

Crises and Capital Requirements in Banking*

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Abstract

We analyse a general equilibrium model in which there is both adverse selection of and moral hazard by banks. The regulator has several tools at her disposal to combat these problems. She can audit banks to learn their type prior to giving them a licence, she can audit them ex post to learn the success probability of their projects, and she can impose capital adequacy requirements. When the regulator has a strong reputation for ex ante auditing she uses capital requirements to combat moral hazard problems. For less competent regulators, capital requirements can *substitute* for ex ante auditing ability. In this case the banking system exhibits multiple equilibria so that crises of confidence in the banking system can occur only when the regulator's reputation is poor. Contrary to conventional wisdom, depending on regulator reputation the appropriate policy response to a crisis of confidence may be to *tighten* capital requirements to improve the quality of surviving banks.

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JEL Classification: D51, D82, E58, G21

1. Introduction

Despite more than a decade of enforcement of the Basle Capital Adequacy Accord, the precise mechanism through which capital regulation promotes banking system stability is still poorly understood. Moreover, the regulatory response to various different banking crises seems to be quite diverse. In turbulent times, should capital requirements be loosened to help struggling banks (as arguably happened in the S&L crisis), or should they be tightened to discourage desperate banks from undertaking further risky activities? In this paper we set up a general equilibrium model with which we attempt to explore these questions.

Two main theories predominate as to the role which capital requirements play. The first of these, which we may informally call the “moral hazard” theory, is most closely associated with economic theorists¹ as well as public choice economists. The idea is that if banks do not have sufficient equity “at stake” when they make their investment decisions then they may make decisions which, though optimal for equity-holders, are suboptimal from the point of view of society as a whole.² For example, banks may be tempted to make excessively risky and even negative net present value investments which maximise the returns to equity at the expense of debt holders or the deposit insurance fund.

¹See for example, Bhattacharya (1982), Rochet (1992).

²In this literature, banks are generally assumed to act in the interest of shareholders; either because the models explicitly assume pure entrepreneurial banks, or (implicitly) because managers have shareholdings or options. For a rationale of this, see Dewatripont and Tirole (1994).

The second theory, which we might call the “safety net” theory, is more associated with practitioners, and, as far as we are aware, this intuitive idea has yet to be formally modelled.³ It is the idea that a bank’s capital forms a kind of cushion against losses for depositors. One might loosely capture this idea by saying that if the bank starts to lose money, equity value must fall to zero before debt-holders start to lose, so depositors cannot lose out if regulation ensures that the bank must be closed or recapitalised before this occurs.

Our theory incorporates both of these rationales for capital regulation, and also a third. Intuitively, capital regulation should have the desirable effect of discouraging unsound and unreliable institutions from setting up operations. We show that indeed this idea provides a further rationale for capital regulation: capital requirements can be used to solve adverse selection problems. In doing so we address some interesting issues.

Firstly, we examine the role of the banking regulator. We show that the presence of moral hazard in the banking system means that competent bankers must receive a rent to reward them for investing and monitoring other agents’ deposits. Depositors, however, do not fully take account of this rent when deciding whether to deposit in banks or not. Thus from a social point of view, depositors are generally insufficiently willing to deposit, so any sound banking system will be smaller than is socially optimal. The regulator’s role is therefore to take actions which maximise the size of the banking sector. This represents a rather broader view of the regulator’s remit than that found in some of the existing literature (e.g. Dewatripont and Tirole, 1993, 1994), where the regulator simply represents the interests of depositors who are too dispersed and ill-informed to represent themselves.

Secondly, if a regulator wishes to use capital requirements to select out bad banks from the system she will have to set capital requirements more tightly than if she desired simply to solve the moral hazard problem of “gambling” by under-capitalised banks.⁴ Thus solving adverse selection problems has a cost in terms of a banking system which is smaller (though on average more productive) than it otherwise would be. Regulators with a good ability to audit banks *ex ante* should therefore prefer the alternative of following a looser capital policy which merely solves the moral hazard problem, while relying on their own auditing skill to avoid chartering unsound banks. Regulators with a poor reputation, on the other hand, should adopt a tight regulatory policy, because by doing so they will gain more in average bank quality than they will lose in bank size. Thus, in contrast to the Basle Accord’s emphasis on a “level playing field” across nations,⁵ we suggest that capital regulation should be tighter in countries where regulator reputation is worse, since it is in effect a substitute for regulator auditing ability.

Thirdly, the regulator’s ability to audit at the *interim* stage and determine in advance of realisation the likely outcome of banks’ investments has an interesting interaction with the above

³Closely related to this intuitive idea is the literature arguing that capital requirements can be used to prevent destructive bank runs (Diamond and Dybvig, 1983; Dowd, 1993; Diamond and Rajan, 2000). Probably the closest formal model to the ‘safety net’ theory is Dewatripont and Tirole (1993*b*). Their story is however much more focussed on providing incentives for those managing banks. For an overview of different theories of banking regulation see Freixas and Rochet (1997) and Gorton and Winton (2002).

⁴For a description of how such gambling occurred in the S&L crisis, see Kane (1989*b*).

⁵The importance for internationally level playing fields is stressed in the original 1988 Basle Accord (paragraph 3) and in the context of the proposed modifications to the Accord (Basle Committee 2002, paragraph 12) .

policy prescription. In general, the more *transparent* are banks' investments (i.e. the easier it is for a regulator to determine early that investments are unprofitable), the looser capital requirements can be set. In our model, if the regulator recognises bad investments early, then she can step in and redistribute all of their returns to depositors before bank equity holders benefit from them. A high probability of such regulatory intervention will reduce the likelihood that bad banks will benefit from bad investments and will thus alleviate both moral hazard and adverse selection problems. It will also render depositing more attractive. This feature of the model therefore incorporates the "safety net" theory of capital regulation, because a diminished equity base reduces the amount of capital which can be redistributed from equity holders to depositors in the event of bad behaviour.

Fourthly, we show that when capital requirements are used to solve adverse selection problems, the economy exhibits multiple equilibria. This is because agents with capital can choose whether to use it to set up and manage a bank, to use it to run their own project, or to deposit it with another agent who may be able to invest it more productively than they can. The equilibrium therefore depends on agents' expectations about the quality of applicants for banking licences. If agents are *pessimistic* about the quality of applicants then the average quality of the financial system will be low and agents will be unwilling to deposit their capital with banks, preferring instead to use it to set up their own banks. Thus in equilibrium all agents with capital apply for licences, the average quality of successful applicants is low, and the pessimistic expectations are confirmed. On the other hand, if agents are *optimistic* about the quality of licence applicants they will anticipate a high quality banking system. They will therefore choose to deposit their capital in a bank rather than to set up a bank, thus confirming the high quality of the banking sector.

Notice that the solution of the adverse selection problem in a pessimistic economy requires setting capital requirements more tightly than the solution of the adverse selection problem in an optimistic economy, since pessimistic beliefs about the banking sector make unsound agents more inclined to apply for a banking licence. We interpret a switch between optimistic and pessimistic beliefs as a *crisis of confidence*. Such crises of confidence will arise only in economies where regulation solves adverse selection problems: that is, *crises occur only in economies where the regulator's reputation is poor*. However, the crises themselves may occur independently of changes to the poor regulator's reputation.⁶ A regulator with a very good reputation will use capital requirements only to solve moral hazard problems and hence will not be vulnerable to such crises.

Finally, we show that the optimal response to crises of confidence depends on how bad the regulator's reputation is, but may be to *tighten* capital requirements. If agents switch from optimistic to pessimistic beliefs, then existing capital regulation is no longer tight enough to prevent unsound agents from applying for banking licences. The regulator has two possible reactions to this. If she has some auditing ability, she could simply accept the deterioration in banking sector, fall back upon her auditing ability to keep out some of the worst applicants, and use capital regulation only to solve moral hazard problems. Thus regulators of medium ability may respond to a crisis of confidence with a loosening of capital requirements, allowing a reduction in the average quality of

⁶This is true in our model, where the two equilibria are sunspots. But one could imagine endogenising the occurrence of crises by applying the analysis of Morris and Shin (1998). This would yield a theory where, conditional on poor regulator reputation, the occurrence of banking crises depends upon fundamentals. See Goldstein and Pauzner (2002).

the banking system because this is preferable to the alternative of a reduction in size of the banking system. Regulators with very little auditing skill may however prefer to respond to the crisis by tightening capital requirements. Although the banking sector will shrink in size they will continue to solve the adverse selection problem and thus maintain a highly productive banking sector despite their poor reputation.

The remainder of this paper is organised as follows. Section 2 describes the agents in the economy and sets out the circumstances under which regulation of the banking sector is necessary. Section 3 describes the regulator and derives her optimal policy as a function of both her reputation and the beliefs which obtain in the economy. Section 4 contains concluding remarks.

2. An Unregulated Banking Sector

In this section we consider a one-period economy without a banking regulator which contains N risk neutral agents. Each agent has an initial endowment of \$1 which may be invested, with any returns being consumed at the end of the period. Each individual agent also has his own ‘project’ in which he may choose to invest. All projects return either 0 (failure) or R (success). If a project is not monitored then it is less likely to succeed and returns R with probability $p_L > 0$. But it is possible by spending $C > 0$ per unit invested upon monitoring the activities of the (exogenous) project management to increase the probability of the high return R to p_H , where $p_H > p_L$. Only $\mu < N$ agents are able to monitor: we call these agents *sound*; the other $(N - \mu)$ agents are said to be *unsound*. An agent’s type is his private information. We assume the costs of monitoring are sufficiently low that it is efficient for agents to monitor if they are able to do so:

$$\Delta p R > C, \tag{1}$$

where $\Delta p \equiv p_H - p_L$. The basic model follows Holmström and Tirole (1997), extended to allow for adverse selection of agents.

