolent social planner (i.e., $\phi = 0.5$).

2.5. Deposit insurance

The assumption in our baseline model that uninsured depositors discipline the banking system by requiring a deposit rate varying with the average quality of a domestic bank is arguably strong. Certainly, the banking system of modern societies is characterised by widespread deposit insurance systems and a resulting lack of market-disciplining reactions of depositors. Notably, during the 2007–2009 financial crisis these deposit insurance systems were even broadened.[15] However, our qualitative results remain unchanged if we introduce a risk-adjusted deposit insurance scheme financed by banks. Such a self-financed scheme is common in most

[15] During the financial crisis, many jurisdictions provided full depositor guarantees. However, the range and implementation of these guarantees differed from pure political commitments such as the assurance of the German chancellor Angela Merkel that "no German depositor would lose any money", to legislative guarantees as in Denmark, which provide a 100% guarantee on savings.

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industrialised countries. Consider a deposit insurance company that has the same information as the depositors in our basic setup, i.e., she cannot observe the riskiness of a single bank but knows the risk level of the banking sector as a whole. In this case, banks must pay a risk premium $\varepsilon[p_L, \Delta p, \theta]$ that decreases with the banking sector quality θ and with the success probabilities of bank assets p_L and Δp. If the deposit insurance company must pay the outstanding liabilities r_D for all failing banks, the risk premium exactly reflects the average riskiness of the banking sector. In other words, the resulting premium captures the expected cost of bailing out the failed bank's depositors $r_D \cdot (1 - (p_L + \theta \triangle p_L))$. However, only solvent banks are able to contribute to the deposit insurance fund, i.e., $\varepsilon[p_L, \Delta p, \theta] \cdot (p_L + \theta \triangle p_L)$. Substituting the expected cost equal to the expected average payments into the deposit insurance fund, yields the fair risk premium for each bank $\varepsilon[p_L, \Delta p, \theta] = \frac{r_D \cdot (1-(p_L+\theta\triangle p_L))}{(p_L+\theta\triangle p_L)}$.

Due to the deposit insurance, depositors do not face any risk: they recoup their money regardless of whether the bank fails. Retaining our assumption of perfect competition among depositors, the equilibrium deposit rate equals the depositors' outside option γ and no longer responds to changes in regulation or supervision. In other words, in an economy with full risk-adjusted deposit insurance, the depositors lose their bank disciplining role and require only the fixed deposit rate $r_D = \gamma$. The active role to discipline banks based on average riskiness is delegated to the deposit insurance company. Nonetheless, our qualitative results remain robust, as the banks' funding cost now consists of the required deposit rate plus the deposit risk premium paid to the deposit insurance. In particular, the banks face aggregate costs of deposit funding ($r_D + \varepsilon[p_L, \Delta p, \theta]$) that are exactly equal to the *PCD* of our model:

$$r_D + \varepsilon[p_L, \Delta p, \theta] = r_D + \frac{r_D \cdot (1 - (p_L + \theta \triangle p_L))}{(p_L + \theta \triangle p_L)} = \frac{\gamma}{p_L + \theta \triangle p_L}.$$

Consequently, all constraints for financial intermediation are unaffected by the introduction of deposit insurance. A risk-adjusted deposit insurance that is financed ex post by the banking sector yields the same qualitative results.[16]

In the following section, we now investigate the role of institutional competition among regulators on the optimal bundle of policy tools.

3. Optimal regulation with international spillovers

The essence of international competition is that the integration of national markets changes the allocation of banks and, consequently, the economic environment for optimal national policies. The institutional framework determines the factors of production for banks. Therefore, the following section analyses a regulator's optimal reply to the globalisation of banking markets, explicitly considering international spillovers. We discuss the conditions under which competition will work properly to improve financial stability. In other words, we address the question: when does the invisible hand of regulatory competition fail such that there is a need for collective action, i.e., the harmonisation of banking regulation à la Basel?

We argue that the effect of regulatory competition crucially depends on the information structure of national regulation in the banking sector. If depositors are able to fully monitor country-specific regulatory regimes and are able to differentiate via adjusted interest rates, jurisdictions evolve into a "club" supplying a regulatory framework for banks. Accordingly we argue that a regulatory product such as banking regulation is characterised for depositors by immobility, rivalry in use and the possibility of exclusion of outsiders.

3.1. Two heterogenous countries

To discuss the impact of regulatory competition, consider two countries $i \in [A, B]$ with $\phi \in \left[0, \frac{c_i}{R\Delta p - m + c_i}\right]$ that are linked through bank mobility. With the home country principle in regulating foreign banks and two symmetric banking sectors, we allow banks to finance projects abroad. However, we assume that the regulator in each country differs with respect to her supervisory efficiency. More specifically, consider country *A* with effort cost c_A and country *B* with effort cost c_B, where $c_A < c_B$ without loss of generality. Ceteris paribus, the ex-ante level of effort, and the resulting share of monitoring banks is $\theta_A^* > \theta_B^*$, and the respective optimal national capital ratios set by the domestic regulator are $k_A^*[\theta_A^*] < k_B^*[\theta_B^*]$. Note that even though country *B* has a higher observable capital requirement, the quality of the banking sector is lower, resulting in a lower average rate of success. As argued above, a less cost efficient supervisor will compensate for a lower quality of the banking sector with higher capital requirements. In other words, a higher-quality banking sector entails lower capital requirements to discipline banks.

Facing the possibility of moving, banks compare their expected profits from remaining in their home country and moving to the foreign jurisdiction. When moving implies switching cost v, a bank of type $i \in [E, G]$, that is settled in country *B* will move whenever $\Pi^i(A) - v > \Pi^i(B)$.

3.2. The club-view: Observable supervision in competing jurisdictions

In this subsection, we assume complete information for all market participants regarding the quality and costs of banking supervision. Consequently, depositors adjust the deposit rates to the average bank quality of the national banking sector and there are additional incentives for banks to move abroad. Facing lower capital requirements in the foreign country, banks that are able to move to another jurisdiction have an incentive to choose the jurisdiction that allows for the highest profits. A potential entrant now chooses his regulatory environment by trading-off the benefits and costs of foreign certification.

Because efficient banks are able to generate higher marginal profits than goofy banks, their rent from moving to the more efficient country is greater compared to the rent for goofy banks.[17]

Facing, lower capital requirements and more favourable deposit refunding rates, banks in country *B* have an incentive to either move to country *A* or at least to refund in country *A*. Intuitively, the first decision may be regarded as opening a subsidiary, and the second may be regarded as opening a branch. Subsidiaries are separate entities from their parent banks, and are subject to the regulation of the host country, whereas branches are subject to the regulation of their parental bank.[18]

[16] Morrison and White (2011) discuss that an ex ante payment may introduce further room for moral hazard. In their framework taxing bankers to pay for the deposit insurance is welfare-neutral, as in our discussion above. A higher deposit insurance reduces the deposit interest rate for banks and increases their return from investing. If banks are taxed, they pay less to the depositors but contribute to the insurance company with their equity capital making moral hazard more likely. Thus, Morrison and White (2011) show that deposit insurance financed by general taxation may be welfare-enhancing and that the optimal level of deposit insurance varies inversely with the quality of the banking sector.

[17] The sufficient condition for $\Delta\Pi^E > \Delta\Pi^G$ is $\Delta p \cdot R - m > 0$: marginal profits should exceed the monitoring cost.

[18] Cerutti et al. (2007) find that regulatory variables have non-marginal effects on the form of foreign bank entry. They conclude that governments may design regulations to favour one structure over another.

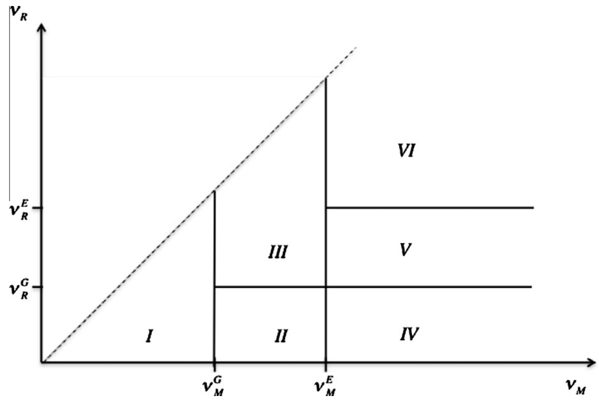

Fig. 4. The jurisdiction choice of mobile banks with perfect observability: The figure illustrates the choice of jurisdiction for foreign lending and moving abroad for each type of bank, where v_M denotes the switching costs to found a subsidiary and v_R the costs to raise funds abroad. Low switching costs (Regions I and II) allow both bank types to move and/or borrow abroad. High switching costs (Regions III and V) allow only efficient banks' mobility, whereas very high costs (Region VI) isolate the jurisdictions from each other.

On the one hand, deposit rates in country *A* are lower than in country *B*, so banks have an incentive to move from *B* to *A*. On the other hand, opening a subsidiary in a foreign country involves higher switching costs compared to opening a branch. Let us denote the cost for moving from one country to the other (founding a subsidiary) as v_M and the cost of staying in the home country but raising funds abroad as v_R. We assume that $v_M > v_R$; i.e., the cost of moving into the foreign country and being regulated under this jurisdiction involves higher switching costs than simply raising funds abroad and remaining regulated in the home country. Depending on the specific level of switching costs, different scenarios arise. Fig. 4 summarises the results.[19]

Consider first the case *I* where overall switching costs are very low $v_R < v_R^G$ and $v_M < v_M^G$; i.e., it is profitable for both efficient and goofy banks to move from country *B* to country *A*. In this case, the banking sector in country *B* disappears, whereas the banking sector in country *A* consists of two pools. However, the overall quality of the banking sector in country *A* is lower than before. If depositors recognise this decrease in banking pool quality, they will require a higher deposit rate compared to autarky. For a given capital requirement in country *A*, a higher deposit rate will result in lower monitoring incentives of efficient banks. To preserve the financial sector, the regulator in country *A* must either increase capital requirements or expend higher effort on supervision. With convex effort costs, the marginal increase in supervision becomes more costly. Therefore, compared to autarky, the regulator in country *A* will increase the capital requirement compared to the effort of supervision. Accordingly, case *I* implies a deviation from the optimum in autarky, resulting in a lower overall pool quality and a higher cost of intervention.

In situation *II*, where $v_R < v_R^G$ and $v_M^G < v_M < v_M^E$, only efficient banks have an incentive to move to the more efficient jurisdiction, whereas goofy banks remain in country *B* trying to borrow from depositors in country *A*. The effects in this case are similar to those in case *I*: financial intermediation in jurisdiction *B* breaks down, depositors in country *A* demand higher deposit rates, and the regulator in country *A* must adapt the optimal policy mix.

We now consider the case *III* of sufficiently high switching costs, i.e., $v_R^G < v_R < v_R^E$ and $v_M^G < v_M < v_M^E$. Only efficient banks in country *B* find it profitable to move to and borrow from jurisdiction *A*. In this case, the pool size and quality of country *A* increase to $E_A + E_B + G_A$, whereas country *B* obtains G_A. Depositors observe this change in each jurisdiction and allow lower interest rates in country *A* due to the enhanced pool quality, whereas financial intermediation in country *B* collapses due to the lack of trust in the quality of the banking sector. Because countries optimally set their capital requirement at the minimum, such that the *MIC* holds, country *B* cannot further increase its capital requirement rate to compensate for the risk of depositors. The only possible reaction is to increase effort in supervision which brings additional costs for taxpayers in jurisdiction *B*.

In case *IV*, no bank has an incentive to move, but both bank types try to borrow in country *A*. Whereas the pool quality in country *A* worsens, the financial sector expands. The resulting deposit rate decreases the monitoring incentives of efficient banks in *A*, whereas efficient banks in *B* continue to face the high capital requirements and engage in monitoring. Therefore, in this case, a relatively small (compared to case *I*) tightening of capital requirements is the optimal regulatory response.

Case *V* describes a situation where only efficient banks try to borrow in the more efficient jurisdiction. In this case, the more efficient jurisdiction exclusively benefits from an increase in pool quality and size. The case *VI* describes autarky.

