Essays on bank monitoring, regulation and competition

Marinc, M.

Chapter 3

Competition and Entry in Banking: Implications for Capital Regulation

Abstract

This chapter assesses how capital regulation interacts with the degree of competitiveness of the banking industry. It particularly asks two questions: *i*) how does capital regulation affect endogenous entry; and *ii*) how do changes in the competitive environment affect bank monitoring choices and the effectiveness of capital regulation? The approach deviates from the extant literature in that it allows for heterogeneous bank quality and recognizes the fixed costs associated with banks' monitoring technologies. The most striking result is that increasing costly capital requirements can lead to *more* entry into banking, essentially by reducing the competitive strength of lower quality banks. I show that an implication of this is that banks on average may want the regulator to impose a higher capital requirement on the industry than is socially optimal. I also show that competition improves the monitoring incentives of better quality banks and deteriorates the incentives of lower quality banks; and that precisely for those lower quality banks competition typically compromises the effectiveness of capital requirements.[1]

Keywords: Competition, Entry, Capital Regulation, Banking
JEL CLASSIFICATION: G21, G28

[1]This chapter is part of joint work with Arnoud Boot.

3.1 Introduction

A key public policy issue concerning the banking sector is how competition and regulation affect the functioning of financial institutions, and specifically, what the interaction is between competition and the effectiveness of regulation. In this chapter, I particularly ask two questions: *i*) how does capital regulation affect endogenous entry; and *ii*) how do changes in the competitive environment affect bank monitoring choices and the effectiveness of capital regulation?

The importance of these issues is unquestionable. The increasingly competitive and dynamic environment of banking puts severe strains on the viability and effectiveness of regulation. Competition also affects the behavior of the players in the industry directly. More competition could induce banks to take more risks, which could undermine the stability of the industry (see Vives (2001a) for a review). Simultaneously, there is a concern about the impact of capital regulation on the competitive dynamics, including level-playing-field issues.

These issues are analyzed in an industrial organization framework in which I distinguish multiple banks, and I let banks differ in quality. These quality differences are linked to banks' abilities to monitor potential borrowers, and affect the riskiness of banks and the profitability of their lending operations. I let banks compete for borrowers and analyze how their choices of monitoring technology, and hence risk, are affected by capital regulation and the intensity of competition. I show that increasing interbank competition – that is, opening up locally segmented markets for cross-market competition (holding the total number of banks fixed) – improves the monitoring incentives of better quality banks and deteriorates the incentives of lower quality banks, and that precisely for those lower quality banks competition typically also compromises the effectiveness of capital requirements. These results point to the difficulty of introducing more competition into protected markets when the local banking system is of low(er) quality.

When I permit endogenous entry, and thus allow for an increase in the aggregate number of banks, I obtain arguably the most striking result of this analysis. I show that existing work has overlooked a key benefit of increasing capital requirements in that it reduces the competitive strength of lower quality banks vis-à-vis high(er) quality banks, and this effect encourages entry. This insight complements observations by practitioners and policymakers that have sometimes argued that the real contribution of the existing Basel I capital requirements is that they have raised capital levels across the industry and, in doing so, improved the stability of the financial system. I show that discouraging weaker players is an important aspect of the link between capital requirements and the quality of the industry. This cleansing effect of capital regulation also gives a moment of pause for the ambitions of the new Basel II capital requirements. Trying to differentiate capital requirements between banks and tailor them to the exact risks taken by these institutions might truly be of secondary importance if raising capital requirements across the board has had such favorable effect on the industry.

While increasing (costly) capital requirements always has a cleansing effect on the industry by discouraging weaker banks, the net effect on entry is positive only when there are sufficiently many lower quality banks in the economy *and* local banking markets are not fully segmented, i.e. interbank competition should be feasible such that market share can be captured from lower quality banks. In such an environment there is a distinct benefit to discouraging lower quality banks that exceeds the direct cost that costly capital requirements impose on the industry.

The reason why capital requirements work against the competitive strength of low-quality banks deserves some further discussion. In this analysis, this is a consequence of deposit insurance. As long as the deposit insurance premium cannot be made fully type (and/or risk) dependent, deposit insurance effectively subsidizes low-quality banks relative to high(er) quality banks. This makes low-quality banks more competitive than they would otherwise be, and makes it more difficult for good banks to gain market share at their expense.[2] The consequence of this is that lending rates are pushed down by the over-competitive low-quality banks, and this discourages entry. Increasing capital requirements mitigates this by reducing the deposit insurance subsidy for lower quality banks, thereby reducing their competitive strength and encouraging entry.[3]

This approach deviates from the extant literature in that it recognizes the fixed costs associated with banks' monitoring technologies. These fixed costs give importance to a bank's scale and hence market share.[4] The fixed costs put low-quality banks at a double competitive disadvantage: they are subjected to a higher unit cost of monitoring (which is an artifact of their intrinsically less efficient monitoring technology) *and* face an amplification of this because of their anticipated smaller scale of operations compared to more competitive good banks. These effects lead to less monitoring and hence more risk for low-quality banks. For good banks, competition allows them to gain market share and this encourages monitoring. I show that these issues turn out to be particularly relevant when countries with different quality banking systems open up their domestic markets to cross-border competition. Strong countries gain, but substantial instability could be expected in weaker countries.

Key to this analysis are the quality differences between banks. These differences create an asymmetric impact of competition on the behavior of banks.[5] This work contrasts with

[2]Although lack of contractability generally makes it infeasible to have deposit insurance premiums fully risk-based (i.e., type and risk dependent) and effectively introduces cross-subsidies, systemic concerns in the banking industry create all kinds of other cross-subsidies and interdependencies. For example, many agree that the functioning of the banking sector depends crucially on the confidence that the public has in the financial system at large. Any such interdependencies could induce similar competitive distortions as analyzed in this chapter.

[3]I assume that capital requirements are binding. Some have observed, however, that banks choose levels of capital above the minimum (see Flannery and Rangan (2004)). This analysis shows that capital requirements are needed for low-quality banks that seek to maximize the deposit insurance subsidy, and thus have little interest in being well capitalized. In contrast, good banks can be expected to be adequately capitalized; for example, to protect their franchise values.

[4]Recent empirical evidence points at scale economies in banking; see, for example, Focarelli and Panetta (2003). For older, more mixed, evidence, see the survey paper by Berger, Demsetz, and Strahan (1999).

[5]Allowing for quality differences introduces effects similar to the ones analyzed in the industrial orga-

the extant literature on banking competition that has primarily been analyzed in a symmetric context with equally capable banks.[6] However, quality differences between banking institutions and banking systems are of primary concern to regulators and policy makers. For example, countries with weak banking systems are reluctant to open up their market to competition because this could undermine their banking systems further. Indeed, this analysis confirms that competition has a negative impact on weak banking systems. Possibly even more troublesome, I show that competition makes capital regulation typically less effective precisely in those weak banking systems, whereas it strengthens the incentive effects of capital regulation in high(er) quality banking systems. Nevertheless, this analysis is rather positive on the role of capital requirements. Capital requirements do mitigate risk-taking incentives, and, when I allow for endogenous entry (and no longer hold the aggregate number of banks fixed), they "cleanse" the banking system by reducing the competitive strength of weak banks, and in doing so could encourage entry.

I also ask how the social welfare maximizing level of capital requirements relates to banks' privately optimal choices of capital, and particularly to the level of capital requirements that the banks would prefer the regulator to impose on the industry. I show that banks may want to have the regulator impose a level of capital requirements that exceeds the social welfare maximizing level.

This chapter is organized as follows. In Section 3.2 I develop the model, including the specification of the competitive environment. Section 3.3 presents some basic results. Section 3.4 analyzes how interbank competition affects the effectiveness of the capital requirements. In Section 3.5, I endogenize entry and analyze how entry is affected by changes in capital requirements. Section 3.6 contains the social welfare analysis and the empirical predictions. Section 3.7 concludes the chapter. All proofs are relegated to Appendix A. Social welfare is extensively analyzed in Appendix B.

3.2 The Model

3.2.1 Preliminaries

There are four players in the model: borrowers (companies asking for loans), depositors (and providers of capital), commercial banks, and the regulator (who sets the capital requirement and provides deposit insurance).

Banks specialize in lending and fund themselves with deposits and capital. I assume that banks acquire core expertise in monitoring borrowers, and that this expertise is valuable to

nization literature that focuses on non-price competition through product differentiation (see, for example, Shaked and Sutton (1982)). Interfirm reallocations to more productive firms are also analyzed in the trade literature (see Melitz (2003) and Syverson (2004)).

[6]See Repullo (2004), Matutes and Vives (2000), and Boyd and De Nicolo (2005). Exceptions are the recent papers by Freixas, Hurkens, Morrison, and Vulkan (2004) and Kopecky and VanHoose (2006) that also allow for heterogeneity in ability between banks. However, neither focuses on the interaction between capital regulation, deposit insurance, and competition, which is the focus of this analysis.

the companies that they finance. In particular, I have the monitoring technology of a bank affect the success probability of the project that the bank is financing. This captures the role that banks play in relationship banking: banks invest in borrower-specific knowledge that might be beneficial to their borrowers.[7]

The funding of the banks comes from (liquid) deposits and capital. The liquidity of deposits is rooted in deposit insurance that I assume to be present. Deposit insurance is available at a fixed cost. This potentially introduces moral hazard on the part of banks and helps explain the role of capital requirements: capital requirements may contain asset substitution moral hazard. Thus this chapter is related to studies of the role of capital in reducing risk-taking; see, for example, Hellmann, Murdock, and Stiglitz (2000).[8] I assume that bank management is aligned with shareholders.

The regulator sets the capital requirement and provides deposit insurance.

3.2.2 Model details

Preferences and time line: There is universal risk neutrality, with r_f representing the riskless interest factor (one plus the interest rate). There are four dates, $t = 0$, 1, 2, and 3. At $t = 0$, the regulator sets the capital requirement k and banks decide whether or not to enter the banking industry. At $t = 1$, each borrower is matched with a bank, and banks decide on their investments in monitoring technology. I call the initial bank that the borrower is matched with the "incumbent bank." This bank makes the borrower an initial offer. At $t = 2$, the borrower might find a second competing bank. If this happens, the initial incumbent bank and competing bank compete as Bertrand competitors. The borrower chooses the best offer. Subsequently, the winning bank collects the necessary capital and deposits, makes the loan, and the borrower invests. Payoffs are realized at $t = 3$. In Figure 3.1 I have summarized the sequence of events.

Borrowers: A borrower needs a single-period loan of \$1 to finance a project at $t = 2$, with a payoff at $t = 3$. All borrowers are identical. A borrower's project has a return of either Y or 0 (zero). The probability of success (i.e. the pay-off Y) depends on a bank's investment in monitoring technology ν_j with $j \in \{I, C\}$, where $j = I$ refers to the incumbent bank and $j = C$ is the competing bank. I let the probability of success be equal to the investment ν_j, and hence normalize ν_j to $\nu_j \in [0, 1]$. All other things being equal, when a borrower can choose between two competing offers, he will choose the bank with the highest ν_j.[9] The aggregate demand for loans from all borrowers is normalized to 1.

Depositors and providers of capital: With complete deposit insurance, depositors are

[7] See Boot and Thakor (2000) and Ongena and Smith (2000) for reviews of relationship banking.

[8] Allen, Carletti, and Marquez (2007) analyze a related rationale for capital. In their analysis, institutions choose capital in response to lending-market induced market discipline. In Morrison and White (2005), raising capital requirements could be an appropriate response to counter a confidence crisis.

[9] Actually, I assume (see later) that a borrower can only switch at a cost. Consequently, the incumbent bank has an incumbency advantage, and the competing (second) bank must overcome this when making its offer.

$t = 0$:

♠ The regulator sets the capital requirement k.

♠ Banks enter the banking industry (if applicable).

$t = 1$:

♠ Each borrower is matched with a bank.

♠ Each bank discovers its type.

♠ Banks invest in monitoring technology.

♠ Each borrower receives an initial offer from his bank.

$t = 2$:

♠ Each borrower searches for a competing bank.

♠ If a second bank materializes, the incumbent bank and the "second bank" compete as Bertrand competitors. If no second bank is available, only the borrower's first offer is available.

♠ Each bank collects the necessary capital and deposits, and funds its borrowers.

♠ Borrowers undertake their projects.

$t = 3$:

♠ Payoffs are realized.

Figure 3.1: Timeline

willing to supply their funds at the risk-free interest rate r_f. The deposit insurance premium is fixed, and to simplify matters I assume that this premium is included in the gross costs of deposits. Hence, the cost of deposits is $r_D > r_f$. Banks face a binding capital requirement k. They collect this proportion k of the total funds needed from the providers of bank capital and $[1 - k]$ from depositors.

Capital is costly. I let the cost of capital equal ρ, where $\rho > r_D$.[10]

Commercial banks: Banks choose to enter the banking industry at $t = 0$. All banks are initially (perceived as) identical. At $t = 1$, with N banks present, each bank is matched with $1/N$ of the borrowers.[11] Banks then learn whether their type τ is good (G) or bad (B), thus $\tau \in \{B, G\}$, and following this they choose their investments in monitoring technology. The cross-sectional probability of being good (γ) or bad ($1 - \gamma$) is known to all. Banks have an intrinsic monitoring ability $\underline{\nu}_\tau$, with $0 < \underline{\nu}_B < \underline{\nu}_G$. A bank can increase its monitoring ability to a higher level ν at a cost $\frac{c}{2}[\nu - \underline{\nu}_\tau]^2$.[12]

Competitive environment: Competition between banks occurs in two phases. In the first phase (at $t = 1$), all N banks are allocated $1/N$ of the total borrowers. Each bank specifies an interest rate offer R for its allocated borrowers. At $t = 2$, borrowers succeed in locating a competing offer with probability q. With probability $[1 - q]$, they do not find a competing offer. When this happens, borrowers have no choice but to accept the initial offer, provided this gives them a non-negative expected return. When a second bank is found, both the initial (incumbent) and the second bank compete as Bertrand competitors. I assume that

[10] See Holmstrom and Tirole (1997) and Diamond and Rajan (2000) for explicit models of why the cost of capital might be higher than the return that depositors demand. Note that this assumption bypasses the question *how* capital is raised, including potential adverse selection problems.

[11] Because all banks are perceived as identical at that moment, this even distribution of borrowers over all banks is quite natural.

[12] Using a generalized cost function satisfying the Inada conditions produces similar results but at a cost of substantial complexity.

at this stage the borrowers and the competing banks can observe the monitoring technology adopted by each bank and their types. Each borrower then chooses the bank that gives the highest expected return net of funding costs.[13]

One important additional consideration is that, if a borrower switches to a competing bank, he incurs a fixed switching cost S. This allows the incumbent bank to earn rents even if the competing bank is equally capable. In other words, the incumbent bank effectively has an incumbency advantage vis-a-vis the competing banks.

3.3 Initial Analysis: Some Basic Results

I solve the model using backward induction. I first determine the strategies and the valuation of the incumbent bank at $t = 2$ conditional on the levels of investment in monitoring technology ν_j. Subsequently, I compute the optimal investments in monitoring technology ν_j at $t = 1$, anticipating the events at $t = 2$.