There are constant returns to investment in projects, so that instead of managing his own project, an agent can deposit his endowment with another agent, who will use it to augment the size of his own project. We call an intermediary which is established to accept such deposits a *bank*: the managing agent accepting the deposits is a *banker*. We will denote by $k - 1$ the dollar amount of other agents’ capital which a bank receives to invest on their behalf. The total amount of investment by a banker will therefore be k , equal to the sum of his own dollar and the other agents’ capital. Investment by banks and the return on investments are verifiable so that bankers cannot steal project returns and cannot invest deposited funds with other banks.

Our accounting convention is as follows. When investors deposit their money with the bank, they sign a *deposit contract* stipulating the sum Q which the banker will receive if his project succeeds. If the bank’s investment succeeds the investor therefore receives a “deposit rate” of $R - Q$ and the banker receives a payment of $R + (k - 1)Q$. Neither the banker nor the investor receives anything if the project fails.⁷ Only a banker can observe the size of the bank which he

⁷An alternative accounting procedure under which the banker received a fee in direct proportion to the size of his bank would be possible and would not have a substantive effect upon our results. We use this method in order to maximise the transparency of the algebra.

manages; this information is not available to outside investors and hence it is impossible for any agent to make a credible commitment to limit the size of the bank which he manages.

Every agent can therefore take one of three actions: he can manage his own project; he can augment his own investment with those of other agents and run a bank; or he can invest his funds in a bank. An equilibrium comprises an action for each agent which maximises his expected income, given the actions of other agents.

Notice that since sound agents' investments (when monitored) are more productive than those of unsound agents, the welfare optimum for this economy will be attained when all funds are managed by sound agents. However, matters are complicated in that an agent's type is his private information and cannot be credibly communicated. When no agent is able to control entry into the banking system we say that the economy is *unregulated*. An equilibrium in which every sound agent runs a bank and performs monitoring is (*constrained*) *efficient*.⁸

There are two conditions for an equilibrium with bank size k to be efficient. Firstly, monitoring must be incentive compatible for sound agents: $(Q(k-1) + R)p_H - Ck \geq (Q(k-1) + R)p_L$, or

$$Q \geq MIC(k) \equiv \frac{Ck - R\Delta p}{\Delta p(k-1)}. \quad (\text{MIC})$$

Note that because monitoring is efficient, sound agents will always monitor if they have no outside capital ($k = 1$). But because monitoring is costly and not contractible, sound agents will not monitor if they have too much outside capital to manage (k large) and the reward for success is insufficiently high (Q low).

Secondly, banking (as opposed to sole trading) must be incentive compatible for sound agents: $(Q(k-1) + R)p_H - kC \geq Rp_H - C$, or

$$Q \geq BIC \equiv \frac{C}{p_H}. \quad (\text{BIC})$$

That is, sound agents will be just indifferent to running a bank if in expectation they receive exactly the cost of monitoring on their outside deposits, independently of the volume of deposits which they manage. The monitoring and banking incentive constraints for sound types - MIC and BIC, respectively - are illustrated in figure 1. The feasible parameter constellations for efficient economies are those above both MIC and BIC.

It transpires that in pure strategy equilibria either all or none of the unsound agents will wish to run banks. The intuition for this is that it is not possible for some unsound agents to be content to run a bank while other unsound agents are content to invest in banks. For then an unsound agent who currently manages a bank could leave the banking system. This would increase the average quality of the banking system, so that the defecting agent would be strictly better off depositing than managing a bank. The converse is true if an unsound agent decides to manage a bank, so the banking system must either grow until it contains all agents, or shrink until it contains only sound agents. This is stated formally in proposition 1 below, whose proof appears in the appendix.

⁸Constrained efficiency might theoretically be achieved by having all sound agents manage banks, and some unsound agents manage banks too. However, we will see below that having a fraction of unsound agents manage banks is not feasible.

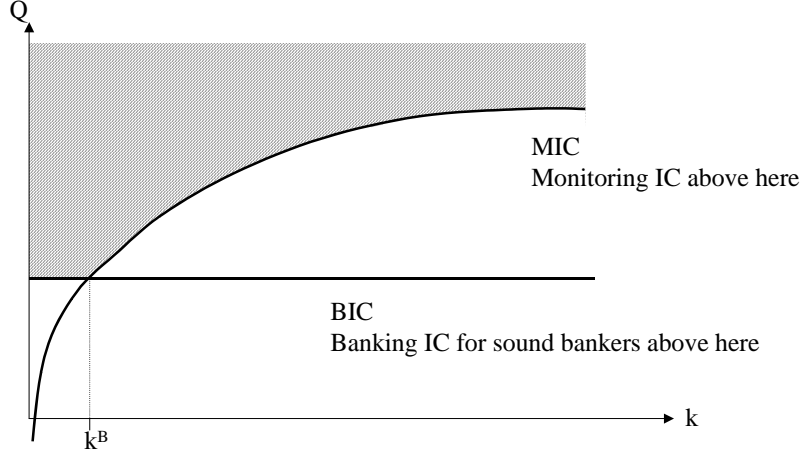


Figure 1: Sound banker participation region.

PROPOSITION 1 *There are no asymmetric pure strategy efficient equilibria in the unregulated economy.*

Proposition 1 tells us that there will be μ or N banks in any efficient unregulated economy. The case with N banks corresponds to autarky and we disregard it. In an efficient unregulated economy, banks therefore return R with probability p_H . In a symmetric equilibrium when the size of a bank is k there are $\frac{N}{k}$ banks: if a new bank enters the market, the size of every bank will therefore shrink from k to $\frac{N}{N/k+1}$. The IC constraint for unsound agents to prefer investment to running a bank is therefore $\left(Q \left(\frac{N}{N/k+1} - 1\right) + R\right) p_L \leq (R - Q) p_H$. This can be re-expressed as:

$$Q \leq B^U(k) \equiv \frac{R\Delta p}{\left(\frac{N}{N+k}\right) k p_L + \Delta p}. \quad (\text{UIC})$$

Finally, in efficient unregulated economies, to avoid autarky bank investment must be individually rational for unsound agents, which implies:

$$Q \leq UIR \equiv R \frac{\Delta p}{p_H}. \quad (\text{UIR})$$

In other words, unsound agents would prefer to manage their own projects unless the amount $Q p_H$ which they must pay to bankers in expectation is less than the incremental value $R \Delta p$ which the latter add. This constraint is illustrated in figure 2.

Proposition 2 establishes the conditions which must obtain for an efficient unregulated economy to be feasible.

PROPOSITION 2 *Define*

$$C^U \equiv \frac{R\Delta p (\mu p_H + \Delta p)}{N p_L + \Delta p (1 + \mu)}.$$

Then efficient unregulated equilibria exist if and only if $C \leq C^U$.

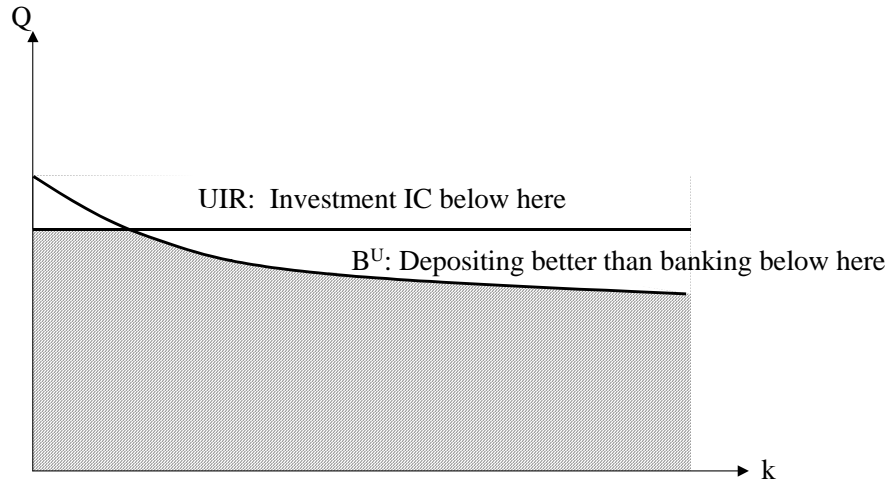


Figure 2: Unsound agent non-banking region.

The proof of this result appears in the appendix. Its intuition is as follows. When no one controls entry to the banking sector, an equilibrium with non-trivial financial intermediaries can exist only if unsound agents do not wish to run a bank. If the cost of monitoring is very low then the sound agents can squeeze out the unsound agents by charging a sufficiently low intermediation cost Q . Another way of putting this is that the sound agents' monitoring technology is so much more efficient than the unsound agents' investments that the former can offer a return on deposits which is so attractive to depositors that the latter are never tempted to run a bank themselves, no matter how large the bank: margins are too low.

