Incentive-Based Lending Capacity, Competition and Regulation in Banking *

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Abstract

This paper studies moral hazard in banking due to delegated monitoring in an environment of aggregate risk and examines its implications for credit market equilibrium and regulation, in a model where banks are price competitors for loans and deposits. It provides a rationale for an incentive-based lending capacity positively linked to the bank's capital and profit margin, for an oligopolistic market structure wherever banks have market power, and for capital requirements. Social-welfare-maximizing capital requirements are lowered in recessions, are higher the more fragmented the banking sector, and are increased when anti-competitive measures are removed. In equilibrium banks earn excessive profits and credit may be rationed.

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1 Introduction

Since the removal of regulatory restrictions on branching, deposit rates, scope of business and so on in the late seventies and early eighties in order to facilitate increased interbank competition, there has been a general move towards re-regulation of banking on a prudential basis, primarily capital requirements. Interestingly, this general trend has been interrupted only during recessions when regulators have been more lenient, justifying this approach on the grounds that capital requirements should be indexed to the business cycle (see Tirole 1994). There is a suggestion that perhaps such leniency may have undesirable consequences, based on recent empirical evidence that suggests that financial market liberalization may contribute to bank crises (see Demirguc-Kunt and Detrajache 1998).

These developments raise the following important questions. Should prudential regulation be related to the intensity of banking competition (market structure)? Should it be linked to the business cycle, with regulators acting more leniently during recessions? And, more fundamentally, what determines the intensity of banking competition, and should the banking system be regulated at all?

Three strands of the literature try to clarify these policy issues and to provide arguments in support of policy makers' attitude. One strand focuses on whether capital requirements are an effective tool for limiting the risk on an asset portfolio whose return is taken as exogenously given in a partial equilibrium framework (Sharpe 1978; Karaken and Wallace 1978; Kohen and Santomero 1980; Bhattacharya 1982; Furlong and Keeley 1989; Keeley and Furlong 1990; Rochet 1992). The basic insight is that capital requirements on banks attenuate moral hazard, reducing banks' incentive to take excessive risk.[1] A second strand analyzes the macroeconomic implications of capital requirements, showing that they may reinforce macroeconomic fluctuations (see Blum and Hellwig 1995; Thakor 1996). Implicitly, this provides an argument for linking capital requirements to the business cycle. However, these models do not explain why capital requirements are there in the first place, or what the costs of lifting them might be. A third strand notes that bank rents act as a mitigating factor against risk-taking by making it more costly for a bank to fail (Bhattacharya 1982; Chan, Greenbaum and Thakor 1992; Hellman, Murdock and Stiglitz 2000).[2] This suggests that capital requirements and profits can be viewed as substitutes in controlling moral hazard in banking.

The implicit assumption underlying all three strands is that fully diversified asset portfolios are not feasible. Indeed, according to a fourth strand, delegated-monitoring theory (Diamond 1984; Ramakrishnan and Thakor 1984; Diamond 1991; Hellwig 1991; Bhattacharya and Thakor 1993), the construction of a fully diversified portfolio whose return is certain eliminates moral hazard entirely and with it, all need for regulation (see Diamond 1984; Dewatripont and Tirole 1994). To reintroduce moral hazard, Holmstrom and Tirole (1997) exclude diversification by allowing for aggregate risk – project returns are correlated. This creates an incentive for banks to take bad risk and provides a role for bank capital in attenuating moral hazard.

From these four strands of literature we learn that systematic risk may lead to moral hazard and that capital requirements and profits play a role in controlling it, although the former may be harmfully pro-cyclical. But we do not learn why the banking system should be regulated at all as opposed to being disciplined by market forces, or how regulation should be designed in terms of its relationship to interbank competition and the business cycle. To address these unanswered questions, this paper develops a model in which the intensity of competition, the role of capital requirements, and bank profits are all endogenously determined. Moreover, the effects of the business cycle, of banking-sector concentration and of structural regulation (entry barriers and market liberalization) on all these variables are analyzed.

A bank acts as a *delegated monitor* in an environment of aggregate risk; that is, project returns are correlated as in Holmstrom and Tirole (1997).[3] Banks borrow from investors and lend to firms, monitoring them in equilibrium, at terms that result from interbank price competition.[4] They act on behalf of shareholders (insiders) whose equity holdings constitute the bank's capital; additional inside capital is too costly to raise (see Smith 1986 for a survey of evidence).

The essential ingredient of the model is moral hazard in banking: insiders may gain by financing privately profitable projects that have negative social value. Indeed, bank monitoring costs can be interpreted as the opportunity costs to insiders of not engaging in insider lending, or colluding with borrowers to undertake high-risk, high-return projects or, more generally, those bringing private benefits. The results are as follows. In equilibrium, banks engage in monitoring: the amount of lending that a bank undertakes is subject to a ceiling — the bank's incentive-based lending capacity — that is positively related to its capital and its endogenous profit margin (the spread between lending and borrowing rates). A corollary is that even if banks compete in prices and there is no product differentiation, bank competition is imperfect: competition for loans is Bertrand-Edgeworth with capacity constraints, the constraints resulting from incentive problems. The incentive-based lending capacity exceeds the bank's capital, i.e. there is scope for outside financing and hence for financial intermediation. However, in the absence of regulation (by market discipline) there is a no-intermediation equilibrium, unless investors act in coordinated fashion *and* banks' profit margins are public information. By contrast, under the same informational constraints, optimal capital requirements permit an intermediation equilibrium in which banks raise outside financing and lend in excess of their capital. Thus, capital requirements are a solution not only to the lack of coordination among dispersed investors but also to the unobservability of such important features as contractual terms with borrowers, and hence profit margins. Capital requirements work by limiting banks' scale of business. They restrict the bank's lending not to exceed its incentive-based lending capacity, in order to retain the bank's incentive to monitor. Rational, albeit unprotected, investors are then willing to fund banks. The equilibrium values of optimal capital requirements and banks' profit margins are inversely related. Social-welfare-maximizing capital requirements are related to the business cycle, via the link between recession, insolvencies and bank capital, and regulators act more leniently during recessions. Capital requirements are raised when entry barriers are removed and are lower the more concentrated is the banking sector. In other words, they depend on the intensity of banking competition. Finally, the equilibrium is a constrained optimum; it differs from the first-best in that banks earn excessive profits and credit may be rationed. Our analysis therefore complements Winton (1995) and Yanelle (1997), who reject perfect competition in Diamond's (1984) environment of costly observability of project returns, where portfolio diversification reduces monitoring (auditing) costs but introduces increasing returns to scale.[5] Winton (1995) allows for a finite economy where diversification is limited. He shows that bank capitalization replaces or complements diversification in reducing default probability and therefore lowering auditing costs, and that the equilibrium banking sector may have several banks. In this paper, project returns are observable at no cost, but there is bank moral hazard. Capitalization and profits jointly determine the bank's risk choice, and, in equilibrium, several banks are active, but capital regulation may be essential to the viability of intermediation.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 derives the bank's incentive-based lending capacity and characterizes the distortions that motivate capital requirements. Section 4 derives social-welfare-maximizing bank-capital regulation and the credit-market equilibrium (borrowing and lending rates and lending volumes) as a function of structural parameters (aggregate bank capital, aggregate loan demand, number of banks). Section 5 delineates the empirical implications of the model, and Section 6 concludes.