Therefore, if depositors anticipate the migration of banks and adjust their country-specific interest rate, we derive the following result regarding national rents in the non-cooperative equilibrium for a one-shot game:

Proposition 2. *For a given regulatory policy $[k^*, \theta^*]$ in autarky, the more efficient a supervisor is, the higher the expected volume of deposits. The overall cost of efficient regulatory intervention increases with the mobility of banks.*

Interestingly, in our framework, bank mobility leads to a collapse of financial intermediation. Sufficiently low switching costs yield the standard result, where the banking sector in the less efficient country *B* always breaks down. However, even in the absence of systemic spillovers on the competing economy *A*, the movement of banks implies negative externalities on the regulatory policy in *A* and changes the redistribution.

To observe how the outcome of regulatory competition affects the rents of the two interest groups, we must only analyse how the optimal policy mix changes. Compared to autarky, the optimal minimum capital ratio in country *A* that prevents a banking crisis is increasing with the mobility of banks. Intuitively, a lower v_M improves financial intermediation in *A*, but lowers the pool quality as long as $v_R < v_R^G$, increasing the minimum capital regulation required to secure financial intermediation. Therefore, the rent of the banking sector will shrink as a result of low switching costs, whereas the rent of taxpayers remains constant. Therefore, with lower switching costs, club competition tends to decrease domestic welfare in both jurisdictions. However, financial intermediation concentrates in the country with higher supervisory efficiency.[20]

3.3. International deposit rates: Unobservable supervision in competing jurisdictions

We now turn to the alternative extreme case, where asymmetric information makes it difficult for depositors to distinguish the characteristics of regulatory systems. The reason may be that it is difficult for them to interpret national banking laws in foreign languages which may act in accordance with unwritten cultural habits

[19] The derivation of the switching cost thresholds may be found in Appendix B.

[20] This effect is similar to the effect analysed in Huddart et al. (1999). When agents hold private information on their specific type, enabling them to choose their preferred jurisdiction makes them reveal their type (here if switching costs are high only good banks are able to move). Therefore the good agents prefer to move to the more efficient market.

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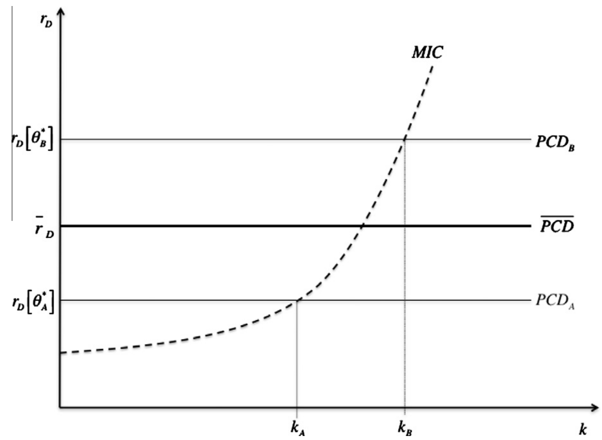

Fig. 5. International deposit rates. If depositors cannot observe the supervisory effort of each country, international refinancing implies the same deposit rate r_D for the banks in each jurisdiction A and B. The low-cost country A faces higher refinancing costs, whereas jurisdiction B benefits from lower interest rates. Here, B has incentives to lower the capital requirement rate k_B, whereas A's capital requirements fail to satisfy the monitoring incentive constraint of efficient banks.

and which may differ in the degree of strictness with which they implement the rules. Depositors may be expected to have an information deficit, and thus may demand a fixed interest rate independently from the bank's localisation.[21]

Because individual jurisdictions are not distinguishable and depositors lend their endowments with any bank without knowing the characteristics of its home jurisdiction, we assume the international deposit rate to be $r_D[\theta_A^*] < \overline{r_D} < r_D[\theta_B^*]$. Fig. 5 illustrates this situation. When banks may only borrow from a pooled deposit market but are regulated with $k_A^*[\theta_A^*] < k_B^*[\theta_B^*]$, the incentive in both countries are distorted. In country B, banks benefit from the lower overall lending rate. However, in country A, a higher deposit rate will prevent the efficient banks from monitoring; i.e., $k_A^*[\theta_A^*]$ is too low to satisfy the monitoring incentive constraint.

Due to the lower capital requirement rate in country A, both types of banks migrate to A. However, because both jurisdictions face the same international deposit rate there is no incentive for borrowing in the more efficient jurisdiction. Therefore, only the scenarios of low and high switching costs are relevant.

If switching costs are sufficiently low, both bank types switch to the jurisdiction with lower capital requirements. The size of the financial sector in A increases. However, with low capital requirements but relatively high deposit rates, efficient banks have no incentive to monitor in A.

The situation is similar to the case of high switching costs, where only efficient banks have an incentive to move to country A. By doing so, these banks face a capital requirement that is too low to incentivise them to monitor. To prevent a collapse, the regulator should in fact increase capital requirements. However, the crux of pooled deposit rates is that the regulator does not benefit from an increase in capital requirements because depositors do not punish non-monitoring efficient banks.

Proposition 3. *With unobservable supervision, each jurisdiction has an incentive to decrease domestic capital standards down to k^{min}.*

Proof. Country B observes an outflow of her banks. If switching costs are low, the entire banking sector disappears. Otherwise, goofy banks remain in country B. However, with an international deposit rate, the smaller banking sector in country B does not break down due to the low pool quality. A regulator caring for the existence of a domestic banking sector will decrease the capital ratio to prevent the outflow of domestic banks. It is straightforward that it is optimal to slightly decrease the capital ratio offered by the other jurisdiction. □

With pooled deposit rates, the undersupply of capital regulation appears to be the non-cooperative equilibrium in the one-shot game. This result may be translated into a supervisory cost level necessary to ensure depositing even with $k^{\min}$. Therefore, the profitability of banks will increase as a result of the *race to the bottom* and the regulatory cost burden is shifted to the taxpayers.[22]

Again, with cross-border banking, both countries will lose in welfare terms compared to the case of autarky such that international harmonisation of capital requirements is desirable for both countries. Therefore, our static model suggests a prisoner's dilemma. However, now the jurisdiction with the lowest supervisory costs is the relative winner of the regulatory race that otherwise will occur.

3.4. Policy implications

We pose in this section the question whether regulatory competition may avoid the existence of a lemons equilibrium at lower costs by mitigating the efficient banks' moral hazard problem. We see that, with open economies, the political equilibrium is no longer the only result of an analysis of the marginal rates of substitution between the costs of supervision and capital requirements. Instead, it reflects the strategic interaction with other jurisdictions in regulatory competition where observable capital ratios become a strategic weapon in the battle for attracting banks. The intuition is that banks seek the most lenient of all possible regulators. In this respect, systems competition becomes counterproductive depending on the opacity of international financial markets. Optimal strategic choices of domestic regulators are rooted in the degree of the observability of differences in country-specific regimes for depositors. If the observability is sufficiently low, domestic capital ratios cannot send any price signals to investors and cannot reward efficient banks in better regulated economies with cheaper refinancing. The optimal cost-minimising policy is no longer feasible.

We gain similar effects if we allow for heterogeneity with respect to the weighting of the rent of the banking sector between both jurisdictions, i.e., in the capturing of a regulator. Suppose both countries are identical with regard to supervisory efficiency ($c_A[\theta_i] = c_B[\theta_i]$). Let k^* be an interior equilibrium in the case of autarky. For this equilibrium, it holds that $k_A^* < k_B^*$ if $\phi_A > \phi_B$. Intuitively, country B values capital regulation more highly than country A does, but B's costs with regard to its equity cost and opportunity cost, in terms of supervision, remain the same. As we have shown above, a higher preference for capital requirements is a stigma in regulatory competition, resulting in a welfare loss if we allow for bank mobility. An obvious implication of this re-interpretation of different regulatory bliss points in capital ratios is that institutional competition will decrease stability when the differential of the regulator's weighting for domestic banks in autarky is sufficiently high between the competing jurisdictions. A larger differential

[21] In other words, in this subsection, regulation is assumed to be a lemon good, and depositors are only able to observe the average supervisory effort and capital regulation of national regulators. The assumption of regulatory policy being a lemon good is not new in the economic literature. Sinn (1997) argues that governments only intervene in private markets if the invisible hand fails (selection principle). Accordingly, he shows that a reintroduction of a market through the backdoor of systems competition does not work.

[22] However, due to the pooling of deposit rates, regulators may now have an incentive to shirk in identifying goofy banks, as supervisory effort creates a positive externality on the other countries' refinancing conditions. If this free-riding effect is severe, we have an unstable lobal economy, where depositors overestimate the average expected repayment. When depositors update their beliefs, the global banking system faces a collapse.

$[\phi_A - \phi_B]$, renders it more likely that competition among regulators plays a role in destabilising the financial sector or, put differently, that the laxity in capital standards by only one captured banking regulator makes regulatory harmonisation more likely to be needed to prevent a collapse.

It is plausible that both jurisdictions have an incentive to cooperate to ensure the lowest combination of capital ratios and supervisory effort that is necessary to maintain global banking. Therefore, regulators demand collective action to govern the global banking sector. This provides an impetus for coordinating capital ratios and striving for an international standard regarding banking capital adequacy, to which we will turn to in the next subsection.[23]

3.5. Incentives for policy coordination

With a loss in utility due to decreasing switching costs for mobile banks, national regulators face a collective action problem and have an incentive to cooperate independently whether there is a club competition or there are international deposit rates. The reduction in regulators' utility is due to the uncoordinated behaviour of competing jurisdictions. If all regulators could agree on the same level of capital standards, there would be no utility-reducing bank flight. Therefore, our model explains a strong demand for harmonising activity of self-interested regulators. Such international coordination may be interpreted as an act of collusion among policy-makers. By removing utility-reducing institutional competition, regulators would be able to reduce the cost of financial stability.

The following proposition provides the necessary and sufficient condition for a level of harmonised capital standards k^H and supervision cost c^H that simultaneously ensure the existence of financial intermediation in both countries.

Proposition 4. *Harmonised capital standards c^H are self-enforceable if and only if:*

- $c^H \in (0, \tilde{c}]$, where $\tilde{c} = c[\theta'] + U[k'] - U[k^H]$;
- $k^H \in [k_A[\theta], k_B[\theta]]$ where $k_A[\theta]$ and $k_B[\theta]$ are the solution of the following programs:

$$k_A[\theta] = \arg\max U_A \text{ such that } U_A[k^H, c^H[\theta^H]] - U_A[k', c[\theta']] \geqslant 0,$$
$$k_B[\theta] = \arg\max U_B \text{ such that } U_B[k^H, c^H[\theta^H]] - U_B[k', c[\theta']] \geqslant 0.$$

We say that both jurisdictions will agree on a common capital standard if the supervision costs for the supranational capital adequacy lie within the interval $c^H \in (0, c[\theta'] + U[k'] - U[k^H]]$ making harmonisation profitable compared to the non-cooperative equilibrium utility $U_i[k', c[\theta']]$. It follows that, for any $c^H \in (0, \tilde{c}]$, there exists a subset of self-enforceable agreements of size $(k_A - k_B)$. In other words, we say that a policy cartel may be welfare-superior even if the supervision cost c^H will increase for all participating jurisdictions that harmonise their capital requirements.

Interestingly, recent contributions to the literature argue that there are network benefits of harmonisation for national regulators that decrease the supervision cost. The intuition for this argument is based on mechanisms of reputation building and is prominently discussed by Tarullo (2008). First, international harmonisation in the sense of Basel provides reassurance to all members that the banking system of all other member countries is sufficiently capitalised, and is stable and sound with a low probability of triggering an international financial crisis. Second, Tarullo mentions that international harmonisation fosters the implementability and efficiency of supervision of internationally active banks. Finally, there are direct benefits for internationally active banks themselves, facing one harmonised capital requirement instead of different regulations in each country where they are active.[24]

Therefore, if network benefits reduce the cost of supervision such that $c^H[e] \leqslant c[e]\ \forall\ e \in [0, e^{\max}]$, it is easy to see that the international convergence of capital adequacy is desirable even with heterogeneous countries. Therefore, the provided welfare-theoretic argument for international agreements is enforced in the presence of network benefits in the spirit of Tarullo (2008). With institutional competition, national regulators are better off by harmonising their capital requirements.