When the monitoring cost is higher, however, unsound agents will wish to run banks which are sufficiently large. Recall from inspection of UIC that the reason why unsound agents only want to run large banks is that bankers receive fees per unit of deposits managed, while the opportunity cost of forgoing the opportunity to deposit is fixed. Therefore, it might be possible by limiting bank size to prevent unsound agents from setting up and running banks. We explore this possibility in the next section. However, since in the unregulated economy it is impossible for agents to commit to limit the size of their banks, entry by unsound agents can be prevented only if the fraction of informed capital $\frac{\mu}{N}$ is so large that in equilibrium banks will be sufficiently small to deter unsound licence applicants.

Figures 2 and 3 illustrate this result. Figure 2 plots the UIR and B^U lines. Depositing in banks is both individually rational and incentive compatible in the shaded region. Figure 3 combines the regions illustrated in figures 1 and 2 in the case where MIC and B^U cross: the proof of proposition 2 demonstrates that this will occur when $C > \frac{R\Delta p^2}{Np_L + \Delta p}$. Denote by k^U the bank size at which these curves cross. Larger banks than this are not feasible because the payment necessary to induce sound agents to monitor would induce all of the unsound agents to set themselves up as bankers, and thus cause degeneration into autarky. The difficulty for the unregulated economy arises because no one observes or controls the volume of deposits banks accept, so the only realisable bank size is $\frac{N}{\mu}$. Thus, as is evident from the diagram, an efficient unregulated equilibrium is feasible

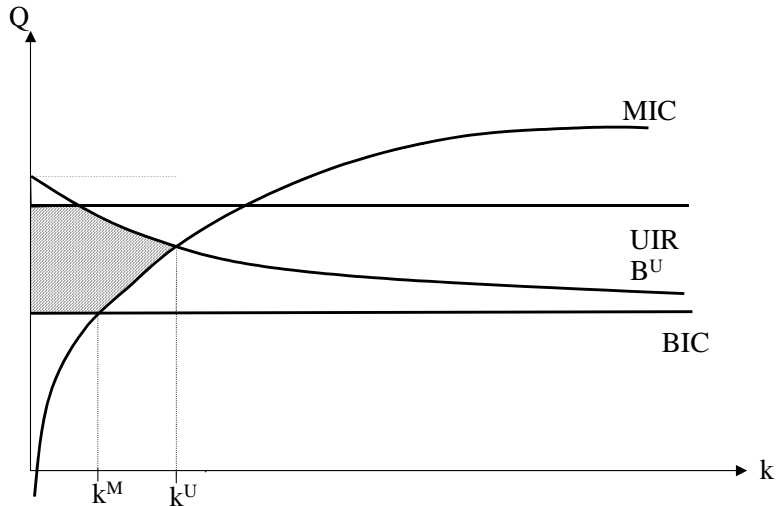


Figure 3: Unregulated equilibria with banks.

only when $\frac{N}{\mu} \leq k^U$, which reduces to $C \leq C^U$. If the cost of monitoring is too high ($C > C^U$), efficient equilibria are not possible and the only possibility in the absence of regulation is autarky, with each agent investing his own endowment.⁹

For the remainder of the paper we will assume that $C > C^U$ so that unregulated efficient equilibria are not feasible. In the next section, we examine how in this case a regulator can improve upon the unregulated situation.

3. A Regulated Banking Sector

3.1. Regulator Technology and Regulatory Game

Sound agents have valuable monitoring skills which are denied to other agents. When only sound agents run banks it follows that social welfare is maximised by maximising the size of the banking sector. When $C > C^U$ social welfare cannot be maximised in an unregulated market because the cost of motivating the sound agents' monitoring is borne by the depositors, who do not fully internalise the monitoring benefits and hence undervalue them and fail to allocate their capital optimally. In this section we introduce a welfare-maximising agent called the *regulator* whose role is to correct for this market failure by controlling entry to the banking sector.

The regulator has three skills. Firstly, she can observe bank size and can therefore impose capital adequacy ratios by limiting the size of the bank to k times the capital of the banker. Secondly, she has access to an imperfect screening technology for evaluating the soundness of licence applicants. Thirdly, after licences have been awarded and investments made the regulator can examine each bank's investment and decide whether to close the bank or leave it open. The

⁹We have illustrated the case where $C < C^U \frac{p_H}{\Delta p}$ so that B^U and BIC do not cross: note that whether or not this occurs is not germane to our discussion as it will always occur for a value of k which exceeds k^U . The crossing point $k^M \equiv \frac{B^U - C}{C_{PL}} \Delta p$ of BIC and MIC is illustrated. It is easy to show that $k^U > k^M$ as we have drawn it if and only if $R\Delta p > C$, which is equation (1).

regulator maximises social welfare by ensuring the existence of a sound banking sector and hence maximising the productive capacity of the economy. She is not *per se* concerned with questions of distribution.¹⁰

Accordingly, the regulator has three policy instruments: she can set a capital adequacy requirement, she can allocate licences, and she can audit banks at the interim stage. For simplicity we assume that enforcement of capital requirements is unproblematic and focus on the other two instruments.¹¹ We assume that the regulator awards precisely μ licences. The licence allocation procedure is as follows. The regulator firstly announces the size k of each bank. Agents decide whether or not they wish to apply for a banking licence and licence applicants form a pool from which the regulator samples repeatedly. Sampled applicants are audited: if the audit indicates that they are sound then they are awarded a licence; if it indicates that they are unsound then they are returned to the pool. We are therefore explicitly ruling out policies under which the number of licences awarded is contingent upon the number of licence applicants (e.g., “If I receive μ applications then I will award μ licences: otherwise I will award no licences”). We do so this mainly because the joint analysis of the optimal number of licences and size of banks is intractable, but our choice can also be justified on two grounds. Firstly, policies such as this one which rely on threats about off-the-equilibrium path behaviour are generally *ex post* suboptimal and are therefore difficult to impose with credibility. Secondly, such policies also rely upon a precise knowledge of μ and hence may not be robust to imprecise parameter knowledge by the regulator.

The ability of the regulator in screening banks for licences is uncertain. There are two types of regulators. The screening technology employed by *good* regulators yields the wrong answer with probability 0; thus if the regulator is good, *ex post* all banks will turn out to be sound. We assume that the technology employed by *bad* regulators yields a fraction of good banks exactly equal to their fraction in the population of licence applicants, i.e. μ/b .¹² No one (including the regulator) knows the regulator’s type. An *ex ante* probability a is assigned that she is good: we call a the regulator’s *ability*.

We assume further that after licences are awarded, any regulator can learn through monitoring and auditing about the quality of banks. Specifically, we assume that after deposits have been made and banks have invested, the expected outcome (i.e. Rp_L or Rp_H) of each bank is revealed to the regulator with probability λ . Project type revelation events are independent across banks and λ is independent of the regulator’s ability. Since λ is independent of the regulator’s ability

¹⁰Our discussion of regulatory tools and the purposes of bank supervision closely follows the description of Mishkin (2001, chapter 11, especially pp. 284 - 286).

¹¹Precise enforcement mechanisms vary between jurisdictions, but typically they rely upon the imposition of sanctions in response to breaches of the law: see Basle Committee on Banking Supervision (1997). For a theory in which regulators may have difficulty committing *ex ante* to imposing capital requirements *ex post*, see Gorton and Winton (2000).

¹²For simplicity, we ignore integer constraints. We could allow the bad regulator’s technology to give the wrong answer with probability $\frac{1}{2}$ independently across applicants which would yield the same expected number of good banks and avoid the integer constraint problem, but this would result in a random number of good banks, and thence considerably more algebraic complexity without any additional economic insight. The key idea which we wish to emphasise is that the bad regulator has a technology where the quality of the banking sector depends on the quality of the applicant pool. At the cost of reduced algebraic tractability we could endow good regulators with an imperfect technology and bad regulators with a technology which outperforms coin-tossing, but this would not affect our qualitative results.

we interpret it as a parameter reflecting the transparency of banks' accounting procedures. If bank accounting is transparent, regulators are more likely to realise early that a bank is in trouble and can react to save some of the assets for depositors.¹³ We assume that after the regulator learns the project's type, she can force the bank to liquidate its investments and distribute *all* of its funds to the bank's depositors if she wishes. Liquidation yields a certain return of Rp_L per dollar invested by the bank. It follows that the regulator will never liquidate a sound bank.¹⁴

Liquidation of unsound banks is *ex post* welfare-neutral and hence a commitment to liquidate them will be credible. Such a commitment will be *ex ante* optimal for two reasons. Firstly, unsound agents lose their endowments after liquidation and hence have a reduced incentive to apply for licences. Secondly, after liquidation depositors in unsound banks receive a share of the banker's endowment, which makes depositing more attractive.

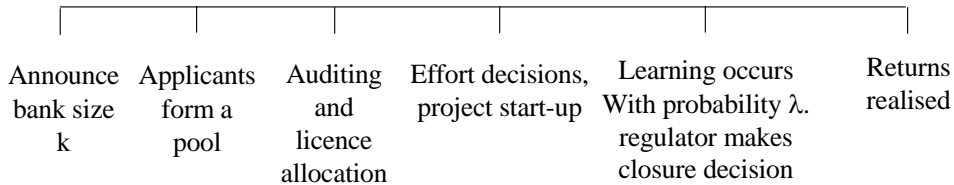


Figure 4: Time line for the regulator game.