2 The Model

We consider a one-period credit market consisting of total measure M of non-atomistic entrepreneurs or firms, total measure I of non-atomistic investors, and n banks (indexed by $i = 1,2..n$), with $n \geq 2$. Agents are risk-neutral, have limited liability, and maximize their end-of-period expected wealth. Each entrepreneur can undertake an investment project that requires one unit of resources. Each investor is endowed with one unit of resources, which can either be stored at the gross return R_d or deposited in a bank. Investors are large in number ($I > M$). A bank takes deposits from investors and lends to entrepreneurs. It acts on behalf of its shareholders, insiders, whose equity holdings constitute the bank's endowment of inside capital. This capital can be either lent to entrepreneurs or stored at the gross rate R_d. Banks are endowed with aggregate capital $A > 0$ that is distributed symmetrically across banks. Thus, $\frac{A}{n}$ is an index of concentration of the banking sector.

2.1 Project Technology and Monitoring

Bank lending is in the form of project financing. A project requires one unit of resources at the beginning of the period and delivers a random return at the end. The realization of this return depends on the macro-state realization at the end of period $\theta \in \{\underline{\theta}, \overline{\theta}\}$, where $\overline{\theta}$ occurs with probability p, and on the project type. A good project (type g) delivers a return of x both in the good state $\overline{\theta}$ and in the bad state $\underline{\theta}$; a bad project (type b) delivers a return of x in $\overline{\theta}$ and of zero in $\underline{\theta}$. Returns are observable and verifiable. Whether a bank-funded project is of type g depends on the bank's choice of action at the beginning of period $a \in \{m, \varnothing\}$, where m indicates "monitor", and $\varnothing$ "not monitor": a monitored project is type g, i.e. it succeeds whatever the macro-state realization; an unmonitored project is type b, i.e. it succeeds only in the favorable macro-state realization $\overline{\theta}$.

Monitoring may consist in the provision of services tailored to the firm, or a constraint on the entrepreneur's choice of project through appropriate debt covenants, whose fulfillment is then monitored. This would be the case if a type b project offered private benefits large enough to lead the entrepreneur to prefer the bad project. In this case non-monitoring, i.e. $\varnothing$, implies that the entrepreneur will undertake the type b project.[6]

Bank monitoring costs $F > 0$ per project. This is a non-pecuniary effort cost to the bank. F may also be interpreted as the opportunity cost of eschewing insider lending, forgoing the potential private benefits of a type b project in collusion with the borrower.

Assumption A1

(an unmonitored project has negative net present value:)

$$px < R_d \tag{1}$$

Assumption A2

(a monitored project has positive net present value:)

$$x > R_d + F \tag{2}$$

Assumption A3

The bank's choice of action is unobservable.

Our assumptions imply that: (i) bank monitoring increases loan value and is unobservable to outsiders and costly to the bank; (ii) the average loan return, conditional upon non-monitoring, is uncertain (its realization depends on the macro-state realization). The first assumption is a necessary condition for a problem of delegation or bank moral hazard vis-a-vis outsiders (investors); the second assumption ensures that this problem cannot be solved through diversification.

In our framework, a bank's outside equity and debt are perfectly equivalent. The relevant difference is between outside and inside financing, where the latter is bounded by $\frac{A}{n}$. We assume that outside financing is in the form of deposits.

2.2 The Credit Game

The game proceeds as follows.

At date 0, the social-welfare-maximizing regulator publicly announces banks' capital requirements. This is the regulation stage. At date 1, each bank $i = 1, 2....n$ offers a gross rate R_i at which it is willing to lend and a gross rate R_{di} at which it is willing to borrow. This is the bank competition stage. Finally, at date 2, banks choose whether to monitor their loan portfolios.[7] This is the monitoring stage.[8] Figure 1 summarizes this sequence of events.

FIGURE 1 ABOUT HERE

The outcome of the bank competition stage determines: i's lending rate, R_i; the deposit rate, R_{di}; the volume of lending, L_i; and deposits, D_i, where L_i satisfies i's flow of funds constraint, $L_i \leq D_i + \frac{A}{n}$.

As usual, the game is solved backwards. We provide below, as a benchmark, the first best solution obtained in the absence of any delegation problem, i.e. if banks' choices of action were observable and contractible or, equivalently, if banks had unlimited liability.

2.3 First Best

Let R^* denote the lending rate that makes it possible to recoup, in expected value, the resources invested in a monitored project:

$$R^* \equiv R_d + F \tag{3}$$

Proposition 1 *If the bank's choice of action were contractible, then: (i) the efficient lending level M would be obtained; (ii) all lending would be monitored, and; (iii) all firms would borrow at R^*.*

This follows simply, because if the action is contractible, then the rate offered to depositors, R_{di}, is set contingent on the action. This is sufficient to ensure that banks internalize the consequences of their choices, i.e. that a bank maximizes its expected profits through monitoring. In the market for loans, banks are pure Bertrand competitors, with each earning zero expected profits in equilibrium.

3 Incentive-Based Lending Capacity and the Social Costs of Market Discipline

We now turn to the case in which the bank's action is unobservable. The credit-portfolio outcome depends on overall economic performance: banks may be tempted to bet that macroeconomic factors will support the performance of firms (that the macro-state realization will be the good one $\overline{\theta}$), thus avoiding costly monitoring and passing the resulting losses on to depositors. In this section we focus on the monitoring stage and derive the bank's monitoring incentive constraint. As a consequence, we obtain conditions on banks' borrowing and lending rates and lending volumes that must necessarily hold in equilibrium. The key result is that the bank finds it profitable to monitor if and only if its lending volume does not exceed a critical value; this incentive-based lending capacity is positively related to its capital and profit margin. In contrast to Section 2, interbank competition is now imperfect: competition for loans is Bertrand-Edgeworth with capacity constraints. We derive the informational constraints necessary to allow intermediation under market discipline, and provide a rationale for regulation imposing capital requirements on banks.

3.1 Incentive-Based Lending Capacity

By assumptions A1-A2, an unmonitored project has negative net present value and a monitored one, positive. Since in equilibrium agents cannot be worse off than with their status-quo payoffs, we immediately obtain the following result.

Proposition 2 *In any equilibrium, all banks monitor.*

That is, projects that are financed have positive net present value. A corollary to Proposition 2 is that i's lending rate, R_i, satisfies:

$$x \geq R_i \geq R^* \qquad . \tag{4}$$

This means that R_i allows the bank to recoup, in expected value, the overall cost of the resources invested in a monitored project. To simplify, we henceforth restrict i's lending-rate strategies R_i to the interval (4).