At $t = 1$ each borrower is matched with a bank (i.e., the incumbent bank). The initial offer that this bank makes is a monopolistic offer. The bank can always improve on this offer when its borrower succeeds in obtaining a competing offer. The incumbent bank optimally sets the interest rate equal to the maximum payoff of the borrower such that it obtains all surplus when competition would materialize; thus

$$R^{\max}(\nu_I|\text{no competition}) = Y. \tag{3.1}$$

At $t = 2$, the borrower finds with probability q a competing bank; with probability $[1 - q]$ the borrower only has access to the offer of the incumbent bank. When the borrower has no access to a competing offer, he accepts the monopolistic offer and loses all rents. When the borrower has a competing offer, both banks compete for the borrower as Bertrand competitors.

The investment that a bank is prepared to make in its monitoring technology depends crucially on the profitability of the lending operation, and hence the competition it anticipates. Recall that each of the N banks is allocated $1/N$ borrower. For this initial allocation, a bank has a role as incumbent bank. Competition implies that it may lose this borrower (and/or be forced to lower its lending rate), but the bank could also gain new borrowers by challenging other (incumbent) banks. I first derive some preliminaries.

A bank maximizes its market value of equity; that is, its expected profits net of costs of debt, discounted by the cost of capital. The value that the incumbent bank derives from its

[13] This formulation is qualitatively identical to a Hotelling framework. It gives us rents in the banking system that are decreasing in the level of interbank competition q, similar to a Hotelling-type specification with transaction costs that are decreasing in q. Actually choosing a Hotelling framework would have complicated the analysis substantially, given the heterogeneity across banks that I have.

$1/N$ initial borrower, conditional on having no competing offer, equals

$$V(\nu_I|\text{no competition}) = \frac{1}{N}\{-k + \nu_I \frac{R^{\max}(\nu_I|\text{no competition}) - [1-k]r_D}{\rho}\}.$$

The bank then obtains all surplus. Inserting (3.1), I can write

$$V(\nu_I|\text{no competition}) = \frac{1}{N}\{-k + \frac{\nu_I X}{\rho}\}, \tag{3.2}$$

where $X \equiv Y - [1-k]r_D$.

The value that the incumbent bank derives from its borrower when he obtains a competing offer is computed as follows. The lowest interest rate $R^{\min}(\nu_C)$ that a competing bank with investment in monitoring technology ν_C is just willing to offer follows from its zero NPV condition[14]

$$-k + \frac{\nu}{\rho}\{R^{\min}(\nu_C) - [1-k]r_D\} = 0. \tag{3.3}$$

The incumbent bank is able to outbid the competing bank if it can make an offer such that the borrower obtains a surplus at least equal to what he could obtain with the best competing bank's offer $R^{\min}(\nu_C)$. I proceed as follows. The maximum interest rate that the incumbent can charge the borrower without losing him to a competitor with $\nu = \nu_C$ is $R^{\max}(\nu_I|\nu_C)$, where $R^{\max}(\nu_I|\nu_C)$ is such that the borrower is indifferent between this offer and the best offer of the competing bank. That is,

$$\nu_I[Y - R^{\max}(\nu_I|\nu_C)] = \nu_C[Y - R^{\min}(\nu_C)] - S, \tag{3.4}$$

where I have taken into account that the borrower incurs a switching cost S when he switches to the competing bank.

Conditional on a competing bank being present with monitoring technology ν_C, the value that the incumbent bank derives from its initial borrower if it decides to respond with offer $R^{max}(\nu_I|\nu_C)$ is

$$V(\nu_I|\text{competition, } I \text{ responds}) = \frac{1}{N}\{-k + \nu_I \frac{R^{\max}(\nu_I|\nu_C) - [1-k]r_D}{\rho}\}.$$

Using (3.3) and (3.4), I can rewrite this as

$$V(\nu_I|\text{competition, } I \text{ responds}) = \frac{S + [\nu_I - \nu_C]X}{\rho N}.$$

If $S + [\nu_I - \nu_C]X < 0$, the incumbent bank is not willing to respond (i.e. does not offer $R^{\max}(\nu_I|\nu_C)$) and hence the competing bank prevails. The value that the incumbent bank

[14]Note that the cost of investing in monitoring technology is incurred at $t = 1$. This is sunk once the competition phase is reached at $t = 2$, and thus is not considered when the bank sets the interest rate.

derives from its initial borrower then equals zero. In total,

$$V(\nu_I|\text{competition}) = \max(0, \frac{S + [\nu_I - \nu_C]X}{\rho N}). \tag{3.5}$$

The incumbent bank can also compete for the borrowers of other banks. Strictly speaking, these other banks are the incumbent banks for those borrowers. To prevent confusion, I will continue to call "this bank" the incumbent bank, and to use ν_I for its technology and ν_C for the technology of the other banks. If the incumbent bank competes for the borrower of another bank with monitoring technology ν_C, the value that it derives from the possibility of obtaining this new borrower is

$$V(\nu_I|\text{new borrower}) = \max(0, \frac{-S + [\nu_I - \nu_C]X}{\rho N}). \tag{3.6}$$

The expression (3.6) is very similar to (3.5), but note that the incumbency advantage now works against "this bank."

An useful result relates to the expected number of other borrowers that a bank can make an offer to:

Lemma 3.1. *The expected number of other borrowers that a bank can make an offer to is q/N.*

To see this, observe that there are $[N-1]$ other banks in the economy. The incumbent bank has a probability $q/[N-1]$ that it can compete for the borrower of any one of these banks.[15] Recall that each of these banks has $1/N$ borrower. Thus the expected number of other borrowers that the incumbent bank can make an offer to is $[N-1] \times \frac{q}{N-1} \times \frac{1}{N} = \frac{q}{N}$.

This lemma highlights that there is a degree of symmetry in this model. That is, the way that I have structured the competition between banks implies that any incumbent bank faces a probability q that others will bid for its $1/N$ borrower. Thus, the fraction q/N of its borrower is – in expected value sense – at risk. However, Lemma 3.1 shows that the flip side is that any incumbent bank can bid in expected value for the fraction q/N of borrowers of other banks.[16] The actual outcome will depend on the quality differentials between banks and their potentially different levels of (investment in) monitoring technology.

I now derive the equilibrium investments in monitoring technology. At $t = 1$, the N banks first learn their types, and then individually choose their levels of investment in monitoring technology. I consider a simultaneous move game and derive a separating Nash equilibrium in pure strategies. In choosing their individual levels of investment in monitoring technology, each bank makes a conjecture about the choices of the other banks. In deriving this separating

[15] For this, see that a borrower receives a competing offer with probability q and there are $[N-1]$ banks that could obtain the opportunity to make this competing offer.

[16] In Section 6.2.1 I also analyze how competition evolves if there is only one-sided competition. What I mean by this is that a bank may face competition from other banks for its own borrowers, but has no access to the borrowers of the competing banks; that is, the borrowers of these other banks are shielded from competition.

Nash equilibrium, I need to put some constraints on the incumbency advantage S. More specifically, I assume

Assumption 3.1: $\frac{X^2}{c\rho N} < S < [\underline{\nu}_G - \underline{\nu}_B]X$.

This assumption can be explained as follows. The lower bound on the incumbency advantage ensures that when an incumbent bank competes with a bank of equal quality its incumbency advantage prevails. That is, this competing bank of equal quality will not find it optimal to overcome the incumbency disadvantage by choosing a much higher investment in monitoring technology. Without an incumbency advantage this could be optimal because capturing the incumbent bank's borrower offers scale advantages justifying the higher investment in monitoring technology. The incumbency advantage makes this strategy too costly and ensures that banks of the same type will choose identical strategies; that is, they will choose the same level of investment in monitoring technology. Thus banks of the same type will not take market share at each others expense.[17]

The upper bound on the incumbency advantage ensures that quality matters in competition; that is, a good bank can overcome the incumbency advantage of a bad bank and take its borrower.

I now proceed as follows. Each bank chooses its investment in monitoring technology ν holding the strategy of other banks fixed. I continue to analyze the problem from the perspective of the incumbent bank. Its investment in monitoring technology is ν_I. The other banks choose ν_C^j, where j refers to one of the other $[N-1]$ banks. I can now write the expected value of the incumbent bank of type τ, $\tau \in \{B, G\}$, net of funding costs, as

$$\begin{aligned} V_\tau(\nu_I) &= \frac{1-q}{N}[-k + \frac{\nu_I X}{\rho}] + \frac{q}{\rho N}\sum_{j=1}^{N-1}\frac{1}{N-1}\max(0, S + [\nu_I - E(\nu_C^j)]X) + \\ &+ \frac{q}{\rho N}\sum_{j=1}^{N-1}\frac{1}{N-1}\max(0, -S + [\nu_I - E(\nu_C^j)]X) - c\frac{[\nu_I - \underline{\nu}_\tau]^2}{2}. \end{aligned} \tag{3.7}$$

In (3.7), the first expression is the bank's profitability when there is no competition; see (3.2). This happens with probability $[1-q]$. The second expression is the expected profit on its initial borrower when there is competition; see (3.5). The summation is over all $[N-1]$ competing banks. The third expression is the incumbent bank's profit from successfully attracting borrowers away from other banks, as given in (3.6). The last expression is the cost of investing in monitoring technology.

Each bank maximizes its analogous expression (3.7). I now have the following result.[18]

[17] Similarly, the lower bound on S, $\frac{X^2}{c\rho N} < S$, effectively puts a lower bound on c. This is important because the lower bound on S ensures that it is prohibitively costly for a bank to overcome its intrinsically lower quality ($\underline{\nu}_B < \underline{\nu}_G$) by choosing a (much) higher level of investment in monitoring technology.

[18] I impose restrictions to guarantee that the monitoring choices are in the interior and the borrowers' projects are sufficiently attractive that all banks are willing to provide funding. These restrictions are shown to be compatible with Assumption 3.1 (see the proof of Proposition 3.1).

Proposition 3.1. *There exists a separating Nash equilibrium consisting of the strategies ν_B^* for bad banks and ν_G^* for good banks, where ν_G^* and ν_B^* equal*

$$\nu_B^* = [1 - q\gamma]\frac{X}{c\rho N} + \underline{\nu}_B, \tag{3.8}$$

$$\nu_G^* = \{1 + q[1 - \gamma]\}\frac{X}{c\rho N} + \underline{\nu}_G. \tag{3.9}$$

From this proposition it readily follows that in equilibrium good banks choose a strictly higher level of monitoring than bad banks.[19] That is, when comparing (3.9) and (3.8), I see that good banks have a higher intrinsic monitoring ability than bad banks ($\underline{\nu}_G > \underline{\nu}_B$), and invest more in additional monitoring because of their anticipated gains in market share due to competition. To see this, observe that ν_G^* is positively affected by the competition parameter q, whereas q affects ν_B^* negatively.

I can now derive a corollary that relates to the effect of capital requirements on monitoring incentives.

Corollary 3.1. *Higher capital requirements improve the monitoring incentives of both good and bad type banks.*

Capital requirements favorably affect monitoring incentives in this model because higher capital forces banks to internalize more risk, which in turn reduces risk-taking incentives, implying more monitoring.[20] This is a typical result, and follows from the objective function of banks in this analysis; that is, banks maximize the value of capital.

3.4 Competition and the Effectiveness of Capital Regulation

I continue to hold the number of banks N fixed; in Section 3.5, I will allow for entry. The focus for now is on interbank competition. The key question analyzed is how relaxing barriers between existing banks (inducing more interbank competition) affects the strategies of banks and the effectiveness of capital regulation.

The type of competition that I analyze in this section could be interpreted as opening up national markets to foreign competitors. Across the globe, I increasingly see that banks are challenged in their home markets by foreign players, but also themselves challenge other banks in their home markets. The reasons for this include globalization, developments in

[19] When good and bad banks are very similar to each other and the incumbency advantage is very high (note that this would violate Assumption 3.1), there exists another (pooling) Nash equilibrium in which all banks focus only on their incumbent borrowers. Neither the good nor the bad banks try to win borrowers from other banks, simply because the high incumbency advantage prevents any type of bank from profiting from non-incumbent borrowers. In the absence of an incumbency advantage (again a violation of Assumption 3.1), no equilibrium exists in pure strategies.

[20] Recall from the specification of the model in Section 3.2 that higher monitoring increases the expected returns on the projects. Strictly speaking, it only reduces risks for all $\nu_\tau > 1/2$.

information technology, and deregulation. In particular, developments in information technology could potentially allow banks to enlarge their geographic area of operations without having a local presence in those markets; this possibly reduces the competitive advantage of local players (see, for example, Petersen and Rajan (2002)).

In this model, these developments positively impact q, the probability that borrowers have access to a competing second offer. I continue to assume symmetry in the structure of competition. That is, in the model that I have developed so far, an incumbent bank faces competition for its own $1/N$ borrower with probability q, but it also receives access to an equal number of borrowers (in expectation) from other banks; see Lemma 3.1. Thus, in expected value sense, the number of borrowers at risk equals the number it could gain. A bank's actual success depends both on its inherent quality and on its investment in monitoring technology relative to that of its competitors.

I now analyze how relaxing barriers to competition between existing banks (i.e., increasing q) affects monitoring incentives and the effectiveness of capital regulation. Following this, I analyze how capital requirements affect the values of good and bad banks.

I first analyze the effect of competition on monitoring incentives. From Proposition 3.1 I can directly show that

Corollary 3.2. *Increasing interbank competition (higher q; holding the number of banks N fixed) decreases the optimal level of monitoring of bad banks (ν_B^*) but increases the optimal level of monitoring of good banks (ν_G^*).*

The intuition for this corollary is as follows. Higher competition reduces the probability that bad banks can hang on to their own borrowers. This diminishes their anticipated market share and hence lowers their incentives to invest in monitoring technology. Good banks, however, benefit from a higher q in that they can steal more borrowers from bad banks. Hence, they expect to gain market share, effectively increasing the returns on their investments in monitoring technology.

This differential impact of competition on monitoring incentives highlights an interesting property of this model. For bad banks, competition implies losing market share and hence higher per-unit costs due to the presence of fixed costs in monitoring technology. For good banks, this is precisely the reverse: competition allows for an increase in market share, and effectively helps to lower the per-unit costs.

A related question is what happens to the effectiveness of capital requirements when competition heats up. From Corollary 3.1 I know that higher capital requirements increase the investments in monitoring technology by both types. What I show next is that competition *strengthens* this positive effect for good banks, but weakens it for bad banks.

Proposition 3.2. *Higher interbank competition (higher q) negatively affects the effectiveness of the capital requirements for bad banks, but it increases the effectiveness of capital regulation for good banks.*

The intuition for this is directly related to that of Corollary 3.2. Competition reduces the marginal benefit of investing in monitoring technology for bad banks but increases this for good banks. Not surprisingly, then, the favorable impact that capital regulation has on monitoring incentives is strengthened for good banks but not for bad banks.

The results so far show that competition has a positive impact on the monitoring incentives of good banks, but undermines those of bad banks both directly (anticipating the smaller market share) and indirectly via reducing the effectiveness of capital regulation. This has implications for regulatory policy. Most importantly, competition undermines the effectiveness of capital regulation precisely for those banks for which it is needed most; that is, the bad banks. For higher quality banks, competition positively impacts the effect of capital regulation on monitoring incentives. Because elevating interbank competition also has a direct positive effect on monitoring incentives for high-quality banks, competition and stability go hand in hand. For bad banks, the opposite holds.[21]

The differential impact of capital regulation on good and bad banks is further highlighted when I look at the effect of capital regulation on the values of good and bad banks. I can derive the following proposition.