Figure 4 illustrates the time line for the game.

Note that all regulators will set k as high as is consistent with the monitoring IC constraint for bankers and with the participation constraint for depositors so as to maximise the volume of monitored investments.

3.2. Constraints with Regulation

The regulator's screening activities do not affect the incentives of the sound agents, but her ability to perform *ex post* auditing does. This is because with probability λ the regulator now discovers that a sound agent has not monitored and forces liquidation (i.e. confiscates his capital and earnings

¹³The importance of bank transparency has been highlighted by the regulators (Basle Committee, 1998). For a description of how lack of transparent accounting can seriously hamper attempts to recover banks assets speedily, see Kane (1989a).

¹⁴This set-up can also be interpreted as a reduced form for the idea that with transparent accounting systems, the general public will learn the likely project outcome for each bank with probability λ and that they will then be able to run on the bank. Suppose that their expected payoff from running is π . If the expected outcome is Rp_L , the depositors will run on the bank in order to stake their claim to $\pi > (R - Q)p_L$ now, rather than waiting until next period. Note that they will not run on sound banks as long as $(R - Q)p_H > \pi$, which must be the case or no bank could expect to survive until its investments matured. If we keep this underlying model in mind, then the independence of λ from regulator ability seems more compelling (see Diamond and Rajan (2000) for more detail on how such a mechanism might be exploited). A system can be *ex post* transparent without the regulator having any particular skill in awarding licences *ex ante*. This interpretation also provides a role for "market discipline" in our model. We could, however, also allow λ to vary with regulator reputation. Our substantive results would be largely unaffected, but prospects would be much grimmer for regulators with poor reputations. In this respect, our model shows that forcing banks to report their earnings promptly and transparently offers a glimmer of hope for regulators in otherwise difficult circumstances.

and redistributes it to depositors).¹⁵ The incentive to monitor is thus improved, and the monitoring IC constraint becomes $(R + Q(k - 1))p_H - C \geq (1 - \lambda)(R + Q(k - 1))p_L$, or

$$Q \geq MIC(k, \lambda) \equiv \frac{Ck - R(\Delta p + \lambda p_L)}{(k - 1)(\Delta p + \lambda p_L)}.$$

The incentives of the unsound agents in the regulated economy are also altered, for three reasons. Firstly, the fact that the regulator audits banks may improve their confidence in the banking system and make them more willing to invest; secondly, the regulator sets limits on bank size which may cause rationing of banking services if they choose to invest in the banking system; and thirdly, the redistribution of liquidated banker funds renders bank depositing more attractive to them. Notwithstanding the changed incentives, we are still able to establish a result analogous to proposition 1:

PROPOSITION 3 *Provided $N > 2\mu$, there are no asymmetric pure strategy equilibria in the regulated economy.*

Proof. In the appendix. □

Proposition 3 tells us that only two belief sets are rational for unsound agents: either they believe that only sound agents will apply to the regulator for a banking licence, or they believe that every agent will apply for a banking licence. In the former case all banks will be sound, irrespective of the regulator's quality: we therefore call these beliefs *optimistic*. In the latter case the expected quality of a randomly chosen bank will be lower, because the regulator may licence some unsound banks: we call these beliefs *pessimistic*.

Proposition 4 establishes conditions under which optimistic and pessimistic expectations are possible.

PROPOSITION 4 *There exist functions $B^O(k)$, $B^P(a, k)$ and $R^{IR}(a, k)$ decreasing in k and with a common intersection point in (k, Q) space such that:*

1. *Optimistic expectations are sustainable if and only if $Q \leq B^O(k)$;*
2. *Pessimistic expectations are sustainable if and only if $Q \geq B^P(a, k)$;*
3. *Banking is individually rational for unsound agents in pessimistic economies if and only if $Q \leq R^{IR}(a, k)$.*

To the right of the intersection point, R^{IR} and B^P are increasing in a and $B^P \leq B^O \leq R^{IR}$.

Proof. In the appendix □

The three lines B^O , B^P and R^{IR} are illustrated in figure 5.

Optimistic expectations are sustainable only if an unsound agent prefers depositing to banking when all banks are sound. This is the case for sufficiently low Q , as in the first part of the

¹⁵Note that none of our substantive results would change if the regulator never learned when sound agents failed to monitor (i.e. that instead of revealing expected outcomes, λ revealed only the type of the agent running the bank). We make this assumption for modelling consistency, and also in the belief that empirically it is easier for regulators to observe *whether* a bank's projects are profitable or not than to observe *why* they are not profitable.

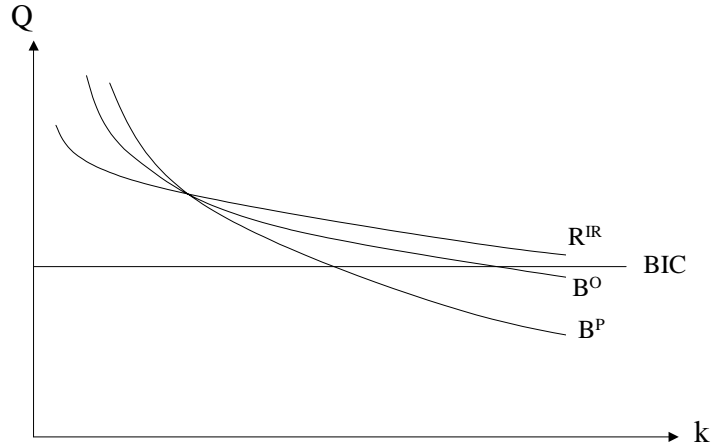


Figure 5: Regulated economy constraints.

proposition. On the other hand, pessimistic expectations are sustainable provided unsound agents prefer to apply for a banking licence when the regulator chooses banks from a pool containing every agent. This is the case when Q is high enough, as in the second part of the proposition. Part 3 follows because unsound agents will deposit rather than self-manage only for low enough Q .

Increasing the size k of the bank renders banking relatively more attractive for unsound agents and hence causes B^O and B^P to decrease. R^{IR} decreases because increases in k reduce the expected value to the depositor of any *ex post* redistribution of an unsound bankers capital. This reduces the expected income from depositing and hence reduces the maximum fee Q at which it is attractive.

To understand why the lines have a common intersection, note that with pessimistic expectations, unsound agents are indifferent along B^P between depositing and running a bank. At the intersection between B^P and R^{IR} they must therefore be indifferent between these activities and running their own projects. Hence at this intersection, unsound bankers earn Rp_L . Similarly, with optimistic expectations, unsound bankers earn Rp_L at the intersection of B^O and R^{IR} . Since unsound banker income is independent of licence applicant quality, the two intersection points must coincide.

In the absence of capital redistribution from unsound bankers, depositors prefer to invest with sound banks. To the right of the intersection point in figure 5, the per-depositor value of redistribution is too small to reverse this preference: we demonstrate below that the equilibria of our model fall in this region and hence that depositors prefer sound to unsound banks. Increased regulator ability a improves the average quality of the banking sector in pessimistic economies and hence makes depositing relatively more attractive. This serves to increase both R^{IR} and B^P .¹⁶

Since to the right of the intersection point depositors prefer sound to unsound banks, they will choose depositing over banking for higher Q with sound than unsound banks: $B^O > B^P$. To understand why $B^O < R^{IR}$, consider the income which an unsound agent makes relative to

¹⁶To the left of the intersection, a higher a reduces the chance of an *ex post* disbursement of banker capital and hence reduces the attractiveness of depositing. Hence, as a increases R^{IR} and B^P both rotate clockwise about the intersection point.

managing his own project when he deposits in a pessimistic economy. If his bank turns out to be sound, he makes a profit \mathcal{G} equal to the one which he would have made from depositing in an optimistic economy. If it turns out to be unsound, then his loss \mathcal{L} per dollar deposited equals his gain per dollar deposited from running a bank. The relative profits and losses cancel one another out along R^{IR} . In an optimistic economy, we show in the appendix that depositors are rationed and deposit a fraction $\frac{(k-1)\mu}{N-\mu}$ (equal to the size of the banking sector divided by the number of depositors) of their endowment. Alternatively, they can if they set up a bank earn \mathcal{L} on $(k-1)$ dollars. The two incomes cancel along B^O . Note that, when the regulator has no *ex ante* screening ability ($a = 0$), the probability that a depositor's bank is sound is $\frac{\mu}{N}$: in this case it follows from our discussion that the ratio of profits and losses is the same along R^{IR} and B^O , and hence that the two lines coincide. Since R^{IR} is increasing in a to the right of the intersection point, it follows that $R^{IR} > B^O$.

Finally, proposition 4 does not mention the relative preferences of agents for banking and managing their own money. We shall be concerned for the remainder of the paper with equilibria in which one of the three constraints in the proposition binds. We demonstrate in the appendix that in this case, agents prefer banking to running their own project. Hence we can disregard the possibility when the depositor IR constraint is satisfied that agents may choose to run their own project.

3.3. Optimal Policy Selection

The regulator's role is to maximise social welfare. She can adopt either of two policies. Firstly, she can limit k and adopt a *tight capital adequacy policy* so as to ensure that only sound agents find banking attractive. Secondly, she can adopt a *loose capital adequacy policy*. This will result in larger banks which will attract unsound bankers so that the average quality of banks will be lower. To understand how the policies work, define k^P and k^{MP} to be respectively the intersection points of B^P with *BIC* and *MIC*, and let k^O , k^{MO} and k^R , k^{MR} be the corresponding points for B^O and R^{IR} .