Proposition 3 below derives i's equilibrium strategy at the monitoring stage. The key observations are that banks have limited liability and that a monitored lending portfolio performs better than an unmonitored one in the bad macro-state $\underline{\theta}$. Therefore:

(i) If i's profit-maximizing choice is to monitor (that is, if $a_i^* = m$), then i is solvent with probability one and $R_{di} = R_d$ satisfies the depositors' participation constraint. Let $R_{di} = R_d$. Then i's expected profit, conditional upon monitoring being the profit-maximizing choice, is:

$$\begin{aligned} \pi(R_i, L_i | a_i^* = m) &= [R_i L_i - R_d(L_i - \tfrac{A}{n})] - F L_i - \tfrac{A}{n} R_d \\ &= [R_i - (R_d + F)] L_i \qquad ; \end{aligned} \tag{5}$$

This is non-negative (by $R_i \geq R^*$);

(ii) If i's profit-maximizing choice is not to monitor (that is, if $a_i^* = \varnothing$), then it is necessarily the case that its lending volume is sufficiently large with respect to capital to ensure that i is insolvent in $\underline{\theta}$ (if it were solvent then it would suffer all the consequences of financing projects with negative net present value, and its profit-maximizing choice would necessarily be to monitor, by assumptions A1-A2 and $R_i \geq R^*$). Hence, if $a_i^* = \varnothing$, then i is solvent *only if* the macro-state realization is good $(\overline{\theta})$, when loans perform well regardless of whether they are monitored. In state $\underline{\theta}$, i loses its capital, so its expected profit is:[9]

$$\pi(R_i, L_i | a_i^* = \varnothing) = p[R_i L_i - R_d(L_i - \frac{A}{n})] - \frac{A}{n} R_d \qquad . \tag{6}$$

Thus, i's profit-maximizing choice is to monitor if and only if:

$$\pi(R_i, L_i | a_i^* = m) \geq \pi(R_i, L_i | a_i^* = \varnothing) \tag{7}$$

that is, iff:

$$\frac{\frac{A}{n}}{L_i} \geq 1 + \frac{F}{(1-p)\, R_d} - \frac{R_i}{R_d} \tag{8}$$

In summary, the bank monitors if and only if the amount of capital that it invests per lending unit, i.e. $\frac{\frac{A}{n}}{L_i}$, does not fall below the threshold level $c(R_i, R_d)$:

$$c(R_i, R_d) \equiv 1 + \frac{F}{(1-p)\, R_d} - \frac{R_i}{R_d} \qquad . \tag{9}$$

Note that $c(R_i, R_d)$ is decreasing in the lending rate R_i and increasing in the cost of funding R_d (by $x \geq R_i \geq R^*$and assumption A1). Thus, the higher i's profit margin, $[R_i - (R_d + F)]$, the greater the amount of lending L_i that it can do for any given capital level without violating the incentive to monitor. Moreover, $c(R_i, R_d) < 1$ (by $R_i \geq R^*$, and assumptions A1-A2). Therefore, if the monitoring-incentive constraint (8) fails to hold, the bank has necessarily over-loaned its capital.[10]

The foregoing can be summarized in the following proposition.

Proposition 3 *Let bank i's lending rate satisfy inequality* (4) , *and its borrowing rate be $R_{di} = R_d$. Then if lending volume satisfies:*

$$\frac{\frac{A}{n}}{L_i} \geq c(R_i, R_d) \qquad , \tag{10}$$

its profit-maximizing choice is to monitor, it is solvent with probability one, its expected profit is non-negative, and the depositors' participation constraint is satisfied. By contrast, if L_i violates inequality (10)*, then for any R_i and $R_{di} \geq R_d$ bank i earning non-negative expected profit would necessarily imply that its profit-maximizing choice is not to monitor, and depositors suffer expected losses.*

If L_i violates condition (10), then for $R_{di} = R_d$ bank i will not monitor (by the incentive constraint (8)), but then it would not monitor for any $R_{di} \geq R_d$ (that is, for any borrowing rate that could possibly satisfy the depositors' participation constraint). Indeed, the higher the cost of funding, the lower the marginal return to monitoring. Unmonitored projects have negative net present value, and bank i's expected profit is non-negative; this is obviously true, since otherwise at the competition stage the bank would have refrained from lending. Consequently, any losses fall on the bank's depositors, so that if L_i were high enough to violate condition (10), then depositors would necessarily suffer expected losses.

Define:

$$L^c\left(R_i, R_d; \frac{A}{n}\right) \equiv \begin{cases} \frac{\frac{A}{n}}{c(R_i,R_d)} & , \quad if \quad c(R_i, R_d) > 0 \\ \\ \infty & , \quad if \quad c(R_i, R_d) \leq 0 \end{cases} \tag{11}$$

For $L_i = L^c(\quad)$ condition (10) is satisfied at equality, and $L^c\left(R_i, R_d; \frac{A}{n}\right)$ is thus the maximum amount of lending at which i finds it incentive-compatible to monitor. In what follows we call $L^c\left(R_i, R_d; \frac{A}{n}\right)$ the incentive-based lending capacity of i, and $c(R_i, R_d)$ i's minimum incentive-based capital requirement. The larger is i's profit margin, $\frac{R_i}{R_d}$, the lower the requirement and the greater the incentive-based lending capacity for any given level of capital.

In equilibrium agents' participation constraints are necessarily satisfied, and this is possible only if the bank's profit-maximizing choice is to monitor (by Proposition 2). Moreover, the depositors' participation constraint holds at equality, because loanable funds are in excess supply. By Propositions 2 and 3 it follows that in equilibrium, i's lending volume satisfies inequality (10), its lending rate satisfies inequality (4), its expected profit is given by

(5), and its unit cost of funding is $R_{di} = R_d$ (i.e. the depositors' participation constraint holds at equality). In view of Proposition 3, we henceforth set $R_{di} = R_d$, $\forall i$.

3.2 The Properties of an Equilibrium and the Social Costs of Market Discipline

Corollary 1 *In equilibrium, bank competition for loans is restrained.*

This follows because the amount of lending that a bank can undertake is limited by (10). Competition for loans is Bertrand-Edgeworth with capacity constraints; this is formally analyzed in the following section. These constraints do not depend on technological factors, as in the industrial organization literature, but are on incentive problems.

We noted that the minimum (incentive-based) capital requirement, $c(R_i, R_d)$, is less than one. We thus have the following result.

Corollary 2 *The maximum amount of lending that a bank can undertake without violating its incentive-compatibility condition to monitor is greater than its capital. Hence, there is scope for financial intermediation.*

But will there be financial intermediation in an unregulated economy? In other words, will depositors be willing to fund unregulated banks?

Corollary 3 *In the absence of regulation (by market discipline), depositors will fund the bank only if all the determinants of the bank's incentive-based lending capacity are public information and individual depositors coordinate their decisions to extend funds to the bank.*

Depositors anticipate that the bank will monitor only if its lending volume does not exceed its incentive-based capacity (by Proposition 3). In the absence of regulatory limits, the only constraint on bank lending is given by the amount of its loanable funds. Depositors will then be willing to fund a bank only if they can force the bank's loanable funds not to exceed its incentive-based capacity. Intermediation can then obtain only if: (i) bank lending capacities are observable, which requires banks' profit margins to be public information, and; (ii) (dispersed) depositors coordinate their decisions so as to effectively constrain bank deposits, D_i, to satisfy $D_i + \frac{A}{n} \leq L^c \left(R_i, R_d; \frac{A}{n}\right)$.[11]

If the contractual terms between banks and borrowers (and hence banks' profit margins) are not public information, then depositors will not fund banks and there will be a no-intermediation equilibrium. We consequently conclude that an unregulated economy may be characterized by underinvestment.

