The Role of Capital Adequacy Requirements in Sound Banking Systems

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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 two tools at her disposal to combat these problems - she can audit banks to learn their type prior to giving them a licence, and she can impose capital adequacy requirements. When the regulator has a strong reputation for screening she uses capital requirements to combat moral hazard problems. For less competent regulators, capital requirements substitute for screening ability. In this case the banking system exhibits multiple equilibria so that crises of confidence in the banking system can occur. We also show that in either case, a system of deposit insurance funded through general taxation will be welfare-improving and will allow capital requirements to be eased.

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In a world with perfect financial markets, capital structure and hence capital regulation are irrelevant (Modigliani and Miller, 1958; Berger, Herring and Szegö, 1995). What then do prudential capital requirements accomplish in the banking sector? The existing literature on this subject is concerned largely with two effects: their ability to reduce risk-shifting by bankers whose assets are insured (Rochet, 1992) and their role in preventing destructive bank runs (Diamond and Dybvig, 1983 ; Diamond and Rajan, 2000). In this paper we consider a model in which reputation is necessary both because bankers are subject to moral hazard and because there is an adverse selection problem between competent and incompetent bankers. Regulators with an adequate technology for auditing incompetent bankers will use capital requirements to combat moral hazard problems in the banking sector, in line with the existing literature; for other regulators, capital requirements can substitute for a poor auditing technology. In the latter case the banking sector will exhibit financial fragility as regulators must respond to depositor pessimism with tighter capital requirements.

In our model there are two types of agents in the economy: "sound" agents who can at a cost monitor their investments in order to increase the probability of a successful outcome; and "unsound" agents who are incapable of such monitoring. Monitoring by sound agents is unobservable and hence must be rewarded. In addressing the problem of moral hazard by sound agents, such rewards render banking an attractive pursuit for unsound agents and hence exacerbate the adverse selection problem which exists between the two types of agent.

We show that in such an environment, an unregulated economy is feasible if and only if either the fraction of informed capital is sufficiently high or the cost of monitoring is sufficiently low. It is otherwise impossible to reconcile the adverse selection and moral hazard problems and the economy will disintegrate into "autarky" or extreme disintermediation.

Banking increases the productivity of the economy and hence is welfare-increasing. If informed capital is scarce and the cost of monitoring is high there is therefore a role for a regulator. The regulator attempts to maximise the volume of deposits managed by sound agents who perform monitoring, subject to the requirement that bank investment must be attractive to depositors. The regulator has two tools at her disposal. Firstly, she can audit agents prior to awarding them a banking licence. The audit reveals the applicant's type with some probability, so that the regulator can use the results of her audit to select among licence applicants. Secondly, she can impose and enforce capital adequacy requirements on banks.

When public confidence in the regulator is sufficiently high, depositors will be satisfied that auditing resolves the adverse selection problem and hence will be prepared to invest in the banking sector, provided monitoring occurs. In this case the role of capital adequacy requirements is to resolve a moral hazard problem. By limiting the size of banks, the regulator ensures that they have enough of their own capital at stake that they do not wish to gamble on the low NPV (but less privately costly) option of not monitoring their investments. Thus in enforcing capital requirements, the regulator provides the banks with a commitment technology to reassure depositors (who cannot observe bank size before they decide to deposit) that banks are indeed monitoring their investments. This regulatory role is consistent with the existing literature. But we also show that regulators with poor reputations who cannot rely upon their auditing ability to resolve the adverse selection problem can use capital adequacy requirements for this purpose. Relative to their more competent peers, regulators with poor repuations must tighten capital adequacy requirements: this will render banking unattractive to unsound agents. This policy is costly because it reduces the amount of capital invested by good banks, whose investments are more productive than those of other agents. We therefore demonstrate that the role, and the required severity, of capital adequacy requirements depends upon the perceived competence of the banking regulator. Thus the maintenance of public confidence in the regulator has a direct impact on the amount of economic activity in the economy: if the preception of the regulator's auditing ability falls, the regulator is forced to reduce the size of the banking sector by tightening capital requirements in order to avoid disintermediation. At the critical ability level where the regulator switches from solving the moral hazard to the adverse selection problem, a small reduction in regulator ability will result in a discrete drop in the size of the banking sector.

We also show that when the regulator is using capital adequacy to substitute for poor auditing ability, there are multiple rational expectations equilibria depending on whether agents have optimistic or pessimistic expectations about the pool of agents which will apply for a licence. If an uninformed agent expects only informed agents to apply for a banking licence, then he anticipates a high quality of bank and so prefers to deposit his funds with a bank and not to apply for a licence. This equilibrium is constrained Pareto efficient. If on the other hand, agents are pessimistic about the pool of licence applicants, expected bank quality is low and so uninformed agents would prefer to apply for a licence to run a bank than to invest in a bank, confirming the low quality of applicants. Thus if and only if the regulator's reputation is sufficiently poor, the economy is vulnerable to panics whereby for given fundamentals the banking system will collapse into autarky if expectations become pessimistic. If such a crisis occurs then contrary to existing received wisdom, the relevant response is to *tighten* capital adequacy requirements further to remove the uninformed agents' incentives to apply for a licence. The regulator can avoid crises altogether by always having very tight capital requirements, but during periods when expectations are optimistic such a policy inefficiently constrains the size of the banking sector by limiting the productive investments which informed agents can make. Thus for regulators with poor reputations there is a clear trade-off between avoiding crises and increasing the extent of productive intermediation.

We also examine the impact of deposit insurance in our setting. We show that a deposit insurance scheme funded through general taxation is welfare-enhancing in our framework. This is because from a welfare perspective the banking system is too small because agents who run banks must be given a rent in order that they have an incentive to exert monitoring effort, and depositors do not take this rent into account when withdrawing their funds. A deposit insurance scheme effectively subsidises agents who choose to invest in banks and thus corrects this externality. Thus in contrast to the existing literature, we show that a deposit insurance scheme allows a welfare-enhancing loosening of capital requirements and an expansion of the banking sector.