(i) Tight Regulatory Policy

The region within which the regulator can achieve the tight capital adequacy policy is illustrated in figure 6. As in the unregulated case, she requires both banking and monitoring to be incentive compatible for sound agents, so that Q and k will be selected to lie above *BIC* and *MIC*. She also requires unsound agents to prefer depositing to banking: this requires that the (k, Q) pair lies below the B^P line in the case where there are pessimistic expectations and below the B^O line when there are optimistic expectations. These cases correspond respectively to the regions shaded with horizontal and vertical lines. Note that when the regulator employs this policy, she is using capital requirements to exclude unsound agents from the banking market: in other words, to resolve an *adverse selection* problem. It is clear from the diagram that the regulator will set k equal to k^O when optimistic expectations obtain and to k^P when pessimistic expectations obtain. Furthermore, by proposition 4, k^P and k^{MP} will both decrease as a worsens, so that the maximum size for

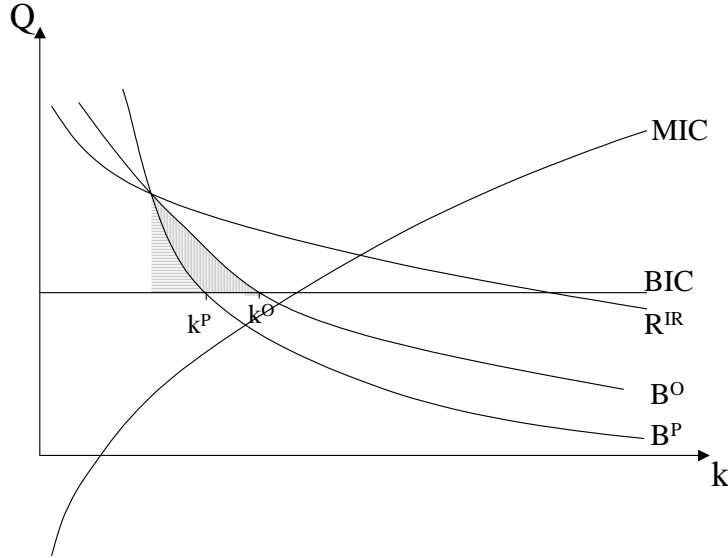


Figure 6: Tight capital adequacy policy.

the banking sector with pessimistic expectations will fall as a falls. When there are optimistic expectations, however, the size of the banking sector under tight regulation is independent of regulatory ability, as it is anticipated that only sound agents will apply for licences (and the MIC constraint does not bind) so the regulator's ability is entirely irrelevant.

(ii) Loose Regulatory Policy

Figure 7 indicates the region within which the regulator can achieve the loose capital requirements policy. With loose capital requirements, the regulator accepts that every agent will choose to apply for a banking licence. Unsound agents must still prefer depositing to running their own project, however. Hence, as in the picture, the B^P and B^O constraints will be violated, and the R^{IR} constraint will bind. (Q, k) will therefore be at the minimum of k^R and k^{MR} . For high abilities a , R^{IR} will be relatively flat and the size of banks will be k^{MR} . In this case, the MIC constraint binds and the regulator is therefore setting capital requirements in order to resolve a *moral hazard* problem. Proposition 4 demonstrates that $\min(k^R, k^{MR})$ will drop as a drops and hence that the maximum size of the banking sector with loose capital requirements will fall as regulator ability falls.

(iii) Optimal Policy Choice

In choosing between the tight and the loose capital policies identified above, the regulator is attempting to maximise the productive capacity of the economy. She must therefore weigh up the benefits which come from a large banking sector (in which sound bankers maximise the productivity of their investments) and the concomitant costs of a lower average quality of banker. The better the regulator's reputation, the larger the banking sector with loose capital requirements can be and

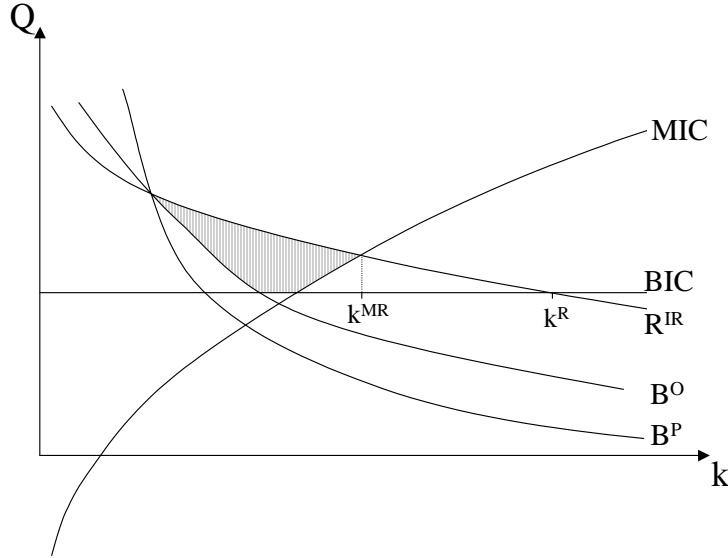


Figure 7: Loose capital adequacy policy.

the higher will be the average quality of the banks within it.

To understand how the trade-off is made, consider firstly the case with optimistic expectations. For non-trivial solutions, we require $\min(k^O, k^{MO}) < N/\mu$, since otherwise the regulator could screen out every unsound agent by setting k equal to its maximum value N/μ . We demonstrate in the appendix (lemma 1) that for sufficiently large C , $\min(k^O, k^{MO}) = k^O < N/\mu$, and we assume from now on that this is the case. As noted in section 3.3.ii, the size $\min(k^R, k^{MR})$ of a loosely regulated bank drops as the regulator's ability drops. Hence the social welfare derived from loose capital regulations drops also. Since the size k^O of a tightly regulated bank is independent of a , so is the social welfare derived from tight capital regulations. The regulator will choose loose capital requirements in order to benefit from larger banks if she has a perfect *ex ante* screening technology ($a = 1$); since R^{IR} and B^O coincide when $a = 0$ she will certainly choose tight capital requirements in this case. At some a_O^* she will therefore switch between tight and loose capital requirements.

The case with pessimistic expectations is more complex. In this case, the welfare derived from loose capital requirements is the same as in the optimistic case. However, because $k^P < k^O$, the welfare derived from tight capital regulation is lower with pessimistic expectations than with optimistic. Hence, in a pessimistic economy the regulator will certainly not switch from loose to tight expectations at a_O^* . Moreover, note from proposition 4 that *both* k^P and $\min(k^R, k^{MR})$ fall as a falls. It is not therefore obvious in this case as it is in the optimistic one that the difference between welfare levels with tight and loose capital requirements is monotonic in a and hence that there is a cross over point $a_P^* < a_O^*$ between tight and loose capital requirements. However, we are able to show in the appendix that this is indeed the case for sufficiently high C . We summarise our discussion as follows:

PROPOSITION 5

1. There exists $a_O^* > 0$ such that when optimistic expectations obtain, the regulator prefers a

tight capital adequacy policy precisely when $a < a_O^*$;

2. For sufficiently high C , there exists $a_P^* > 0$ with $a_P^* < a_O^*$ such that when pessimistic expectations obtain, the regulator prefers a tight capital adequacy policy precisely when $a < a_P^*$.

We assume for the remainder of the paper that C is high enough for part (2) of the proposition to hold.

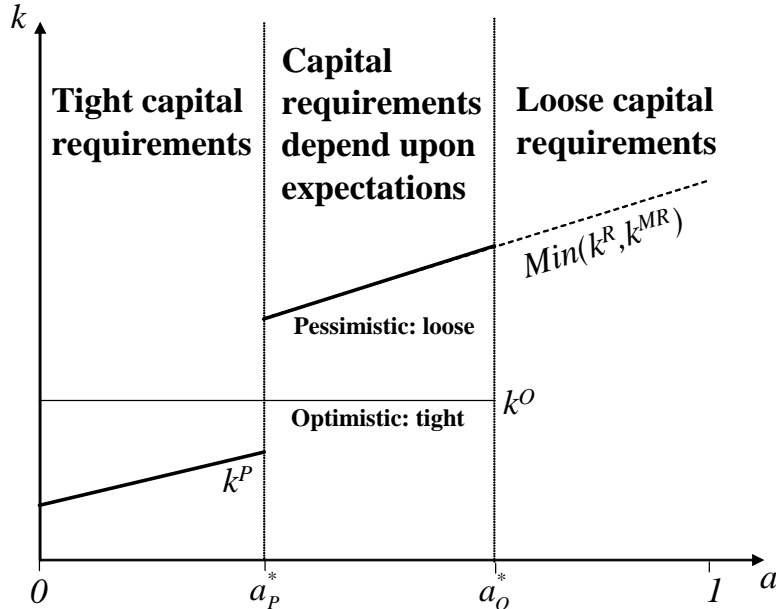


Figure 8: Bank size vs. regulator reputation.