4 Competition and the Optimal Regulation of Bank Capital

If market discipline fails to produce an intermediation equilibrium in which depositors fund banks, the question is: Can (social-welfare-maximizing) bank regulation lead to financial intermediation and dominate market discipline? If so, how should such regulation be designed?

These are the questions addressed in this section. Solving for an equilibrium of the regulation game, we find that: (i) in contrast with the case of market discipline (Corollary 3), banks are subject to capital requirements and lend in excess of their capital, even if the contractual terms with borrowers are not observable to depositors and regulators; (ii) capital requirements increase when aggregate bank capital and/or the number of banks increases relative to the aggregate demand for lending and banking competition is more intense; (iii) the equilibrium is a constrained optimum. It differs from the first-best in that banks earn excessive profits and credit may be rationed.

We shall now derive these results in formal terms. We assume that contractual terms between the bank and its borrowers (namely, the lending rates R_i) are either unobservable or too costly to observe. Thus a bank's capital requirement cannot be conditioned on its profit margin; so the regulator sets an unconditional capital requirement c, and each bank $i = 1, ...n$ cannot lend in excess of $\frac{\frac{A}{n}}{c}$, i.e.:

$$L_i \leq \frac{\frac{A}{n}}{c} \quad , \quad i = 1, 2.....n \quad .$$

This allows us not only to derive an explicit credit-market-equilibrium solution, but also to extract clear-cut predictions on unconditional capital requirements that are consistent with what is actually observed.

An unmonitored project has negative net present value, and a monitored one, positive. To maximize social welfare, therefore, the projects that are undertaken must be monitored. By Proposition 3, it follows that the optimal capital requirement, denoted by c^*, necessarily satisfies bank monitoring incentive constraints:

$$c^* \geq c(R_i, R_d), \quad i = 1, 2....n \qquad ,$$

where $c(R_i, R_d)$ is $i's$ minimum (incentive-based) capital requirement as given by (9) ; $i's$ lending rate R_i is the outcome of lending competition at date 1, given structural parameters and the capital requirement set at date 0.

Under our simplifying assumption of rectangular demand for loans, maximizing social welfare is tantamount to maximizing the measure of projects undertaken or, equivalently, aggregate lending, subject to bank monitoring incentive constraints:

$$\max_c \sum_{i=1}^{n} L_i \tag{12}$$

$$s.t.$$

$$\sum_{i=1}^{n} L_i = \min(M, \tfrac{A}{c})$$

$$c \geq c(R_i, R_d), \quad i = 1, 2....n$$

where $\frac{A}{c}$ is the overall amount of lending that banks can undertake given the capital requirement c, and M is the total measure of projects, or equivalently the aggregate demand for loans. However, we wish our results to apply, at least qualitatively, to the more general case of downward-sloping aggregate demand for lending.[12] We thus assume that the regulator's objective is to maximize the expected surplus of real investment activity that accrues to firms, or equivalently to *minimize* bank rents subject to bank monitoring incentive constraints. The regulator's problem then amounts to choosing c so as to maximize the overall lending that banks can undertake, subject to bank monitoring incentive constraints:

$$\max_c \frac{A}{c} \tag{13}$$

$$s.t.$$

$$c \geq c(R_i, R_d), \quad i = 1, 2....n \tag{14}$$

Note that the optimal c that solves problem (13) is a solution to the problem of social-welfare maximization (12); this c is the lowest within the interval of values that maximize social welfare. Solving problem (13) amounts to *minimizing* the capital requirement c subject to the constraint that each bank $i = 1, ...n$ finds it incentive-compatible to monitor (condition (14)). Indeed, the lower the capital requirement, the greater the amount of lending that banks can undertake, the more intense the competition in lending, the lower the lending rates and hence the higher is the expected surplus of real investment activity that accrues to firms, provided that c satisfies the incentive constraint (14). But if c violated inequality (14), then regulation would fail to constrain lending not to exceed the bank's incentive-based capacity: in equilibrium depositors would not fund banks (by Proposition 3 and its Corollary 3).

4.1 Optimal Capital Requirement and Credit Market Equilibrium

We solve for an equilibrium of competition in lending and for the optimal c. This is the lowest c that satisfies inequality (14), given that depositors, who learn c from the regulator's public announcement at date 0, correctly infer that the incentive constraint (14) is satisfied and that banks will monitor. Given this rational inference, depositors are willing to fund banks, and banks remunerate deposits at the rate R_d (by Proposition 3).

Structural parameters, $A, n,$ and M, and the capital requirement c jointly determine the lending competition regime, which depends on which of the following mutually exclusive conditions is satisfied:

$$n\frac{\frac{A}{n}}{c} \leq M \tag{15}$$

$$(n-1)\frac{\frac{A}{n}}{c} \geq M \tag{16}$$

$$\frac{M}{n-1} > \frac{\frac{A}{n}}{c} > \frac{M}{n} \tag{17}$$

If inequality (15) holds, then the overall amount of lending that banks can undertake does not exceed aggregate demand, and the equilibrium strategy of a bank is to offer the monopoly rate x. By contrast, if inequality (16) holds, then a bank's competitors can cover the whole market, competition in lending is unrestricted, and in equilibrium the expected profits of banks are driven to zero. If neither condition (15) nor (16) holds, that is if A, n, M, and c satisfy inequality (17), then there is no equilibrium in pure strategies, for the same reasons as in the standard Bertrand-Edgeworth model (Tirole 1988, Chapt.5, and the literature there cited). [13]

The optimal capital requirement satisfies the incentive constraint (14), and i's lending rate, R_i, satisfies inequality (4). That is $R^* \leq R_i \leq x$, $\forall i$ and banks' expected profits are non-negative. Thus, the optimal capital requirement, c^*, necessarily satisfies:

$$\overline{c} \geq c^* \geq \underline{c} \tag{18}$$

$$\overline{c} \equiv c(R^*, R_d) = 1 + \frac{F}{(1-p)\,R_d} - \frac{R^*}{R_d}$$

$$\underline{c} \equiv c(x, R_d) = 1 + \frac{F}{(1-p)\,R_d} - \frac{x}{R_d}$$

where: $1 > \overline{c} > \underline{c}$ (by assumptions A1-A2).

Suppose that the minimum value of the capital requirement, $\underline{c}$, satisfies inequality (15), which is true if and only if:

$$\frac{A}{M} \leq \underline{c} \tag{19}$$

then for $c = \underline{c}$ banks compete according to the (collusive) regime defined by condition (15).

Lemma 1 *If condition* (19) *holds, i.e. if aggregate bank capital is sufficiently scarce, then:*

$$c^* = \underline{c} \equiv c(x, R_d) \tag{20}$$

and credit is rationed if inequality (19) *is strict.*

Proof. See Appendix.

If aggregate bank capital is scarce (i.e., if condition (19) is satisfied), then the optimal capital requirement c^* attains its minimum $\underline{c}$. The total amount of lending that banks can undertake does not exceed aggregate demand (because A, M and $c = c^*$ satisfy inequality (15)), banks implicitly collude on the monopoly lending rate and undertake the maximum incentive-compatible volume of lending:

$$\sum L_i = nL^c(x, R_d; \frac{A}{n}) \tag{21}$$

If inequality (19) is strict, this falls below aggregate demand, M.