However, it is worth mentioning that the one-sided harmonisation of capital requirements without the explicit contracting of minimum supervision has its dark side. Our model suggests that supervision serves a crucial role in ensuring financial intermediation. We show that any harmonised capital requirement regulation above the first-best regulation in autarky will lead to supervisory effort below the first best. The reason is that according to Proposition 1, the optimal response of a certain regulator to an exogenous increase of capital standards is to spend less resources on supervision. Therefore, under such circumstances, the incentives of the regulator in jurisdiction A to invest in supervision erodes. Paradoxically, a more efficient producer of bank quality exerts less supervisory effort. Vice versa, the regulator in B faces lower harmonised minimum capital standards and should increase resources into supervision – if this is observable and contractible in the policy cartel. Otherwise, she may also have an incentive to decrease effort in screening out goofy banks and to free-ride. As demonstrated above in Lemma 1, financial intermediation may then break down independently of the harmonised level of capital standards if the resulting pool quality of banks in the policy cartel falls below a critical threshold.

4. Discussion

4.1. Empirical evidence

The key message of our paper is the two-way interaction between capital standards and supervision. According to our model, the fraction of goofy banks in the domestic banking sector depends on the regulator's willingness to supervise. The reason for introducing sophisticated supervision is to address the adverse selection problem in the banking sector. By sorting out goofy banks, the supervisor increases the average quality of banks in the sector, which decreases the interest rate that depositors demand for lending their money. This selection process also reduces the size of the national banking sector. This argument is in line with recent empirical findings as well as the origins of bank supervision in the US.[25] According to Mitchener and Jaremski (2012), the rise of

[23] Indeed, some authors argue that the genesis of the Basel Accords may support the idea of such a destructive regulatory race (see Kapstein, 1992). In the 1980s, it was a common opinion that raising the capital requirements for US banks negatively affects their international competitiveness unless foreign banks were forced to recapitalise in a similar fashion. In light of the Mexican crisis in 1982, this idea provided the impetus for US authorities to push for an international agreement on capital ratios.

[24] Following Schüler and Heinemann (2005) who find clear evidence for the existence of economies of scale in the banking supervision of financial markets in Europe, one may incorporate this cost-saving effect of regulatory unions in our model by a downward shift of the cost function in supervision.

[25] Heider et al. (2009) demonstrate that liquidity crises occur when the adverse selection problem between banks becomes acute. The authors show that the (interbank) market breaks down when the quality of the individual bank is unknown, such that efficient banks prefer to hoard liquidity rather than lending in the interbank market. In the light of the 2007–2009 crisis, Flannery et al. (2013) argue that market collapses are encouraged by cyclical increases in asset opacity and that the regulator must take steps to ensure that transparency via supervision persists even as equity values fall.

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formal supervisory institutions in the US responded to state banks' closures and banking panics by the time the Federal Reserve System was founded. Their results suggest that the amount of supervision is positively correlated with the size of the banking sector, i.e., the number of banks. However, the authors argue that "states implemented their optimal or desired level of supervision and changed it based on environmental factors rather than slowing ramping up expenditures in some linear way". Moreover, Dincer and Neyapti (2008) show empirically that the combination of past financial crises and prevailing levels of financial market development are a precondition that positively affects the quality of the regulatory and supervisory frameworks adopted in a country.

Our result that the optimal effort in ex-ante supervision inversely depends the level of capital requirements, is supported by several cross-country studies based on the Worldbank dataset of 107 countries. Barth et al. (2006) find that the stringency of capital requirements is negatively associated with the share of denied bank applications. This finding is in line with our story that a country that alleviates the adverse selection problem may allow banks to operate with lower equity capital. Furthermore, in response to the 2008 financial crisis, many countries made capital regulation more stringent, whereas domestic bank entry requirements mostly remained unchanged. Barth et al. (2012) develop an index that proxies the hurdles that entrants must overcome to obtain a bank license. This index does not show a significant change in crisis countries.

We also discuss the consequences of differences in individual optimal policy mixes in an integrated financial world where banks actively shop for regulators. We distinguish between the two cases of a fully observable policy mix and the case of internationally pooled deposit rates, where depositors cannot observe the individual characteristics of countries. In the first case, international financial integration increases the financial sector of a country that is more efficient in supervision at a higher cost of intervention, whereas the relatively inefficient country's banking sector shrinks. In an opaque world, where the national supervisory effort is not observable, we find that the moral hazard problem of banks cannot be solved. Moreover, regulators may have an incentive to reduce capital requirements to free-ride on the international deposit rate. The result is an unstable global banking sector, where depositors believe that the banking sector is safer than it actually is. If depositors update their beliefs, financial intermediation collapses. These negative spillovers are more serious, when differences between countries are more pronounced. This relationship is in line with the findings of Houston et al. (2012), who provide empirical evidence that supports the lemon result. Banks transfer funds to financial markets with less regulation. Their study indicates that bank flows are positively related to the stringency of capital regulation imposed on banks in their source country, and negatively related to regulations in the recipient country. However, these effects are stronger if the recipient country is a developed country with strong property and creditor rights, a finding that is also in line with our model prediction.

4.2. Dynamic aspects

The static partial equilibrium focus of our model allows us to gain a deeper understanding of the relations and mechanism between the different policy instruments analysed. The optimal design of regulatory interventions consists of both capital standards as well as the regulation of the domestic pool quality via supervision.

Our qualitative results remain robust in a dynamic setting. To see this, consider a dynamic setting with free entry and exit. In such a setting, the regulator may decide whether to renew licenses at the beginning of each legislative period. Then, in any legislative period, the regulator selects her optimal mix of capital standards and supervision, i.e., entry regulation depending on the specific circumstances of the economy in each period.

Furthermore, in a repeated game, the solution to the negative effects of free bank movement is an agreement on international capital requirement standards that prevents a regulatory race with other jurisdictions. In an infinitely repeated version of the regulatory game, cooperation could emerge as an evolutionarily stable equilibrium due to the threat of future punishments through a deregulation race. Provided that regulators are sufficiently patient and not myopic, cooperation among jurisdictions would also be a possible Nash equilibrium but many other strategy profiles are possible equilibria as well. Because the multiplicity of equilibria is endemic in repeated games, there exists no guarantee that cooperation emerges naturally. Moreover, cooperating in every period would be a best response only against another cooperating jurisdiction. Therefore, a sub-game perfect equilibrium requires both jurisdictions to cooperate and to expect the others to cooperate as well. An international agreement on both policy instruments may facilitate such mutual expectations, thereby selecting the cooperation equilibrium from the multiple equilibria of a dynamic game. Considering that governors tend to be impatient and face a finite legislative period, the cooperation equilibrium is even less likely as a stable equilibrium because a necessary condition for cooperation in a repeated prisoner's dilemma is that the same agents interact with each other for infinite rounds. International harmonisation, therefore, may play an important role in establishing a cooperative equilibrium, even in repeated games.

5. Conclusion

We build a simple framework to jointly discuss the stability and welfare implications of capital standards and supervisory enforcement in the context of international regulatory competition. In our model, banking regulators seek to prevent a market breakdown. Direct forms of regulation (supervision) enhance the ability of the average bank to control risk whereby indirect regulation via capital requirements establishes incentives that elicit socially desired monitoring activity by banks. Therefore, both regulatory instruments reduce the banking sector's vulnerability to a collapse. However, each instrument imposes a cost on different interest groups. The opportunity cost of capital regulation is borne by the banking sector, whereas the cost of supervision is borne by the taxpayer. We show that in closed economies, there exists a unique optimal policy mix that outweighs the cost and benefits of each instrument. Specifically, we demonstrate how countercyclical capital standards within a feasible set may be an optimal response to economic fluctuations and reflect the depositors' loss of confidence in the banking sector's quality.

The regulator's objective function trades off the cost of capital regulation for the banking sector with the losses from taxation due to the enhancement of transparency via supervision. We demonstrate that the regulator minimises the costs when she chooses the optimal policy mix. However, political economy considerations like the ability to collect tax revenues may create additional constraints, but do not change our fundamental results.

We also argue that supranational agreements, which impose international uniformity in minimum capital requirements, as in the Basel Accords, may provide the incentive to the most efficient supervisors to exert less effort in supervision, thereby, missing an important input factor of financial stability. The inefficiency arises from the unobservability and non-contractibility of supervisory standards. If countries are not homogeneous with respect to their supervisory efficiency or degree of capturing, any international capital requirement standard that neglects supervisory efforts

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leaves room for free-riding, and thus may even destabilise the global financial sector. Therefore, our model suggests that the implementation of binding minimum supervisory standards is essential for international financial stability. In this context, our findings show that the regulator's choice between international capital standards and domestic supervision is strategically rich and a promising area for future research. In particular, it would be interesting to analyse the strategic interaction of both instruments in a broader framework with inter-temporal feedback effects.

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Appendix A. Proof of Proposition 1

The regulator may stabilise the opaque banking sector via a production function with two input factors. Both instruments – capital standards k and supervision θ – reduce market inefficiencies that goofy banks cause. The regulator considers only the rent of efficient banks as goofy banks strictly reduce welfare. The regulator thereby places a weighting factor ϕ on the profit of efficient banks and maximises her utility subject to the monitoring incentive-constraint of the efficient banks, the participation constraint of efficient banks, and the participation-constraint of depositors.

Assume that θ is a linear increasing function of effort; thus, effort can be simplified to $e = \theta$, $c[\theta] = \frac{c}{2} \cdot \theta^2$. The maximisation problem of the regulator can be written as

$$\max_{e,k} \; U = \phi \cdot (p_H(R - r_D[\theta](1-k)) - m - \rho \cdot k) - (1-\phi) \cdot \frac{c}{2} \cdot \theta^2$$

s.t.

$$r_D[\theta] = \frac{\gamma}{p_L + \theta \triangle p},$$
$$k \geqslant 1 - \frac{\left(R - \frac{m}{\Delta p}\right)}{r_D},$$
$$k \leqslant \frac{p_H(R - r_D) - m}{\rho - p_H \cdot r_D}$$
$$0 \leqslant k \leqslant 1, \; 0 \leqslant \theta \leqslant 1.$$

The first optimality condition with respect to the capital standard is

$$\frac{\partial U}{\partial k} = \left[\phi \cdot \{p_H \cdot r_D[\theta] - \rho\} < 0 | \rho > \frac{p_H}{p_L}\gamma\right],$$

The first term captures the marginal benefit of an increase in capital standards resulting from the decreasing cost of deposits (decreasing refinancing rate and decreasing amount of deposits), whereas the second term ρ is simply the marginal cost of capital. Because equity funding is costly, the marginal benefit of lower deposit costs never outweighs the marginal cost. Therefore, the second constraint is binding – the regulator tries to reduce costly capital requirements to a minimum and simply requires banks to refund their investments with a minimum requirement that ensures that the monitoring incentive constraint holds.

The optimality condition with respect to supervisory effort is

$$\frac{\partial U}{\partial \theta} = -\phi p_H \frac{\partial r_D[\theta]}{\partial \theta}(1-k) - (1-\phi) \cdot c \cdot \theta.$$
$$= \phi\left(\frac{p_H \Delta p \cdot \gamma(1-k)}{(p_L + \theta \triangle p)^2}\right) - (1-\phi) \cdot c \cdot \theta$$
$$= \phi\left(\frac{p_H \Delta p \cdot r_D[\theta] \cdot (1-k)}{(p_L + \theta \triangle p)}\right) - (1-\phi) \cdot c \cdot \theta.$$

The first two terms capture the benefits of increased enforcement: the former reflects the induced increase in efficient banks' rent (marginal increase of the number of efficient banks in the pool of the domestic banking sector multiplied with their expected profit); the latter describes the cost-savings of refinancing as a consequence of a higher fraction of efficient banks. Therefore, more supervisory effort – a higher pool quality – will always improve the profitability of efficient banks. Comparing the increase in marginal profits (weighted with ϕ) with the marginal costs of supervision, the regulator selects an optimal level of enforcement. If the regulator does not consider the profits at all ($\phi = 0$), the optimal effort spent is zero.