Our analysis is illustrated in figure 8, which depicts the optimal choice of capital requirements as a function of regulator reputation. Recall that the regulator has to choose between setting loose capital requirements, in which case banks are large but of lower average quality, and setting tight requirements, in which case banks are smaller but are guaranteed to be sound. When the regulator's ability to screen banks is sufficiently high ($a > a_O^*$), the deleterious effect upon bank quality of loose capital requirements is small compared to the benefits of large bank size and the regulator always sets loose capital requirements. When the regulator has sufficiently low screening ability ($a < a_P^*$), bank quality with loose capital requirements is extremely low and the regulator therefore always sets tight capital requirements. Finally, recall that the size of a tightly regulated banking sector is higher with optimistic than with pessimistic expectations. Tight capital regulation is therefore relatively more attractive when optimistic expectations obtain. Hence for intermediate ability levels ($a_P^* \leq a \leq a_O^*$) the regulator will set tight capital requirements with optimistic expectations, and loose requirements with pessimistic expectations.

3.4. Banking Crises

Our model admits two possible sets of rationally-held (self-fulfilling) beliefs. Proposition 3 demonstrates that unsound agents can have optimistic expectations about the quality of the banking

sector, in which case they will refrain from licence application, or they can have pessimistic expectations, in which case they will all apply for a licence whenever this is desirable. Suppose that a shift in occurs from optimistic to pessimistic expectations when a tight capital adequacy policy is in place. Such a change could be interpreted as a ‘crisis of confidence’ in the banking system. Notice that this can rationally occur independently of any change in fundamentals or in the regulator’s reputation. In this case, the regulator can select one of two courses of action.

Firstly, she can elect to retain a tight capital adequacy policy, continuing to use capital requirements to solve the adverse selection problem. She will do so precisely when $a_P^*(C, \lambda)$. In this case she will react to the lowering of expectations by *tightening* capital requirements from k^O to $k^P < k^O$. In other words, she will deliberately *institute* a credit crunch as the optimal *response* to a crisis of confidence. This prediction is in contradiction to other stories in which confidence crises are a consequence of credit crunches. Our model could thus explain the credit crunch of the late 1980s when capital requirements were significantly tightened in response to concern over banks’ exposure to derivatives markets and over their losses in loans to less developed countries.

The second possible response to a crisis of confidence is to relax capital requirements and to adopt a loose capital adequacy policy. This will occur when $a_P^* < a < a_O^*$. In this case the regulator allows expectations to become ‘self-fulfilling’. The quality of the banking system declines but its size expands. Our model thus demonstrates that relatively strong regulators will elect to fall back upon their reputation when there is public concern over the quality of banks.

One could also consider a simple extension of our model where the regulator is unsure *ex ante* whether the public’s expectations will be optimistic or pessimistic and has to choose her regulatory policy before they are revealed to her. Then assuming that the regulator’s reputation is sufficiently poor that she wishes to set capital levels to solve the adverse selection problem, two forms of regulation are possible. The regulator can hope for optimistic expectations and follow a looser regulatory policy ($k = k^O$) which will maximise the size of banks and so allow the largest possible amount of funds to be channelled into profitable investments, presumably promoting faster economic growth. But if she does so the economy will be vulnerable to panics if expectations turn out instead to be pessimistic. Alternatively she can follow a tighter regulation policy ($k = k^P$) which ensures that panics will not occur despite her poor reputation for auditing, but this means that when expectations are optimistic the banking sector is inefficiently small, and so output is inefficiently low. So the regulator faces a trade-off between inefficiently limiting production and avoiding crises of confidence. It should be clear that it may in fact be optimal to allow the economy to be vulnerable to panics if these occur with sufficiently low probability and if the regulator expects to be able to react quickly enough by changing policy. Thus in our model a banking crisis does not necessarily constitute evidence of bad regulatory policy.

4. Conclusion

In recent years, banking crises have become increasingly common and increasingly expensive to deal with.¹⁷ Prudential regulation of banks is supposed to prevent or at least to reduce the frequency

¹⁷See Hellman, Murdock and Stiglitz (2000) for a discussion of the increasing costs of banking crises and for an explanation based on financial liberalisation.

of such crises. In this paper we have examined the role of the regulator in the auditing of banks and in the setting of capital requirements in preventing crises. In doing this we departed from the existing debate in the literature, which has largely ignored the impact of regulator reputation on policy. We have shown that *if public confidence in the regulator's ability to detect bad banks through audit is sufficiently high then crises will not occur*. Capital adequacy requirements are then useful mainly in restricting bank size to be small enough to avoid moral hazard problems. Such regulation can be looser the better is the regulator's reputation for auditing banks. We also show that capital regulation can be looser in economies where accounting procedures are more transparent.

On the other hand, if the regulator's reputation is poor, then crises may occur. The regulator then has several policy options. She can follow a loose regulation policy which will maximise the size of banks and so allow the largest possible amount of funds to be channelled into profitable investments. But if she does so, the quality of the banking sector will be low. Alternatively she can follow a tight regulation policy which raises the average quality of the banking system, at the cost of reducing its size. Other things being equal, poor regulators must always follow tighter capital regulation policy than good regulators.

Existing international regulation of bank capital focuses on the need to ensure a "level playing field" to ensure fair competition among financial institutions from different countries. Our analysis suggests that this emphasis may be misplaced, since within a given country it is optimal to have stricter regulations when expectations are pessimistic, when accounting is less transparent, and the regulator's reputation for identifying incompetent banks gets worse. In other words, a less competent regulator should impose tighter capital adequacy requirements. This suggests that other things being equal we should not impose a uniform standard across all countries, as is currently *de facto* the case with the Basle accord. Such a one-size-fits-all approach is likely to precipitate crises in countries with poor regulators and inefficiently limit bank size in economies with very competent regulators. Instead, a better policy would be to tie the laxity of capital requirements in an economy to a measure of the 'reputation' of that economy's banking regulator for rooting out problems before they occur. For example, if a country has experienced few bank collapses in the past, this country could be allowed to have looser capital requirements than one which has experienced frequent banking crises. Although outside the scope of this paper, one can also imagine that such a structure might have other beneficial effects, such as enhancing the incentives for efficient oversight by banking regulators and for 'peer-monitoring' among banks. Indeed, *de facto* some regulators with less strong reputations for oversight have already moved in this direction by imposing tighter regulation than the Basle Accord requires. This fact may seem difficult to rationalise if one thinks of regulators as trying to improve the position of their own financial institutions in the world; yet makes perfect sense within the context of our theory, because regulators can substitute for the public's lack of confidence in their lack of screening ability by imposing tighter regulation.

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Appendix

Proof of Proposition 1

Consider an efficient unregulated economy in which b banks exist and assume that an equilibrium exists for $N > b > \mu$. Let $\beta_U(b) \equiv (Q(\frac{N}{b} - 1) + R)p_L$ be the expected income which an unsound banker earns in a b bank economy and let $\eta_b \equiv \frac{\mu}{b}p_H + (1 - \frac{\mu}{b})p_L$ be the unconditional probability that a bank in such an economy earns R on its investments.

Unsound bankers must prefer bank management to investment in a bank, so that $\beta_U(b) \geq (R - Q)\eta_{b-1}$. Equivalently,

$$Q \geq \frac{R\mu b \Delta p}{N(b-1)p_L + \mu b \Delta p}. \quad (2)$$

Depositors must prefer bank investment to establishing another bank: $(R - Q)\eta_b \geq \beta_U(b+1)$, or

$$Q \leq \frac{R\mu(b+1)\Delta p}{Nb p_L + \mu(b+1)\Delta p}. \quad (3)$$

Equations 2 and 3 can be satisfied simultaneously provided

$$\frac{R\mu b \Delta p}{N(b-1)p_L + \mu b \Delta p} \leq \frac{R\mu(b+1)\Delta p}{Nb p_L + \mu(b+1)\Delta p}.$$

This reduces to $b^2 - 1 \geq b^2$ which is a contradiction. It follows that any efficient equilibrium must have $b = \mu$ or $b = N$, as required.

Proof of Proposition 2

An efficient equilibrium can exist provided there exists Q which satisfies conditions MIC, BIC, UIC and UIR. Note firstly that $MIC(1) = -\infty$, $MIC'(k) > 0$ and $MIC(k) \rightarrow \frac{C}{\Delta p} > BIC$ as $k \rightarrow \infty$ and secondly that $B^U(1) = \frac{R\Delta p}{(\frac{N}{N+1})p_L + \Delta p} > UIR$, $\frac{d}{dk}B^U(k) < 0$ and $B^U(k) \rightarrow \frac{R\Delta p}{Np_L + \Delta p}$ as $k \rightarrow \infty$. An efficient unregulated equilibrium is guaranteed to exist provided MIC is always below UIR and below B^U . Since B^U crosses UIR from above this is equivalent to the requirement that $\frac{C}{\Delta p} \leq \frac{R\Delta p}{Np_L + \Delta p}$, or $C \leq \frac{R\Delta p^2}{Np_L + \Delta p}$. If $C > \frac{R\Delta p^2}{Np_L + \Delta p}$ then MIC and B^U cross at $k^U \equiv \frac{N\Delta p(Rp_H - C)}{C(Np_L + \Delta p) - R\Delta p^2}$. An efficient equilibrium can exist provided $k < k^U$. In such an equilibrium, $k = \frac{N}{\mu}$ so the existence requirement is $\frac{N}{\mu} \leq k^U$, which reduces to $C \leq C^U$, as required.