Suppose that the maximum capital requirement, $\overline{c}$, satisfies inequality (16), which is true if and only if:

$$\frac{A}{M} \geq \overline{c}\left(\frac{n}{n-1}\right) \tag{22}$$

then for $c = \overline{c}$, banks compete according to the (perfect) competition regime defined by condition (16).

Lemma 2 *If condition* (22) *holds, i.e. if aggregate bank capital is sufficiently abundant, then:*

$$c^* = \overline{c} \equiv c(R^*, R_d) \tag{23}$$

and the first-best optimum is attained.

Proof. See Appendix.

If aggregate bank capital is sufficiently abundant (i.e., if condition (22) is satisfied), then the optimal capital requirement c^*attains its maximum $\overline{c}$, and A, M, n and $c = c^*$ satisfy inequality (16), so that a bank's competitors can cover the whole market. Competition in lending is so intense that rates are driven to the zero-profit value R^*, and since no bank's lending exceeds its incentive-based capacity, all banks monitor. The equilibrium attained is the first-best optimum.

It is worth remarking that as n increases, condition (22) weakens; that is, the larger the number of competing banks, the more likely an equilibrium where banks lend at the zero-profit rate and the capital requirement attains its peak value $\overline{c}$.

If neither condition (19) nor (22) holds, i.e. if :

$$\underline{c} < \frac{A}{M} < \overline{c}\left(\frac{n}{n-1}\right) \qquad , \tag{24}$$

then at c^* neither condition (15) nor (16) holds. When inequality (24) holds, namely for intermediate values of aggregate bank capital, the competition regime is that defined by condition (17): in equilibrium banks will use mixed lending-rate strategies. Lemma 3 below derives c^* for A , n and M that satisfy inequality (24). The key to the lemma is as follows.

(i) Assume condition (17) is satisfied. Then, as we prove below (Proof of Lemma 3), each bank $i = 1, ...n$ randomizes its lending rate according to an atomless distribution function, μ, with support $\left[\underline{R}\ , \ \overline{R}\ \right]$, where $\underline{R}$ denotes the lower bound, and $\overline{R}$ the upper bound. Let the capital requirement, c, satisfy:

$$c \geq c(\underline{R}\ , R_d) \quad . \tag{25}$$

Then, because the lending rate realization of each bank $i = 1, ...n$ satisfies $\underline{R} \leq R_i \leq \overline{R}$, the incentive constraint (14) is met. Therefore, $a_i^* = m$, $i = 1, ...n$, and all banks monitor.

All rates in the support of μ yield the same (maximal) payoff, denoted by $\overline{\pi}$. The distribution μ, $\underline{R}$, $\overline{R}$ and $\overline{\pi}$ are the solution to:

$$[R_i - (R_d + F)] \left\{ \left[M - (n-1) \frac{\frac{A}{n}}{c} \right] (\mu(R_i))^{n-1} + \frac{\frac{A}{n}}{c} \left[1 - (\mu(R_i))^{n-1} \right] \right\} = \overline{\pi} \tag{26}$$

$$\overline{R} = \underset{R_i \leq x}{\arg\max} \, [R_i - (R_d + F)] \left[M - (n-1) \frac{\frac{A}{n}}{c} \right] \tag{27}$$

$$\mu(\underline{R}) = 0 \tag{28}$$

$$\mu\left(\ \overline{R}\ \right) = 1 \tag{29}$$

The left-hand side of functional equation (26) gives i's expected profit at any lending rate $R_i \in \left[\underline{R}\ , \ \overline{R}\ \right]$, given that: a) its competitors randomize their lending rates according to distribution μ with support $\left[\underline{R}\ , \ \overline{R}\ \right]$; b) it monitors lending, that is $a_i^* = m$ (which holds by (25)), and remunerates depositors at R_d. Indeed, the expression $[R_i - (R_d + F)]$ is i's profit per unit of lending conditional upon $a_i^* = m$ and its unit cost of funding being R_d (by (5)). The expression in curly brackets gives i's expected lending volume: if i is the bank with the highest lending rate, then it faces the residual demand for lending, $M - (n-1) \frac{\frac{A}{n}}{c}$, and the capital requirement is not binding; that is, it lends $M - (n-1) \frac{\frac{A}{n}}{c}$ (by (17)); this occurs with probability $(\mu(R_i))^{n-1}$.

In any other event, the capital requirement is binding; that is, i's lending volume is $\frac{\frac{A}{n}}{c}$ (by (17)). The right-hand side of equation (27) is the monopoly rate on the residual demand left to a bank when all the rivals undercut its rate. Because a bank that sets its rate to the upper bound of the support is undercut by all the rivals, the highest rate ever charged in equilibrium is $\overline{R}$ given by (27). Clearly $\overline{R} = x$, the monopoly rate given the rectangular demand curve.

Solving functional equation (26) for $\mu(R_i)$ leads to:

$$\mu(R_i) = \left\{ \frac{[R_i - (R_d + F)] \frac{\frac{A}{n}}{c} - \overline{\pi}}{\left(n\frac{\frac{A}{n}}{c} - M\right)[R_i - (R_d + F)]} \right\}^{\frac{1}{n-1}} \tag{30}$$

$$\mu(\underline{R}) = 0 \Longleftrightarrow [\underline{R} - (R_d + F)] \frac{\frac{A}{n}}{c} = \overline{\pi} \tag{31}$$

$$\mu(\overline{R}) = 1 \Longleftrightarrow \overline{\pi} = [x - (R_d + F)] \left[M - (n-1) \frac{\frac{A}{n}}{c} \right] \tag{32}$$

where $\overline{R} \equiv x$ (by (27)). We then have that the upper bound of the support $\overline{R}$ is the monopoly rate x, the lower bound $\underline{R}$ is the solution to (31), and the expected profit of each bank $i = 1, ...n$, is $\overline{\pi}$ as given by (32); by (17), this is strictly positive. Note that distribution μ, $\underline{R}$ and $\overline{\pi}$ are uniquely determined for a given c. Moreover, both $\underline{R}$ and $\overline{\pi}$ are strictly increasing in c; that is, the higher the capital requirement, the higher are bank rents. For any given c, equations $(30) - (32)$ and $\overline{R} = x$ characterize the Bertrand-Edgeworth equilibrium for a rectangular demand curve (for the more general case of a downward-sloping demand curve see Tirole 1988, Chapt.5, and the references there cited). This is the unique symmetric equilibrium for a given c (by $(30) - (32)$ and (27)).

(ii) Given that in the competition regime defined by condition (17), each bank $i = 1, ...n$ randomizes its lending rate according to distribution μ with support $[\underline{R}\ ,\ x]$, the optimal c is:

$$c^* = c(\underline{R}\ , R_d) \equiv 1 + \frac{F}{(1-p)\, R_d} - \frac{\underline{R}}{R_d} \quad . \tag{33}$$

That is, c^* is the minimum value that satisfies the monitoring incentive constraint (14). For $c = c^*$ as given by (33), the bank with the lowest lending rate is exactly indifferent between monitoring and not monitoring.