In identifying the relationship between capital requirements and regulator reputation, we extend the existing literature in this field. Boot and Thakor (1993) consider the distortionary effect which a selfish concern with perceived reputation can have upon regulatory behaviour, but do not examine the dependence upon reputation of optimal policy. Morrison (2000) examines the effect of regulator reputation upon the optimal mix of deposit insurance provision and bank charter value when there is no adverse selection problem. The difficulties which excessive banking sector competition causes are also examined by Hellman, Murdock and Stiglitz (2000), who show that when competition is intense, Pareto optimal outcomes may be feasible in the presence of moral hazard only when capital requirements are supplemented with deposit rate ceilings. Giammarino, Lewis and Sappington (1993) examine the effects of adverse selection when the regulator is compelled to offer deposit insurance, while Gorton and Winton (1995) suggest that the lemons problem may be a rationale for allowing risky banks to exist.

The remainder of this paper is organised as follows. Section 1 describes the agents in the economy and describes the circumstances in which regulation of the banking sector is necessary. Section 2 describes the regulator and derives her optimal policy as a function of both her regulation and the beliefs which obtain in the economy. Section 3 examines the welfare consequences of a deposit insurance scheme which is funded out of general taxation. Section 4 contains concluding remarks.

1 An Unregulated Banking Sector

We consider an economy which contains N risk neutral agents and several projects. Each agent has an initial endowment of \$1 which will be deployed in a project. All projects return 0 (failure) or R (success). If a project is not monitored then it is less likely to succeed and returns R with probability $p_L > 0$. 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*. Agents know their type, but this is not publicly observable. We assume that monitoring is efficient:

$$\Delta pR > C, \tag{1}$$

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

Projects are scaleable so that instead of managing their own project, an agent can deposit his endowment with another agent, so that the latter can use it to augment the size of his own project. We call an intermediary which is established to accept such deposits for this purpose a *bank*: the managing agent accepting the deposits is a *banker*. The dollar amount of other agents' capital which a bank receives to invest on their behalf is denoted by $k - 1$. Thus the total amount of investment by such a bank will be k: his own dollar and the other agents' capital. Investment by banks and the return on investments is verifiable so that bankers cannot steal project returns and cannot invest deposited funds with other banks. Our accounting convention is as follows. If the bank's investment succeeds, the banker receives R per unit of his own capital invested. When investors deposit their money with the bank, they sign a *deposit contract* stipulating the return Q which the banker receives per unit deposited by outside investors if the return on investments is R. Thus the 'deposit rate' received by investors in a bank is $R-Q$

if the bank's investment succeeds and 0 otherwise[1]. Only a banker can observe the size of the bank which he runs; 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 runs.

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 where only sound agents run banks. 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*. We say that an equilibrium in which every sound agent runs a bank and performs monitoring is *rational*.

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

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

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

[1] An 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. Our method was selected in order to maximise the transparency of the algebra.

for sound agents: $(Q(k-1)+R)\,p_H - kC \geq Rp_H - C$, or

$$Q \geq BIC \equiv \frac{C}{p_H.} \tag{BIC}$$

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 rational unregulated 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 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 could leave the banking system, increasing the average quality of the banking system, and he would be strictly better off investing in than running a bank. The converse is true if an unsound agent joins the banking system, so the banking system must either grow until it contains all agents, or shrink until it contains only sound agents. This is stated formally proposition 1 below.

Proposition 1 *There are no asymmetric pure strategy rational equilibria in the unregulated economy.*

Proof. Consider a rational unregulated economy in which b banks exist and assume that an equilibrium exists for $N > b > \mu$. Let $\beta_U(b) \equiv \left(Q\left(\frac{N}{b}-1\right)+R\right)p_L$ be the expected income which an unsound banker earns in a b bank economy and let $\eta_b \equiv \frac{\mu}{b}p_H + \left(1-\frac{\mu}{b}\right)p_L$ 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,

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

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

$$Q \leq \frac{R\mu\,(b+1)\,\Delta p}{Nbp_L + \mu\,(b+1)\,\Delta p}. \tag{3}$$

Equations 2 and 3 can be satisfied simultaneously provided

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

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

Proposition 1 tells us that there will be μ or N banks in any rational unregulated economy. The case with N banks corresponds to autarky and we disregard it. In a rational 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 then the size of every bank will therefore shrink from N 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:

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

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

$$Q \leq UIR \equiv R\frac{\Delta p}{p_H}. \tag{UIR}$$

In other words, unsound agents would prefer to manage their own projects unless the amount which they must pay to bankers in expecation is less than the incremental value which the latter add. This constraint is illustrated in figure 1.

Proposition 2 establishes the conditions which must obtain for an unregulated rational economy to exist.

Proposition 2 *Define*

$$C^U \equiv \frac{R\Delta p^2}{Np_L + \Delta p}.$$

Then

1. *If $C \leq C^U$ then rational unregulated equilibria are guaranteed to exist;*

2. *If $C > C^U$ then k^U given by equation 4 is positive and rational unregulated equilibria exist if and only if $\frac{N}{\mu} \leq k^U$.*

$$k^U \equiv \frac{N\Delta p\,(Rp_H - C)}{C\,(Np_L + \Delta p) - R\Delta p^2}. \tag{4}$$

Proof. An 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 $MIC\,(k) \to \frac{C}{\Delta p} > BIC$ as $k \to \infty$ 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 $B^U\,(k) \to \frac{R\Delta p}{Np_L + \Delta p}$ as $k \to \infty$. A rational unregulated equilibrium is guaranteed to exist provided MIC is always below UIR and below B^U. Since B^U lies below UIR this is equivalent to the requirement that $\frac{C}{\Delta p} \leq \frac{R\Delta p}{Np_L + \Delta p}$, or $C \leq C^U$ as required.