Proposition 3.3. *Higher capital requirements* always *reduce the value of a bad bank $V_B(\nu_B^*)$, but increase the value of a good bank $V_G(\nu_G^*)$ as long as competition is sufficiently strong (high q) and the quality of the banking industry is sufficiently low (low γ).*

The key to understanding this result is that capital regulation has two effects on the industry. The first effect is that capital imposes a cost on each bank because capital is more expensive than deposits. This, in isolation, reduces the value of each bank, and is the familiar result. However, a second more subtle effect is at work as well: capital regulation reduces the deposit insurance subsidy that goes to low-quality banks. That is, flat-rate deposit insurance is most valuable to bad banks, and this makes them artificially stronger competitors.[22] Capital regulation mitigates this and helps good banks capture higher rents when competing with bad banks. This has a positive impact on the value of good banks and reduces the value of bad banks.

Proposition 3.3 shows that the positive effect of capital regulation on the value of a good bank depends crucially on q and γ. Good banks can only gain from higher capital requirements when q is high, meaning that the banking system is rather open and competitive, such

[21] A qualification can be made. Diversification effects across banks are not present in this model. Consequently, only the success probability matters for stability. For good banks, this success probability is positively affected by competition via an increase in monitoring incentives. However, competition will generally reduce rents and this could negatively affect stability when I take into account diversification effects. Bank stability would then not only depend on the failure probability of one borrower, but also on diversification effects across borrowers and hence the level of rents the bank earns on borrowers that succeed. Similarly, taking into account diversification effects across banks would lend importance to the level of rents. What I get is that if diversification effects are considered competition has a smaller positive effect on stability for good banks. For bad banks, things would become even worse.

[22] In a very different analysis, Winton (1997) argues that deposit insurance may facilitate entry by effectively underwriting de novo banks that investors are not familiar with.

that much is gained by weakening the competitive strength of bad banks. This effect is most important when many bad banks are present (i.e., γ is low).

To understand this further, let's reexamine the competition between good and bad type banks. I focus on the case in which an incumbent good bank faces competition from a bad bank. The rents that the good bank earns equal $\frac{1}{\rho N}[S + [\nu_G^* - \nu_B^*]\{Y - [1-k]r_D\}]$; see (3.5). Observe that these rents are increasing in the capital requirement k. This is the consequence of the negative effect that capital requirements have on the rents that a bad bank derives from the flat-rate deposit insurance; this reduces its competitive strength and benefits the good banks. To see this, note that a good bank faces a net cost of deposits equal to $\nu_G^*[1-k]r_D$ whereas for a bad bank this is $\nu_B^*[1-k]r_D$. Because $\nu_G^* > \nu_B^*$ deposits are effectively subsidized for bad banks. This mispricing of flat-rate deposit insurance thus unfairly helps bad banks, and makes them fiercer competitors for good banks. Higher capital requirements partially eliminate this distortionary effect.

Proposition 3.3 provides an intriguing perspective on the impact of capital requirements. Capital requirements, despite their costs, could benefit good banks under well-defined circumstances. In Section 3.5 I explore this further, and focus in particular on the impact of capital requirements on entry; that is, I endogenize N.

The competition that I have analyzed so far focuses on interbank competition. In the model this means that I focus on q, while keeping the number of players N fixed. What this implies is that *within-market* competition intensifies, for example due to developments in information technology or deregulation. In the context of two countries that introduce cross-border competition, the results show that the country with low-quality banks will become even riskier and the country with high-quality banks gains and becomes safer. The direct consequence is that opening up borders is bad for the stability of a low-quality banking system and good for the stability of a high-quality banking system.

Similarly, the effectiveness of capital regulation is typically negatively affected in a low-quality system, yet favorably affected in a high-quality system. The impact of capital regulation on the valuation of banks is different as well. Low-quality banks lose value whereas high-quality banks gain value as long as the quality of the banking system is sufficiently low and q, the parameter of within-market competition, is sufficiently high.

3.5 Endogenous Entry

I now allow for entry into banking by endogenizing the number of banks N. The probability that a borrower finds a competing bank, q, now also depends on the number of banks N operating in the banking system. In particular, I assume that the probability of finding a competing bank is increasing in N; that is, $\frac{\partial q}{\partial N} > 0$.[23]

[23] Observe that q can still be largely determined by local institutional arrangements. I also let $\frac{\partial [q/N]}{\partial N} < 0$. This is a quite natural property that implies that the probability that a borrower receives his competing (second) offer from any one particular bank is decreasing in N.

I first analyze how monitoring choices and bank values are affected by N, the number of banks in the economy. Subsequently, I endogenize N.

Lemma 3.2. *An increase in the number of banks N decreases both the investments in monitoring, ν_G^* and ν_B^*, and the values of banks, $V_G(\nu_G^*)$ and $V_B(\nu_B^*)$.*

This lemma is intuitive. A higher number of banks reduces the anticipated market share of each bank, and this discourages investments in monitoring technology.

I now endogenize N, and hence allow for entry. The entry decision is made at $t = 0$. At that moment, each prospective bank does not yet know its own (future) type, but assesses its expected quality based on the cross-sectional probability distribution $\{\gamma, [1-\gamma]\}$. Each bank computes whether its expected profits from entering exceed the cost of entry F, anticipating the competitive environment (including the number of banks already present).[24]

To prevent complexity due to discreteness in the number of banks, I let N be a continuous variable, such that N^* is determined by the equilibrium condition:

$$[1-\gamma]\bar{V}_B^* + \gamma\bar{V}_G^* = F. \tag{3.10}$$

The values $\bar{V}_B^*$ and $\bar{V}_G^*$ are the equilibrium valuations of the bad and good banks at the point where $N = N^*$.

I am particularly interested in how capital regulation affects entry. The next proposition shows that higher capital requirements could encourage entry. The competition parameter q is the one that obtains in equilibrium before I change the level of capital requirements.

Proposition 3.4. *The effect of capital regulation on entry is as follows:*

1. *When competition is low ($q < \bar{q}$), higher capital requirements decrease entry.*
2. *When competition is high ($q \geq \bar{q}$), higher capital requirements:*
   (a) *increase entry for $\gamma \in [\gamma_1(q), \gamma_2(q)]$;*
   (b) *decrease entry for $\gamma \in [0, \gamma_1(q)) \cup (\gamma_2(q), 1]$.*

This proposition points at a striking feature of capital regulation: higher capital requirements could – despite their costs – induce more entry into the industry. This happens when the banking industry is of intermediate quality, $\gamma \in [\gamma_1(q), \gamma_2(q)]$, and competition is sufficiently high ($q \geq \bar{q}$). To see this, note from Proposition 3.3 that higher capital requirements can only induce more entry when these requirements positively affect the value of good banks (otherwise both the bad and the good banks' valuations would be decreasing in the level of capital requirements, which would certainly lead to less entry). Proposition 3.3 then tells us that the level of competition should be sufficiently high (high q), and γ should be sufficiently

[24] I consider only the following simple entry procedure: banks decide on entering sequentially in random order. Note that the order does not matter because all prospective entering banks are identical, and they assess their quality based on the cross-sectional probability distribution $\{\gamma, [1-\gamma]\}$.

low. What Proposition 3.4 shows is, that for higher capital requirements to induce more entry, a lower bound is needed on γ as well. This can be easily understood. If γ is too low, a prospective entering bank believes that it will turn out to be of low quality as well. In this case, it expects its value to be negatively affected by higher capital requirements (see Proposition 3.3), which discourages it from entering.

I can now analyze what happens to the effectiveness of capital regulation as an instrument to encourage monitoring when entry is endogenous. Observe that in the absence of endogenous entry (see Corollary 3.1) capital regulation always has a positive impact on monitoring incentives. I am now ready to prove the following corollary, which shows that this positive impact could be dampened by endogenous entry.

Corollary 3.3. *The effect of capital requirements on investment in monitoring technology for both good and bad banks is weakened when capital regulation encourages entry and strengthened when capital regulation induces less entry.*

Corollary 3.3 in combination with Proposition 3.4 offers some challenges for regulators. Capital regulation has a direct positive effect on investments in monitoring technology (Corollary 3.1), but this effect is mitigated by the higher entry that capital regulation could induce (Case 2a in Proposition 3.4). What this indicates is that under circumstances such as those in Case 2a restrictions on entry could improve on the effectiveness of capital regulation.

If capital regulation discourages entry (Cases 1 and 2b), the effectiveness of capital regulation is actually enhanced and hence entry restrictions would be redundant.

3.6 Social Welfare and Empirical Predictions

This section does three things. First, it analyzes what the optimal capital requirements are from a social welfare point of view and how this relates to the private incentives of banks. Further analysis of social welfare is relegated to Appendix B and Appendix C. Subsequently, this section focuses on the empirical predictions that are generated by this analysis. Third, it relates this analysis to the literature.

3.6.1 Social welfare

In the analysis so far I have assumed that the capital requirements set by the regulator are binding. An important issue is what precise incentives banks have. What level of capital would they prefer? Proposition 3.3 shows that for q sufficiently high and γ relatively low, a good bank wants the regulator to impose a higher capital requirement on the industry. This will elevate its value.[25] This is not surprising, observing the "cleansing role" of capital that I have identified. However, a bad bank would always prefer capital requirements to be as

[25]The regulator imposes a uniform capital standard on the industry that is consistent with the lack of observability of bank type ex ante in this setting. If capital requirements could be made contingent on bank type, good banks would prefer the regulator to impose capital requirements only on bad banks.

low as possible. As Proposition 3.3 shows, its value is decreasing in the level of the capital requirements. For now I hold the number of banks N fixed.

The question I would like to answer now is how the level of capital requirements preferred by good banks compares to the welfare optimal level. Observe that the welfare optimal level of capital requirements takes into account the externality that banks impose on the deposit insurer. That is, a failure of a bank typically imposes a loss for the deposit insurer. Because banks do not bear these losses, they would not have an incentive to privately choose capital to reduce this externality. As is well known, in a homogeneous banking industry this will always put the welfare maximizing level of capital above the level that banks choose privately (see Hellmann, Murdock, and Stiglitz (2000) and Repullo (2004)). However, the heterogeneity in banking quality in this analysis gives good banks an incentive to favor high(er) capital because this reduces the competitive strength of bad banks. Actually, in the spirit of Proposition 3.4, I can prove that a bank that does not know its quality might favor positive capital requirements. That is,

Proposition 3.5. *For sufficiently high interbank competition q, $q > \hat{q}$, and intermediate values of γ, banks prefer the regulator to impose a positive level of capital on the industry.*

The intuition is very similar to Proposition 3.4. Imposing positive (costly) capital requirements only helps banks if this reduces the competitive strength of bad banks (which is only valuable if interbank competition q is sufficiently high). Also, each bank should anticipate that "enough" bad banks will be present (i.e., γ not too high) and the banks' expectations about their own quality should not be too low (i.e., lower bound on γ needed).

Proposition 3.5 offers some interesting insights in that it shows that in a heterogeneous industry capital requirements are desired by the industry itself. This contrasts with a homogeneous industry, in which banks would privately set capital as low as possible. Observe that this contrast is somewhat subtle. In a heterogeneous industry, banks would *individually* choose low capital, but realize that they are better off if the regulator enforces high(er) capital levels across the industry. So banks prefer capital regulation to be present.[26]

What the preceding discussion implies is that I have uncovered a new rationale for capital regulation. Banks, realizing that the competitive playing field will be spoiled by some that turn out to be of low quality later, prefer that capital regulation be put in place to guarantee a more balanced competitive environment.

I have not yet provided an answer to the question how the level of capital that the banks want to have imposed relates to the socially optimal level of capital. Recall that the regulator wants to have capital regulation in place to limit the losses to the deposit insurance

[26] In this analysis, capital regulation and capital levels are committed to *prior* to banks discovering their type (and borrowers discovering the bank type). Hence, the chosen levels of capital do not reveal information about type. If I allowed banks to choose their levels of capital *after* they get to know their own type, this would make bad banks interested in choosing a positive level of capital only if that could prevent borrowers from finding out the banks' low quality (i.e., they then may want to mimic good banks). Observe that this will create a very sophisticated competition game between banks for borrowers because borrowers would not know the quality of banks making offers and hence would have difficulty choosing between offers.

fund, whereas banks may desire capital regulation to guarantee a "balanced" competitive environment. In deciding on the welfare optimal level of capital, the regulator maximizes the total surplus of banks, borrowers, and deposit insurance fund.[27] I now establish that the private optimum may exceed the welfare maximizing level of capital requirements.

Proposition 3.6. *For high values of interbank competition q, $q > \bar{q}$ (with $\bar{q} \geq \hat{q}$), and intermediate values of γ, banks prefer the regulator to impose capital requirements that are strictly above the welfare optimal level.*

The intuition is that the level of capital that banks would want to have imposed is increasing in the level of interbank competition q; that is, at higher q it becomes more important to contain the competitive distortion that low-quality banks inflict. In the limit (for q high enough), k approaches 1. The regulator's optimum for the level of capital is, however, always strictly less than one. To see this, note that, for k approaching 1, banks no longer fund themselves with deposits and hence the externality imposed on the deposit insurer vanishes. Thus, the regulator's choice of capital would – given its cost – never approach 1.[28]

3.6.2 Empirical predictions

This analysis produces several predictions that should be brought to the data. Various pieces of existing empirical evidence are available and will be discussed where applicable. An important step in testing the various predictions is distinguishing between the two competition measures, q and N. The measure q, reflects the intensity of competition between existing banks. The other measure of competition is the number of banks N. Observe that in the model q is the probability with which borrowers can receive a competing offer. This is affected by the number of banks N in the market, but is also (or even primarily) determined by institutional factors such as the degree of stringency of anti-trust enforcement. The number of banks N also measures bank size and degree of concentration.

The predictions are as follows:

i. Increasing the openness/competition measure q shifts market share from bad to good banks. This follows from the discussion surrounding Proposition 3.1. Good banks benefit from a higher q and gain market share, whereas bad banks lose market share. This prediction is supported by Stiroh and Strahan (2003), who observe that competition reallocates assets from badly performing banks to good ones.

ii. Competition (increasing q) undermines stability in a low-quality banking market but strengthens it in high-quality banking markets. This prediction follows from the results

[27]Observe that this implies that the regulator does not care about competition per se (only the total surplus of banks and borrowers matters). In the welfare optimization, I have not taken into account the potential externality that bank instability could impose on the economy at large.

[28]I have not analyzed what happens when I allow for entry. Under the assumptions of Proposition 3.5, this will weaken the banks' preferences for positive capital requirements.

in Corollary 3.2. There is some supporting evidence for this in the recent literature. In particular, Boyd and De Nicolo (2005), Beck, Demirgüç-Kunt, and Levine (2005) show that competition and stability could go hand in hand. This analysis points to the importance of the quality of the banking system for this to hold.

iii. The effectiveness of capital regulation in discouraging risk-taking is negatively affected by competition (q) for low-quality banks but not so for high-quality banks. This follows from Proposition 3.2 that shows that for bad (good) banks capital is less (more) effective in encouraging investments in monitoring technology when competition heats up.

iv. Raising capital requirements positively affects the values of good banks when competition (q) is sufficiently high, and the average quality of the banking system is not too high (see upper bound on γ in Proposition 3.3). The value of bad banks is always negatively affected. A way of testing this prediction is by looking at the valuation effects of the introduction of higher capital requirements.

v. Strengthening capital requirements encourages entry in banking markets that are of *intermediate* quality and sufficiently competitive (high q); otherwise it discourages entry. This prediction follows from Proposition 3.4.

vi. Increasing the number of players N in the industry (such that average market share is diluted) reduces investments in monitoring technology and reduces the effectiveness of capital regulation for all banks. This prediction follows from Lemma 3.2 and Corollary 3.3 and comes from the scale economies in the monitoring technology. What this prediction implies is that augmenting competition via the number of players N differs radically from augmenting competition via the openness parameter q. As predictions ii and iii show, increasing q has a favorable effect on high-quality banks.