(iii) When inequality (24) holds and $c = c^*$ as given by (33), then condition (17) is fulfilled.

Lemma 3 *If condition* (24) *holds, i.e. if aggregate bank capital is neither scarce nor abundant, then:*

$$c^* = c(\underline{R}\,, R_d) \equiv 1 + \frac{F}{(1-p)\,R_d} - \frac{\underline{R}}{R_d}$$

where, $\underline{R}$ *is the solution to* (31) *given* $c = c^* \equiv c(\underline{R}\,, R_d)$.

Proof. See Appendix.

For A, n and M that satisfy inequality (24), the optimal capital requirement c^* exceeds the minimum value $\underline{c}$, attained when banks collude on the monopoly rate (when condition (19) holds), and falls below the maximum, $\overline{c}$, attained when competition drives profits to zero (when condition (22) holds). Furthermore, the lending competition regime is that defined by condition (17): in the symmetric equilibrium each bank $i = 1, ...n$, randomizes according to distribution μ with support $[\underline{R}, x]$, monitors lending, and earns strictly-positive profit $\overline{\pi}$ as given by (32).

Figure 2 illustrates the comparative statics of c^*, with respect to A, M, n that satisfy inequality (24).

FIGURE 2 ABOUT HERE

For curve C, $c = c(\underline{R}\,, R_d)$; that is, $a_i^* = m$, $i = 1, ...n$ (banks monitor) on and above curve C. For curve B, $[\underline{R} - (R_d + F)]\,\frac{\frac{A}{n}}{c} = [x - (R_d + F)]\left[M - (n-1)\,\frac{\frac{A}{n}}{c}\right]$; that is, a bank's expected profit (conditional upon $a_i^* = m$) at the lower bound $\underline{R}$ equals the payoff at any rate in the support, which is $\overline{\pi}$ as given by (32). The intersection of these curves gives c^*. As $\frac{A}{M}$ or n increases, curve B shifts upwards to B'. Accordingly, c^* increases as $\frac{A}{M}$ or n increases. The reason is simple: as either $\frac{A}{M}$ or n increases, the amount of lending by a bank when it is undercut by its competitors shrinks, and when it sets its rate it places more weight on undercutting considerations. This means that profit margins, and hence marginal returns to monitoring, decrease. Raising the capital requirement restores monitoring incentives. The comparison of optimal capital requirements derived from Lemmas 1-3 confirms that this result holds for any A, M and n.

Proposition 4 *The equilibrium values of banks' profit margins and optimal capital requirements are inversely related. Social-welfare-maximizing capital requirements increase when aggregate bank capital and/or the number of banks increases relative to the aggregate demand for lending. The (constrained) optimum entails financial intermediation and deviates from the first best whenever aggregate bank capital is not sufficiently abundant (i.e., when condition* (22) *fails to hold). In this case, banks earn excessive profits and credit is rationed if inequality* (19) *is strict.*

Proposition 4 summarizes the results in Lemmas 1-3. As the ratio of aggregate bank capital to the aggregate lending demand, $\frac{A}{M}$, increases, the economy moves from an equilibrium in which banks make monopoly profits and the capital requirement attains its minimum $\underline{c}$ (for $\frac{A}{M}$ that satisfies (19), Lemma 1) to one in which profits are strictly positive but below the monopoly level and the capital requirement is in an intermediate range, that is $\underline{c} < c^* < \overline{c}$ (for $\frac{A}{M}$ that satisfies (24), Lemma 3), and finally to an equilibrium in which profits are zero and the capital requirement attains its maximum $\overline{c}$ (for $\frac{A}{M}$ that satisfies (22), Lemma 2). An increase in the number of banks n, produces similar effects. If aggregate bank capital is not so scarce as to satisfy condition (19), then as n increases profits fall and the capital requirement rises (by Lemma 3). Furthermore, as n increases, condition (22) weakens; therefore the higher the number of banks, the more likely an equilibrium in which banks lend at the zero profit rate and the capital requirement attains its maximum $\overline{c}$. These results stem from the fact that $\frac{A}{M}$, n and c jointly determine the intensity of competition and hence profit margins and monitoring incentives. For any given c, as $\frac{A}{M}$ and/or n increases, the bank's market power diminishes because its competitors can serve a greater portion of aggregate demand, banks compete more aggressively, and their profit margins shrink. The marginal return to monitoring thus decreases as $\frac{A}{M}$ and/or n increases. Raising the capital requirement restores monitoring incentives.

We therefore conclude that unlike market discipline (Corollary 3), optimal capital requirements make financial intermediation possible. Optimal capital requirements diminish at the end of a recession, since banks have less capital as a result of cyclically-induced insolvencies; they are higher when the banking system is more fragmented, and increase when entry barriers are removed and competition becomes fiercer.

5 The Predictions of the Model

This section summarizes the predictions of the model with regard to the endogenous variables: lending rates, return on capital, optimal capital requirement and the probability of a firm's being denied credit.

Depending on parameter values $(\frac{A}{M}, n, R_d, x, F)$ there are three possible regimes: the monopoly, credit-rationing regime (condition 19); the Bertrand-Edgeworth mixed-strategy regime (condition 24); and the zero-profit perfectly competitive regime (condition 22). This is depicted in Figure 3.

FIGURE 3 HERE

where

$$\overline{c} \equiv c(R^*, R_d) = 1 + \frac{F}{(1-p)\, R_d} - \frac{R^*}{R_d}$$

$$R^* \equiv R_d + F$$

$$\underline{c} \equiv c(x, R_d) = 1 + \frac{F}{(1-p)\, R_d} - \frac{x}{R_d}$$

Exogenous parameter values determine which regime the endogenous variables belong to and their values within that regime. Figure 4 depicts the bank lending rate, R_i, as a function of $\frac{A}{M}$ for any given (n, R_d, x, F).[14] Similarly, Figure 5 depicts bank profit per unit of capital, $\frac{\pi_i}{\frac{A}{n}}$; Figure 6 depicts the optimal capital requirement, c^*. Figure 7 depicts the probability of a firm's being denied credit, $P_r = \max\left[1 - \frac{\frac{A}{c^*}}{M}, 0\right]$, where $\frac{A}{c^*}$ is the overall lending volume given aggregate capital A and the optimal capital requirement c^*. This probability is strictly positive and decreasing in $\frac{A}{M}$ whenever condition (19) holds and aggregate capital is scarce.

FIGURES 4,5,6,7

ABOUT HERE

An increase in n, number of competing banks, shifts $\frac{n}{n-1}\ \overline{c}$ to the left. The (zero-profit) perfectly competitive regime expands, and within the intermediate mixed-strategy regime expected lending rates and expected profits fall and the optimal capital requirement rises (see Figures 4-6, where $n' > n$). A decrease in R_d, the return offered to depositors by the outside option, leads to an increase in $\overline{c}$. This means that the region where banks earn strictly positive profits expands, leading to an increase in profits and a decrease in the optimal capital requirement both in the monopoly and in the intermediate mixed-strategy regime. Moreover, $\underline{c}$ decreases with R_d, so that the probability of a firm's being denied credit when capital is scarce also decreases accordingly (see Figure 7, where $\underline{c}' \equiv c(x, R_d')$, $R_d' < R_d$). An increase in project return, x, or a decrease in monitoring cost, F, produces similar effects, with the exception of lending rates in the monopoly and mixed-strategy regimes, which increase whenever x increases.