If $C > C^U$ then MIC and B^U cross at $k = k^U$. A rational unregulated equilibrium can exist provided $k \leq k^U$. In such an equilibrium, $k = \frac{N}{\mu}$ and the second part of the result follows immediately. ∎

The intuition for this result 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. When the monitoring cost is higher then if banks are sufficiently large, unsound agents will wish to run banks. Since 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 sufficiently large so that in equilibrium banks will be sufficiently small.

[Figure 1]

The result in the case where $C > C^U$ is best understood by reference to figure 1, which shows the various incentive constraints (MIC, UIR, B^U and BIC) which must be simultaneously satisfied as functions of bank size k. From our earlier discussion, unregulated rational equilibria are possible only in the shaded region, above BIC and MIC, and below UIR and B^U. B^U and MIC cross at bank size k^U. Larger banks than this are not feasible because the payment necessary to induce sound agents to monitor would induce all 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 value for bank size k is $\frac{N}{\mu}$: all unsound agents deposit their endowments in banks. Thus, as is evident from the diagram, an unregulated rational equilibrium is feasible only when $\frac{N}{\mu} < k^U$.[2] If the fraction of capital initially held by sound agents $\frac{\mu}{N}$ is too small, rational equilibria are not possible and the only possibility in the absence of regulation is autarky: each agent invests his own endowment.

For the remainder of the paper we will assume that $C > C^U$ and $\frac{N}{\mu} > k^U$ so that unregulated rational equilibria are infeasible. In the next section, we examine how in this case a regulator can improve upon the unregulated situation.

[2] We 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

$$k^B \equiv \frac{Rp_H - C}{Cp_L} \Delta p$$

of BIC and MIC is illustrated. It is easy to show that $k^U > k^B$ as we have drawn it if and only if $R\Delta p > C$, which is equation 1

2 A Regulated Banking Sector

We now introduce a welfare-maximising agent called the *regulator* who controls entry to the banking sector. The regulator has two 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 auditing technology for evaluating licence applicant types. The regulator's role is to maximise social welfare. She accomplishes this 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.

The regulator has two policy instruments: she can allocate licences and she can set a capital adequacy requriement. The licence allocation procedure is as follows. The regulator firstly announces the number of licences which she will award and 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 ("If I receive μ applications then I will award μ licences: otherwise I will award no licences"). We do so for two reasons: firstly, such policies are ex post sub optimal and are therefore incredible; secondly, such policies rely upon a precise knowledge of μ and hence are not robust to imprecise parameter knowledge.

There are two types of regulators. The auditing technology employed by *good* regulators yields the wrong answer with probability 0; the technology which *bad* regulators employ yields the wrong answer with probability $\frac{1}{2}$. At the cost of reduced algebraic tractibility we could endow good regulators with and imperfect and bad regulators with a technology which outperforms coin-tossing, but this would not affect our qualitative results. The regulator knows her type but it is not observable. Other agents assign an *ex ante* probability a that she is good: we call a the regulator's *ability*[3].

We firstly characterise the regulator's optimal policy and then turn to the behaviour of the agents in the new, regulated, environment.

Lemma 3 *All regulators allocate precisely μ banking licences and set k equal to the maximum value which is commensurate with the existence of a banking sector.*

The proof of this result appears in the appendix. The intuition is that good regulators will always allocate a licence to every sound agent and 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. If a bad regulator deviates from this policy then her type becomes public knowledge and to deal with the consequential adverse selection problem she must significantly tighten capital adequacy requirements: this is the subject of proposition 7 below. For any given reputation level bad regulators will choose to pool with good regulators if the expected volume of monitored capital with pooling exceeds the volume without it: we demonstrate that this will always be the case in regulated economies.

The incentive constraints for the sound agents are unchanged from the unregulated economy above. As we discuss below, however, the incentives of the unsound agents in the regulated economy are altered for two reasons. Firstly, the fact that the regulator audits banks may improve their confidence in the banking system and make them more willing to invest; and secondly, the regulator sets

[3]The assumption that the regulator knows her type is used below to prove that the regulator always issues μ licenses (lemma 3). We could alternatively assume that the regulator's type is unknown but that the number of licenses is fixed exogenously. Joint analysis of the size and number of banks when the regulator's type is drawn from a continuum is outside the scope of this paper.

limits on bank size which may cause rationing of banking services if they choose to invest in the banking system. Nevertheless, we are still able to establish a result analogous to proposition 1.

Proposition 4 *There are no asymmetric pure strategy equilibria in the regulated economy.*

Proof. In the appendix. ■

Proposition 4 tells us that only two belief sets are rational for bad agents: either they believe that all agents will apply to the regulator for a banking licence, or they believe that only sound agents will apply for a licence. In the former case the likely quality of a randomly chosen bank is lower than in the latter, when all banks will be sound, independently of the regulator's ability. We therefore call the former beliefs *pessimistic* and the latter ones *optimistic*.

Lemma 5 describes the comparative statics of regulated economies in which *all* agents apply for a banking licence. In this case, the more able the regulator is perceived to be, the higher the perceived probability both that a randomly selected bank is sound and that it returns R.

Lemma 5 *Let α, η be the respective unconditional probabilities that a randomly selected bank in an economy in which all agents apply for a licence is sound and that a randomly selected bank will return R. Then $\frac{\partial \alpha}{\partial a} \geq 0$ and $\frac{\partial \eta}{\partial a} \geq 0$.*

Proof. In the appendix. ■

When $k < \frac{N}{\mu}$ and all agents choose to apply for a banking licence some rationing of bank deposits is necessary. Each agent will deposit a fraction $\frac{\mu}{N}$ of his funds in a bank and will manage the remainder himself.