3.6.3 The impact of heterogeneity

Now I will connect my analysis to the literature that involves heterogeneity. I will first link it to contributions by Melitz (2003) and Syverson (2004) to the general IO literature. Subsequently, I will focus on the literature on heterogeneity in banking. In the trade literature Melitz (2003) analyzes the intra-industry effects of international trade using a Dixit and Stiglitz (1977) model of competition extended for firm heterogeneity. He shows that opening up borders for trade increases the total productivity of firms and hence total welfare, essentially by a reallocation of resources from low-quality to high-quality firms. I extend Melitz (2003) to the case of banking, and show that increasing capital requirements spurs the reallocation of market share toward better banks. If this effect is sufficiently strong, the banking industry as a whole may benefit from higher (although costly) capital requirements.

Syverson (2004) shows that pressure from the demand side affects firm heterogeneity in the industry. High competition for customers forces less productive firms to exit the market and, in doing so, lower firm heterogeneity. In my analysis, higher capital requirements "cleanse" the banking system by reducing the competitive strength of weak banks. This effectively neutralizes them, albeit there is strictly speaking no exit.

My analysis contrasts with the extant literature on banking competition that has primarily been analyzed in a symmetric context with equally capable banks. Keeley (1990) argues that competition lowers bank rents and may induce risk taking. My analysis shows that heterogeneity reinforces Keeley's result for low-quality banks but not necessarily for high-quality banks. That is, low-quality banks lose market share in competition with high-quality banks. Hence, the incentives of low-quality banks for prudent behavior (i.e., investments in monitoring technology) decline together with their franchise values. In contrast, good banks gain market share in competition with bad banks. This makes their investments in monitoring technology more valuable. Hence, competition can increase the stability of higher quality banking system.

These results are also in contrast with the results of Hellmann, Murdock, and Stiglitz (2000). They show that higher capital requirements may encourage bank risk taking. The reason is that when capital is costly, higher capital requirements negatively affect the franchise value of banks, and at such lower franchise value, a bank has less incentives to invest in monitoring technology. Note that these results critically depend on homogeneity in quality in the banking system. Repullo (2004) mediates their concern by showing that higher capital requirements contain risk shifting behavior of a bank directly and this effect is always stronger than the indirect effect through lowered franchise values. My analysis shows that higher capital requirements may increase a good bank's value although capital is costly. In particular, higher capital requirements protect higher quality banks by discouraging low-quality banks. This might be beneficial for the industry as a whole.

Only few contributions in the banking literature allow for heterogeneity in ability between banks. Kopecky and VanHoose (2006) argue that higher capital requirements may only affect a subset of banks with the lowest levels of capital. They show that higher capital requirements unambiguously increase the market loan rate and reduce aggregate lending, but have an ambiguous effect on loan quality. In my analysis higher capital requirements lead to less risk taking in banking. However, this effect is smaller for low-quality banks (see Proposition 3.2) and if there is more entry in the banking industry (see Corollary 3.3). Finally, Freixas, Hurkens, Morrison, and Vulkan (2004) show that low-quality borrowers would borrow at a bank with a weaker screening technology whereas high-quality borrowers would select a bank with a strong screening technology. This borrower "preference" effect is not part of my analysis. They do not focus on the interaction between capital regulation, deposit insurance and competition, which is the focus of my analysis.

3.7 Conclusions

I believe that this chapter contributes some key insights to understanding the interaction between competition and regulation. Heterogeneity between banks and the fixed costs of monitoring technology are important building blocks for understanding banking. I have shown that these lead to drastic shifts in market shares when competition heats up.

This analysis of competition between banks of different quality shows that capital regulation has a substantial impact on the competitive dynamics. The most striking conclusion from this analysis is that increasing costly capital requirements could encourage entry in markets that are sufficiently open for interbank competition. This result comes from the distortions that flat-rate deposit insurance introduces in banking. Implicitly, such deposit insurance benefits lower quality banks most, and makes them fiercer competitors than they otherwise would have been. Capital requirements are an effective regulatory tool that mitigates this distortion, and in doing so increases the value of entry. This points at a complementarity between capital regulation and deposit insurance that goes further than the typical insight that capital regulation mitigates the risk-taking incentives induced by deposit insurance. Capital requirements have a "cleansing" effect mitigating the artificial competitive advantage of low-quality banks that deposit insurance induces.

This insight also addresses a potential criticism of this analysis. I have assumed that capital requirements are binding; however, in the real world I often see banks operate at levels of capital significantly above the regulatory minimum (see Flannery and Rangan (2004)). Note however that in this analysis capital plays a crucial role in disciplining lower quality banks, and arguably precisely for these riskier banks capital regulation should be expected to be most binding. This analysis shows that capital regulation protects higher quality banks (and the financial system at large) from low-quality "fly-by-night" operators.

An arguably less surprising insight from this analysis is that competition weakens low-quality banking systems even further, including the effectiveness of capital regulation in such systems, while strengthening high-quality banking systems. This result confirms the anxiety that regulators may have about opening up their weak domestic banking markets to foreign competition; the stability consequences could be quite negative. However, it would be wrong to use this as an argument against opening up domestic markets. Rather, it points at the way in which domestic markets should be opened to competition. This chapter shows that having low-quality domestic banks compete with higher quality foreign banks will cause substantial instability. Anticipating a loss in market share, the weak domestic banks will cut back on investments in monitoring and in doing so elevate their riskiness. This may not happen if foreign entry leads to takeovers of domestic institutions. Such takeovers would not cause a reduction in monitoring because market share is no longer at risk.

In future work, the optimality of capital regulation and deposit insurance deserves further study. The optimality of these instruments in the face of even more competitive environment of banking is a key public policy issue. This chapter has taken these arrangements as given, and focused on their impact on the competitive dynamics. The good news that I have uncovered is that capital requirements help mitigate the competitive distortions that deposit insurance induces.

3.8 Appendix A

Proof of Lemma 3.1

Observe that there are $[N-1]$ other banks in the economy. The incumbent bank has a probability $q/[N-1]$ that it can compete for the borrowers of any one of these banks. Recall that each of these banks has $1/N$ borrower. Thus the expected number of other borrowers that the incumbent bank can make an offer to is $[N-1] \times \frac{q}{N-1} \times \frac{1}{N} = \frac{q}{N}$. ■

Proof of Proposition 3.1

Conjecture that good banks prevail over incumbent bad banks and, when banks of the same type compete, the incumbency advantage prevails. Using (3.7) one has

$$V_B = \frac{1-q}{N}[-k + \frac{\nu_B X}{\rho}] + \frac{q}{\rho N}[1-\gamma]\{S + [\nu_B - \nu_B^*]X\} - c\frac{[\nu_B - \underline{\nu}_B]^2}{2}, \tag{3.11}$$

$$V_G = \frac{1-q}{N}[-k + \frac{\nu_G X}{\rho}] + \frac{q\gamma}{\rho N}\{S + [\nu_G - \nu_G^*]X\} + \frac{2q}{\rho N}[1-\gamma][\nu_G - \nu_B^*]X - c\frac{[\nu_G - \underline{\nu}_G]^2}{2} \tag{3.12}$$

The first terms in (3.11) and (3.12) represent the profits of the incumbent bank from its borrower without a competing offer. This happens with probability $[1-q]$. With probability q, the borrower finds a competing bank. A bad incumbent bank only retains its borrower when he gets the second offer from another bad bank. This happens w.p. $q[1-\gamma]$, see the second term in (3.11). A good bank can retain its incumbent borrower when he gets an offer from another good bank. This occurs w.p. $q\gamma$, see the second term in (3.12). In addition, a good bank retains its incumbent borrower when he receives an offer from a bad bank. This happens with probability $q[1-\gamma]$. Moreover, it can take new borrowers from other bad banks, also with the same probability $q[1-\gamma]$; see the third term in (3.12).

Implicitly in (3.7), (3.11), and (3.12), I have used the assumption that banks are always willing to bid for borrowers. That is, borrowers' projects are sufficiently profitable such that banks are willing to lend. Whether a bank succeeds in holding on to, or acquiring, a borrower depends on its own strength (quality and investment in monitoring technology), the strength of its competitor, and the incumbency advantage. A sufficient condition for this is

$$-k + \frac{\underline{\nu}_B X}{\rho} - \frac{S}{\rho} > 0. \tag{3.13}$$

The condition in (3.13) implies that a bad bank at its minimum intrinsic monitoring level $\underline{\nu}_B$ could profitably lend to a borrower of another bank (but loose out in the competition!). I further use this condition in the proof of Lemma 3.2.

Each type maximizes its value, holding the strategy of the other type fixed. Use (3.11) and (3.12) to obtain

$$\frac{\partial V_B}{\partial \nu_B}(\nu_B^*) = \frac{1-q}{\rho N}X + \frac{q}{\rho N}[1-\gamma]X - c[\nu_B^* - \underline{\nu}_B] = 0, \tag{3.14}$$

$$\frac{\partial V_G}{\partial \nu_G}(\nu_G^*) = \frac{1-q}{\rho N}X + \frac{q}{\rho N}\gamma X + 2\frac{q}{\rho N}[1-\gamma]X - c[\nu_G^* - \underline{\nu}_G] = 0, \tag{3.15}$$

which imply (3.8) and (3.9). Note from (3.14) and (3.15) that $\frac{\partial V_B}{\partial \nu_B}(\nu_B = 0) > 0$ and $\frac{\partial V_G}{\partial \nu_G}(\nu_G = 0) > 0$. This shows that each bank's investment in monitoring technology is positive. Note also that the second-order conditions are negative. Thus, the optimal levels of monitoring are (3.8) and (3.9). Insert $\nu_B = \nu_B^*$ and $\nu_G = \nu_G^*$ from (3.8) and (3.9) into (3.11) and (3.12) to obtain

$$V_B^* = \frac{1-q}{N}[-k + \frac{\underline{\nu}_B X}{\rho}] + q[1-\gamma]\frac{S}{\rho N} + \frac{X^2}{2c[\rho N]^2}\{1 - 2q + q^2[2-\gamma]\gamma\}, \tag{3.16}$$

$$\begin{aligned} V_G^* &= \frac{1-q}{N}[-k + \frac{\underline{\nu}_B X}{\rho}] + q\gamma\frac{S}{\rho N} + \frac{1+q[1-2\gamma]}{\rho N}[\underline{\nu}_G - \underline{\nu}_B]X \\ &+ \frac{X^2}{2c[\rho N]^2}\{[1-q]^2 - q^2\gamma^2\}. \end{aligned} \tag{3.17}$$

Now I check that (3.8) and (3.9) indeed satisfy my conjectures. Assumption 3.1 guarantees that $[\underline{\nu}_G - \underline{\nu}_B]X > S$. Use this and (3.8) and (3.9) to obtain $[\nu_G^* - \nu_B^*]X > S$, hence

$$\nu_G^* X - S > \nu_B^* X. \tag{3.18}$$

The expression in (3.18) implies that a good bank prevails over an incumbent bad bank; obviously, then, an incumbent good bank prevails over a competing bad bank.

I show next that for a good bank it is not profitable to increase its level of monitoring sufficiently to steal borrowers from other good banks; that is, to deviate from ν_G^* to $\hat{\nu}_G \gg \nu_G^*$. Use (3.7) to compute the value of a good bank that chooses the level of monitoring $\hat{\nu}_G$,

$$\hat{V}_G = \frac{1-q}{N}[-k + \frac{\hat{\nu}_G X}{\rho}] + 2\frac{q}{\rho N}\gamma[\hat{\nu}_G - \nu_G^*]X + 2\frac{q}{\rho N}[1-\gamma][\hat{\nu}_G - \nu_B^*]X - c\frac{[\hat{\nu}_G - \underline{\nu}_G]^2}{2}. \tag{3.19}$$

Maximizing (3.19) w.r.t. $\hat{\nu}_G$ yields

$$\hat{\nu}_G^* = \underline{\nu}_G + [1+q]X/c\rho N. \tag{3.20}$$

Insert $\hat{\nu}_G = \hat{\nu}_G^*$ from (3.20) into (3.19) and use (3.8) and (3.9) to obtain

$$\hat{V}_G^* = \frac{1-q}{N}\{-k + \frac{\underline{\nu}_B X}{\rho}\} + \frac{1+q[1-2\gamma]}{\rho N}[\underline{\nu}_G - \underline{\nu}_B]X + \frac{X^2}{2c[\rho N]^2}[1-q]^2. \tag{3.21}$$

To show that the deviation to $\hat{\nu}_B^*$ is not profitable, observe from (3.21) and (3.17) that

$$V_G^* - \hat{V}_G^* = \frac{q\gamma}{\rho N} S - \frac{X^2}{2c[\rho N]^2} q^2\gamma^2. \tag{3.22}$$

Because $\frac{X^2}{c\rho N} < S$ (see Assumption 3.1), it immediately follows that the expression in (3.22) is positive; hence a good bank will not steal borrowers from other good banks.

I now show that a bad bank does not have an incentive to increase its investment in monitoring from ν_B^* to $\hat{\nu}_B \gg \nu_B^*$ to attract borrowers from other bad banks. From (3.7) one has

$$\hat{V}_B = \frac{1-q}{N}[-k + \frac{\hat{\nu}_B X}{\rho}] + 2\frac{q}{\rho N}[1-\gamma][\hat{\nu}_B - \nu_B^*]X - \frac{c}{2}\hat{\nu}_B^2. \tag{3.23}$$

Maximizing (3.23) w.r.t. $\hat{\nu}_B$ yields

$$\hat{\nu}_B^* = \{1 + q[1-2\gamma]\}X/c\rho N + \underline{\nu}_B. \tag{3.24}$$

Insert $\hat{\nu}_B = \hat{\nu}_B^*$ from (3.24) into (3.23) and use (3.8) to obtain

$$\hat{V}_B^* = \frac{1-q}{N}\{-k + \frac{\underline{\nu}_B X}{\rho}\} + \frac{X^2}{2c[\rho N]^2}[1-q]^2. \tag{3.25}$$

Observe that the deviation to $\hat{\nu}_B^*$ is not profitable (use (3.16) and (3.25)):

$$V_B^* - \hat{V}_B^* = q[1-\gamma]\frac{S}{\rho N} - \frac{X^2}{2c[\rho N]^2} q^2[1-\gamma]^2. \tag{3.26}$$

Because $\frac{X^2}{c\rho N} < S$ (see Assumption 3.1), it follows that (3.26) is positive, and a bad bank will not steal borrowers from other bad banks.