Proof of Proposition 3

Suppose that b agents apply for a licence in an efficient economy and that the regulator has ability a . Let

$$\alpha_b = a + (1 - a)\frac{\mu}{b}$$

be the probability that an arbitrary bank is sound and let r_b be the expected payout from investment in a bank:

$$r_b = \alpha_b(R - Q)p_H + (1 - \alpha_b)\left\{(1 - \lambda)(R - Q)p_L + \lambda R p_L \frac{k}{k - 1}\right\}.$$

The first of these terms is the expected return from investing in a sound bank. The expression in curly brackets is the return from investing in an unsound bank: the first of the terms gives the expected return if the bank's quality is not detected by the regulator and the second includes the redistribution of banker funds in the event that the bank's low quality is detected. Finally, note that the income which unsound bankers earn from running an unsound bank is $(1 - \lambda)(R + (k - 1)Q)p_L$.

Let R_b be the proportion of wealth which a depositor will invest in a bank given that the regulator is bad. As we demonstrate in the proof of proposition 4, $R_b = \frac{(\mu-1)\mu}{N-2\mu+\frac{\mu^2}{b}}$. In any asymmetric pure strategy efficient equilibrium, unsound depositors must prefer not to become bankers and unsound bankers must prefer not to become depositors. In other words,

$$R_b r_b + (1 - R_b) R p_L \geq (1 - \lambda) [R + (k - 1) Q] p_L \geq R_{b-1} r_{b-1} + (1 - R_{b-1}) R p_L. \quad (4)$$

When an unsound agent applies for a licence, he knows that he will be unsuccessful and hence will be a depositor if $a = 1$. It follows that it suffices to show that 4 cannot be satisfied when $a = 0$. Straightforward manipulation yields:

$$\begin{aligned} \frac{\partial}{\partial b} [R_b (r_b - R p_L) + R p_L]_{a=0} &= \frac{\mu^2 (k - 1)}{b^2 \left(N - 2\mu + \frac{\mu^2}{b} \right)} \left\{ \left[(R - Q) (\Delta p + p_L) - p_L R \lambda \frac{k}{k - 1} \right] \left(\frac{\mu^2}{(N - 2\mu) b + \mu^2} - 1 \right) \right. \\ &\quad \left. + \frac{\mu}{N - 2\mu + \frac{\mu^2}{b}} \left[(1 - \lambda) (R - Q) p_L - \frac{R p_L}{k - 1} (k (\lambda + 1) - 1) \right] \right\}. \end{aligned}$$

Since $N > 2\mu$, the first of these terms is clearly negative. The second term has the same sign as $(1 - \lambda)(R - Q)p_L - \frac{R p_L}{k-1}(k(\lambda + 1) - 1) < (R - Q)p_L - R p_L \frac{k}{k-1} < 0$: this concludes the proof.

Proof of Proposition 4

Deposit rationing – If the regulator chooses to restrict k , this may result in equilibrium in deposit rationing. We start by considering its effect. We assume that when the demand for deposit contracts exceeds their availability, all depositors invest an equal proportion of their funds in a bank and self-manage the remainder. Note that in equilibrium no sound agent without a licence will wish to deposit, since at best he will deposit with another sound agent who will charge Q for managing his deposit. Suppose that in addition, all unsound agents without a licence will wish to deposit: this is the case in the equilibria which concern us. If there are μ banks of which $s \leq \mu$ are sound then unsound agents will manage to deposit only the following fraction of their endowment:

$$\frac{(k - 1) \mu}{N - \mu - (\mu - s)} = \frac{(k - 1) \mu}{N - 2\mu + s}; \quad (5)$$

the numerator of this expression is the volume of permitted deposits, equal to the total size of the banking sector less the endowment of the bankers, and the denominator is the number of agents wishing to deposit, equal to the number of agents without licences minus the number of sound agents without licences.

Alternative notation – It is convenient when reasoning about the regulated economy to define the quantities \mathcal{L} and \mathcal{G} to be respectively the expected loss and gain which an unsound agent experiences when making a deposit in an unsound or a sound bank, compared to managing his own project. Then

$$\begin{aligned}\mathcal{L} &= Rp_L - \left\{ (R - Q)(1 - \lambda)p_L + \lambda Rp_L \frac{k}{k-1} \right\}, \\ \mathcal{G} &= (R - Q)p_H - Rp_L = R\Delta p - Qp_H.\end{aligned}$$

With this notation, the expected return to an unsound agent from managing a bank is

$$Rp_L + \mathcal{L}(k - 1),$$

the expected income from depositing when there are optimistic expectations is

$$Rp_L + \frac{(k - 1)\mu}{N - \mu}\mathcal{G},$$

and the expected income from depositing when pessimistic expectations obtain is

$$Rp_L + \frac{(k - 1)\mu}{N - \mu} \left[a\mathcal{G} + \frac{(1 - a)}{N - \mu} (\mu\mathcal{G} - (N - \mu)\mathcal{L}) \right].$$

The first of the terms in the square brackets corresponds to the case where the regulator is good and the second to the case where the regulator is bad. In this case, note that the rationing fraction is modified in line with equation 5 and that the depositor will make a profit or a loss, according to the type of banker which he encounters.

Constraints – We now derive the constraints in the proposition. Optimistic expectations are sustainable only if unsound agents prefer bank investment to licence application when it is anticipated that all banks are sound:

$$\frac{\mu}{N - \mu}\mathcal{G} \geq \mathcal{L}. \quad (\text{OPIC})$$

Rearranging gives us the following equivalent expression in (k, Q) space:

$$Q \leq B^O(k) \equiv \frac{R \left(\mu\Delta p + \lambda p_L \left(\frac{N - \mu}{k - 1} \right) \right)}{N(1 - \lambda)p_L + \mu(p_H - (1 - \lambda)p_L)}.$$

Similarly, pessimistic beliefs are sustainable only if unsound agents prefer to apply for a banking licence rather than to invest in a bank when they anticipate that all agents will apply for a banking licence:

$$\mathcal{L}(N - a\mu) \geq \mathcal{G}\mu \left(\frac{aN - 2a\mu + \mu}{N - \mu} \right). \quad (\text{PESSIC})$$

This equation can similarly be rearranged to give the following necessary condition in (k, Q) space for pessimistic beliefs to obtain:

$$Q \geq B^P(a, k) \equiv \frac{R((k - 1)\mu(a(N - 2\mu) + \mu)\Delta p + \lambda(N - \mu)(N - a\mu)p_L)}{(k - 1)(\mu(a(N - 2\mu) + \mu)p_H + (1 - \lambda)(N - \mu)(N - a\mu)p_L)}.$$

The IR condition for unsound agents to invest in a bank rather than to run their own project when there are pessimistic beliefs is the following:

$$\frac{aN - 2a\mu + \mu}{N - \mu}\mathcal{G} \geq (1 - a)\mathcal{L}, \quad (\text{RIR})$$

or

$$Q \leq R^{IR}(a, k) \equiv R \frac{(aN - 2a\mu + \mu) \Delta p + \frac{\lambda p_L}{k-1} (1-a)(N-\mu)}{p_H (aN - 2a\mu + \mu) + p_L (1-a)(N-\mu)(1-\lambda)}.$$

Finally, we define $B^{OP}(a, k)$ to be the locus of points in (k, Q) space along which unsound agents are indifferent between banking and running their own projects. Along B^{OP} , $Rp_L + \mathcal{L}(k-1) = Rp_L$ or

$$\mathcal{L} = 0. \quad (\text{BOP})$$

Hence $B^{OP}(a, k) = \frac{R\lambda}{(k-1)(1-\lambda)}$.

We can re-write the BIC constraint as follows:

$$\mathcal{G} = R\Delta p - C. \quad (\text{BIC1})$$

Common intersection point – It is clear from equations OPIC, PESSIC, BOP and RIR that the four lines all pass through $(\mathcal{L} = 0, \mathcal{G} = 0)$, or $\left(Q = R \frac{\Delta p}{p_H}, k = 1 + \lambda \frac{p_H}{\Delta p(1-\lambda)}\right)$. Equation BIC1 implies that $\mathcal{G} > 0$ on *BIC* and hence that intersection point must occur for $Q > BIC$, as in figure 5.

Constraints decreasing in k – To differentiate with respect to k , note that $\frac{d\mathcal{L}}{dk} = \frac{dQ}{dk} (1-\lambda)p_L + \lambda R \frac{p_L}{(k-1)^2}$ and $\frac{d\mathcal{G}}{dk} = -\frac{dQ}{dk} p_H$, whence, using OPIC, $\frac{dB^{OP}}{dk} \left[(1-\lambda)p_L + \mu \frac{p_H}{N-\mu} \right] + \lambda R \frac{p_L}{(k-1)^2} = 0$ and $\frac{dB^{OP}}{dk} < 0$. The result for the other lines follows similarly.

R^{IR} and B^P increasing in a – Differentiate R^{IR} and B^P with respect to a and manipulate to obtain:

$$\begin{aligned} \frac{\partial}{\partial a} R^{IR}(a, k) &= \frac{R(N-\mu)^2 p_L \left((1-\lambda) \Delta p - \frac{\lambda p_H}{k-1} \right)}{\left((a(N-2\mu) + \mu) p_H + (1-a)(1-\lambda)(N-\mu)p_L \right)^2}; \\ \frac{\partial}{\partial a} B^P(a, k) &= \frac{R(N-\mu)^3 \mu p_L \left((1-\lambda) \Delta p - \frac{\lambda p_H}{k-1} \right)}{\left(\mu(a(N-2\mu) + \mu) p_H + (1-\lambda)(N-\mu)(N-a\mu)p_L \right)^2}. \end{aligned}$$

Both expressions are positive precisely when $k > 1 + \lambda \frac{p_H}{\Delta p(1-\lambda)}$: in other words, to the right of the intersection point.