If the participation constraint of banks is non-binding, there exists a unique interior solution for the optimal level of supervisory effort if effort costs are sufficiently high. Using the binding monitoring constraint $1 - k = \frac{(R - \frac{m}{\Delta p})}{r_D[\theta]}$, gives:

$$\frac{\partial U}{\partial \theta} = \phi p_H \left(\frac{R \cdot \Delta p - m}{p_L + \theta \triangle p}\right) - (1-\phi) \cdot c \cdot \theta.$$

We define $A_1[\theta] = \phi p_H \left(\frac{R \cdot \Delta p - m}{p_L + \theta \triangle p}\right)$ and $A_2[\theta] = (1-\phi) \cdot c \cdot \theta$. Without any efficient banks, $A_1[0] = \phi \frac{p_H}{p_L}(R \cdot \Delta p - m) > 0 = A_2[0]$. Note that $A_[1]$ is continuously decreasing $\frac{\partial A_1}{\partial \theta} < 0$, while A_2 is continuously increasing $\frac{\partial A_2}{\partial \theta} > 0$ in θ. Therefore, if $A_1[1] = \phi (R \cdot \Delta p - m) < (1-\phi) \cdot c = A_2[1]$, there is a unique value $\theta^* \in (0,1)$ that fulfils the first order condition.

In particular, if $(1-\phi) \cdot c > \phi(R \cdot \Delta p - m)$. For a given level of effort cost, the first order condition then implicitly defines a unique optimal supervisory level:

$$\theta^* = \frac{1}{2}\left(\frac{\sqrt{(1-\phi)^2 \cdot p_L^2 - \phi \cdot \frac{4 \cdot p_H \cdot \Delta p(R \cdot \Delta p - m)}{c}}}{(1-\phi) \cdot \Delta p} - \frac{p_L}{\Delta p}\right).$$

This implies a capital requirement level

$$k[\theta^*] = 1 - \frac{1}{\gamma}(p_L + \theta^* \triangle p)\left(R - \frac{m}{\Delta p}\right).$$

Taking the partial derivative of the regulator's optimal supervisory effort w.r.t. k, yields

$$\frac{\partial^2 U}{\partial k \partial \theta} = -\phi\left(\frac{p_H \Delta p \gamma}{(p_L + \theta \triangle p)^2}\right) < 0.$$

It follows that capital standards and supervision behave as substitutes for the regulator.

Appendix B. Switching costs

Consider the case where country A is able to supervise her banks at lower marginal costs than country B. Therefore, $\theta_A > \theta_B$, $k_A[\theta_A] < k_B[\theta_B]$, and if the characteristics of both jurisdictions are observable by depositors, banks in country A may refund their investments at a more favourable rate than in country $Br_D[\theta_A] < r_D[\theta_B]$. For simplicity, we denote the deposit rate in each country as $r_D[\theta_i] = r_i$.

We first analyse the critical switching costs for efficient banks from country *B* moving to country *A*. The efficient bank will move to *A* whenever $\Pi^E(A) - \vartheta > \Pi^E(B)$. More specifically

$$p_H((R - r_A)(1 - k_A)) - m - \rho \cdot k_A - v_M$$
$$> p_H((R - r_B)(1 - k_B)) - m - \rho \cdot k_B.$$

This can be summarised as follows:

$$v_M < v_M^E := p_H((R - r_A)(1 - k_A) - (R - r_B)(1 - k_B)) + \rho \cdot (k_B - k_A).$$

To be willing to move abroad, the switching costs for an efficient bank should not outweigh the additional revenue per deposit and the saving in capital investment. Therefore, the critical switching cost equals the gain in profitability from moving in the foreign jurisdiction. In the same way, we may derive the moving condition for goofy banks:

$$v_M < v_M^G := p_L((R - r_A)(1 - k_A) - (R - r_B)(1 - k_B)) + \rho \cdot (k_B - k_A).$$

Because efficient banks are more productive than goofy banks, the critical cost is greater for efficient banks than for goofy banks:

$$v_M^E - v_M^G = \Delta p \cdot ((R - r_A)(1 - k_A) - (R - r_B)(1 - k_B)).$$

Now, consider the case in which a bank does not move to the foreign jurisdiction, but opens branches and borrows at the lower deposit rate. An efficient bank has the incentive to do so as long as the earned profit outweighs the costs connected with opening up a branch:

$$p_H((R - r_A)(1 - k_B)) - m - \rho \cdot k_B - v_R$$
$$> p_H((R - r_B)(1 - k_B)) - m - \rho \cdot k_B.$$

This case results in the following condition:

$$v_R < v_R^E := p_H(r_B - r_A)(1 - k_B).$$

and similarly for the goofy bank:

$$v_R < v_R^G := p_L(r_B - r_A)(1 - k_B).$$

Again, the efficient bank is more productive and outweighs higher switching costs: $v_R^E - v_R^G = \Delta p \cdot (r_B - r_A)(1 - k_B)$. Yet, the gain in profitability from moving compared to opening a branch is greater for each type:

$$v_M^E - v_R^E = (p_H(R - r_A) + \rho)(k_B - k_A),$$

and similarly:

$$v_M^G - v_R^G = (p_L(R - r_A) + \rho)(k_B - k_A).$$

Fig. 4 illustrates the six cases.

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Essay IV

Risk Weighted Capital Regulation and Government Debt

Risk Weighted Capital Regulation and Government Debt

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Abstract

Microprudential capital requirements are designed to reduce the excessive risk taking of banks. If banks are required to use more equity funding for risky assets they invest more funds into safe assets. This paper analyzes a government that simultaneously regulates the banking sector and borrows from it. I argue that a government may have the incentive to use capital requirements to alleviate its budget burden. The risk weights for risky assets may be placed relatively too high compared to the risk weight on government bonds. This could have a negative impact on welfare. The supply of loans for the risky sector shrinks, which may have a negative impact on long term growth. Moreover, the government may be tempted to increase its debt level due to better funding conditions, which increases the risk of a future sovereign debt crisis. A short term focused government may be tempted to neglect the risk and, thereby, may introduce systemic risk in the banking sector.

Keywords: Capital Requirement Regulation; Government Debt

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1. Introduction

The recent financial crisis and the resulting economic crises have illustrated the vulnerability of the banking sector and its negative externalities on real sector development. One main cause of the vulnerability of the banking sector is that banks are partly shielded against the downside risk of their investments by explicit insurance of their deposit liabilities and implicit insurance in the form of government support. The main instrument that is used to prevent banks from taking excessive risk is risk sensitive capital requirement regulation. Optimal regulation reduces the risk shifting of banks and can implement the optimal risk allocation. However, a government may face an inherent conflict of interest when setting the risk weights for bank assets. On the one hand, governments regulate banks to limit their exposure to risk and the related negative externalities of such risk. On the other hand, banks are also a source of financing government debt as pointed out by Calomiris and Haber (2011).

This paper analyzes the inherent conflict of interest and the possible implications for optimal capital requirement regulation and discusses possible welfare implications. Based on a simple model, it is shown that a government which simultaneously regulates the banks and borrows from them, may have the incentive to overregulate risky investments compared to safe investments if those safe investments are government bonds. The interesting point made here is that the government can influence its budget indirectly via risk weighted capital regulation and, thus, may circumvent the monetary policy monopoly of the central bank. This calls into question whether or not governments should be entitled with setting the optimal risk weights for capital requirement regulation.

If government bonds are indeed safe, the overregulation of risky assets may not decrease overall welfare. However, if the risk of government default increases due to its indebtedness, a limitedly liable government can have the incentive to neglect this risk partially, participating in risk shifting on its own. This might result in increased systemic risk and a vulnerable government, with detrimental effects on welfare.

The idea that the financial sector is a potential source of easy resources for a government to finance its debt has been already discussed by McKinnon (1973). He defines financial repression as a set of policies, laws, regulation, taxes, distortions, qualitative and quantitative restrictions, and controls that are imposed by governments, which do not allow financial intermediaries to be active at their full technological potential. This point abstracts from the optimal degree of regulation in banking that is justified by the existence of moral hazard and other market failures. Financial repression considers any policy that goes beyond the regulation that deals with the negative externalities of financial markets. Roubini and Sala-i Martin (1992) conclude that regulation in the form of financial repression tends to reduce financial intermediation from its optimal level, and thereby has negative effects on the long term growth of the economy.

However, to the author's knowledge, the government's incentives for a biased setting of risk weights in capital requirements has not yet been discussed, and it is the goal of this paper to close this gap.

In the aftermath of the financial crisis, strengthening capital requirement regulation became the major concern of regulators. The goal of recent regulatory reforms, such as the third Basel Accord, is to increase the quantity and the quality of the equity base, which banks use to refund their investments. However, the discussion of the risk weights for bank assets has been of limited concern.

The impact of banking capital regulation on the portfolio composition of banks is well studied. The Basel I accord was criticized for applying too broad risk weights among assets. By searching for yield, the banks have the incentive to reshuffle their portfolios to the highest risk assets with accordingly higher returns within one risk class. The Basel II and III changes and enhancements aim to reduce this regulatory arbitrage. The broad risk classes for capital requirements were amended according to external ratings under the standard approach. As in Basel II, the Basel III agreement sets a zero risk weight to AAA-AA- rated governments while loan assets require a significantly higher risk weight. Moreover, the new Basel accord expects large and sophisticated banks to implement the IRB approach, which requires an individual assessment of government risk. However, the recommendations of the Basel agreements are not binding for national government regulators. In fact, when the European Union implemented the Basel II approach in the form of the Capital Requirement Directive[1], a zero risk weight for sovereign bonds of the European Union members, regardless of their risk rating, was sustained under the standardized approach.[2]

[1]Basel II was implemented into European law by DIRECTIVE 2006/48/EC, Article 89(1)(d), which was amended by the Directive 2009/111/EC. The zero risk weight exception for Member States is still valid.

[2]"Exposures to Member States' central governments and central banks denominated and funded in the domestic currency of that central government and central bank shall be assigned a risk weight of 0 %." (Directive 2006/48/EC, Annex VI, Part1(4))

Moreover, the European directive allows for the IRB approach the permanent partial use rules, according to which, the IRB approach can be applied to corporate exposures, whereas the risk weight applied to the member state government exposures remains zero.[3]

The comparatively low risk weight for government bonds can certainly be justified with very low observed government defaults. However, the recent government debt crisis and the continuous deterioration of government risk ratings casts doubts on this certainty. This reluctancy to implement the risk sensitive amendments made by the Basel II approach may serve as anecdotal evidence of the tendency to privilege government bonds. This biased regulation had a detrimental effect in the aftermath of the financial crisis. Jablecki (2012, p.6) summarizes this effect as follows "[...] by imposing a zero risk weight on all EU sovereign exposures - irrespective of the governments' fiscal conditions' - the CRD [Capital Requirement Directive] encouraged banks to load up on debt issued by the most risky euro-area governments, reducing the yields that these governments would have had to pay creditors otherwise".

Brunnermeier et al. (2011) present a detailed discussion on how the over-investment of banks in government debt has created a "vicious circle" in which a doubt on the government's safety creates a crisis in those banks' safety which have invested heavily in government bonds. The stressed banks in turn need to be supported by the government, which increases government debt further eroding the government's solvency.

Both effects have been supported with empirical evidence. Reinhart and

[3] The EU-wide Stress Test Aggregate Report of the European Banking Authority (2011) revealed that only 36 out of 90 banks applied the IRB approach to sovereign debt.

Rogoff (2011) find empirical evidence that a systemic banking crisis increases the probability of a subsequent government debt crisis. Borensztein and Panizza (2009) find support that the occurrence of a sovereign debt crisis increases the probability of a banking crisis.