I now show that an incumbent bad bank has no incentive to increase its investment in monitoring technology to $\tilde{\nu}_B \gg \nu_B^*$ to hold on to its borrower when competing with a good bank. If a bad bank chooses $\tilde{\nu}_B$, one has (use (3.7)),

$$\tilde{V}_B = \frac{1-q}{N}[-k + \frac{\tilde{\nu}_B X}{\rho}] + \frac{q}{\rho N}\gamma\{S + [\tilde{\nu}_B - \nu_G^*]X\} + 2\frac{q}{\rho N}[1-\gamma][\tilde{\nu}_B - \nu_B^*]X - c\frac{\tilde{\nu}_B^2}{2}. \tag{3.27}$$

Maximizing (3.27) w.r.t. $\tilde{\nu}_B$ gives

$$\tilde{\nu}_B^* = \{1 + q[1-\gamma]\}X/c\rho N + \underline{\nu}_B. \tag{3.28}$$

Insert $\tilde{\nu}_B = \tilde{\nu}_B^*$ from (3.28) into (3.27) and use (3.8) and (3.9) to obtain

$$\tilde{V}_B^* = \frac{1-q}{N}\{-k + \frac{\underline{\nu}_B X}{\rho}\} + q\gamma\frac{S - [\underline{\nu}_G - \underline{\nu}_B]X}{\rho N} + \frac{X^2}{2c[\rho N]^2}\{[1-q]^2 - q^2\gamma^2\}. \tag{3.29}$$

Use (3.16) and (3.29) to see that

$$V_B^* - \tilde{V}_B^* = q\gamma \frac{[\underline{\nu}_G - \underline{\nu}_B]X - S}{\rho N} + q[1-\gamma]\frac{S}{\rho N} - \frac{X^2}{2c[\rho N]^2}q^2[1-2\gamma]. \tag{3.30}$$

Because $\frac{X^2}{c\rho N} < S$ and $S < [\underline{\nu}_G - \underline{\nu}_B]X$ (see Assumption 3.1), one can see that (3.30) is positive, and hence an incumbent bad bank will not try to hold on to its borrower when competing with a good bank.

Finally, note from (3.8) and (3.9) that the following condition guarantees that ν_G^* and ν_B^* are in the interior for all $q, \gamma \in [0,1]$:

$$2X/c\rho N + \underline{\nu}_G < 1. \tag{3.31}$$

This condition, the restriction (3.13), and Assumption 3.1 are easily simultaneously satisfied (e.g., choose X high enough to satisfy (3.13), and then choose sufficiently high N to satisfy Assumption 3.1 and (3.31)). This completes the proof. ■

Proof of Corollary 3.1

Differentiate (3.8) and (3.9) w.r.t. k and recall that $X \equiv Y - [1-k]r_D$, to obtain

$$\frac{\partial \nu_B^*}{\partial k} = \frac{[1-q\gamma]r_D}{c\rho N} \quad \text{and} \quad \frac{\partial \nu_G^*}{\partial k} = \frac{\{1+q[1-\gamma]\}r_D}{c\rho N}, \tag{3.32}$$

which are both positive. ■

Proof of Corollary 3.2

Differentiate (3.8) and (3.9) w.r.t. q, to obtain

$$\frac{\partial \nu_B^*}{\partial q} = -\frac{\gamma}{c\rho N}X < 0 \quad \text{and} \quad \frac{\partial \nu_G^*}{\partial q} = \frac{1-\gamma}{c\rho N}X > 0. \tag{3.33}$$

Thus, competition increases the investment in monitoring technology for a good bank, but not for a bad bank. ■

Proof of Proposition 3.2

Differentiate both expressions in (3.32) w.r.t. q to get

$$\frac{\partial^2 \nu_B^*}{\partial q \partial k} = -\frac{\gamma}{c\rho N}r_D < 0 \quad \text{and} \quad \frac{\partial^2 \nu_G^*}{\partial q \partial k} = \frac{1-\gamma}{c\rho N}r_D > 0.$$

Hence, competition elevates the effectiveness of capital regulation for a good bank, but not for a bad bank. ■

Proof of Proposition 3.3

Differentiating (3.16) w.r.t. k and rearranging yields

$$\frac{\partial V_B^*}{\partial k} \;=\; [\underline{\nu}_G - \underline{\nu}_B]\frac{r_D}{\rho N}\{-[1-q]\alpha - \zeta[1-q^2[2-\gamma]\gamma]\}, \tag{3.34}$$

where I have used the following definitions

$$\alpha \equiv \frac{1 - r_D\underline{\nu}_B/\rho}{[\underline{\nu}_G - \underline{\nu}_B]r_D/\rho} - \frac{2X}{c\rho N[\underline{\nu}_G - \underline{\nu}_B]} \quad \text{and} \quad \zeta \equiv \frac{X}{c\rho N[\underline{\nu}_G - \underline{\nu}_B]} > 0. \tag{3.35}$$

Rewrite α as $\alpha = 1 + \frac{1 - r_D\underline{\nu}_G/\rho - 2Xr_D/c\rho^2 N}{[\underline{\nu}_G - \underline{\nu}_B]r_D/\rho}$. Substitute for $\underline{\nu}_G$ from (3.31) to obtain

$$\alpha > 1 + \frac{1 - \frac{r_D}{\rho}[1 - 2X/c\rho N] - \frac{2Xr_D}{c\rho^2 N}}{[\underline{\nu}_G - \underline{\nu}_B]r_D/\rho}. \tag{3.36}$$

Rearrange (3.36) to get $\alpha > 1 + \frac{1 - r_D/\rho}{[\underline{\nu}_G - \underline{\nu}_B]r_D/\rho} > 1$. Note from the definition of ζ in (3.35) and the fact that $\frac{X^2}{c\rho N} < [\underline{\nu}_G - \underline{\nu}_B]X$ (see Assumption 3.1) that $\zeta < 1$. Thus,

$$\alpha > 1 \quad \text{and} \quad 0 < \zeta < 1. \tag{3.37}$$

Note that $\gamma[2-\gamma]$ is maximized for $\gamma = 1$. Use this and (3.37) in (3.34) to see that $-[1-q]\alpha - \zeta[1-q^2[2-\gamma]\gamma] \le -[1-q]\alpha - \zeta[1-q^2] < 0$. This implies that $\frac{\partial V_B^*}{\partial k} < 0$, and proves that the value of a bad bank is always negatively affected by stricter capital requirements.

For a good bank, use (3.17) to see that

$$\frac{\partial V_G^*}{\partial k} \;=\; [\underline{\nu}_G - \underline{\nu}_B]\frac{r_D}{\rho N}\{-[1-q]\alpha + 1 + q[1-2\gamma] - \zeta[1-q^2[1-\gamma^2]]\}. \tag{3.38}$$

Observe that for $q = 0$, the expression (3.38) simplifies to $\left.\frac{\partial V_G^*}{\partial k}\right|_{q=0} = [\underline{\nu}_G - \underline{\nu}_B]\frac{r_D}{\rho N}[-\alpha + 1 - \zeta]$, which (using (3.37)) is always negative. In addition, note that

$$\left.\frac{\partial V_G^*}{\partial k}\right|_{q=1,\gamma=0} = 2[\underline{\nu}_G - \underline{\nu}_B]\frac{r_D}{\rho} > 0.$$

Observe that $\frac{\partial V_G^*}{\partial k}$ is monotonically increasing in q and decreasing in γ. Hence by continuity one can see that capital regulation increases the value of a good bank for q sufficiently high and γ sufficiently low. This completes the proof. ■

Proof of Lemma 3.2

I need to show that ν_B^* and ν_G^* are decreasing in N. Differentiate (3.8) and (3.9) w.r.t. N to get

$$\frac{\partial \nu_B^*}{\partial N} = -\frac{[1-q\gamma]X}{c\rho N^2} - \frac{\gamma X}{c\rho N^2}\frac{\partial q}{\partial N}, \tag{3.39}$$

$$\frac{\partial \nu_G^*}{\partial N} = -\frac{\{1+q[1-\gamma]\}X}{c\rho N^2} - \frac{1-\gamma}{c\rho N}[\frac{q}{N} - \frac{\partial q}{\partial N}]. \tag{3.40}$$

Note that the ratio q/N is subject to the regularity condition, $\frac{\partial[q/N]}{\partial N} < 0$, implying that the expected number of other borrowers that the incumbent bank can make an offer to is decreasing in N. This should hold because, while q is increasing in N, the market – with a higher N – must be shared among more competing banks, reducing each bank's share. Transform $\frac{\partial[q/N]}{\partial N} < 0$ to get $\frac{q}{N} - \frac{\partial q}{\partial N} > 0$. Use this and $\frac{\partial q}{\partial N} > 0$ together with (3.39) and (3.40) to see that $\frac{\partial \nu_B^*}{\partial N} < 0$ and $\frac{\partial \nu_G^*}{\partial N} < 0$.

Now I prove that V_B^* and V_G^* are decreasing in N. Differentiate (3.16) and (3.17) w.r.t. N to obtain

$$\frac{\partial V_B^*}{\partial N} = -\frac{1-q}{N^2}[-k + \frac{\underline{\nu}_B X - S}{\rho}] - [1-q\gamma]\frac{S}{\rho N^2} - \frac{X^2}{2c\rho^2 N^3}\{1-2q+q^2[2-\gamma]\gamma\}, \tag{3.41}$$

$$\frac{\partial V_G^*}{\partial N} = -\frac{1-q}{N^2}[-k + \frac{\underline{\nu}_B X - S}{\rho}] - \{1-q[1-\gamma]\}\frac{S}{\rho N^2} - \frac{\{1+q[1-2\gamma]\}}{\rho N^2}[\underline{\nu}_G - \underline{\nu}_B]X - \frac{X^2}{2c\rho^2 N^3}\{1-2q+q^2[1-\gamma^2]\}. \tag{3.42}$$

I now make the following substitutions. First, recall from (3.13) that $-k + [\underline{\nu}_B X - S]/\rho > 0$. I will use the substitution $S < -\rho k + \underline{\nu}_B X$. Second, use Assumption 3.1, in particular substitute for S and $[\underline{\nu}_G - \underline{\nu}_B]X$ the expression $\frac{X^2}{c\rho N}$. All these substitutions in (3.41) and (3.42) give

$$\frac{\partial V_B^*}{\partial N} < -\frac{X^2}{2c\rho^2 N^3}\{2[1-q\gamma] + 1 - 2q + q^2[2-\gamma]\gamma,$$

$$\frac{\partial V_G^*}{\partial N} < -\frac{X^2}{2c\rho^2 N^3}\{2[1-q[1-\gamma]] + 1 + q[1-2\gamma] + 1 - 2q + q^2[1-\gamma^2]\}.$$

This can be further rearranged to

$$\frac{\partial V_B^*}{\partial N} < -\frac{X^2}{2c\rho^2 N^3}\{1 - q\gamma + [1-q][2-q\gamma] + q^2\gamma[1-\gamma]\}, \tag{3.43}$$

$$\frac{\partial V_G^*}{\partial N} < -\frac{X^2}{2c\rho^2 N^3}\{1 - q[1-\gamma] + 1 - q\gamma + 2[1-q] + q^2[1-\gamma^2]\}. \tag{3.44}$$

Because q and γ are limited to the interval $[0,1]$, the expressions in (3.43) and (3.44) are always negative. This concludes the proof. ■

Proof of Proposition 3.4

Differentiating (3.10) w.r.t. k one can obtain

$$-\{[1-\gamma]\frac{\partial \bar{V}_B^*}{\partial N}+\gamma\frac{\partial \bar{V}_G^*}{\partial N}\}\frac{\partial N}{\partial k}=[1-\gamma]\frac{\partial \bar{V}_B^*}{\partial k}+\gamma\frac{\partial \bar{V}_G^*}{\partial k}. \tag{3.45}$$

I know from Lemma 3.2 that $\frac{\partial \bar{V}_B^*}{\partial N}<0$ and $\frac{\partial \bar{V}_G^*}{\partial N}<0$. Hence, the sign of $\frac{\partial N}{\partial k}$ equals the sign of the right side of (3.45); that is, higher capital induces more entry iff

$$[1-\gamma]\frac{\partial \bar{V}_B^*}{\partial k}+\gamma\frac{\partial \bar{V}_G^*}{\partial k}>0. \tag{3.46}$$

Use (3.34) and (3.38) to simplify (3.46) to get that higher capital induces more entry iff

$$DV(\gamma,q)>0, \tag{3.47}$$

where

$$DV(\gamma,q)\equiv-[1-q]\alpha+\gamma\{1+q[1-2\gamma]\}+\zeta[-1+3q^2\gamma[1-\gamma]]\}, \tag{3.48}$$

α and ζ as defined in (3.35), and conditions in (3.37).

I first observe what impact higher capital has on entry at a fixed q. Observe that for a fixed q the function $DV(\gamma,q)$ for γ is an inverse parabola. Note that $DV(\gamma=0,q)=-[1-q]\alpha-\zeta<0$. In addition, I have $DV(\gamma=1,q)=-[1-q][\alpha-\gamma]-\zeta<0$. This means that higher capital always reduces entry at $\gamma=0$ and $\gamma=1$. This and the parabolic shape of the function $DV(\gamma,q)$ implies the following for the intermediate values of γ. There exist solutions to the equation $DV(\gamma,q)=0$ denoted by $\gamma_1(q)\in[0,1]$ and $\gamma_2(q)\in[0,1]$ iff $DV(\gamma,q)>0$ for at least one $\gamma\in[0,1]$.

Now I show that $DV(\gamma,q)>0$ for at least one $\gamma\in[0,1]$ iff competition q is high enough; that is, $q\geq\bar{q}$. First, note that

$$DV(\gamma,q=0)<-\alpha+\gamma-\zeta, \tag{3.49}$$

which is negative for all $\gamma\in[0,1]$. Second, observe that

$$DV(\gamma=1/2,q=1)=1/2+\zeta[-1+3/4]>0. \tag{3.50}$$

These two facts and the monotonicity of $DV(\gamma,q)$; that is,

$$\frac{\partial DV(\gamma,q)}{\partial q}=\alpha+\gamma[1-2\gamma]+6\zeta q\gamma[1-\gamma]>0, \tag{3.51}$$

imply that there exist a certain $\bar{q}$ such that $DV(\gamma,q)<0$, that is, higher capital discourages entry, for all $\gamma\in[0,1]$ if $q<\bar{q}$. For high competition (i.e., $q\geq\bar{q}$), I have two regions of γ. In the first region (i.e., $\gamma\in[0,\gamma_1(q))\cup(\gamma_2(q),1]$), I have $DV(\gamma,q)<0$ and higher capital discourages entry. In the second region (i.e., $\gamma\in[\gamma_1(q),\gamma_2(q)]$), I have $DV(\gamma,q)\geq0$ and higher capital induces more entry. ■

Proof of Corollary 3.3

First, I compute the impact of entry on monitoring of bad banks. Partially differentiate (3.8) w.r.t. k to obtain

$$\frac{\partial \nu_B^*}{\partial k} = -\frac{X}{c\rho N}[\gamma \frac{\partial q}{\partial N} + \frac{1-\gamma q}{N}]\frac{\partial N}{\partial k} + \frac{1-q\gamma}{c\rho N} r_D. \tag{3.52}$$

Observe that (3.52) equals (3.32), except for the additional term

$$-\frac{X}{c\rho N}[\gamma \frac{\partial q}{\partial N} + \frac{1-\gamma q}{N}]\frac{\partial N}{\partial k}. \tag{3.53}$$

Observe that $\gamma \frac{\partial q}{\partial N} + \frac{1-q\gamma}{N} > \gamma \left[\frac{\partial q}{\partial N} - \frac{q}{N}\right]$, which is always positive because $\frac{\partial [q/N]}{\partial N} < 0$ (see Lemma 3.2). This means that (3.53) is positive as long as $\frac{\partial N}{\partial k} < 0$ and negative if $\frac{\partial N}{\partial k} > 0$. Thus, the monitoring incentives induced by additional capital are strengthened if capital discourages entry, and weakened if capital encourages entry.

