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

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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.

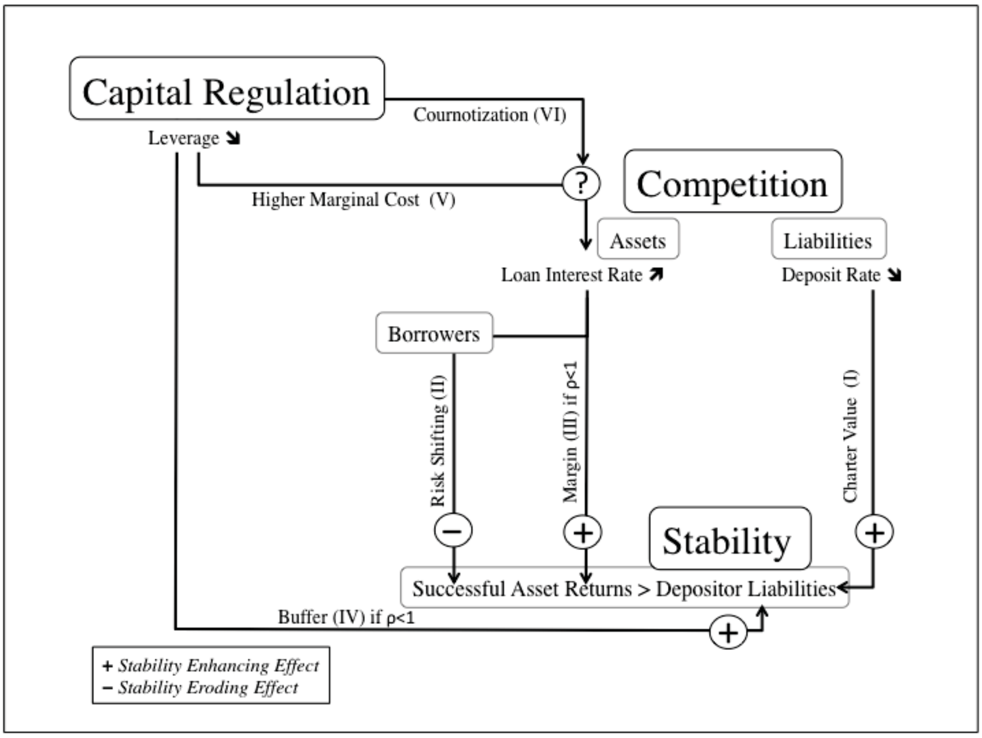
2. Literature Review

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:

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

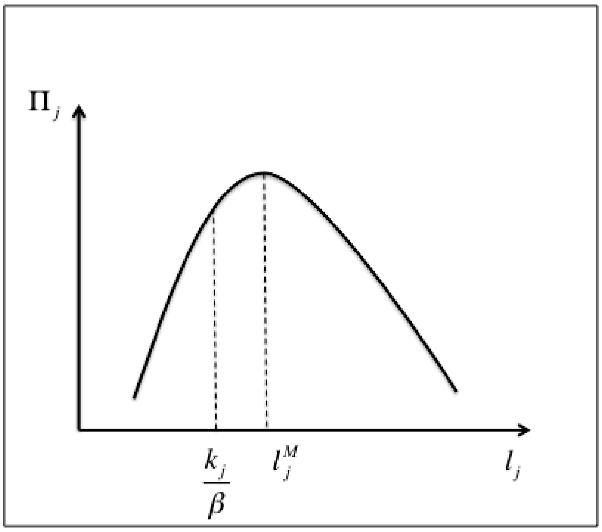
Consider now the case where the raised amount of equity is "sufficiently small". The first stage amount of equity is sufficiently small if, firstly, the capacity to provide loans to borrowers from the first stage capital decision bindingly constrains the price competition $K < \beta L(r_D)$. Secondly, 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 $h(L) := (1-p)(r\,(L)-r_D(1-\beta))$ 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:

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

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] $\square$

[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.

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:

$$\begin{aligned} F(x,p) &= P\left[\phi\left(\tfrac{\phi^{-1}(p) - \sqrt{\rho} \cdot z}{\sqrt{1-\rho}}\right) \leq x\right] \\ &= P\left[-z \leq \frac{\sqrt{1-\rho} \cdot \phi^{-1}(x) - \phi^{-1}(p)}{\sqrt{\rho}}\right] = \phi\left(\frac{\sqrt{1-\rho} \cdot \phi^{-1}(x) - \phi^{-1}(p)}{\sqrt{\rho}}\right) \end{aligned} \tag{29}$$

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 $P\left[x < \hat{x}\right]$:

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

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 $\phi\left(\phi^{-1}(p)\right) = p$ 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 $F\left(\hat{x}, p\right)$ when referring to $F\left(\hat{x}(\beta, r(L)), p(r(L)\right)$.

of the Cournotization effect.