The depositors' outside option can be realistically posited to be government securities, and hence R_d as determined by monetary policy (as in Thakor 1996). The model thus predicts that expansive monetary policy leads to an increase in banks' profits, lowers firms' cost of capital and reduces credit rationing in the capital-crunch regime. Indeed, as Figure 7 shows, a capital crunch can be cured by recapitalizing banks or by expanding the money supply. The latter works by reducing banks' cost of funding and thereby increasing their incentive-based lending capacity. This immediately explains the reduction of credit rationing in the capital-scarcity regime. The reduction in firms' cost of financing results from the more intense competition sparked by the increase in lending capacities. Table 1 summarizes the model's comparative statics.

TABLE 1: Comparative Statics

	Lending rate	Profit per unit of capital	Optimal capital requirement c^*	Credit Rationing[1]
Aggregate Capitalization: $\frac{A}{M}\uparrow$	$\downarrow$	$\downarrow$	$\uparrow$	$\downarrow$
Credit Market Liberalization : $n\uparrow$	$\downarrow$	$\downarrow$	$\uparrow$	$=$
Monetary Policy Expansion: $R_d\downarrow$	$\downarrow$	$\uparrow$	$\downarrow$	$\downarrow$
Project Profitability:				
$x\uparrow$	$\uparrow$	$\uparrow$	$\downarrow$	$\downarrow$
$F\downarrow$	$\downarrow$	$\uparrow$	$\downarrow$	$\downarrow$

[1] For $\frac{A}{M} < \underline{c}$

There is considerable empirical evidence that a scarcity of bank capital limits lending. The 1989-1992 credit crunch in the US has been relabeled the "capital crunch" (see Bernanke and Lown, 1991). Peek and Rosengren (1997) document that the US branches of Japanese banks cut their lending because their parents' capital position had declined. There is also evidence that regulators are indeed more lenient during banking recession (see Tirole, 1994). Berger, Kyle and Scalise (2000) report episodes of the relaxation of supervision to alleviate credit shortages. For the insurance industry, Gron (1994) finds that decreases in aggregate net worth result in higher underwriting margins, i.e. higher profitability and prices, consistent with the capacity-constraint hypothesis. Properly testing this model would require examining the empirical relationship between bank lending profits per unit of capital and the model parameters $(\frac{A}{M}, n, R_d, x, F)$ as discussed above, possibly using regime-switching analysis techniques.

The foregoing applies to symmetric banks with aggregate capital evenly distributed. The analysis of asymmetric banks is cumbersome. Our conjecture is that the concentration of capital in a few hands would put upward pressure on borrowers' costs, with larger banks setting higher rates with higher probability than small banks, along the lines of Allen and Hellwig (1993) for Bertrand-Edgeworth competition between asymmetric duopolists. An empirical analysis should thus allow for an indicator of bank capital concentration.

6 Conclusions

This paper has shown that when variables such as a bank's profit margin are not observable to depositors, market discipline may fail to deter banks from underinvestment in monitoring of borrowers, thereby causing depositors to withhold funds from banks and making intermediation impossible. Introducing regulation in the form of capital requirements makes financial intermediation possible. Moreover, optimal capital requirements are related to aggregate bank capital and hence to the business cycle, via the link between recession, insolvencies and bank capital. They also depend on the degree of concentration of the banking sector and on structural regulation, e.g. entry barriers. Optimal requirements are higher when entry barriers are removed and when the banking industry is more fragmented; that is, optimal requirements depend on the intensity of competition. The outcome of banking competition departs from the perfect-competitive result in that banks earn excessive profits and credit may be rationed. This is true in an optimally regulated economy (by Proposition 4) and it is true *a fortiori* in an unregulated economy in which a bank's lending volume would be further limited by its capital. These results suggest that delegated monitoring in an environment of aggregate risk is sufficient for interbank competition to be imperfect and may account for the cyclical behavior of banks' profit margins and of the cost of financing to borrowers. The results also explain regulators' leniency during recessions and the increased focus on capital adequacy rules following credit market liberalization in the US and Europe. They also suggest that the ongoing consolidation of the banking sector should lead to lower capital requirements.

The analysis also suggests a novel channel for monetary policy. Expansive policy affects the credit market equilibrium by reducing banks' cost of funding and thereby increasing their incentive-based lending capacity. Borrowers' cost of financing diminishes as a result of the consequently sharper competition in lending. Yet interbank competition is imperfect, so banks' profit margins increase because the reduction in their funding cost is not fully passed on to borrowers. Thanks to higher profit margins, the optimal capital requirement falls. Monetary policy can thus substitute for or complement recapitalization of banks to alleviate credit shortages.

What drives these results is the conflict of interests between the bank's shareholders, insiders, and depositors. These agency problems set an upper bound on the amount of loans that bank insiders find optimal to monitor. We call this upper bound the bank's incentive-based lending capacity, and it is positively linked to its (endogenous) profit margin and (inside) capital. Capital requirements function by effectively restricting the bank's scale of business not to exceed this upper bound. This makes the analysis especially relevant to institutional environments in which the protection of depositors and outside shareholders is limited. But even in more developed environments with functioning financial markets, capital appears costly to raise (see Smith 1986 for a survey of the evidence) and the equity value of the banking sector affects lending (see Sharpe 1995). Bank capital will then still constrain the bank's scale of business, and capital requirements ought to be set so as to align the latter to that compatible with its monitoring incentives (i.e. the capital requirements derived in Proposition 4).

The paper has assumed away deposit insurance. Clearly, an optimal insurance scheme would contemplate the capital requirements derived here. Failure in prudential regulation, coupled with depositors' and/or shareholders' protection, either explicit or implicit, would imply no effective constraint on the bank's loanable funds. Banks would find it optimal to choose scales of business greater than that compatible with sound and prudent management. This does not necessarily imply bank failures. Indeed, banks will be solvent in the lucky event that macro-economic conditions support firms' performance, i.e., when the state realization is $\overline{\theta}$. Interpreting $\overline{\theta}$ as a price-bubble state and $\underline{\theta}$ as a burst bubble allows us to explain the recent Asian experience.