I proceed similarly for good banks. Differentiate (3.9) w.r.t. k to obtain

$$\frac{\partial \nu_G^*}{\partial k} = \frac{X}{c\rho N^2}\{[N\frac{\partial q}{\partial N} - q][1-\gamma] - 1\}\frac{\partial N}{\partial k} + \frac{1+q[1-\gamma]}{c\rho N} r_D. \tag{3.54}$$

The expression in (3.54) is equal to (3.32), except for the additional term

$$\frac{X}{c\rho N^2}\{[N\frac{\partial q}{\partial N} - q][1-\gamma] - 1\}\frac{\partial N}{\partial k}. \tag{3.55}$$

As in the proof of Lemma 3.2, $\frac{\partial q/N}{\partial N} < 0$ implies $\frac{q}{N} - \frac{\partial q}{\partial N} > 0$, hence $N\frac{\partial q}{\partial N} - q < 0$. Thus, (3.55) is positive as long as $\frac{\partial N}{\partial k} < 0$ and negative if $\frac{\partial N}{\partial k} > 0$. This means that the effectiveness of capital requirements increases (or decreases) when capital requirements induce less (or more) entry. ■

Proof of Proposition 3.5

Assume that Assumption 3.1 holds for any k and also the condition (3.31) for an interior optimum. Following Proposition 3.4, positive capital is desired in two cases. In the first case, $DV(\gamma, q|k=0) > 0$, where $DV(\gamma, q|k)$ is defined as $DV(\gamma, q)$ in (3.48) and constants α and ζ are computed at specific k such that the conditions in (3.37) hold. In the second case, $DV(\gamma, q|k=0) < 0$, yet positive at higher values of k. Because (3.16) and (3.17) are quadratic functions of k, the value of a bank in this case has a maximum either at $k=0$ or at $k=1$. In fact, by symmetry of the quadratic functions the value of a bank at $k=1$ exceeds that at $k=0$ if $DV(\gamma, q|k=\frac{1}{2}) > 0$. In sum, banks want to have positive capital requirements as long as $DV(\gamma, q|k=0) > 0$ or $DV(\gamma, q|k=\frac{1}{2}) > 0$. This is the case for a sufficiently high q (i.e., $q > \hat{q}$) and for an intermediate γ (see Proposition 3.4). ■

Proof of Proposition 3.6

First, I show that the welfare optimal level of capital is strictly less than 1. I compute the welfare contribution of a bank by summing together the bank and borrower surplus, the expected loss to the deposit insurance fund, and entry costs. One has

$$W_B(\nu_B) = \frac{1-q\gamma}{N}[-k+\frac{\nu_B X}{\rho}] - c\frac{[\nu_B-\underline{\nu}_B]^2}{2} - \frac{[1-\nu_B][1-k]r_D[1-q\gamma]}{\rho N} - F, \quad (3.56)$$

$$W_G(\nu_G) = \frac{1+q[1-\gamma]}{N}[-k+\frac{\nu_G X}{\rho}] - c\frac{[\nu_G-\underline{\nu}_G]^2}{2} - \frac{[1-\nu_G][1-k]r_D\{1+[1-q\gamma]\}}{\rho N} - F - \frac{q[1-\gamma]}{\rho N}S. \quad (3.57)$$

Social welfare is the sum of the welfare contributions of the individual banks; that is, $TW(\nu_B,\nu_G) = N\{\gamma W_G(\nu_B) + [1-\gamma]W_B(\nu_G)\}$. Use (3.56) and (3.57) and maximize w.r.t. k to obtain

$$\frac{\partial TW}{\partial k}(k=k_{reg}) = \frac{1}{N}[-1+\frac{r_D}{\rho}] + \frac{[1-k_{reg}]r_D^2}{c\rho^2 N} = 0.$$

Note that $\frac{\partial^2 TW}{\partial k^2} < 0$. Solve for the welfare optimal capital requirement k_{reg} to obtain $k_{reg} = \max(0, 1 - \frac{c\rho^2 N[1-\frac{r_D}{\rho}]}{\{1+\gamma[1-\gamma]q^2\}r_D^2})$, which is strictly less than 1.

I now show that the privately optimal capital requirements are increasing in q and reach 1 for a sufficiently high q and intermediate γ. Again Assumption 3.1 and (3.31) hold for any k. First, if $DV(\gamma,q|k=0)>0$, where $DV(\gamma,q|k)$ is defined in (3.48), optimal capital requirements are positive. Note from (3.50) that $DV(\gamma=1/2, q=1|k)>0$ and from (3.51) that $\frac{\partial DV(\gamma,q|k)}{\partial q} > 0$ for all k. This guarantees that bank values are maximized at capital requirements equal 1, for sufficiently high q and intermediate γ. Because $k_{reg}<1$, there exists a $\bar{q} \geq \hat{q}$ such that for $q>\bar{q}$ and intermediate γ banks want the regulator to choose capital requirements equal 1, which is above the welfare optimal level. Second, if $DV(\gamma,q|k=0)<0$ and $DV(\gamma,q|k=\frac{1}{2})>0$ banks want the regulator to set capital requirements equal to 1 (see Proposition 3.5) and $\bar{q}=\hat{q}$. ■

3.9 Appendix B: Social Welfare Analysis

In this appendix I analyze in more detail what kind of capital regulation is optimal from the social welfare maximization point of view. First, I consider a situation in which banks are of equal type. Second, I extend this analysis to good and bad banks.

3.9.1 Banks of equal type

I first assume that banks are of the same type; that is, $\underline{\nu} = \underline{\nu}_B = \underline{\nu}_G$. Social welfare consists of four parts; namely, the values of banks, consumer surplus, cost to the deposit insurance fund and costs of entry. First, I compute the values of equal type banks. Banks cannot take each other's market share (see Proposition 3.1). I can write the value of a bank with monitoring level ν competing with a bank with monitoring ν^* as (see (3.7))

$$V(\nu) = \frac{1-q}{N}[-k+\frac{\nu X}{\rho}] + \frac{q}{\rho N}\{[\nu-\nu^*]X]+S\} - c\frac{[\nu-\underline{\nu}]^2}{2}. \quad (3.58)$$

Second, I evaluate the consumer surplus. In the case of no competition, the incumbent bank leaves borrowers with no profits. However, in the case of competition borrowers receive the total profits of the project net of funding costs (i.e., νX) lowered by the profits of their bank $[\nu - \nu^*]X + S$. Hence, the consumer surplus of borrowers of one bank equals

$$CS(\nu) = [1-q] \times 0 + \frac{q}{\rho N}\{\nu X - [\nu - \nu^*]X - S\}. \tag{3.59}$$

Third, in expectations the deposit insurance fund carries the following cost. The bank fails with probability $1-\nu$. In this case, the deposit insurance fund repays deposits in the total value of $\frac{[1-k]r_D}{\rho N}$. The expected loss to the deposit insurance fund L per bank is

$$L(\nu) = [1-\nu]\frac{[1-k]r_D}{\rho N}. \tag{3.60}$$

Fourth, each bank when entering incurs entering costs F. In sum, the social welfare that one bank generates is

$$W(\nu) = V(\nu) + CS(\nu) - L(\nu) - F. \tag{3.61}$$

Insert (3.58), (3.59) and (3.60) into (3.61) to compute the welfare contribution of one bank

$$W(\nu) = \frac{1}{N}[-k + \frac{\nu X}{\rho}] - c\frac{[\nu - \underline{\nu}]^2}{2} - \frac{[1-\nu][1-k]r_D}{\rho N} - F. \tag{3.62}$$

Social welfare is $TW = N \times W$; that is,

$$TW(\nu) = [-k + \frac{\nu X}{\rho}] - Nc\frac{[\nu - \underline{\nu}]^2}{2} - \frac{[1-\nu][1-k]r_D}{\rho} - NF. \tag{3.63}$$

Banks invest in monitoring to maximize their values in (3.58), which gives the optimal monitoring levels[29]

$$\nu^* = \frac{X}{c\rho N} + \underline{\nu}. \tag{3.64}$$

I can show the following lemma.

Lemma 3.3. *The individually chosen level of monitoring ν^* is lower than the welfare optimal level of monitoring ν_{reg}.*

Proof: Maximize (3.63) w.r.t. ν to obtain

$$\frac{\partial TW}{\partial \nu}(\nu_{reg}) = \frac{Y}{c\rho N} - c[\nu_{reg} - \underline{\nu}] = 0,$$

which yields

$$\nu_{reg} = \frac{Y}{c\rho N} + \underline{\nu}. \tag{3.65}$$

[29]Note that (3.64) can be obtained from the heterogeneous model by saying that one type of banks prevails. Set $\gamma = 0$ and $\underline{\nu}_B = \underline{\nu}$ in (3.8) or set $\gamma = 1$ and $\underline{\nu}_G = \underline{\nu}$ in (3.9). In the case of $\gamma = 0$, there are only bad banks and in the case of $\gamma = 1$, only good banks exist.

Note that $\frac{\partial^2 TW}{\partial \nu^2} < 0$. Compare (3.65) to (3.64) to note that $\nu_{reg} > \nu^*$ because $Y > X$. ■

The intuition for Lemma 3.3 is that the profit maximization of each bank differs from the welfare maximization of the regulator. In addition to maximizing profits of banks and borrowers' surplus, the regulator also strives to minimize the expected losses to the deposit insurance fund. Increasing monitoring of a bank above the privately optimal level augments a bank's stability and social welfare.

The regulator, however, can have difficulties in directly controlling a bank's monitoring levels. Although it is in the bank's interest to expose its monitoring capabilities to its borrowers, it can hide the level of monitoring from the regulator. In this case, the regulator cannot directly control banks' monitoring.

The regulator can influence banks' monitoring levels indirectly through capital regulation. Setting sufficiently high capital requirements induces banks to invest more in monitoring. The regulator solves the following maximization problem in order to maximize social welfare.

$$k_{reg} = \arg\max_{k} TW(\nu^*). \tag{3.66}$$

I show the following result.

Proposition 3.7. *With one type of bank the welfare optimal capital requirement k_{reg} is given by*

$$k_{reg} = \max(0, 1 - \frac{c\rho^2 N}{r_D^2}[1 - \frac{r_D}{\rho}]). \tag{3.67}$$

Proof: Insert (3.64) for ν into (3.63) to obtain

$$TW = [-k + \frac{\nu X}{\rho}] + \frac{X^2}{2c\rho^2 N^2} - \frac{[1-\nu][1-k]r_D}{\rho N} + \frac{X}{c\rho^2 N^2}[1-k]r_D - NF.$$

Rearrange to obtain

$$TW = [-k + \frac{\nu Y - [1-k]r_D}{\rho}] + \frac{Y^2 - r_D^2[1-k]^2}{2c\rho^2 N} - NF. \tag{3.68}$$

Maximize (3.68) w.r.t. k to obtain

$$\frac{\partial TW}{\partial k}(k = k_{reg}) = \frac{1}{N}[-1 + \frac{r_D}{\rho}] + \frac{[1-k_{reg}]r_D^2}{c\rho^2 N} = 0.$$

Solve for k_{reg} to obtain (3.67). Note also that the $\frac{\partial^2 TW}{\partial k^2} < 0$. ■

The intuition for Proposition 3.7 is the following. The presence of deposit insurance induces a bank to underestimate risk and invest in monitoring less than is welfare optimal. The regulator, which also considers possible losses to the deposit insurance fund, wants banks to monitor more and to be safer. Setting capital requirements above zero achieves this goal.

The welfare optimal capital requirement is greater than zero if capital is a relatively cheap source of financing; that is, if the cost of capital approaches the cost of debt, $\rho <$

$\frac{r_D}{2}[1+\sqrt{\frac{4}{cN}+1}]$. Only in this case, the benefits of higher monitoring prevail over the additional costs of financing.

I can show the following.

Corollary 3.4. *If banks are of the same type, the welfare optimal capital requirement k_{reg} does not change with competition q.*

Proof: The welfare optimal capital requirement is given by (see (3.67))

$$k_{reg} = \max(0, 1 - \frac{c\rho^2 N}{r_D^2}[1 - \frac{r_D}{\rho}]). \tag{3.69}$$

Note that k_{reg} is not a function of competition q. ■

Social welfare is independent of interbank competition q for banks of equal quality. This is because competition has no other role but to transfer rents from banks to their borrowers which has no effect on a social welfare. Despite high competition, banks hold on to their market share and competition has no influence on the monitoring levels (see (3.64)). Recall that capital works as a mechanism to increase monitoring levels. Because monitoring levels are unchanged, the regulator has no incentives to change its level of optimal capital requirements. Technically speaking, the welfare function does not change with competition; consequently, the level of capital that maximizes this function is independent of competition.

I now observe the individual choice of capitalization of banks. Banks first commit to capital; and after commitments are observable, they invest in monitoring.

Corollary 3.5. *If banks could individually choose their level of capital, they would have chosen zero capital.*

Proof: Assume that all banks have the conjectured level of capital k_0. I show that any bank will deviate to the lowest level of capital. First, I show that banks choose zero capital under the conjecture that they cannot take new borrowers. I compute the value of a bank that deviates from capital k_0 to $\hat{k}$ whereas all other banks stick to k_0. The deviating bank chooses monitoring $\hat{\nu}$ whereas all others choose ν^* as given in (3.64).

A value that the deviating bank derives from its $1/N$ initial borrowers, conditional on having no competing offers, equals

$$\hat{V}(\text{no competition}) = \frac{1}{N}[-\hat{k} + \hat{\nu}^* \frac{\hat{X}}{\rho}], \tag{3.70}$$

where I have used $\hat{X} = Y - [1 - \hat{k}]r_D$. If there is competition, rewrite (3.4) to obtain

$$\hat{\nu}[Y - R^{\max}(\hat{\nu}|\nu^*)] = \nu^*[Y - R^{\min}(\nu^*)] - S, \tag{3.71}$$

where $R^{\min}(\nu^*)$ is defined by (compare with (3.3))

$$-k_0 + \frac{\nu^*}{\rho}\{R^{\min}(\nu^*) - [1 - k_0]r_D\} = 0. \tag{3.72}$$

I compute the incumbent bank's profits as

$$\hat{V}(\text{competition}) = \frac{1}{N}[-k + \hat{\nu}\frac{R^{\max}(\hat{\nu}|\nu^*) - [1-k]r_D}{\rho}]. \tag{3.73}$$

Use (3.71) and (3.72) to compute the value that the deviating bank derives from its borrowers conditional on having competing offers:

$$\hat{V}(\text{competition}) = \frac{1}{N}[-\hat{k} + k_0] + \frac{1}{\rho N}\{\hat{\nu}\hat{X} - \nu^* X_0 + \hat{\nu}S\}, \tag{3.74}$$

where I have used $X_0 = Y - [1 - k_0]r_D$.