Optimistic beliefs are sustainable only if unsound agents prefer bank investment to licence application when it is anticipated that only sound agents manage banks. This will be true if the payment to bankers is low enough (or equivalently, deposit rates are high enough) to tempt unsound agents away from the prospect of managing their own bank:

$$(R-Q)\,p_H\frac{k\mu}{N}+Rp_L\left(1-\frac{k\mu}{N}\right)\geq((k-1)\,Q+R)\,p_L,\text{ or}$$

$$Q\leq B^O\,(k)\equiv\frac{Rk\mu\Delta p}{N\,(k-1)\,p_L+k\mu p_H}. \tag{OPIC}$$

Similarly, pessimistic beliefs are sustainable only if unsound agents prefer to apply for a banking licence rather than to invest in a bank when it is anticipated that all agents apply for a banking licence. This will be true if the payment to bankers is large enough:

$$Q\geq B^P\,(k,a)\equiv\frac{Rk\mu\,(\eta-p_L)}{N\,(k-1)\,p_L+k\mu\eta}. \tag{PESSIC}$$

Note that $\frac{\partial B^P}{\partial\eta}=Rk\mu p_L\,((k-1)\,N+k\mu)\,/\,[N\,(k-1)\,p_L+k\mu\eta]^2>0$ so that $B^O\,(k)$ is strictly above $B^P\,(a,k)$.

Finally, the IR condition for uninformed agents to invest in a bank when there are pessimistic beliefs is

$$Q\leq Q_{IR}\,(a)\equiv\frac{R\,(\eta-p_L)}{\eta}. \tag{QIR}$$

The various incentive constraints for the regulated economy are as illustrated in figure 2. In the appendix (lemma 11), we establish that B^O and B^P are decreasing in bank size k as illustrated, and also that $B^P$and Q_{IR} are decreasing in a. The intuition for this is obvious: as bank size increases, the total reward $Q\,(k-1)$ to successfully managing a bank increases proportionately, so unsound agents become more tempted to run banks, and must be deterred from doing so by appropriate reductions in Q. If the regulator is perceived as more able, banks are more likely to succeed and other things being equal, unsound agents will be more willing to invest in the banking system instead of becoming banks (B^Pfalls) and to make a larger payment to bankers in case of success (Q_{IR} rises).

Let k^B intersection point of BIC and MIC, let k^O be the intersection point of B^O and BIC and let k^P be the intersection point of BIC with B^P. These are the critical bank sizes at which the economy switches between different 'regimes' where the different incentive constraints bind. The significance of these points will become evident shortly. Lemma 6 establishes the relationship between k^B, k^O and k^P.

Lemma 6 *$k^B > k^O > k^P$ and k^P is increasing in a.*

We now define some important thresholds for regulator ability a. Firstly, when it exists define k_η to be the intersection point between the MIC and $Q_{IR}(a)$ lines:

$$k_\eta \equiv \frac{Rp_L \Delta p}{C\eta - R\Delta p(\eta - p_L)}.$$

MIC increases asymptotically to $\frac{C}{\Delta p}$, so k_η exists precisely when $Q_{IR}(a) < \frac{C}{\Delta p}$: equivalently, when $C\eta > R\Delta p(\eta - p_L)$.

Define a^{MH} to be the infimum of

$$A^{MH} \equiv \{a \in [0,1] : Q_{IR}(a) \geq BIC\}$$

if A^{MH} is non-empty, and to be 1 otherwise. If $a \geq a^{MH}$ then $Q_{IR}(a) \geq BIC$ (lemma 11) so that the participation constraints of both depositors and bankers can be simultaneously satisfied when all agents apply for banking licences. In this case the maximum size of a bank is given by the intersection $k_{\eta(a)}$ of MIC and $Q_{IR}(a)$, as in figure 2.

Define a^{NCR} to be the supremum of

$$A^{NCR} \equiv \left\{a \in [0,1] : k_{\eta(a)} \text{ exists and } k_{\eta(a)} \leq \frac{N}{\mu}\right\}$$

if A^{NCR} is non-empty, and to be 0 otherwise. If $a > a^{NCR}$ then either $k_{\eta(a)}$ is undefined, in which case MIC and $Q_{IR}(a)$ do not intersect at all, or MIC and $Q_{IR}(a)$ intersect at some k greater than the highest feasible bank size $\frac{N}{\mu}$. In both cases there is no upper limit upon the size of a bank.

In the following proposition we examine the properties of a^{MH} and a^{NCR}.

Proposition 7 *Suppose that unregulated rational economies are impossible so that $C > C^U$. Define $C^R = \mu C^U$ and $C^A = \mu \frac{p_H}{\Delta p} C^U$, so that $C^U < C^R < C^A$. Let $\underline{\eta} \equiv p_L + \frac{\mu}{N} \Delta p$ be the value for η when $a = 0$. The parameters a^{MH} and a^{NCR} which are defined above have the following properties:*

1. *If $C \leq C^R$ then $a^{MH} = 0$ and $a^{NCR} = 0$;*

2. *If $C^R < C \leq C^A$ then $a^{MH} = 0$ and $a^{NCR} \geq 0$ with equality precisely when $\frac{N}{\mu} \geq k_{\underline{\eta}}$;*

3. *If $C > C^A$ then $a^{NCR} \geq a^{MH} > 0$. In this case, if k_{p_H} exists and is less than k^B then $a^{MH} = a^{NCR} = 1$; otherwise $a^{MH} < 1$;*

4. *If $C > C^R$ then for every a, $a^{NCR} \geq a$ if and only if the following hold, with equality holding precisely when $a = 1$:*

   (a) $C\eta(a) > R\Delta p (\eta(a) - p_L)$;

   (b) $k_{\eta(a)} \leq \frac{N}{\mu}$;

5. *For $a > a^{NCR}$ the regulator audits applicants but does not impose a capital adequacy requirement*

6. *For $a^{MH} \leq a < a^{NCR}$ the regulator audits applicants and imposes a maximum size $k_{\eta(a)}$ upon banks which is increasing in a. All agents apply for a banking licence;*

7. *For $a < a^{MH}$ only sound agents will apply for a banking licence.*

   (a) If agents have optimistic beliefs then the regulator imposes a maximum size k^O upon banks;

   (b) If agents have pessimistic beliefs then the regulator imposes a maximum size k^P upon banks. k^P is strictly below k^O and is increasing in a.