Observing this diabolic loop in the current sovereign debt crisis, the question arises: Why does a regulator have the incentive to indirectly subsidize government debt with unbalanced relative risk weights for capital requirement regulation?

Livshits and Schoors (2009) present a simple model and some empirical evidence of a Russian data set that a government may not have the right incentive to include sovereign risk in prudential regulation as this could lower the cost of financing the debt and may postpone the sovereign default.

In contrast, this paper argues that a regulator may have an incentive to increase the relative risk weight for risky assets beyond the optimal point if the government does is not prone to default risk.

The goal of a financial regulator without any fiscal interest is modeled as in Tirole (1994), according to which the regulator represents the interest of the depositors and intervenes in the case of a banker's insolvency by guaranteeing outstanding debt to depositors in exchange for control rights of the bank. This view leads to a narrow goal of the regulator, who is not concerned with maximizing social welfare but is, instead, interested in minimizing the negative externality of banks' excessive risk taking.

Moreover, in contrast to the narrow goal of the regulator, this paper also allows the government regulator to pursue the additional goal of current budget maximization. This is a very simplified approach to a government's objective, but it is commonly used in public choice theory.[4] Introducing a more sophisticated objective function of the government, would however, not change the basic results as long as the government has an incentive to increase its debt above the level that would result from microprudential regulation. By setting excessively high risk weights on risky assets, such as loans to entrepreneurs, banks' funds are channeled into safe assets, such as government bonds. Assuming that equity funding is costly to the banker a higher risk weight on assets increases the marginal costs and thereby channels more funds into less weighted assets. Hence, for a given market size and funds available, higher risk weights for risky assets create higher demand for low risk assets.

The paper proceeds as follows: in chapter two, a simple model of banker's risk shifting is introduced and it is shown how an optimal capital requirement for risky assets can reduce or eliminate this risk shifting. By extending the objective function of the regulator for short term consumption, the regulator with fiscal interests is introduced and his regulatory choice is compared with the optimal regulation. In chapter 3, the welfare implications are briefly discussed. Chapter 4 concludes.

[4]The argument goes back to Niskanen (1971) who introduces a model in which politicians' preferences are directly linked to an increase in their bureau's budget. The budget maximizer as one extreme and also the mixed incentives of a government are commonly used in the analysis of public choice e.g. Haucap and Kirstein (2003) discuss four types of a government: a welfare maximizer, a Leviathan that is only interested in budget maximization, an industry friendly government and a green government in order to analyze the optimal pricing of pollution permits. The two latter types of governments have mixed incentives of the two extremes. I follow their approach by discussing the extreme case of a not fiscally interested and a fully interested government, a Leviathan, and any mixed incentives in between the two cases.

2. The Model

Consider an economy with two dates $t = 1, 2$. Agents make their decisions at $t = 1$ and returns are realized at $t = 2$. The economy is populated with four different types of agents: bankers, households, borrowers, and a government regulator.

2.1. The Bankers

There is a continuum of bank owner-managers[5] , normalized to one, which are risk neutral and receive an endowment $W = 1$ in $t = 0$.

I assume that bank owner-managers, which I call from here on simply bankers, have the unique skill to profitably provide loans L to borrowers. The assumption that only bankers are able to profitably provide loans to borrowers reflects the incomplete market paradigm for financial markets. In particular, I assume that the loan market is segmented such that risky borrowers cannot borrow directly from households. This market friction constitutes one of the raison d'être for banks.[6] Due to their unique skills to screen and monitor borrowers, banks facilitate access to funding to profitable investment projects that could not be carried out otherwise because borrowers lack access to financial markets.[7] However, to keep the model simple, the

[5]The bank owner-manager may also reflect a consortium of a mass of shareholders and a delegated manager if the manager's interests are aligned with the shareholders and there is no conflict of interest among shareholders.

[6]Freixas and Rochet (2008) offer a comprehensive overview on the incomplete market paradigm for financial markets. They argue that banks play an important role in improving the efficient allocation of capital by: 1) Offering liquidity and payment services, 2) transforming assets, 3) managing risks, and 4) processing information and monitoring borrowers (Freixas and Rochet, 2008, p.2).

[7]This is a simplification, since established firms with a good reputation and collateral obviously have access to direct financial market funding. A vast literature deals with the

costly monitoring and screening effort by banks that is necessary for loans to be profitable is not explicitly modeled.

In order to invest in loan assets, banks can attract insured deposits from households at a risk insensitive deposit rate r_D. Moreover, I assume that there is a deposit insurance risk premium, that is fixed and normalized to zero. For brevity, I define $R_D = 1+r_D$ to be the gross repayment on deposits. Since depositors are insured, the deposit repayment is not contingent on the riskiness of a bankers investment, and deposits take the form of a simple debt contract. Combined with the deposit insurance, the simple debt contract structure creates incentives for excessive risk taking, since banks are at least partly shielded from the downside risk of their risky investments.[8]

Bank owners are assumed to maximize their consumption over the two periods. In order to introduce a private cost of equity capital to the banker I assume that in contrast to households the owners are impatient, i.e. they discount their consumption at $t = 2$ with a discount factor $1/\rho$ where I assume that $\rho > R_S$, with $R_S = 1 + r_S$ the gross repayment on safe assets, i.e., government bonds. The factor ρ, thereby may be interpreted as $\rho = 1+i$ with i being the individual discount rate. The assumption $\rho > R_S$ thus implies that $i \geq r_S$, the banker's individual discount rate is higher than the

reasons for the coexistence of market and bank debt. For a good overview, see Freixas and Rochet (2008). Most prominent is the discussion of the role of banks as delegated monitors that screen borrowers as discussed by Broecker (1990), prevent Moral Hazard as most prominently discussed by Holmström and Tirole (1997), and are able to punish borrowers as discussed e.g. by Diamond (1984). For simplicity, this paper neglects the coexistence of market and bank debt and only focuses on firms that lack access to financial markets.

[8]As Merton (1974) pointed out, deposit insurance creates an option value that banks can exploit by risk shifting.

safe interest rate on government bonds.[9] The assumption reflects the idea of the CAP-Model that the return on an assets increases with the riskiness compared to the market risk. However, while the CAPM is based on the assumption of risk-averse investors, this simple model includes a premium on equity based on impatience in consumption. Therefore, the risk-neutral banker behaves as if he was risk-averse and the investment of equity in the risky bank is privately costly to the banker but not to the society. Moreover, as shown later, debt financing is partly subsidized by a deposit insurance, and thus inside equity funding is comparably more costly to the banker, because depositors do not require to be compensated for the risk of default of the bank.

To keep the model simple, I assume that banks have a constrained capacity to invest. In particular, I assume that a bank's optimal balance sheet size is fixed and normalized to unity.[10] Denote with x the proportion a banker invests into safe assets and with $1-x$ the proportion of investment in risky

[9] A government could also be allowed to go bankrupt. In this case, also the deposits become risky, since in case of government default, depositors receive nothing. However, deposits remain the least risky investment with the same risk of default as the "safe" investment which is the government bond as they are both repaid as long as the government is solvent.

[10] Consider otherwise, that banks can also choose the optimal balance sheet size. Since we will consider decreasing returns to investments in risky assets, the balance sheet size itself is a function of the banker's optimal investment decision. To see this, consider assume that the management of a bank yields a convex cost function of the bank's balance sheet size S, i.e., $C(S) = \frac{S^2}{\theta 2}$. A single banker chooses the proportion of investments in safe assets x and the balance sheet size. With decreasing returns to the investment in risky loans, the return of investments is a function of x. Denote the utility of the banker as $U = p(R(x))S - C(S)$, then the optimal balance sheet size is determined by $S = \theta p(R(x))$. This would considerably complicate the analysis without changing the main implications that are sought to be analyzed. Since this paper does not aim at discussing the optimal size of banks, the balance sheet size is, therefore, assumed to be exogenous.

loan assets.

2.2. The Households

Furthermore, consider a continuum of households, normalized to one, also with an endowment of $W = 1$ at the beginning of $t = 1$. Households are assumed to be risk-neutral and maximize their consumption at date $t = 2$.[11] The assumption that households cannot consume in $t = 1$ is a simple way to create the need to safe money. Due to a lack of monitoring and screening skills, households can not directly invest their endowment in risky assets. In order to be able to consume in $t = 2$ households, thus, either invest their endowments in government bonds or as insured deposits. Because all banks together may, at the maximum, borrow an aggregate amount of 1 from households in the form of deposits, and the depositors aggregate endowment is $W = 1$, the depositors have no market power and will be willing to deposit their endowment at the bank as long as $R_D \geq R_S$ since both assets have the same risk, i.e., are safe assets in the basic setting. However, as discussed later, the government overtakes the outstanding debt of a banker in case of banker's insolvency and therefore insures the deposits. As a result, even if the government is not safe, deposits have the same risk level as government bonds. Assuming that the households will provide the maximum endowment possible to banks if $R_D = R_S$, it becomes clear, that banks will have to pay $R := R_D = R_S$ to the depositors in order to raise deposits.[12]

[11]This assumption abstracts from the usual liquidity insurance problem of depositors. However, with a known proportion of impatient and patient households, the result would remain unchanged.

[12]The assumption of households preference for deposits is an epsilon argument, i.e., if they are indifferent, banks only need to pay an ϵ more than government bonds. However,

2.3. The Borrowers

There is a continuum of penniless borrowers that receive loans L from the banker, which they invest into a project that returns B with a positive probability p, and zero otherwise. I assume that the projects to which borrowers have access are profitable, i.e., I assume that $p \cdot B > \rho$. Intuitively, the expected gross return from risky projects is assumed to be higher than the private opportunity cost of bankers to invest in those returns. The investment in risky projects is therefore socially desirable.

The returns of investment projects are assumed to be perfectly uncorrelated. Due to a lack of collateral and transparency, borrowers can not get direct funding from households but need to apply for loans from specialized banks. The bank loan is a simple debt contract that limits the liability of the borrower, therefore, the banker receives the repayment on the loan R_L only in case of success.[13] The profit from an investment in the borrower's risky project is the expected net return minus a cost function that is convex in the loan amount, i.e., the investment in the risky project. In particular, I assume the explicit form of the cost function to be $\frac{d}{2}L^2$. Therefore, I can write the expected profit of a risky project as $\Pi^F = p\left((B - R_L)L - \frac{d}{2} \cdot L^2\right) + (1-p)\left(-\frac{d}{2}L^2\right)$. The loan repayment is decreasing in aggregated investment, i.e., the indirect loan demand is assumed to be a decreasing function of overall investment. To understand the intuition, consider a representative penniless borrower, who faces the following

the preference can also be motivated by liquidity and service arguments such as access to ATM and electronic payment systems.

[13]Again, $R_L = 1 + r_L$ is for brevity the gross repayment which consists of the loan interest rate r_L plus one.

utility function:

$$U^F(L) = \max\{\Pi^F; 0\} \cdot (1-\tau) \tag{1}$$

In case of success, the borrower makes a profit of which he has to pay a tax τ to the government. In order to maximize its utility, the representative borrower demands a loan amount $L^* = \text{argmax } U^F(L)$. Because he is limited liable, the utility of a penniless borrower can only be non-negative, a strictly positive demand for loans exists for small loan repayments. In particular, the first partial derivative with respect to L is either negative, such that $L^* = 0$ or the optimal loan demand derived from the first order condition is given by $L^* = \frac{B-R_L}{d}$. The optimal loan demand is decreasing in the loan repayment. Considering that each banker invests a total amount of 1 into assets, such that x is the amount the banker invests in government bonds, and $L = 1-x$ is the share that is invested into risky loans. Therefore, the indirect demand function for bank loans can be written as

$$R_L = B - d(1-x) \tag{2}$$

Here, B can be interpreted as the reservation price, the maximum loan interest payment borrowers are able to pay. In particular, strategic interaction among banks is neglected because it would not change the general result of this model.