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

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

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

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.

References

Admati, A., DeMarzo, P., Hellwig, M., Pfleiderer, P., 2010. Fallacies, irrelevant facts, and myths in the discussion of capital regulation: Why bank equity is not expensive. Working Paper Series, Stanford University.

Allen, F., Carletti, E., 2011. New theories to underpin financial reform. Journal of Financial Stability, 1–8.

Allen, F., Carletti, E., Marquez, R., 2011. Credit market competition and capital regulation. Review of Financial Studies 24 (4), 983–1018.

Allen, F., Gale, D., 2000. Corporate governance and competition. Corporate Governance, 23–84.

Allen, F., Gale, D., 2004. Competition and financial stability. Journal of Money, Credit and Banking 36 (3,2), 453–486.

Barth, J. R., Caprio, G., Levine, R., 2005. Rethinking bank regulation: Till angels govern. Cambridge University Press.

Beck, T., De Jonghe, O., Schepens, G., 2011. Bank competition and stability: Reconciling conflicting empirical evidence. Paolo Baffi Centre Research Paper (2011-97).

Beck, T., Demirguc-Kunt, A., Levine, R., 2006. Bank concentration, competition, and crises: First results. Journal of Banking and Finance 30 (5), 1581–1603.

Berger, A., Klapper, L., Turk-Ariss, R., 2009. Bank competition and financial stability. Journal of Financial Services Research 35, 99–118.

Boyd, J., De Nicolò, G., Jalal, A., 2009. Bank competition, risk and asset allocations. IMF Working Paper 143.

Boyd, J. H., De Nicolò, G., 2005. The theory of bank risk taking and competition revisited. The Journal of Finance 60 (3), 1329–1343.

Calomiris, C. W., Herring, R. J., 2012. Why and how to design a contingent convertible debt requirement. Brookings-Wharton Papers on Financial Services.

Carletti, E., Hartmann, P., 2003. Competition and stability: What's special about banking? Essays in Honour of Charles Goodhart, 202 – 229.

Davidson, C., Deneckere, R., 1986. Long-run competition in capacity, short-run competition in price, and the cournot model. The RAND Journal of Economics 17, 404–415.

Gale, D., 2003. Financial regulation in a changing environment. In: Courchene, T., Neave, E. (Eds.), Framing Financial Structure in an Information Environment. John Deutsch Institute for the Study of Economic Policy.

Hakenes, H., Schnabel, I., 2011. Capital regulation, bank competition and financial stability. Economic Letters 113, 256–258.

Hellmann, T. F., Murdock, K. C., Stiglitz, J. E., 2000. Liberalization, moral hazard in banking, and prudential regulation: Are capital requirements enough? The American Economic Review 90 (1), 147–165.

Keeley, M. C., 1990. Deposit insurance, risk, and market power in banking. The American Economic Review 80 (5), 1183–1200.

Kreps, D. M., Scheinkman, J. A., 1983. Quantity precommitment and bertrand competition yield cournot outcomes. The Bell Journal of Economics 14 (2), 326–337.

Martinez-Miera, D., 2009. Capital requirements and bank failure. CEMFI-UIMP PhD Dissertation.

Martinez-Miera, D., Repullo, R., 2010. Does competition reduce the risk of bank failure? The Review of Financial Studies 23 (6669), 3638–3664.

Matutes, C., Vives, X., 2000. Imperfect competition, risk taking, and regulation in banking. European Economic Review 44 (1), 1–34.

Repullo, R., 2004. Capital requirements, market power, and risk-taking in banking. Journal of Financial Intermediation 13 (2), 156–182.

Schaeck, K., Cihak, M., 2011. Banking competition and capital ratios. European Financial Management 18, 836–866.

Schaeck, K., Cihak, M., Wolfe, S., 2009. Are competitive banking systems more stable? Journal of Money, Credit and Banking 41 (4), 711–734.

Schliephake, E., Kirstein, R., 2013. Strategic effects of regulatory capital requirements in imperfect banking competition. Journal of Money, Credit and Banking 45 (4), 675–700.

Stiglitz, J. E., Weiss, A., 1981. Credit rationing in markets with imperfect information. The American Economic Review 71 (3), 393–410.

Tirole, J., June 1988. The Theory of Industrial Organization. The MIT Press, Cambridge, MA.

Vasicek, O. A., 2002. Loan portfolio value. RISK, 160–162.

Appendix A. Proof of Lemma 3

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

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

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:

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

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.

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