[Figure 2]

Proof. If $Q_{IR}(0)$ lies above MIC so that the two lines do not intersect then certainly $a^{MH} = 0$. Since the supremum of MIC is $\frac{C}{\Delta p}$ this is equivalent to the requirement that $C \leq C^R$. In this case $k_{\eta(a)}$ is undefined for every a and so $a^{NCR} = 0$, which establishes part 1.

If $C^R < C$ then $Q_{IR}(0)$ intersects MIC. If $Q_{IR}(0) > BIC$ then $a^{MH} = 0$: this occurs precisely when $C \leq C^A$. In this case $a^{NCR} = 1$ if and only if $k_{\eta(a)} \leq \frac{N}{\mu}$ for every a: equivalently, if and only if $k_{\underline{\eta}(a)} \leq \frac{N}{\mu}$. This establishes part 2.

If $C > C^A$ then $Q_{IR}(0) < BIC$ so that $a^{MH} > 0$. If k_{p_H} exists and is less than k^B then A^{MH} is empty and so $a^{MH} = 1$ and since $1 \geq a^{NCR} \geq a^{MH}$ it follows that $a^{NCR} = 1$, too. If k_{p_H} is undefined or k_{p_H} is defined and is greater than k^B then there exists a left neighbourhood N of $a = 1$ with $N \subseteq A^{MH}$, so that $a^{MH} < 1$. This establishes part 3.

If $C > C^R$ then for every a, $\sup A^{NCR} \geq a$ if and only if firstly $k_{\eta(a)}$ is defined and secondly $k_{\eta(a)} \leq \frac{N}{\mu}$. These are the two conditions for part 4 of the proposition.

The positioning of a^{MH} and a^{NCR} is illustrated in figure 2 for the case where k_{p_H} is defined and greater than $\frac{N}{\mu}$ and where $Q_{IR}(0) < BIC$.

We remarked in the definition of a^{NCR} that for $a > a^{NCR}$, the regulator will audit applicants but will not impose a capital adequacy requirement, so part 5 is proved.

We know from lemma 3 that the regulator will select the largest bank size k which is consistent with the existence of a banking system. In doing so, she will violate equation OPIC and all agents will therefore apply for a banking licence. A banking system is then feasible if and only if $Q_{IR}(a) \geq BIC$: equivalently, if and only if $a \geq a^{MH}$. Within this region, the maximum possible size of a bank is given by the intersection of MIC and $Q_{IR}(a)$ – in other words, by $k_{\eta(a)}$. That $k_{\eta(a)}$ is increasing in a is obvious from figure 2 and is an immediate consequence of lemma 11, which establishes part 6.

If $a < a^{MH}$ then $Q_{IR}(a) < BIC$ and so participation constraints for bankers and depositors cannot be simultaneously satisfied when all agents apply for a banking licence so the regulator must set k so as to ensure that only sound agents apply for a banking licence. The appropriate banking policy will depend upon the type of the economy.

An optimistic economy is sustainable provided conditions BIC, MIC and OPIC are simultaneously satisfied. This can be accomplished by setting $k = k^O$ as indicated in figure 2. This policy is not dependent upon a.

In a pessimistic economy, all agents will apply for licences whenever this behaviour is rationally sustainable. To prevent this, the regulator must ensure that conditions BIC and MIC are satisfied and that condition PESSIC is violated. This can be accomplished by setting $k = k^P$ as indicated. As noted in lemma 6, k^P is increasing in a. This concludes the proof. ■

Note from the proof of proposition 7 that for $a > a^{MH}$, the MIC constraint binds and for $a \leq a^{MH}$, the BIC constraint binds and the MIC constraint is slack. We interpret this observation as follows. When the regulator's ability exceeds a^{MH}, she can rely upon her auditing ability to resolve the adverse selection problem which unsound agents encounter in a pessimistic economy. She therefore uses the capital adequacy regulations simply to reduce the size of the banking sector to a level where monitoring by sound agents is incentive compatible: in other words, to resolve a moral hazard problem. When the cost C of monitoring is sufficiently high (above C^A) then for low levels of regulator ability (below a^{MH}), unsound agents do not trust her judgement and she cannot resolve their adverse selection problem through auditing. She therefore tightens capital adequacy requirements to a level where they remove the incentive for unsound agents to apply for licences. In other words, capital adequacy requirements for low ability regulators exist to resolve a problem of adverse selection, while capital adequacy requirements for high ability regulators exist to resolve a moral hazard problem.

[Figure 3]

The results of proposition 7 are summarised in figure 3 for the case where $\frac{N}{\mu} < k^{NCR}$. In the region $a^{NCR} < a \leq 1$ the regulator audits but because the proportion of informed capital is large enough, banks are sufficiently small that there is no moral hazard problem and she imposes no capital adequacy requirement. For $a^{MH} < a \leq a^{NCR}$ the regulator audits and sets the maximum bank size equal to k^{MH} as indicated. When $a < a^{MH}$ capital adequacy policy exists to correct the adverse selection problem which faces depositors and it must therefore prevent licence application by unsound agents. The appropriate policy will depend upon the economy type as indicated. In optimistic economies the regulator will set $k = k^O < k^B$ for every $a < a^{MH}$ so that a discontinuous drop in the size of the banking sector will occur in response to a reduction in regulator auditing ability. In pessimistic economies the regulator will set $k = k^P < k^O$ and the size of the banking sector will be increasing in the regulator's ability a as indicated. This implies that in an extended dynamic version of the model, a regulatory concern with reputation is not necessarily misplaced (cf. Boot and Thakor, 1993). The higher the regulator's ability, the larger the banking sector which the economy can sustain and the higher is social welfare. Thus even a social welfare maximising regulator should be concerned with the impact of her actions on her reputation.