Appendix

Proof of Proposition 2

Suppose to the contrary that in an equilibrium i does not monitor. Then i's expected lending revenue would be pR_iL_i, which (by $R_i \leq x$ and assumption A1) falls below the opportunity cost of invested resources R_dL_i . Depositors and/or the bank would suffer expected losses, thus violating the condition that at equilibrium agents' participation constraints are necessarily satisfied. ■

Proof of Lemma 1

When condition (19) holds and $c = \underline{c} \equiv c(x, R_d)$, then condition (15) is satisfied: no matter what rates i's competitors offer, i's lending volume is constrained by the regulatory ceiling $\frac{\frac{A}{n}}{c}$, and the equilibrium strategy of each bank $i = 1, ...n$ is therefore $R_i = x$; the minimum value of the capital requirement, $c = c(x, R_d)$, then satisfies the incentive constraint (14) , and hence solves the regulator's optimization problem. ■

Proof of Lemma 2

If condition (22) holds, then $c = \overline{c} \equiv c(R^*, R_d)$ satisfies inequality (16): the equilibrium strategy of each bank $i = 1, ...n$ is $R_i = R^*$ (which implies that the incentive constraint (14) is met). This is true because i cannot be better off at $R_i > R^*$, as by (16) in this case it would lend nothing and would be worse off at $R_i < R^*$. The capital requirement would be binding, i.e. $L_i = \frac{\frac{A}{n}}{c} \equiv L^c\left(R^*, R_d; \frac{A}{n}\right)$, and profits would be lower than at R^*. ■

Proof of Lemma 3

From observation (**iii**) above, we have that when inequality (24) holds and $c = c(\underline{R}\ , R_d)$, then the competition regime is that defined by condition (17); (**ii**) has established that if under condition (17) banks randomize their lending rates according to distribution μ with support $[\underline{R}\ , \ x]$, then $c = c(\underline{R}, R_d)$ is optimal. It remains to be proved that when condition (17) holds, the equilibrium of competition in lending is indeed one in which each bank randomizes its lending rate according to distribution μ with support $[\underline{R}\ , \ x]$. This is true because: i) x is the monopoly rate on the residual demand left to a bank when all the rivals undercut its rate; ii) given that bank i's competitors use this strategy, its expected profit for any $R_i \in [\underline{R}\ , \ x]$ attain the maximum value $\overline{\pi}$, by (26). Thus i cannot be better off by randomizing with a different distribution with support $[\underline{R}\ ,\ x]$, and it would be worse off by setting a rate lower than $\underline{R}$. At $R_i < \underline{R}$, i's lending volume would be the same as at $\underline{R}$; that is, its lending volume would still be constrained by the lending ceiling $\frac{\frac{A}{n}}{c}$, so that its expected profit would be strictly lower than at $\underline{R}$ and hence lower than $\overline{\pi}$. Since by (30) − (32), μ, $\underline{R}$, $\overline{\pi}$ are uniquely determined, the equilibrium derived is the unique symmetric equilibrium. ■

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Footnotes

[1]Capital requirements may be costly, though. This has been shown by Besanko and Kanatas (1996) for a bank whose total assets are given and capital requirements dictate the financing mix between debt –deposits– and outside equity. The costs of capital requirements are the agency costs of outside equity a la Jensen and Meckling (1976). Moreover, capital is costly because of the liquidity costs of equity versus demand deposits (Gorton and Winton 1995).

[2] Keeley (1990) finds a direct relationship between the US reforms that increased competition and the increase in the number of bank failures in the 1980s.

[3] Following Hellwig (1991), Bhattacharya and Thakor (1993), Dewatripont and Tirole (1994) and Freixas and Rochet (1997), we interpret "monitoring" broadly. It can consist of: i) screening projects in an adverse-selection environment (as in Ramakrishnan and Thakor 1984, Broecker 1990); or ii) preventing opportunistic behaviour by the borrower during the realization of the project (as in Diamond 1991, Holmstrom and Tirole 1997).

[4] We thus explicitly model monitoring institutions as intermediaries that compete in prices for loans and deposits. This is in contrast to Holmstrom and Tirole (1997), where monitoring institutions are price takers, in that the rate of return on capital is determined by market clearing.

[5] Indeed, with uncorrelated project returns, the larger the number of loans, the more diversified the credit portfolio, the lower the probability of default and the lower auditing costs; for a fully diversified bank, the costs are nil.

[6] Monitoring may also consist in testing of an entrepreneur's credit worthiness (at a cost) in an adverse-selection environment where a given percentage of the entrepreneur population have type g projects and the rest type b projects, and the test result is a success or a failure depending on project type. In this case, F is the cost of performing a test, divided by the probability of an entrepreneur's being endowed with a type g project.

[7] Arguably, a bank could monitor only part of its loans. However, such

a strategy is strictly dominated either by monitoring all loans or none. This will be clarified in Section 3 (see footnote 9).

[8] Since the bank's action is unobservable, its timing is irrelevant; thus a game in which the bank makes its monitoring choice (contingent on its lending and borrowing rates and lending volume) at the outset is perfectly equivalent to the one defined here.

[9] We can now see why monitoring a fraction $0 < \lambda < 1$ of the loan portfolio is a strictly dominated strategy. If the bank chooses $0 < \lambda < 1$ is insolvent in $\underline{\theta}$, then it would be better off by choosing $\lambda = 0$, i.e. $a_i = \varnothing$, thus avoiding monitoring costs altogether; by contrast, if it is solvent, then it suffers all the consequences of financing $(1-\lambda) L_i$ projects with negative net present value, so it would be better off choosing $\lambda = 1$, i.e. $a_i = m$.

[10] With T periods, the bank maximizes expected discounted profits, and with $T \longrightarrow \infty$, it chooses strategies corresponding to the infinitely-repeated static Nash equilibrium. It chooses monitoring if:

$$\pi(R_i, L_i|a_i^* = m)\left(\frac{1}{1-\delta}\right) \geq \pi(R_i, L_i|a_i^* = \varnothing)\left(\frac{1}{1-\delta p}\right)$$

where δ is the discount factor. The monitoring-incentive compatibility condition (8) becomes:

$$\frac{\frac{A}{n}}{L_i} \geq c(R_i, R_d; \delta)$$

where $c(R_i, R_d; \delta)$ is the minimum incentive-based capital requirement for a T-period horizon:

$$c(R_i, R_d; \delta) = \left(\frac{1}{1-\delta}\right)\left\{1 + \frac{F\,(1-\delta p)}{(1-p)\,R_d} - \frac{R_i}{R_d}\right\}$$

This is less than $c\,(R_i, R_d)$ whenever $\delta > 0$ – i.e. future profits have positive weights in the bank's objective function. However, this paper's results also carry over to the multiperiod environment whenever $0 \leq \delta < 1$, i.e. future profits are weighted less than current profits.

[11] We have not considered the trivial case in which bank capital is so great that the bank's incentive constraint is never binding, i.e. $L^c\left(R^*, R_d; \frac{A}{n}\right) \geq M$ and each bank $i = 1, ...n$, monitors regardless of its amount of loanable funds.

[12] This would be the case if undertaking a project required entrepreneurial effort and its (non-pecuniary) cost differed across entrepreneurs according to some distribution function over the total measure of firms – entrepreneurs.

[13] Note that, for a given n, and, $\frac{A}{M}$, as c decreases the lending competition regime shifts from monopoly – for c that satisfies inequality (15) – to the Bertrand-Edgeworth regime – for c that satisfies inequality (17) – and from this to the perfectly competitive (zero-profit) regime – for c that satisfies inequality (16). Thus minimizing the capital requirement subject to monitoring-incentive constraint (14), does indeed amount to minimizing bank rents, subject to banks' finding it incentive-compatible to monitor.

[14] In the intermediate range, that is when $\underline{c} < \frac{A}{M} < \overline{c}\left(\frac{n}{n-1}\right)$, banks randomize lending rates (by Lemma 3); R_i on the vertical axis should be interpreted as expected lending rate.