2.4. The Government Regulator

In regulating the bankers, the government regulator that has no fiscal interest has the goal of reducing the excessive risk taking of banks via adequate risk weighted capital requirements. The regulator aims at internalizing the negative externalities of the deposit insurance without aiming at maximizing overall welfare. The idea is, that when the banker does not bear the full cost of funding its investment due to the deposit insurance on deposit funding, he will invest too much of his funds into risky loans. In particular, the unregulated limitedly liable banker will invest more in risky loans than he would if he was fully liable for his outstanding debt. In particular, the investment in safe assets of a fully liable bank x^* is greater than the investment of a limitedly liable bank $x^* > \hat{x}$. As in the real world, the regulator can not directly regulate the asset portfolio composition of a banker's investment, which would be the first best solution. This could be justified by a lack of information on the specific asset characteristics, that is only known by the banker.

However, the regulator can indirectly influence the portfolio composition by setting regulating the liability side of the bank's balance sheet. In order to do so, the regulator forces the bankers to refund a share of their risky investments with privately costly equity, i.e., he puts a relative risk weighted capital requirement Δ on risky loan assets. The relative risk weight Δ makes investments into risky loans relatively more costly to the banker than investments in safe government bonds, and therefore decreases the investment in risky assets and increases the investments in safe assets. In other words, the banker's investment in safe assets $\hat{x}(\Delta)$ is an increasing function of the relative risk weight Δ^*. In this way, the regulator can force the banker to invest exactly the same amount of funds into risky assets as the banker would invest when he was fully liable, i.e., first best investment amount. In order to force banks to internalize the cost of their risk shifting, the regulator implements the risk weighted capital requirement for risky assets that disciplines banks to behave as if they were fully liable such that $\hat{x}(\Delta^*) = x^*$

However, as discussed above, the government regulator also borrows from the banks, which can influence his optimal decisions. Therefore, it is assumed that the government has no endowments in $t = 1$ but receives tax income $\tau \cdot U^F$ in $t = 2$ from successful borrowers.

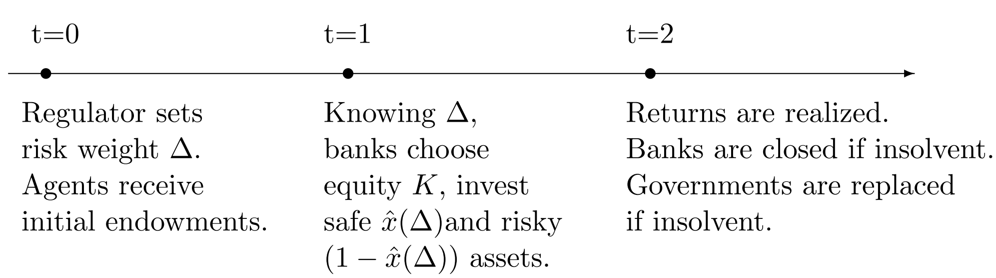
In order to be able to repay current debt and provide public goods as well as bailing out the liabilities of defaulted banks, the government issues government bonds as safe assets in $t = 1$ with the promise of a fixed gross repayment of R_S in $t = 2$. In order to guarantee interior solutions, I assume that $p \cdot (B - d) < R_S$. This assumption implies that due to the increasing cost of conducting risky projects, i.e., the decreasing returns from risky investments, the gross return from risky investments if all funds are channeled into it is lower than the return on safe investments. In other words, it is socially not optimal to invest all funds into the risky projects of borrowers. Moreover, this implies that $p \cdot (B - d) < \rho$: it is not optimal to invest the aggregate banker's endowment into risky assets. Together with the earlier assumption of profitable initial investments $p \cdot B > \rho$ the assumption above secures that it is neither optimal to invest all funds in safe nor risky assets, but in a portfolio of both assets.

The government's objective when borrowing is to maximize its budget, which is reflected as the objective to maximize current consumption. Depending on the focus of the government regulator, the goal of budget maximization enters the regulator's objective function with weighting factor ϕ measuring the fiscal interest of a government regulator. In the basic model, it is assumed that government bonds are indeed safe, i.e. that the government regulator receives an endowment in $t = 2$ that enables him to pay back the bond obligations.

2.5. Decisions and Timing

The timing is as follows: the households and bankers receive their initial endowments and the regulator decides on the optimal relative risk weight for risky assets compared to safe assets Δ as a minimum capital requirement regulation. After the agents received their endowments, the bankers collect funds from depositors, decide to invest inside equity, invest deposits and equity into assets, and consume the residual in $t = 1$. In $t = 2$, the bankers receive the returns from their successful asset investments. If they are solvent, they repay their debt to depositors and consume any profits. If insolvent, the bank is closed and the banker's outstanding debt is cleared by the deposit insurance, which is covered the government in this model. Because the banker consumes the part of his endowment, which he does not invest as equity, he is penniless in $t = 2$ and, thus, also limitedly liable. In case of bank default, the banker receives a payoff of zero, while equity that was invested in $t = 1$ is sunk.

Figure 1: The Timeline of the Decisions Taken



3. The Banker's Investment Decision

3.1. The First Best Investment

As a benchmark, I first discuss the optimal investment choice of bankers in the absence of externalities and without regulation. Therefore, consider a world, where a banker is fully liable. After receiving his endowment in $t = 1$, the representative banker has to decide how much to invest of its own endowment as inside equity investment K. The banker borrows the residual $1 - K$ as deposits from households at the promised repayment R_D. He then invests the deposits and own equity in a portfolio of a share x of safe government bonds with repayment R_S and in a share $(1 - x)$ of loan asset with repayment $R_L(x)$. In the benchmark, the banker is fully liable to repay the deposit liability even if his asset investments default.

The banker then chooses K, and respectively $D = 1 - K$ and the asset portfolio composition x to maximize his expected intertemporal consumption. As he is impatient he discounts the expected future consumption in time $t = 2$.

$$E(U^{fl}(K, x)) = c_1 + \frac{1}{\rho} \cdot E(c_2) \tag{3}$$

$$s.t.$$

$$c_1 = W - K$$

$$E(c_2) = p\left(xR_S + (1 - x)R_L(x) - (1 - K)R_D\right) + (1 - p)\left(R_S x - (1 - K)R_D\right)$$

Because of the full liability, the consumption of the banker can be negative in $t = 2$. In particular, it will be negative when the bank invests no own equity as shown in the following lemma.

Lemma 1. *If the risky loan investment defaults, the banker's consumption c_2 is negative when he proportion of equity investment is smaller than the* *investment in risky assets.*

Proof. With probability $(1-p)$, the loan asset investment defaults and the banker receives $(R_S x - (1-K)R_D)$. As discussed above, the deposit rate is driven down to $R = R_D = R_S$, which implies $R(x-1-K)$ such that consumption becomes negative whenever $1 - x > K$. $\square$

This follows from the zero profit of the safe investment, which does not create a buffer against losses. The partial derivative of the expected future consumption with respect to equity investment K is:

$$\frac{\partial E(U^{fl})}{\partial K} = -1 + \frac{1}{\rho} \cdot R_D \tag{4}$$

As discussed above, the deposit rate is driven down to $R = R_D = R_S$. Under the assumption that $\rho > R_S$ the right hand side of equation (4) is negative, such that even a fully liable banker chooses to leverage his portfolio with deposits as much as possible.

Lemma 2. *A fully liable banker invests no inside equity but all deposits into a portfolio with* $(1-x^*) = \frac{B - \frac{R}{p}}{2d}$ *risky loan assets and* x^* *government bonds.*

Proof. Because $\frac{\partial E(U^{fl})}{\partial K} < 0$ the banker optimally chooses to invest no inside equity. With $K = 0$ the partial derivative of the expected consumption function with respect to x becomes:

$$\frac{\partial E(U^{fl})}{\partial x} = p(R - R_L(x) + (1-x)R_L'(x)) + (1-p)R \stackrel{!}{=} 0.$$

Solving the first order condition for the optimal investment into risky loan assets $1 - x^*$ yields $(1-x^*) = \frac{B - \frac{R}{p}}{2d}$ $\square$

Intuitively, the optimal portfolio decision equalizes the marginal profit of the safe investment, which is zero, with the marginal profits of the risky investment.

I now introduce the economic problem that the banker is only limitedly liable, i.e., after he consumed his initial endowment, he cannot made liable if the asset returns from his investment portfolio fall short of his liabilities to depositors. In other words, from now on, I exclude the possibility of negative consumption.

3.2. The Banker's Investment Decision without Regulation

If the banker is limitedly liable, his future consumption can be at minimum zero. He therefore wants to maximize the following expected utility function.

$$E(U^{ltd}(K,x)) = c_1 + \frac{1}{\rho} \cdot E(c_2) \tag{5}$$

$$s.t.$$

$$c_1 = W - K$$

$$E(c_2) = \max\{p\,(xR_S + (1-x)R_L(x) - (1-K)R_D)$$
$$+(1-p)\,(R_S x - (1-K)R_D)\,;0\}$$

Lemma 3. *The unregulated banker prefers to consume all his endowments in $t = 1$ and borrow $D = 1$ from insured depositors.*

Proof. The right hand side of first order partial derivative with respect to inside equity investments is negative in each case, i.e., $\frac{\partial E(U^{ltd})}{\partial K} = -1 < 0$ if $E(c_2) = 0$ and $\frac{\partial E(U^{ltd})}{\partial K} = -1 + \frac{1}{\rho} \cdot R_D < 0$, otherwise. Therefore, the unregulated bank will always prefer to consume all its endowments in $t = 1$. □

With $K = 0$, the profit from bank investment is never positive, if the loan investment fails. Therefore, the first order condition with respect to the optimal portfolio choice variable x becomes

$$\frac{\partial E(U^{ltd})}{\partial x} = \frac{1}{\rho} \cdot p\,[R - R_L(x) + (1-x)R_L'(x)] \overset{!}{=} 0 \tag{6}$$

The marginal benefit from investing in the loan asset should equal the marginal benefit from investing in the safe asset, which is zero. Using the linear indirect demand function, the optimal investment of an unregulated bank into risky assets is

$$(1 - \hat{x}) = \frac{B - R}{2d} \tag{7}$$

Lemma 4. *A Limitedly liable banker takes excessive risk in the form of higher loan asset investments compared to optimal investment with full liability.*

Proof. Consider from Lemma 2 the optimal investment of a fully liable bank: $(1 - x^*) = \frac{1}{2}\frac{B - \frac{R}{p}}{d}$. For any positive default probability of risky assets $p < 1$, it holds that $\frac{R}{p} > R$ such that $(1 - x^*) < (1 - \hat{x})$ or $x^* > \hat{x}$ a fully liable banker invests more funds into safe assets and less into risky assets. $\square$

3.3. The Banker's Investment Decision with Regulation

A risk weighted capital requirement in this model is reflected by a relative risk weight for risky loans compared to safe loans: $K \geq (1 - x) \cdot \Delta$. The relative risk weight $\Delta \in [0, 1]$ is a stark simplification of the granulated capital requirements of the Basel II and III accords but covers in essence the main mechanisms of the influence of risk weights on the portfolio choice of bankers.

A more realistic approach to Basel II would be a capital requirement $K \geq (w_S \cdot x + w_L(1 - x))\delta$, where δ is the unweighted percentage, i.e, 8 % of assets under Basel II, w_S is the risk weight for safe assets and w_L is the risk weight for risky assets. A zero risk weight for safe assets immediately results in $w_L \cdot \delta$, which corresponds to the Δ in the simplified approach. With a nonzero risk weight for safe assets the requirement can be written as $K \geq (w_S \cdot \delta + (w_L - w_S)\delta(1 - x))$. In this case, the optimal portfolio decision of the banker will not only be influenced by the overall size of the capital requirement but also by the relative risk weight, i.e., the decision is influenced by $(w_L - w_S)\delta$. This relative risk weight is also captured by the simplified Δ above. If the Δ corresponds to the relative risk weight $(w_L - w_S)\delta$ it is noteworthy that Δ can be increased by a higher risk weight for risky assets as well as by a lower risk weight for safe assets, respectively. This implies that a correct risk weight for risky loan assets but a comparatively too low risk weight for the safer asset, such as government bonds, is also reflected in a higher Δ.