Note that in the adverse selection region, k^P is strictly less than k^O. It follows that in this region, a change in agent beliefs can precipitate a regulator-imposed reduction in the size of the banking sector. We interpret this as a credit squeeze. Credit squeezes in our model are necessary to prevent the collapse of the banking system in response to a worsening of investor sentiment, but they will only happen when the regulator's reputation is sufficiently poor.

It is worth noting that in our model, together with the regulator's monitoring ability, capital adequacy requirements are a sufficient instrument to achieve the constrained welfare optimum. This is in contrast to Hellman et al. (2000), where the efficacy of capital requirements is improved by the addition of a deposit insurance ceiling. In our model, if capital requirements actually bind, then there is excess demand for banking services, i.e. depositors would like to deposit more money, but the banks cannot accept these deposits because they do not have enough capital. This means that banks will not compete by raising deposit rates to increase the volume of their deposits, but rather will set Q to extract all of the depositors' surplus: a deposit rate ceiling thus arises endogenously.

3 Deposit Insurance

In this section we study the welfare effects of a deposit insurance scheme in the regulated economy analysed above. We assume that the scheme is paid for via an ex ante lump sum tax ρ upon each of the agents in the economy, and the amount thus raised will be returned ex post to the depositors of failed banks. Agents are risk neutral so the tax yields no welfare benefits as a consequence of the insurance which it provides: in fact, the income from bank deposits remains stochastic and deposit insurance simply generates a subsidy for deposit holders.[4] Notwithstanding this, we demonstrate below that, by changing the incentives to invest in bank deposits, deposit insurance is welfare-increasing.

Suppose that the deposit insurance scheme generates an expected payment $\mathcal{P}$ per depositor of failed banks. Then the IR constraint for unsound agents to

[4] The risk neutrality of agents in the model means that it is in fact irrelevant whether the tax is returned to depositors only if their bank fails, or in some other way, e.g. through some other form of lottery or as a lump sum subsidy. Of course, with any amount of risk aversion, payment when the bank fails would become strictly preferred to these various alternatives, so we stick to this conventional format in what follows, whilst retaining the tractibility of risk neutrality.

invest in banks with deposit insurance becomes:

$$\eta (R - Q) + (1 - \eta) \mathcal{P} \geq p_L R \tag{DQIR}$$

Note that this is slacker than the constraint without deposit insurance (QIR) because of the extra payment $\mathcal{P}$ when the bank fails.

When $a < a^{MH}$ so that capital adequacy requirements act to resolve an adverse selection problem, the IC constraints for unsound bankers to refrain from licence application with optimistic and pessimistic beliefs are altered from OPIC and PESSIC to DOPIC and DPESSIC respectively:

$$Q \leq B^{DO}(k) \equiv \frac{Rk\mu\Delta p + \mathcal{P}k\mu (1 - p_H)}{N(k-1) p_L + k\mu p_H} \tag{DOPIC}$$

$$Q \leq B^{DP}(k) \equiv \frac{Rk(\eta - p_L) + \mathcal{P}k\mu (1 - \eta)}{N(k-1) p_L + k\mu\eta} \tag{DPESSIC}$$

The ex ante tax will be invested by the regulator in the banking sector so as to maximise its expected ex post value. The total expected funds available to the regulator ex post to pay out to the depositors of failed banks is therefore $N\rho \times \eta R$. Since every agent's endowment will be reduced by the tax, the size of the banking sector will be $(1 - \rho) \mu k$. Inside (equity) capital is not insured and so $(1 - \rho) \mu (k - 1)$ will be insured and the MIC constraint will be unaffected by deposit insurance. The budget constraint for insurance is therefore:

$$(1 - \eta)(1 - \rho) \mu (k - 1) \mathcal{P} = N\rho\eta R. \tag{DBUDG}$$

Since the regulator wishes to maximise the size of the banking sector for a given Q and $\mathcal{P}$, equation DBUDG will bind in equilibrium. Moreover, when $a > a^{MH}$, equations MIC and DQIR will bind; when $a < a^{MH}$ equation BIC will bind and either equation 5 or 5 will bind, according to whether expectations are optimistic or pessimistic.

Lemma 8 $\left.\frac{\partial \rho}{\partial k}\right|_{\rho=0} = \frac{\mu(R\Delta p - C)}{NR\Delta p(k-1)}$ *if MIC binds.*

Proof. In the appendix. ■

We now consider the welfare consequences of a deposit insurance scheme. The are two cases to consider: where all agents apply for a licence in the absence of deposit insurance, and where only sound agents do so. In the former case, we have $a \geq a^{MH}$ so that the MIC constraint binds. In the latter case, $a < a^{MH}$ and the BIC constraint binds.

When all agents apply for a licence the expected number of sound bankers is $\mu\left(\frac{\eta - p_L}{\Delta p}\right)$ and the expected number of sound agents who do not receive a licence is $\mu\left(\frac{p_H - \eta}{\Delta p}\right)$. The expected total welfare is then

$$\begin{aligned} \mathcal{W}^P &= \frac{\mu\left(Rp_H - C\right)(1-\rho)}{\Delta p}\left[\left(\eta - p_L\right)k + p_H - \eta\right] \\ &\quad + Rp_L\left\{N - \frac{\mu}{\Delta p}(1-\rho)\left[\left(\eta - p_L\right)k + p_H - \eta\right]\right\}. \end{aligned} \tag{5}$$

The first line of this expression is the expected return from all projects managed by sound agents. The number of remaining projects appears in the curly brackets on the second line.