In sum, the value of the deviating bank is

$$\hat{V}^* = [1-q]V(\text{no competition}) + qV(\text{competition}) - \frac{c[\hat{\nu} - \underline{\nu}]^2}{2}. \tag{3.75}$$

Insert (3.70) and (3.74) into (3.75) to obtain

$$\hat{V}^* = \frac{1-q}{N}[-\hat{k} + \hat{\nu}\frac{\hat{X}}{\rho}] + \frac{q}{N}[-\hat{k} + k_0 + \frac{1}{\rho}\{\hat{\nu}\hat{X} - \nu^* X_0 + S\}] - \frac{c[\hat{\nu} - \underline{\nu}]^2}{2}. \tag{3.76}$$

Note that the deviating bank maximizes its value in (3.76) by investing

$$\hat{\nu}^* = \frac{\hat{X}}{c\rho N} + \underline{\nu} \tag{3.77}$$

in monitoring technology. If condition (3.31) holds for all k; that is,

$$2Y/c\rho N + \underline{\nu} < 1, \tag{3.78}$$

the level of monitoring as given in (3.77) cannot be higher than 1. Insert (3.77) and (3.64) into (3.76) into obtain

$$\hat{V}^* = \frac{1}{N}[-\hat{k} + \underline{\nu}\frac{\hat{X}}{\rho} + \frac{\hat{X}^2}{2c\rho^2 N}] - \frac{q}{N}[-k_0 + \frac{\nu^* X_0}{\rho}]. \tag{3.79}$$

Differentiate (3.79) w.r.t. $\hat{k}$ to obtain

$$\frac{\partial \hat{V}^*}{\partial \hat{k}} = \frac{1}{N}\{-1 + \frac{r_D}{\rho}[\underline{\nu} + \frac{\hat{X}}{c\rho N}]\}. \tag{3.80}$$

Note that condition (3.78) guarantees that $\underline{\nu} + \frac{\hat{X}}{c\rho N} < 1$, hence (3.80) is negative for any $\hat{k}$. In sum, the bank would deviate to $\hat{k} = 0$.

I now show that the conjecture that banks hold on to their market share is correct as long as Assumption 3.1 holds for any k; that is, as long as

$$\frac{Y^2}{c\rho N} < S < [\underline{\nu}_G - \underline{\nu}_B][Y - r_D]. \tag{3.81}$$

If the deviating bank takes additional borrowers, its value is

$$\hat{V} = \frac{1-q}{N}[-\hat{k} + \hat{\nu}^* \frac{\hat{X}_0}{\rho}] + \frac{2q}{N}[-\hat{k} + \frac{1}{\rho N}\{\hat{\nu}^* \hat{X} - \nu X_0\}] - \frac{c\hat{\nu}^{*2}}{2},$$

and its optimal monitoring level is $\hat{\nu}^* = \frac{[1+q]\hat{X}}{c\rho N} + \underline{\nu}$. The value that the deviating bank extracts from the new borrower is

$$\hat{V}(\text{new borrower}) = \frac{1}{N}[-\hat{k} + k_0] + \frac{1}{\rho N}[\underline{\nu}[\hat{X} - X_0] + \hat{\nu}^* \hat{X} - \nu^* X_0 - S].$$

Insert expressions for $\hat{\nu}$ and ν to obtain

$$\begin{aligned}\hat{V}(\text{new borrower}) \quad = \quad & \frac{-\hat{k} + k_0}{N} + \frac{1}{\rho N}\{\underline{\nu}[\hat{k} - k_0]r_D + \frac{\{Y - [1-\hat{k}]r_D\}^2}{c\rho N} - \\ & \frac{\{Y - [1-k_0]r_D\}^2}{c\rho N} + \frac{q\hat{X}^2}{c\rho N} - S\}.\end{aligned}$$

Rearrange to obtain

$$\hat{V}(\text{new borrower}) = \frac{\hat{k} - k_0}{N}[-1 + \frac{1}{\rho}\{\underline{\nu} r_D + r_D[\hat{X} + X_0] + \frac{q\hat{X}^2}{c\rho N} - S\}]. \tag{3.82}$$

Note that (3.78) guarantees that $-1 + \frac{r_D}{\rho}[\underline{\nu} + \frac{2\hat{X}}{c\rho N}] < 0$ and (3.81) guarantees that $\frac{q\hat{X}^2}{c\rho N} < S$. This shows that (3.82) is negative.

In sum, each bank finds it profitable to lower its level of capital to zero regardless of the capitalization levels of competing banks. Hence, in equilibrium all banks set zero level of capital. ■

The intuition for Corollary 3.5 is the following. Capital is expensive. Because each bank's choice of monitoring is observable to the borrower deciding on which loan to take, a bank does not need costly capital to commit to a high(er) monitoring choice. That is, banks individually find it profitable to deviate to as low a level of capital as possible regardless of the level of capital of their competing banks. Hence, in equilibrium banks choose the lowest level of capital possible, this being zero or the minimum capital requirements set by the regulator.

Corollary 3.5 together with Proposition 3.7 provides a role for capital regulation. Although banks privately strive toward zero capital, the regulator follows positive welfare optimal capital requirements. This is different in Allen, Carletti, and Marquez (2007). They show that banks may privately commit to higher capital requirements than demanded by the regulator. Two differences in the model create the discrepancies in the results. First, in Allen, Carletti, and Marquez (2007) monitoring is unobservable. Banks commit to high capital to guarantee high monitoring to their borrowers. In my case, monitoring is observable and there is no need for capital from this perspective. Second, in Allen, Carletti, and Marquez (2007) banks choose high capital only if competition is high. High capital becomes important only if banks are at risk of losing their market share. In my case, Assumption 3.1 prevents a shift of the market share between equal type banks. Having high capital does not help a bank obtain new borrowers. Hence, individual incentives toward high capital are diminished.

A potentially different question is what level of capital banks would like the regulator to impose on the industry. In this formulation, banks could not deviate from the regulatory set capital requirements. In this case, banks choose k to maximize their values in (3.58). That is, banks solve the following maximization problem.

$$k_{opt} = \arg\max_{k} V(\nu^*).$$

I can show the following result.

Corollary 3.6. *The banking industry wants the regulator to set zero level of capital requirements.*

Proof: Insert the equilibrium level of monitoring $\nu = \nu^*$ from (3.64) into (3.58) to obtain

$$V^* = \frac{1-q}{N}[-k + \frac{\underline{\nu} X}{\rho} + \frac{X^2}{c\rho^2 N}] + q\frac{S}{\rho N} - \frac{X^2}{2c[\rho N]^2}.$$

Rearrange to obtain

$$V^* = \frac{1-q}{N}[-k + \frac{\underline{\nu} X}{\rho}] + q\frac{S}{\rho N} + \frac{X^2}{2c[\rho N]^2}[1-2q]. \tag{3.83}$$

Differentiate (3.83) w.r.t. k to obtain

$$\frac{\partial V^*}{\partial k} = \frac{1-q}{N}\{-1 + \frac{r_D}{\rho}[\underline{\nu} + \frac{X}{c\rho N}]\} - \frac{qX^2}{2c[\rho N]^2}. \tag{3.84}$$

Observe that $\nu^* = \underline{\nu} + \frac{X}{c\rho N}$. Condition (3.78) guarantees that $\nu^* < 1$, hence (3.84) is always negative. ■

Setting higher capital requirements imposes a higher cost on the industry and this is not in the interest of banks. Corollary 3.6 is even stronger than Corollary 3.5. Deviation to high levels of capital is not profitable even if all banks deviate together.

3.9.2 Good and bad banks

Now I extend the analysis to the heterogeneous banks; that is, $\underline{\nu}_G > \underline{\nu}_B$. Social welfare consists of social welfare that pertains to bad banks and social welfare arising from good banks.

I now compute the social welfare of bad banks. The social welfare consists of four parts; namely, the values of banks, consumer surplus, cost to the deposit insurance fund, and costs of entry. First, I can write the expected value of a bad bank with monitoring level ν_B as (see (3.7))

$$V_B(\nu_B) = \frac{1-q}{N}[-k + \frac{\nu_B X}{\rho}] + \frac{q[1-\gamma]}{\rho N}\{[\nu_B - \nu_B^*]X] + S\} - c\frac{[\nu_B - \underline{\nu}_B]^2}{2}. \tag{3.85}$$

The first expression in (3.85) denotes the profits of a bad bank if its $\frac{1}{N}$ borrowers find no other offer, which occurs with probability $[1-q]$. The second expression in (3.85) denotes the profits of a bad bank if its borrowers find a competing bad bank, which occurs with a probability $q[1-\gamma]$. The monitoring level of a competing bank is ν_B^*. A bad bank loses a proportion of its market share and its profits are zero when required to compete against a good bank. The last expression represents costs of investing in monitoring. Note that in total a bad bank having initially $\frac{1}{N}$ borrower keeps the following market share

$$\frac{1}{N}\{1 - q + q[1-\gamma]\} = \frac{1}{N}[1 - q\gamma].$$

Second, I evaluate the consumer surplus. In the case of no competition, the incumbent bad bank leaves borrowers with no profits. However, in the case of competition borrowers receive the total profits of the project net of funding costs $\nu_B X$ lowered by the profits of their bank $[\nu_B - \nu_B^*]X + S$. Hence, the consumer surplus of borrowers of one bank equals

$$CS_B(\nu_B) = [1-q] \times 0 + \frac{q[1-\gamma]}{\rho N}\{\nu_B X - [\nu_B - \nu_B^*]X - S\}. \tag{3.86}$$

Third, in expectations the deposit insurance fund carries the following cost. The bank fails with probability $1 - \nu_B$. In this case, the deposit insurance fund repays all deposits in the total value of $\frac{[1-k]r_D}{\rho N}[1-q\gamma]$. The expected loss to the deposit insurance fund L per bank is

$$L_B(\nu_B) = [1 - \nu_B]\frac{[1-k]r_D}{\rho N}[1 - q\gamma]. \tag{3.87}$$

Fourth, each bad bank when entering incurs entering costs of F. In sum, the welfare per bad bank is

$$W_B(\nu_B) = V_B(\nu_B) + CS_B(\nu_B) - L_B(\nu_B) - F. \tag{3.88}$$

Insert (3.85), (3.86) and (3.87) into (3.88) to compute the welfare contribution of one bank

$$W_B(\nu_B) = \frac{1-q\gamma}{N}[-k + \frac{\nu_B X}{\rho}] - c\frac{[\nu_B - \underline{\nu}_B]^2}{2} - \frac{[1-\nu_B][1-k]r_D[1-q\gamma]}{\rho N} - F. \tag{3.89}$$

The welfare effect of good banks differs from (3.89) in two ways. First, good banks take new borrowers in competition from bad banks, which occurs with probability $q[1-\gamma]$.

Hence, each good bank obtains in total $\frac{1+q[1-\gamma]}{N}$ borrowers. A bank's profits and the cost to the deposit insurance fund are increased by a factor $1+q[1-\gamma]$ due to additional market share. More specifically, the factor $1-q\gamma$ in (3.89) is replaced by $1+q[1-\gamma]$. Second, the shift of the market share incurs switching costs $\frac{q[1-\gamma]}{\rho N}S$. Expressions for the cost of investment in monitoring technology and entry costs remain the same as in (3.89), except that a good bank monitors with ν_G. The welfare effect of a good bank is

$$\begin{aligned} W_G(\nu_G) &= \frac{1+q[1-\gamma]}{N}[-k+\frac{\nu_G X}{\rho}] - c\frac{[\nu_G-\underline{\nu}_G]^2}{2} - \frac{[1-\nu_G][1-k]r_D\{1+[1-q\gamma]\}}{\rho N} \\ & -F - \frac{q[1-\gamma]}{\rho N}S. \end{aligned} \tag{3.90}$$

The social welfare is the sum of the welfare effects of all banks:

$$TW(\nu_B, \nu_G) = N\{\gamma W_G(\nu_B) + [1-\gamma]W_B(\nu_G)\}. \tag{3.91}$$

I can obtain the following preliminary result.

Lemma 3.4. *Social welfare increases in q.*

Proof: Insert (3.8) into (3.89) to obtain

$$W_B = \frac{1-q\gamma}{N}[-k + \frac{\underline{\nu}_B Y - r_D[1-k]}{\rho} + \frac{[1-q\gamma]^2}{2c\rho^2N^2}\{Y^2 - r_D^2[1-k]^2\}. \tag{3.92}$$

Insert (3.9) into (3.90) to compute

$$W_G = \frac{1+q[1-\gamma]}{N}[-k + \frac{\underline{\nu}_B Y - r_D[1-k]}{\rho} + \frac{\{1+q[1-\gamma]\}^2}{2c\rho^2N^2}\{Y^2 - r_D^2[1-k]^2\}. \tag{3.93}$$

Use (3.91) to obtain

$$\begin{aligned} TW &= \frac{1}{N}[-k + \frac{\underline{\nu}_B Y - [1-k]r_D}{\rho}] + \gamma\{1+q[1-\gamma]\}[\underline{\nu}_G - \underline{\nu}_B]\frac{Y}{\rho N} + \\ & + \frac{1+\gamma[1-\gamma]q^2}{2c\rho^2N^2}\{Y^2 - [1-k]^2r_D^2\} - \frac{\gamma[1-\gamma]q}{\rho N}S - NF. \end{aligned} \tag{3.94}$$

Now differentiate (3.94) w.r.t. q to obtain

$$\frac{\partial TW}{\partial q} = \frac{\gamma[1-\gamma]}{\rho N}\{[\underline{\nu}_G - \underline{\nu}_B]Y - S\} + + \frac{2\gamma[1-\gamma]q}{N^2}\{Y^2 - [1-k]^2r_D^2\}. \tag{3.95}$$

Use Assumption 3.1 to see that $[\underline{\nu}_G - \underline{\nu}_B]Y > S$ and (3.13) to see that $Y > [1-k]r_D$. This yields $\frac{\partial TW}{\partial q} > 0$. ■

This lemma points to the distribution effect of competition. Higher comptition q means that more borrowers obtain financing at good banks, which increases the efficiency of a banking system raising social welfare.

The regulator should strive to increase interbank competition q as much as possible. It could do this by several means. Banks' activities should be under constant antitrust surveillance. Also transparency on the loan market should be as high as possible.

Now I observe whether the individually chosen monitoring levels correspond to the welfare optimal ones.

Lemma 3.5. *Individually chosen levels of monitoring are lower than the welfare optimal ones, i.e.* $\nu_B^* < \nu_{B,reg}$ *and* $\nu_G^* < \nu_{G,reg}$.

Proof: Maximize (3.89) w.r.t. ν_B to obtain

$$\frac{\partial W_B}{\partial \nu_B}(\nu_{B,reg}) = \frac{1-q\gamma}{N}[\frac{Y}{\rho}] - c[\nu_{B,reg} - \underline{\nu}_B] = 0,$$

which yields $\nu_{B,reg} = \frac{[1-q\gamma]Y}{c\rho N}$. Observe from (3.8) that $\nu_{B,reg} > \nu_B^*$.

Maximize (3.90) w.r.t. ν_G to obtain

$$\frac{\partial W_G}{\partial \nu_G}(\nu_{G,reg}) = \frac{1-q\gamma}{N}[\frac{Y}{\rho}] - c[\nu_{G,reg} - \underline{\nu}_G] = 0,$$

which yields $\nu_{G,reg} = \frac{[1-q\gamma]Y}{c\rho N}$. Observe from (3.9) that $\nu_{G,reg} > \nu_G^*$. ■

The intuition for Lemma 3.5 replicates that of Lemma 3.3. The regulator considers the expected losses to the deposit insurance fund. Consequently, the regulator would like banks to increase their levels of monitoring above their privately optimal levels.

Indirectly, the regulator can impose higher monitoring by setting capital requirements above zero. That is, well capitalized banks invest in monitoring more (see Corollary 3.1). The regulator maximizes social welfare in (3.91) by setting capital requirements to k_{reg}. That is, the regulator solves the following maximization problem:

$$k_{reg} = \arg\max_k TW(\nu_B^*, \nu_G^*). \tag{3.96}$$

I can now show the following result.