The inside equity investment of the banker must at least equal a percentage Δ of its risky loan investment. As discussed above, a banker prefers consumption over investing inside equity, hence, the minimum equity requirement that the regulator sets will be a binding constraint to the bankers optimal investment decision $K = (1-x) \cdot \Delta$. Inserting the binding requirement into equation (5) yields the regulated banker's objective function.

$$E(U^{reg}(x)) = c_1 + \frac{1}{\rho} \cdot E(c_2) \tag{8}$$

$$s.t.$$

$$c_1 = W - (1-x) \cdot \Delta$$

$$E(c_2) = \max\{p\,(xR_S + (1-x)R_L(x) - (1-(1-x)\cdot\Delta)R_D)$$
$$+(1-p)\,(R_S x - (1-K)R_D)\,;0\}$$

Lemma 5. *For a relative risk weighted capital requirement $\Delta < 1$, the regulated banker does not make positive profits when his assets default.*

Proof. Recall from Lemma 1 that a banker defaults when his assets default whenever $(1-x) > K$. Substitution of the binding relative risk weighted capital requirement $K = (1-x) \cdot \Delta$ gives $(1-x) > (1-x) \cdot \Delta$, such that the banker defaults whenever $\Delta < 1$. $\square$

In the case of $\Delta = 1$, the banker is forced to refund 100% of his assets with equity, such that he cannot default. However, this extreme regulation implies that the banker looses his role as a financial intermediary and is therefore excluded from the analysis.[14]

Lemma 5 shows that a regulated limited liable banker, i.e., a banker that is regulated with $\Delta < 1$ expects future consumption to be $E(c_2) = p\left(xR_S + (1-x)R_L(x) - (1-(1-x)\cdot\Delta)R_D\right)$ because with probability $1-p$ the bank makes negative profits such that the banker receives zero. This leads to the first order condition for the optimal portfolio choice variable x of

$$\frac{\partial E(U^{reg})}{\partial x} = \Delta + \frac{1}{\rho} \cdot p\left[(1-\Delta)R - R_L(x) + (1-x)R_L'(x)\right] \stackrel{!}{=} 0 \qquad (9)$$

Solving for the optimal portfolio investment gives the optimal investment in risky assets as a function of the regulation Δ:

$$(1-\hat{x}(\Delta)) = \frac{B - \frac{\Delta\rho}{p} - (1-\Delta)R}{2d} \qquad (10)$$

It is straightforward to show that the investment choice of the representative bank into safe assets is increasing in the risk weight for risky assets: Note,

[14] Corresponding to the discussion above, Δ reflects the difference of risky and safe risk weights times the general capital requirement, i.e, $(w_L - w_S)\delta$. The risk weight w_L for a corporate may be above 100% , e.g. claims on corporations are assigned with a risk weight of up to 150% under the Standard Approach when the corporation rated below BB^-. However, even with a zero risk weight $w_S = 0$ the difference $(w_L - w_S)$ is multiplied by the general capital requirement δ, i.e., 8% under Basel II and up to 13 % under Basel III such that even under the higher requirements of Basel III it is feasible to assume that $\Delta < 1$.

that if the banker is not allowed to receive funds from depositors but has to refund his investment with equity only, i.e., $\Delta = 1$, the optimal investment of the regulated banker would be lower than the first best investment, due to the high opportunity cost of equity investment. In the other extreme case, when $\Delta = 0$ the banker's investment choice equals equation (7), the unregulated case.

Moreover, the partial derivative of the optimal safe investment choice with respect to the capital requirement regulation is positive:

$$\frac{\partial \hat{x}(\Delta)}{\partial \Delta} = \frac{1}{2}\frac{\rho - pR}{pd} > 0 \tag{11}$$

A higher risk weight for loan assets reduces investment in risky assets and increases investment in government bonds.

3.4. The Optimal Risk Weight of a Regulator without Fiscal Interest

Under the assumption that the regulator cannot regulate the asset side of the bank but only the liability side, the first best outcome cannot be implemented.[15] However, the regulator can force the bankers to internalize the cost of their excessive risk taking with the help of minimum capital requirement. The regulator thereby takes the investment decision $\hat{x}(\Delta)$ of bankers as given. To force the banker to internalize the full cost of his investment decision the regulator sets a Δ^* such that the regulated banker

[15]Actually, regulation under the Basel accords concentrates on liabilities of the bank rather than the regulation of assets: The main reason for this focus is the asymmetric information on the asset characteristics. As banks are specialized in evaluating the risk and return characteristics of their assets it is difficult, if not impossible, for a regulator to determine the optimal asset portfolio composition. However, anticipating that the incentives of bankers are disturbed by their limited liability, the regulator can correct these incentives by requiring the banker to invest sufficient equity funds.

implements $\hat{x}(\Delta^*) = x^*$. Formally, he sets $\Delta^* = \text{argmax}\{E(U^{fl}(x(\Delta))\}$ such that the Δ^* chosen fulfill the first order condition of the fully liable banker with reaction function $\hat{x}(\Delta)$.

Proposition 1. *The regulator without fiscal interest sets an optimal capital requirement risk weight for loan assets that balances the banker's benefit from limited liability with the private opportunity costs of investing equity*

$$\Delta^* = \frac{R \cdot (1-p)}{\rho - pR}.$$

Proof. The first order condition is

$$p(R - B + 2d(1 - x(\Delta)) + (1-p)R \stackrel{!}{=} 0.$$

Using equation (10) and solving for Δ yields the Δ^* for which it is true that $1 - \hat{x}(\Delta^*) = 1 - x^*$, i.e.:

$$(1 - \hat{x}(\Delta^*)) = \frac{B - \frac{\Delta\rho}{p} - (1-\Delta)R}{2d} = \frac{pB - pR - \Delta(\rho - pR)}{2dp}$$

Inserting $\Delta^* = \frac{R \cdot (1-p)}{\rho - pR}$ and using Lemma 2 yields:

$$\frac{pB - pR - R(1-p)}{2dp} = \frac{B - \frac{R}{p}}{2d} = (1 - x^*)$$

□

It is worth noting that the optimal capital requirement risk weight, and hence the demand for safe assets, is increasing in the risk less government bond rate R.

3.5. A Regulator with Fiscal Interests

This section analyzes how a regulator sets the capital requirement when he also has fiscal interests. In other words, I assume that the regulator gains some utility from forcing banks to integrate the negative externality of their investment. However, the regulator also gains utility from maximizing his current budget and, thus, wants banks and households to invest in government bonds. I focus on a short term oriented regulator that only values current consumption in $t = 1$. In particular, I assume that, besides regulating the banking sector, the government regulator wants to maximize his budget in $t = 1$.[16]

Requiring banks to refund their investments with inside equity in this model has two effects on: Firstly, the bank internalizes the risk and, therefore, invests less in loan assets compared to the unregulated decision. Secondly, the inside equity crowds out deposit investments of households. Since households have access to the sovereign debt market, those households that can not deposit their savings at a bank invest their savings in government bonds.

A regulator with fiscal interests then wants to maximize the weighted sum of utility he gets from setting Δ^* and the utility from his current budget $\hat{x}(\Delta) + (1 - \hat{x}(\Delta))\Delta$. The current budget consists of two terms, where the first term is the direct investment in government bonds from banks as a function of capital regulation and the second term the increased investment from households that cannot deposit their savings at banks due to the capital requirement. Both terms are increasing in the capital requirement, though the second term at a decreasing rate, since banks invest less in risky loans to minimize their private cost of capital requirements. Denote with $\Gamma(\Delta, \phi)$

[16]The weight that a government regulator puts on budget maximization can also be interpreted as a measure for the necessity to raise new debt in order to server outstanding debt. This is not explicitly modeled in this simple static model, but the intuition would be, that a government with high outstanding debt from earlier periods would have a greater interest to maximize its budget than a government that has low outstanding debt.

the utility of a regulator with fiscal interest, where the government regulator weights the goal of current budget maximization with ϕ and the achievement on his goal of optimal regulation with $(1-\phi)$.

$$\hat{\Delta}(\phi) = \text{argmax}\{(1-\phi)E(U^{fl}(x(\Delta)) + \phi\,[\hat{x} + (1-\hat{x})\cdot\Delta]\} \tag{12}$$

If $\phi = 0$, the regulator has no fiscal interest and sets the optimal capital requirement, i.e., $\hat{\Delta}(0) = \Delta^*$. However, if $\phi > 0$, the government regulator sets a capital requirement strictly greater than the optimal regulation.

Proposition 2. *A regulator with fiscal interests sets a higher relative risk weighted capital requirement on risky loan assets than a regulator without fiscal interests.*

Proof. The first order condition can be solved for Delta:

$$\Delta = \frac{p\,(1-\phi)\,(1-p)\,R^2 + (((2-\rho)\,\phi + \rho) - \rho\,(1-\phi))\,R - \phi\,(\rho + pB)}{(\rho - pR)\,(p\,(1-\phi)\,R + (\rho - 2)\,\phi - \rho)}$$

The second partial derivative with respect to Δ is negative:

$$-\frac{1}{2}\,\frac{(1-\phi)\,(\rho - pR)^2}{pd} - \frac{\phi\,(\rho - pR)}{pd} < 0$$

The partial derivative of the optimal regulation with respect to ϕ is positive:

$$\frac{\partial\Delta}{\partial\phi} = \frac{pB - R + \rho - R}{((1-\phi)\,\rho - p\,(1-\phi)\,R + 2\,\phi)^2} > 0$$

Here the basic assumptions are used, i.e. that $pB > \rho$ and $\rho \geq R$. The higher ϕ, i.e., the more interested the regulator is in current budget maximization, the higher he sets the relative risk weighted capital requirement for risky loan assets. □

To get an intuition, consider the case where $\phi = 1$, the case of a Leviathan regulator that is only interested in maximizing his budget in $t = 1$. In this case, the first order condition can be summarized to the following condition:

$$\Delta = \min\left[\frac{1}{2}\left(1 + \frac{p(B-R)}{\rho - pR}\right), 1\right] = 1$$

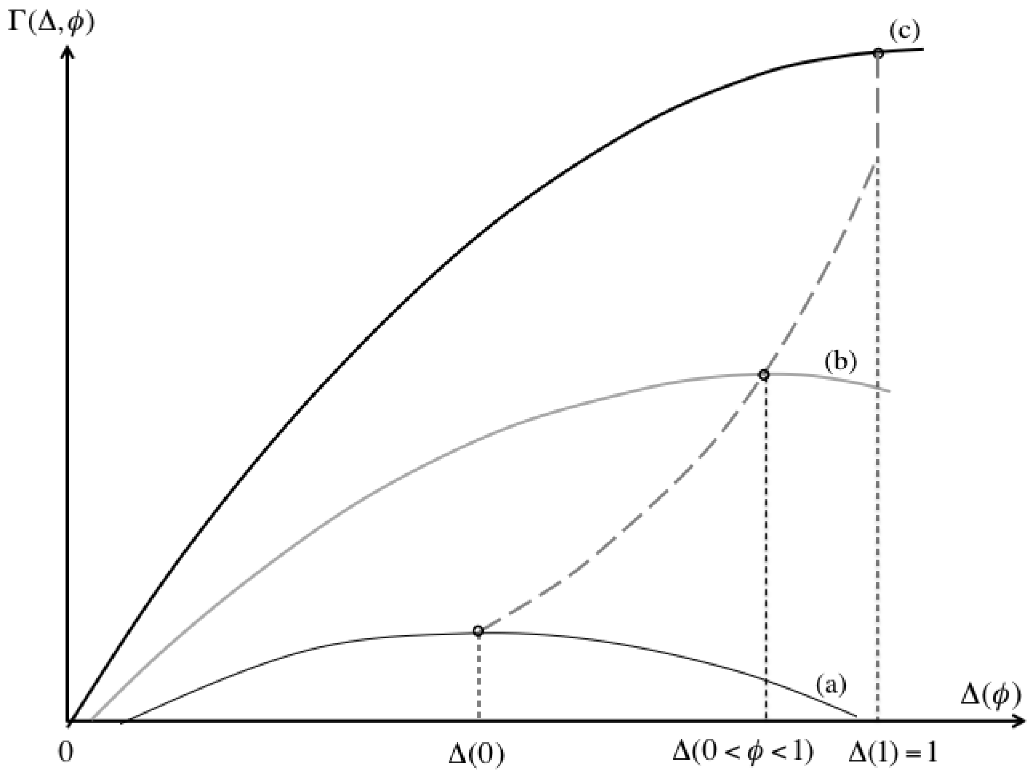
For the basic assumptions $pB > \rho$ and $\rho > R$, the first term is strictly greater than one, such that a Leviathan regulator would always choose the corner solution and sets the relative risk weighted capital requirement for risky loans equal to one.