When only sound agents apply for a licence the total welfare $\mathcal{W}^O$ is given by:

$$\mathcal{W}^O = \left(Rp_H - C\right)(1-\rho)k\mu + \left[N - (1-\rho)k\mu\right]p_L. \tag{6}$$

Proposition 9 *It is possible to increase welfare by providing deposit insurance. Moreover, capital requirements will be reduced when there is deposit insurance.*

Proof. In the appendix. ■

The intuition for this result is straightforward. Consider firstly the case where $a \geq a^{MH}$ so that MIC and DQIR bind. The imposition of a tax ρ has two consequences which have opposing effects upon welfare. Firstly, note that the tax is invested in the banking sector and that depositors only receive its proceeds if they also invest in the banking sector. This renders investment more attractive, so that the investors' IR constraint is relaxed so that a larger Q can be levied and the banking sector can be expanded without violating the MIC constraint.

Secondly, note that the tax is levied upon *everyone* in the economy, including the sound agents. This is inevitable as the regulator cannot distinguish between the two types of agent, but it has the undesirable consequence of reducing the amount of capital available to sound bankers and hence of reducing the size of the banking sector. The proof of proposition 9 demonstrates that when $a > a^{MH}$, the equilibrium bank size $k_{\eta(a)}$ without taxation is always sufficiently high for the first of these effects to outweigh the second.

Secondly, consider the case where $a < a^{MH}$ so that BIC binds and either DOPPIC or DPESSIC also binds: since all banks are run by sound agents the QIR constraint is no longer relevant. All of the agents in the economy are taxed and the aggregate tax is returned to those agents who invest in a bank. This has the effect of making bank investment more attractive relative to bank management: in other words, of relaxing the appropriate IC constraint so that a larger bank can be managed. When $a < a^{MH}$ the ex ante size of the banking sector is small relative to the size of the pool of uninformed agents and for small levels of taxation, the extent to which the constraint is relaxed always exceeds the deleterious consequences of a tax upon informed capital.

The way in which deposit insurance acts to increase welfare is instructive. Notice that in our model, the banking sector is too small, from a social point of view. This is because unsound agents do not internalise the rents which sound agents earn from managing deposits and hence are too eager to withdraw their funds from sound banks. Therefore it is beneficial to subsidise bank investment. Deposit insurance does not create a moral hazard problem because banks' own capital is not insured. In fact, because it makes investors more willing to invest in banks, it allows banks to charge a higher management fee (offer a lower deposit rate), thereby increasing bankers' stake in the success of their project and thus *reducing* the temptation to moral hazard. It is for this reason that in our model, optimal capital requirements will always be more lenient in the presence of a deposit insurance scheme.

Although a small increase in taxation from zero increases welfare as a consequence of the relaxed capital standards (proposition 9), taxation has a detrimental effect in that it reduces the capital that potential bankers start with and thus reduces the size of their banks. The optimal taxation level is the one where these two effects have equal magnitudes. The negative effect which taxation has upon bankers' capital base in our model implies that, in contradiction to the received wisdom on this topic, bankers should not themselves finance the deposit insurance scheme. This would push the burden of taxation disproportionately onto sound agents and so shrink productive investments and the banking sector. A subsidy out of general taxation such as the one used in our model spreads the burden of taxation more evenly across agents and increases expected production.

4 Conclusion

In recent years, banking crises have become increasingly common and increasingly expensive to deal with. Prudential regulation of banks is supposed to prevent or at least to reduce the frequency 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 ability. This also suggests 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 we have shown that the economy will exhibit multiple rational expectations equilibria. In this case, capital requirements are used to sort sound from unsound types of banks: that is, to solve an adverse selection problem. Consider a simple extension of the model where the regulator does not know with certainty ex ante whether the public's expectations will be optimistic or pessimistic. Then one can see that two forms of regulation are possible. The regulator 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 economy will be vulnerable to panics. Alternatively she can follow a tight regulation policy which ensures that panics will not occur despite her poor reputation for auditing, but this means that the banking sector is restricted to being inefficiently small when expectations are optimistic, and so output is inefficiently low.

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 and the regulator's reputation for identifying incompetent banks is 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.

We also show that, contrary to received wisdom, in the presence of a deposit insurance scheme, capital requirements can be looser without causing moral hazard. The reason is that, other things being equal, deposit insurance provides a general subsidy to the banking system, making depositing one's funds in a bank more attractive. This allows bankers to offer lower deposit rates and still attract deposits. Since the bankers' residual claim on his profits is thus increased, he has less incentive to gamble on high private benefit low NPV outcomes, so the moral hazard problem in banking is less severe. This means that the capital requirements on banks can be eased when there is deposit insurance.

Appendix

It is convenient to define

$$w = \frac{1}{2}(1-a);$$

w is the unconditional probability which other agents assign to the event that the regulator's technology yields the wrong signal.