$B^{OP} < B^P \leq B^O \leq R^{IR}$ – Straightforward though tedious manipulations yield the following:

$$\begin{aligned} B^P - B^{OP} &= \frac{R\mu(a(N-2\mu) + \mu) \left((1-\lambda) \Delta p - \frac{\lambda p_H}{k-1} \right)}{(1-\lambda) (\mu(a(N-2\mu) + \mu) p_H + (1-\lambda)(N-\mu)(N-a\mu)p_L)}; \\ B^O - B^P &= \frac{(1-a) R(N-\mu)^2 \mu p_L \left((1-\lambda) \Delta p - \frac{\lambda p_H}{k-1} \right)}{(\mu p_H + (1-\lambda)(N-\mu)p_L) (\mu(a(N-2\mu) + \mu) p_H + (1-\lambda)(N-\mu)(N-a\mu)p_L)}; \\ R^{IR} - B^O &= \frac{a R(N-\mu)^2 p_L \left((1-\lambda) \Delta p - \frac{\lambda p_H}{k-1} \right)}{(\mu p_H + (1-\lambda)(N-\mu)p_L) \left((a(N-2\mu) + \mu) p_H + (1-a)(1-\lambda)(N-\mu)p_L \right)}. \end{aligned}$$

Once again, each of these expressions is positive precisely to the right of the intersection point: when $k > 1 + \lambda \frac{p_H}{\Delta p(1-\lambda)}$. Note moreover that $(R^{IR} - B^O)|_{a=0} \equiv 0$.

Note that, as stated in the text, whenever one of (OPPIC), (PESSIC) and (RIR) is binding to the right of the intersection point $(\mathcal{L} = 0, \mathcal{G} = 0)$, unsound agents strictly prefer banking to running their own project and hence that we can ignore the constraint (BOP) for the remainder of the paper.

LEMMA 1 *If condition (6) is satisfied then $k^O < k^{MO} < N/\mu$; if it is not then the inequalities are all reversed:*

$$C \geq \frac{R\mu p_H (\Delta p + \lambda p_L)}{\mu p_H + (1 - \lambda) (N - \mu) p_L}. \quad (6)$$

Proof. Let k^M be the intersection between *MIC* and *BIC*, i.e the bank size at which sound agents' monitoring constraint becomes stronger than their participation constraint. It is clear from inspection of figure 5 either $k^O < k^{MO} < k^M$ or $k^O > k^{MO} > k^M$.

Setting $Q = C/p_H$ in B^O and *MIC* (k, λ) gives us

$$\begin{aligned} k^M &= 1 + \frac{((R\Delta p + \lambda p_L) - C) p_H}{(1 - \lambda) C p_L}; \\ k^O &= 1 + \frac{\lambda R (N - \mu) p_L p_H}{C (1 - \lambda) (N - \mu) p_L - (R\Delta p - C) \mu p_H}. \end{aligned}$$

Simple manipulations give us $k^O < k^M$ iff $k^M < \frac{N}{\mu}$, which is true iff condition (6) is satisfied. \square

Proof of Proposition 5

Part (1) of the proposition follows by the argument in the text.

For part (2), note firstly that if a_P^* exists, it must be less than a_O^* since $B^P < B^O$. Now define the *welfare gap* $G(a)$ to be the difference between welfare in tightly and loosely regulated economies when pessimistic expectations obtain:

$$G(a) = (k^P - 1) - (\min(k^R, k^{MR}) - 1) \frac{\mu + a(N - \mu)}{N}.$$

The regulator will elect to set tight capital requirements with pessimistic expectations precisely when $G(a) > 0$. So to prove part (2), it is sufficient to demonstrate that for sufficiently high C , $G'(a)$ is negative, and that $G(0) > 0$.

We firstly compute k^P , k^R and k^{MR} , by finding the intersection points of B^P with *BIC* and of R^{IR} with *BIC* and *MIC* respectively:

$$\begin{aligned} k^P &= 1 + \frac{R\lambda (N - \mu) (N - a\mu) p_H p_L}{C (1 - \lambda) (N - \mu) (N - a\mu) p_L - (\mu (a(N - 2\mu) + \mu) p_H (R\Delta p - C))}; \\ k^R &= 1 + \frac{(1 - a) R\lambda (N - \mu) p_H p_L}{C (1 - \lambda) (N - \mu) (1 - a) p_L - p_H ((a(N - 2\mu) + \mu) (R\Delta p - C))}; \\ k^{MR} &= \frac{R (N - a\mu) p_L (\Delta p + \lambda p_L)}{(1 - a) C (1 - \lambda) (N - \mu) p_L - (a(N - 2\mu) + \mu) (R\Delta p (\Delta p + \lambda p_L) - C p_H)}. \end{aligned}$$

We use these to determine the welfare gap. Firstly, when $k^R < k^{MR}$, substitution and extensive manipulation yields

$$\begin{aligned} G(a)|_{k^R < k^{MR}} &= \frac{R\lambda (N - \mu) (N - a\mu) p_H p_L}{C (1 - \lambda) (N - \mu) (N - a\mu) p_L - (\mu (a(N - 2\mu) + \mu) p_H (R\Delta p - C))} \\ &\quad - \left(\frac{(1 - a) R\lambda (1 - \frac{\mu}{N}) (a(N - \mu) + \mu) p_H p_L}{C (1 - a) (1 - \lambda) (N - \mu) p_L - ((a(N - 2\mu) + \mu) p_H (R\Delta p - C))} \right). \end{aligned}$$

Whence further manipulation yields, when $k^R < k^{MR}$,

$$G'(a)|_{k^R < k^{MR}} = R\lambda(N - \mu)^2 p_H p_L \times \left\{ - \left(\frac{a(a(N - 2\mu) + 2\mu) p_H (R\Delta p - C) + (1 - a)^2 C (1 - \lambda) (N - \mu) p_L}{N(C(1 - a)(1 - \lambda)(N - \mu) p_L - ((a(N - 2\mu) + \mu) p_H (R\Delta p - C)))^2} \right) + \frac{(N - \mu) \mu p_H (R\Delta p - C)}{(C(1 - \lambda)(N - \mu)(N - a\mu) p_L - (\mu(a(N - 2\mu) + \mu) p_H (R\Delta p - C)))^2} \right\}. \quad (7)$$

When $k^R > k^{MR}$, manipulation again yields the following:

$$G(a)|_{k^R > k^{MR}} = \frac{R\lambda(N - \mu)(N - a\mu) p_H p_L}{C(1 - \lambda)(N - \mu)(N - a\mu) p_L - (\mu(a(N - 2\mu) + \mu) p_H (R\Delta p - C))} - \frac{a(N - \mu) + \mu}{N} \times \left\{ -1 + \frac{R(N - a\mu) p_L (\Delta p + \lambda p_L)}{C(1 - a)(1 - \lambda)(N - \mu) p_L - (a(N - 2\mu) + \mu) (R\Delta p (\Delta p + \lambda p_L) - C p_H)} \right\},$$

and

$$G'(a)|_{k^R > k^{MR}} = \frac{N - \mu}{N} + \frac{R\lambda(N - \mu)^3 \mu p_H^2 (R\Delta p - C) p_L}{(C(1 - \lambda)(N - \mu)(N - a\mu) p_L - (\mu(a(N - 2\mu) + \mu) p_H (R\Delta p - C)))^2} - \frac{(a(N - \mu) + \mu)}{N} \frac{R(N - \mu)^2 (R\Delta p - C) p_L (\Delta p + \lambda p_L)^2}{(C(1 - \lambda)(1 - a)(N - \mu) p_L - (a(N - 2\mu) + \mu) (R\Delta p (\Delta p + \lambda p_L) - C p_H))^2} - \frac{(N - \mu)}{N} \frac{R(N - a\mu) p_L (\Delta p + \lambda p_L)}{C(1 - \lambda)(1 - a)(N - \mu) p_L - (a(N - 2\mu) + \mu) (R\Delta p (\Delta p + \lambda p_L) - C p_H)}. \quad (8)$$

Note that when $a = 0$, R^{IR} coincides with B^O , and hence that $k^R < k^{MR}$. Hence:

$$G(0) = \frac{R\lambda\mu \left(1 - \frac{\mu}{N}\right) p_H p_L}{C(1 - \lambda)(N - \mu) p_L - \mu p_H (R\Delta p - C)} + \frac{R\lambda(N - \mu) p_H p_L}{C(1 - \lambda)(N - \mu) p_L - \mu \frac{\mu}{N} p_H (R\Delta p - C)}.$$

For C sufficiently close to its maximum value $R\Delta p$ this is clearly positive, as required.

Finally, we require $G'(a)$ to be negative for sufficiently high C . Substituting into equations (7) and (8) yields the following in both cases:

$$G'(a)|_{C=R\Delta p} = -\frac{\lambda(N - \mu) p_H}{N(1 - \lambda) \Delta p} < 0,$$

as required.