Proposition 3.8. *The welfare maximizing capital requirement is given by*

$$k_{reg} = \max(0, 1 - \frac{c\rho^2 N[1-\frac{r_D}{\rho}]}{\{1+\gamma[1-\gamma]q^2\}r_D^2}). \tag{3.97}$$

Proof: Differentiate (3.94) w.r.t. k to obtain

$$\frac{\partial TW}{\partial k}(k = k_{reg}) = \frac{1}{N}[-1+\frac{r_D}{\rho}] + \{1+\gamma[1-\gamma]q^2\}\frac{[1-k_{reg}]r_D^2}{c\rho^2 N^2} = 0. \tag{3.98}$$

Solve this for k_{reg} to obtain

$$1 - k_{reg} = \frac{[1-\frac{r_D}{\rho}]c\rho^2 N}{\{1+\gamma[1-\gamma]q^2\}r_D^2}, \tag{3.99}$$

which yields (3.97). Note also that $\frac{\partial^2 TW}{\partial k^2} < 0$. ■

The intuition for Proposition 3.8 matches that of Proposition 3.7. Due to deposit insurance, banks underestimate risk and insufficiently invest in monitoring. The regulator increases banks' investments in monitoring and social welfare by setting positive capital requirements.

The comparative statics with respect to the optimal capital requirements are as follows.

Corollary 3.7. *The welfare maximizing capital requirement k_{reg} is decreasing in the number of banks N.*

Proof: Differentiate part of (3.97) as follows.

$$\frac{\partial}{\partial N}[\frac{1}{N} + \gamma[1-\gamma]\frac{q^2}{N}] = -\frac{1}{N^2} + \frac{2\gamma[1-\gamma]}{N}\frac{\partial q}{\partial N} - \gamma[1-\gamma]\frac{q^2}{N^2}. \tag{3.100}$$

Note that

$$\frac{\partial}{\partial N}[\frac{1}{N} + \gamma[1-\gamma]\frac{q^2}{N}] < \gamma[1-\gamma][\frac{2}{N}\frac{\partial q}{\partial N} - \frac{q^2}{N^2} - \frac{4}{N^2}] < 2\gamma[1-\gamma]\frac{\partial[q/N]}{\partial N} < 0. \tag{3.101}$$

Thus, $\frac{\partial k_{reg}}{\partial N} < 0$. ■

Lowering the number of banks in the banking industry augments the size of each bank. However, capital regulation is especially effective for big banks. To see this, note that the fixed cost of investment in monitoring makes it optimal for small banks to invest a little in monitoring technology both from their individual profit maximization view and from the welfare optimal point of view. Hence, capital regulation does not play a large role for small banks. For large banks, the investment in monitoring technology is high, as is the discrepancy between privately optimal and welfare optimal levels of monitoring. This makes capital regulation effective. In sum, the regulator sets higher capital requirements if banks are large; that is, for low N.

I can now show the following result.

Corollary 3.8. *The welfare maximizing capital requirement k_{reg} is increasing in competition parameter q.*

Proof: Differentiate (3.97) w.r.t. q to obtain $\frac{\partial k_{reg}}{\partial q} > 0$. ■

Raising capital requirements augments the differences between banks through limiting the distortions of deposit insurance (see the intuition for Proposition 3.3). Increasing the differences between banks enhances social welfare through the effect of competition. In particular, competition shifts the market share from bad to good banks. The stronger competition is, the more positive its redistribution effect is and the more important the differences are between banks. That is, the positive effect of capital requirements is the greatest if competition is high. Because the cost of capital is fixed, the welfare optimal capital requirement k_{reg} increases with competition q.

Corollary 3.8 contrasts with Corollary 3.4. The competition parameter q affects the welfare optimal capital requirement k_{reg} in a heterogeneous banking system because of the shift of the market share. In a homogeneous banking system, banks hold on to their borrowers. Consequently, in a homogeneous banking system the competition parameter q has no effect on the welfare optimal level of capital requirements.

A different question is what level of capital banks would want the regulator to set. The preferences of good and bad banks toward capital requirements are in conflict with those of the regulator, who strives toward the welfare optimal level of capital requirements. The group of good banks would like the regulator to set the capital requirement $k_{G,opt}$ to maximize $V_G(\nu_G^*)$, see (3.7). On the other hand, the group of bad banks would lobby the regulator to set the capital requirement $k_{B,opt}$ in order to maximize $V_B(\nu_B^*)$, see (3.7),

$$k_{G,opt} = \arg\max_k V_G(\nu_G^*) \quad \text{and} \quad k_{B,opt} = \arg\max_k V_B(\nu_B^*). \tag{3.102}$$

The maximization problem in (3.102) differs from the welfare maximization in (3.96) due to two main reasons. First, banks do not consider expected losses to the deposit insurance fund, whereas the regulator does. Second, banks in (3.102) optimize the profits of banks of their own type. That is, good banks try to compel the regulator to set the capital requirements that are the best for good banks but not necessarily for bad banks.

The following result extends Proposition 3.3.

Proposition 3.9. *Bad banks want the regulator to set the capital requirement to zero; that is, $k_{B,opt} = 0$. Good banks want the regulator to increase the level of capital requirements as long as competition is sufficiently strong (high q) and the quality of the banking industry is sufficiently low (low γ).*

Proof: The proof is similar to the proof of Proposition 3.3 and is therefore omitted. ■

High capital requirements not only result in a higher cost of financing, but also hamper the competitive ability of bad banks. Consequently, bad banks would opt for zero capital requirements. However, high capital requirements, despite their higher cost, bring the enhanced position of good banks into competition with bad banks. In a highly competitive and low-quality banking industry, good banks often find themselves competing with bad banks. Thus, for high q and low γ, good banks suggest that the regulator increases capital requirements.

Corollary 3.9. *For sufficiently high q and low γ, good banks would want the regulator to increase capital requirements above the welfare optimal level.*

Proof: I assume that Assumption 3.1 holds for all k. In this case (3.81) holds. Note that (3.81) guarantees that (3.37) holds for all k, hence Proposition 3.3 holds for all k. That is, because bad banks want to lower capital requirements for all k, their optimal capital requirements are zero. If q is sufficiently high and γ sufficiently low, good banks want to increase capital requirements for all k, hence they would like to have $k = 1$, which is above the welfare optimal capital requirement k_{reg} (observe from (3.97) that $k_{reg} < 1$). ■

The reason for this corollary is that good banks would like to enhance the quality difference with respect to bad banks so that they can extract higher rents from their borrowers when competing with bad banks. Higher capital achieves precisely this. It increases the quality difference between good and bad banks because bad banks can no longer obtain cheap funding from insured deposits. In the expected value sense, higher differences allow good banks to extract higher rents from the borrowers, hence they want to have high capital requirements. However, the regulator maximizes total welfare, including the consumer surplus. Thus, the regulator prefers to set lower capital requirements due to higher costs of capital financing.

In our basic model, an entering bank does not yet know its type. However, it knows the cross-sectional distribution $\{\gamma, 1-\gamma\}$ of being good or bad. I analyze what level of capital an entering bank would impose on the regulator.

Proposition 3.10. *An entering bank wants the regulator to increase the level of capital requirements if competition is sufficiently high (i.e., $q \geq \hat{q}$), and the quality of the banking industry is intermediate (i.e., $\gamma \in [\hat{\gamma}_1(q), \hat{\gamma}_2(q)]$).*

Proof: The proof is similar to the proof of Proposition 3.4 and is therefore omitted. ■

Proposition 3.10 extends Proposition 3.4. Higher capital requirements increase the differences between good and bad banks. Whereas bad banks earn zero profits due to high competition for all levels of capital, good banks earn higher rents in competition with bad banks if capital requirements are high. For the intermediate qualities of a banking industry good banks often compete with bad banks. This makes capital requirements beneficial for banks on average.

Corollary 3.10. *For sufficiently high q and intermediate γ, an entering bank would want the regulator to increase capital requirements above the welfare optimal level.*

Proof: I assume that Assumption 3.1 holds for all k. In this case (3.81) holds. Note that (3.81) guarantees that (3.37) holds for all k, hence Proposition 3.4 holds for all k. That is, if $q < \bar{q}$ and $\gamma \in [\gamma_1(q), \gamma_2(q)]$, entering banks' values increase at the level of capital requirements k for all values of k, hence entering banks would like to set $k = 1$, which is above the welfare optimal capital requirement k_{reg} (observe from (3.97) that $k_{reg} < 1$). ■

The reason for this corollary is that banks want to increase the quality differences between themselves to extract higher rents from borrowers. Higher capital augments the difference in quality between good and bad banks. That is, good banks take higher rents from borrowers when competing with bad banks. The expected profit of an entering bank goes up to the extent that the borrowers are worse off. Although increasing capital requirements above the welfare optimal level might positively affect the expected value of entering banks, it hampers social welfare through the negative effect on the consumer surplus. In this case the regulator, which maximizes social welfare, wants to set capital requirements below the level that is optimal for entering banks.

3.9.3 Welfare with endogenous entry

I now analyze the welfare effects of entry.

Lemma 3.6. *Social welfare is decreasing in N.*

Proof: I assume that the condition in (3.13) holds for all k. That is,

$$-1+\frac{\underline{\nu}_B Y}{\rho}-\frac{S}{\rho}>0. \tag{3.103}$$

This guarantees that a bank that is a monopolist always offers loans to its borrowers even though it is financed completely by capital.

Differentiate (3.94) w.r.t. N to obtain

$$\begin{aligned}\frac{\mathrm{d}TW}{\mathrm{d}N} &= -\frac{1}{N^2}[-k+\frac{\underline{\nu}_B Y-[1-k]r_D}{\rho}]-\frac{1}{\rho N^2}\{[\underline{\nu}_G-\underline{\nu}_B]Y-S\}-\frac{2}{N^3}\{Y^2-[1-k]^2 r_D^2\}\\ &+\frac{\partial[q/N]}{\partial N}\frac{\gamma[1-\gamma]}{\rho N}\{[\underline{\nu}_G-\underline{\nu}_B]Y-S\}+\frac{\partial[q/N]}{\partial N}\frac{2\gamma[1-\gamma]q}{N}\{Y^2-[1-k]^2 r_D^2\}-F. \end{aligned}\tag{3.104}$$

Use $[\underline{\nu}_G-\underline{\nu}_B]Y>S$ from Assumption 3.1, $\frac{\partial[q/N]}{\partial N}<0$ and the condition in (3.103) to see that $\frac{\partial TW}{\partial N}<0$. ■

The intuition for this corollary stems from the fixed cost of monitoring, which creates economies of scale. With low N, banks are bigger but the costs of monitoring are fixed. Thus, the cost per borrower is lower and the banks' efficiency is increased. In addition, fewer banks have to pay entry cost F.

The welfare implications of opening up a banking system are different in good and bad banking systems. Social welfare decreases with the number of banks in the banking system. Proposition 6.1 shows that opening up borders induces more entry in bad banking systems but no additional entry in good banking systems. Together with Lemma 3.6, this means that opening up a bad banking system hampers social welfare. In contrast, opening up a good banking system has no direct effect on social welfare. In fact, the indirect effect of opening up a good banking system might be an increase in interbank competition q, which leads to an improvement in social welfare.

Note also that two parameters of competition q and N act in an opposite way (compare Lemma 3.6 with Lemma 3.4). Regulators should strive to increase interbank competition q keeping the number of banks N fixed.

I can now show the following result.

Proposition 3.11. *If increasing capital requirements augments entry, the regulator sets lower capital requirements when entry is possible.*

If increasing capital requirements lowers entry, the regulator sets higher capital requirements when entry is possible.

Proof: The proof directly follows from Corollary 3.7. ■

When entry is possible, higher capital requirements affect the number of entering firms. If capital requirements increase entry (Part 2a of Proposition 3.4), banks on average are of lower size. Consequently, capital regulation is less effective. That is, the marginal benefits of higher capital decrease and the marginal cost stays the same. Hence, the regulator sets lower capital requirements.

If capital requirements decrease entry, (Part 1 and Part 2b of Proposition 3.4) banks on average are of bigger size. Consequently, capital regulation is more effective and the regulator sets higher capital requirements.

3.9.4 Influence on the real economy

So far the social welfare/private optimum comparison has only involved the expected losses to the deposit insurance fund, which is taken into account from the social welfare point of view, but not from a bank's private optimum determination. However, social welfare is more than just focusing on the losses to the deposit insurance fund. As I have highlighted in the main text, it also involves stability considerations; that is, externalities to the real economy and other financial institutions. One way of capturing these externalities is looking at the average success probability of banks across the economy. This is not different from focusing on the average monitoring intensity of banks per borrower, which is also the average success probability of the borrower. I can show that competition in general improves the average success probability in the economy. That is, I can prove the following proposition.

Proposition 3.12. *Increasing competition via elevating q augments the average success probability of the borrowers.*

Proof: The average monitoring per borrower is defined as

$$E(\nu) = [1-\gamma][1-q\gamma]\nu_B^* + \gamma\{1+q[1-\gamma]\}.$$

Insert (3.8) and (3.9) into obtain

$$E(\nu) = \{1+q^2\gamma[1-\gamma]\}\frac{X}{c\rho N} + [1-\gamma][1-q\gamma]\underline{\nu}_B + \gamma\{1+q[1-\gamma]\}\underline{\nu}_G. \tag{3.105}$$

Now differentiate (3.105) to obtain

$$\frac{\partial E(\nu)}{\partial q} = 2q\gamma[1-\gamma]\frac{X}{c\rho N} + \gamma[1-\gamma][\underline{\nu}_G - \underline{\nu}_B], \tag{3.106}$$

which is always positive. ■

The intuition for Proposition 3.12 is the following. Competition has two effects. First, competition increases the levels of monitoring technologies of good banks but decreases monitoring of bad banks (see Corollary 3.2). Interestingly, an increase in monitoring of good banks is exactly compensated with a decrease of monitoring of bad banks. Hence, the average monitoring *per bank* does not change with competition parameter q. However, higher competition q also means that good banks acquire additional borrowers. Good banks become more important than bad banks due to their larger size. More specifically, more borrowers are monitored by good banks with high levels of monitoring and fewer by bad banks with low levels of monitoring. Consequently, the average monitoring level *per borrower* augments with q.

Proposition 3.12 provides a very positive view on competition. It is true that high competition lowers the levels of monitoring of bad banks and makes them less stable. However, competition also shifts the market share from bad to good banks. That is, bad banks lose their size and become less important in the average stability sense.

I can observe the effect of capital on the average success probability.

Corollary 3.11. *Higher capital requirements increase the average success probability the most if competition is high (high q) and the quality of the banking industry is intermediate $\gamma = 1/2$.*

Proof: Differentiate (3.105) w.r.t. k to obtain

$$\frac{\partial E(\nu)}{\partial k} = \{1 + q^2\gamma[1-\gamma]\}\frac{r_D}{c\rho N}. \qquad (3.107)$$

Note that (3.107) increases in q and is the highest for $\gamma = \frac{1}{2}$. ■

The first part of Corollary 3.11 is explained as follows. High competition shifts a greater proportion of the market share from bad to good banks. Proposition (3.2) shows that capital regulation is more effective for good banks. Because high competition increases the share of good banks, it also increases the effectiveness of capital regulation.

The second part of Corollary 3.11 dwells on the observation that the shift of the market from bad to good banks is the highest in the intermediate quality banking industry. This first of all increases the share of good banks the most. Second, it also allows good banks to grow in size the most. Both effects increase the effectiveness of capital regulation.