In contrast, a regulator without fiscal interest sets a capital requirement strictly smaller than one, i.e. $\Delta^* < 1$ for $\rho > R$.

Moreover, as shown in the proof of Proposition 2, the capital requirement set by the regulator is strictly increasing in his fiscal interest ϕ, when the expected return from loan investment outweighs the banker's private cost of capital. The more a regulator is fiscally interested, i.e, the more he values current budget maximization (higher ϕ), the higher he sets the relative risk weight for loan assets, deviating from the optimal risk weight, i.e.: $\frac{\partial \Delta(\phi,R)}{\partial \phi} > 0$. Thereby, the regulator channels funds from bankers and households to investments in government bonds.

Figure 2 illustrates three different types of the government regulator. The thin black line, labeled (a), depicts the regulator's utility without any fiscal interest. He will set the risk weight for risky loan assets as described in Proposition 1. The thin grey line, labeled (b), illustrates the case of a partly fiscally interested regulator. The maximum of his utility function is reached at a higher relative risk weight for risky loan assets. The bold black line, labeled (c), depicts the utility of a regulator that is only concerned with fiscal interests, i.e., that only derives utility from current consumption. Such

Figure 2: The Regulator's Utility as a function of Δ and ϕ



a Leviathan optimally chooses a corner solution where he sets the risk weight as high as possible, which would be equal to full inside equity funding in our model framework. The dashed grey line depicts all feasible utility maximizing $\Delta(\phi)$ for $\phi \in [0, 1]$. A higher regulator's interest results in a higher overall utility level because in this simple setting the budget maximization adds utility to the utility gained from optimal regulation.

Basically, the regulator can implement any bank investment portfolio decision in the interval $[\hat{x}(0), \hat{x}(1)]$by setting a certain Δ. In other words, the risk weight decision directly influences how much the banking sector invests in safe assets $\hat{x}$. It is easy to verify that $x(\Delta(0)) < x(\Delta(\phi))$ for $\Delta(\phi) > \Delta(0)$, because x is linearly increasing in Δ. The benevolent regulator channels less funds into government bonds than the regulator with fiscal interests.

4. Welfare Considerations

The goal of optimal regulation to internalize the cost of risk shifting to the bank's optimal portfolio choice does not necessarily coincide with the welfare maximizing regulation of the banking sector. In particular, with no additional social cost of bank default, the regulation of banks in this simple model would be welfare decreasing. To see this, consider the welfare generated in terms of consumption.

In $t = 1$, the endowment of households is invested in banks and government bonds depending on the regulation. Banks consume $W - K$ and the government consumes K. The net welfare effect is zero, since higher regulation just shifts consumption from banks to the government regulator.

In $t = 2$, the productive return from the risky projects $\Pi^F(1 - \hat{x}(\Delta))$ is generated and split between the banks and the firms in terms of the loan interest rate. The residual profit of borrowers is shared between the successful entrepreneurs and the government according to the tax rate. Households receive and consume R, either from successful banks or the government in case of bank default. The government pays back its obligations to banks and households. Hence, the net welfare Y generated is the net profit from successful entrepreneurs $Y = (1 - x(\Delta)) \cdot p(B - \frac{d}{2}(1 - x(\Delta)))$.

Without any social cost of bank default, the net impact of investment in government bonds is a reduction in welfare. In particular, the capital regulation that maximizes the net profit from successful entrepreneurs is:

$$\Delta^Y = argmax(1 - \hat{x}(\Delta)) \cdot p(B - \frac{d}{2}(1 - \hat{x}(\Delta))) = -\frac{p(B+R)}{\rho - pR} < 0 \tag{13}$$

Therefore, any capital regulation $\Delta > 0$ reduces welfare, because it reduces investment into the productive but risky sector. However, as the recent financial crisis has illustrated, bank failures are costly because of the contagion to other solvent banks, the disappearance of know how and private information on borrowers, as well as the disturbance of trust, financing, and payment flows. I assume that these costs are linear to the bank failure, though as the last crisis has shown, the costs could very well be convex, i.e. the more banks fail the higher are the marginal costs to society. Introducing these social costs s proportional to the banks that default, the welfare function can be written as

$$Y = (1 - x(\Delta)) \cdot p(B - \frac{d}{2}(1 - x(\Delta)) - s(1-p) \cdot (1 - x(\Delta)) \tag{14}$$

Proposition 3. *With moderate social cost of bank default, a fiscally interested capital regulation harms social welfare.*

The detailed proof can be found in the Appendix A. The intuition is that, with moderate social cost associated with bank default, i.e. $s \in \left[0, \frac{1}{2}\left(\frac{B+R}{1-p} + R\right)\right]$, setting a capital regulation $\Delta(\phi) > \Delta^*$ strictly reduces welfare. However, if the social costs are very high, i.e. $s > \frac{1}{2}\left(\frac{B+R}{1-p} + R\right)$ welfare can be increased by fiscally interested regulation. However, a regulator with high fiscal interest may not consider the constraint of government solvency and, therefore, may risk the detrimental welfare consequences of a sovereign default.

5. Discussion

The paper argues that a government regulator, who simultaneously regulates the banking sector and borrows from it, may have the incentive to increase risk weights for risky loan assets beyond the optimal level in order to ease its own debt financing. In particular, the government regulator may have an incentive to overregulate risky assets compared to safe assets. This incentive to overregulate is particularly interesting, since the most prominent international guidelines for prudential capital regulation, the Basel accords, only provide standards for minimum capital requirements but not for maximum requirements. Therefore, the Basel agreements leave room to overregulate classes of assets compared to less risky assets. By overregulating the risky assets, the government regulator can indirectly increase the demand for government bonds, thereby undermining the separation of monetary and fiscal policy.

Likewise, biased risk weighted capital regulation may be implemented in the form of underregulated safe assets compared to risky assets. If risky assets receive a fair risk weight that indeed reflects the fundamental risk of the asset, the government with fiscal interest may have an incentive to relatively underregulated the government bond compared to the risky asset. Anecdotal evidence may be found in the implementation of the Basel II agreement into European law. Deviating from the recommendations of Basel II, the Capital Requirement Directive imposed a zero-risk weight on all EU sovereign bonds. Arguably this lowest possible risk weight encouraged European banks to invest massively in these EU bonds because irrespective of the individual sovereign risk, the bank could invest without any additional equity requirement. In times of low interest rates but rare equity, the cheap borrowed capital was, therefore, channeled into EU government bonds.

In each of the two theoretical cases, biased capital ratios increase the demand for government bonds. This eases government spending and thus circumvents the monetary policy monopoly of an independent institution as the central bank. In other words, through risk weighted capital regulations, governments can indirectly influence their refunding conditions. Moreover, reduced cost of government debt may increase government spending. The increase in current government debt may jeopardize the government's solvency of tomorrow. However, if the yield on government bonds does not (fully) reflect the riskiness of the government regulator, this higher risk is not (fully) taken into account by the regulator with fiscal interests. This result points to an additional problem in the Eurozone, where government bond yields did not fully reflect the individual risk of each Eurozone member state. Besides the direct incentive to increase government debt due to cheap financing, the government regulator has the incentive to introduce biased regulation, thereby forcing banks to increase their investments in government bonds.

This could lead to an additional problem. Due to the excessive investment in government bonds, all banks are more correlated. If the government bonds can default, the systemic risk in the banking sector increases. If the financial distress of the regulator results in a systemic crisis of the banking sector, the feedback effect on the government through the safety net can drive the government and its banking sector into an insolvency circle.

The policy implications of the presented analysis are threefold: In the aftermath of the financial crisis, the reformers in the Basel Committee focused on the size and quality of the regulatory equity. In addition, anticyclical equity buffers are introduced. However, the calibration of the risk weights barely changed and the standards of implementation and supervision are no component of the reforms. This focus on the fine-tuning of the risk weighted capital regulation overlooks incentive problems regarding the national and supranational implementation of the Basel Accords. The problem of upwards biased capital adequacy regulation may be encountered by a simple maximum leverage ratio as discussed in the Basel III reform.

Moreover, the analysis suggests the equity regulation should be delegated to an independent authority because it has the power to indirectly influence monetary policy. For example, the delegation of regulatory policy, especially the imposition of risk weights, to an independent institution like the central bank could avoid the inherent conflict of interest. Finally, the analysis suggests that higher indebted governments have a higher incentive to bias capital regulation. In the process of international harmonization of banking regulation, the harmonization of maximum government debt levels may also alleviate the adverse incentives of governments to bias the regulation.

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Appendix A. Proof of Proposition 3

Proof. In $t = 1$, banks consume

$$W - K$$

Households invest

$$-W$$

The government consumes

$$x + K$$

and borrowers receive

$$1 - x$$

The net welfare is

$$W - K - W + x + K + 1 - x = 1.$$

In $t = 2$, banks consume

$$p(xR + (1 - x)R_L - (1 - K)R)$$

Households receive $p(1 - K)R$ from successful banks and $(1 - p)(1 - K)R$ from the government, taking over the liabilities from defaulting banks

$$p(1 - K)R + (1 - p)(1 - K)R + KR = R$$

The government receives tax income and pays pxr to banks or depositors in case of default, pays $(1-p)(1-K)R - KR$

$$\tau \cdot p(1-x)(B - R_L - \frac{d}{2}(1-x)) - pxR - (1-p)(1-K)R$$

and borrowers receive

$$(1-\tau) \cdot p(1-x)(B - R_L - \frac{d}{2}(1-x))$$

The intertemporal net welfareis

$$Y := 1 + p(1-\hat{x}(\Delta))(B - \frac{d}{2}(1-\hat{x}(\Delta))).$$

Using equation (10) the net welfare can be expressed in terms of the capital requirement:

$$1 + \left(\frac{1}{2} \frac{B\,(p(B-R) - \Delta(\rho - pR))}{pd} - \frac{1}{8} \frac{(p(B-R) - \Delta(\rho - pR))^2}{dp^2} \right) p$$

The first order condition with respect to Δ is

$$-\frac{1}{4} \frac{(p(B-R) - \Delta(\rho - pR))\,(\rho - pR)}{dp^2} p \overset{!}{=} \frac{1}{2} \frac{B\,(\rho - pR)}{pd}$$

Solving for delta gives:

$$\Delta^W = -\frac{pB + pR}{\rho - pR} < 0$$

Introducing the social cost of bank default, the social welfare function becomes

$$Y^s := 1 + p(1-x)(B - \frac{d}{2}(1-x)) - s(1-p)(1-x)$$

Solving the first order condition for Δ gives:

$$\Delta^W(s) = \frac{2(1-p)s - p\,(B+R)}{\rho - pR}$$

The welfare optimal $\Delta^W(s)$ is between 0 and 1 for $s \in \left[\frac{B+R}{2(1-p)}, \frac{(\rho-pR)+(B+R)}{2(1-p)}\right]$. For $s = \frac{(\rho-pR)+R(1-p)}{2(1-p)}$, the welfare optimal Δ equals the benevolent regulator's choice. Therefore, for $s \leq \frac{(\rho-pR)+R(1-p)}{2(1-p)}$, the welfare is decreasing if the regulator has fiscal interests and sets a risk weighted capital regulation that is higher than the regulation that internalizes the risk shifting of limitedly liable banks. $\square$