Suppose that the economy contains M agents, of whom m are sound. Write $p_n(M,m)$ for the probability that the nth licence awarded goes to a sound bank. Denote by S the event that an audited bank is sound and by s the event that the regulator receives a sound signal from her auditing technology. Then

$$\begin{aligned} p_1(M,m) = P[S|s] &= \frac{P[s|S]\,P[S]}{P[s|S]\,P[S] + P[s|\neg S]\,P[\neg S]} \\ &= \frac{(1-w)\,m}{(1-w)\,m + w\,(M-m)}. \end{aligned}$$

For $n > 1$ we have the following relationship:

$$p_n(M,m) = [1 - p_1(M,m)]\,p_{n-1}(M-1,m) + p_1(M,m)\,p_{n-1}(M-1,m-1) \tag{7}$$

Lemma 10 *For $n \geq 1$ and for every m, $p_{n+1}(M,m) < p_n(M,m)$.*

Proof. We proceed by induction. For the base case:

$$\begin{aligned} p_2(M,m) &= (1-p_1(M,m))\,p_1(M-1,m) + p_1(M,m)\,p_1(M-1,m-1) \\ &= \frac{(1-w)\,m}{(1-w)\,m + w\,(M-m)} \left\{ \frac{w\,(M-m)}{(1-w)\,m - w + w\,(M-m)} \right. \\ &\quad \left. + \frac{(1-w)\,(m-1)}{(1-w)\,m - (1-w) + w\,(M-m)} \right\}. \end{aligned}$$

This is less than $p_1(M,m)$ provided the expression enclosed in curly brackets is below 1. Since $w \leq \frac{1}{2}$, the expression is less than or equal to

$$\frac{w\,(M-m) + (1-w)\,(m-1)}{w\,(M-m) + (1-w)\,(m-1)} = 1,$$

as required.

For the inductive step, assume that the lemma holds for all integers up to $n-1$. Then applying the inductive hypothesis to equation 7,

$$\begin{aligned} p_n(M,m) &\leq (1-p_1(M,m))\,p_{n-2}(M-1,m)+p_1(M,m)\,p_{n-2}(M-1,m-1) \\ &= p_{n-1}(M,m). \end{aligned}$$

■

Proof of Proposition 4

Consider an economy in which b agents, including the μ sound agents, apply for a banking licence, and where μ licences are awarded. Let η_b be the probability in such an economy that a randomly selected bank returns R on its investments. We claim that η_b is strictly decreasing in b.

To prove the claim, note that $\eta_b = \alpha_b(p_H - p_L)+p_L$, where $\alpha_b = \sum_{n=1}^{\mu} \frac{1}{\mu} p_n(b,\mu)$ is the probability that a randomly selected bank is sound when b agents, including the sound ones, apply for a licence. With probability a the regulator is good and $\alpha_b = 1$, so it sufficies to demonstrate that $\frac{\partial \alpha_b}{\partial b} < 0$ when the regulator has a bad technology. Note that in this case $w = 1/2$ and $p_1 = \frac{\mu}{b}$. Suppose that $p_{r-1}(b,\mu) = \frac{\mu}{b}$. Then equation 7 implies that

$$p_r(b,\mu) = \frac{b-\mu}{b}\frac{\mu}{b-1} + \frac{\mu}{b}\frac{\mu-1}{b-1} = \frac{\mu}{b}\frac{b-\mu+\mu-1}{b-1} = \frac{\mu}{b}$$

so by induction, $p_i(b,\mu) = \frac{\mu}{b}$ for $i = 1,\ldots,b$ and the claim follows immediately by differentiation of the expression for α_b.

Suppose that $N > b > \mu$ so that some unsound agents apply for a banking licence and some do not. For b agents to wish to apply for a licence, we require

$$(Q(k-1)+R)\,p_L \geq (R-Q)\,\eta_{b-1}, \tag{8}$$

and for the remainder not to apply for a licence, we require

$$(Q(k-1)+R)\,p_L \leq (R-Q)\,\eta_{b+1}. \tag{9}$$

Equations 8 and 9 together imply that $\eta_{b-1} \leq \eta_{b-1}$, which contradicts the strict monotonicity of η_b with respect to b.

Proof of Lemma 5

Note that $\alpha = \sum_{n=1}^{\mu} \frac{1}{\mu} p_n (N, \mu)$.Lemma 10 implies that $\frac{\partial \alpha}{\partial w} \leq 0$. Since $\eta = \alpha (p_H - p_L) + p_L$ we therefore have $\frac{\partial \alpha}{\partial w} \leq 0$. The proposition follows immediately.

Comparative Statics of Incentive Constraints

Lemma 11 *$\partial B^O / \partial k < 0$; $\partial B^P / \partial k < 0$; $\partial B^P / \partial a < 0$; $\partial Q_{IR} / \partial a > 0$.*

Proof. $\partial B^O / \partial k = -NR\mu p_L \Delta p / \left[N (k-1) p_L + k\mu p_H\right]^2 < 0$;
$\partial B^P / \partial k = -NR\mu p_L (\eta - p_L) / \left[N (k-1) p_L + k\mu\eta\right]^2 < 0$;
$\partial B^P / \partial a = \frac{\partial \eta}{\partial a} \times RNk (k-1) \mu p_L / \left[N (k-1) p_L + k\mu\eta\right]^2 < 0$;
$\partial Q_{IR} / \partial a = \frac{\partial \eta}{\partial a} \times R p_L / \eta^2$. ■

Proof of Lemma 6

Setting BIC equal to MIC and solving for k yields

$$k^B = \frac{(Rp_H - C) \Delta p}{C p_L}.$$

Define $\tilde{B}^O \left(k, \tilde{k}\right) \equiv \frac{r \Delta p}{(k-1) p_L + \tilde{k} \mu p_H}$. Note that

$$\frac{\partial \tilde{B}^O}{\partial k} = r\mu \Delta p N (k-1) p_L / \left[N (k-1) p_L + \tilde{k} \mu p_H\right]^2 > 0$$

and that $B^O (k) = \tilde{B}^o (k, k)$ so that $B^O < \tilde{B}^O \left(k, \frac{\mu}{N}\right) = \frac{R \Delta p}{k p_L + \Delta p}$. $B^O \left(k, \frac{\mu}{N}\right)$ intercepts BIC when $k = k^B$. Since $B^O \left(k^B\right) < \tilde{B}^O \left(k^B, \frac{\mu}{N}\right) = BIC$ we must have $k^B > k^O$. Similarly, because $B^P < B^O$ it follows that $k^O > k^P$. That k^P is increasing in a follows immediately from $\partial B^P / \partial a < 0$ (lemma 11).

Proof of Lemma 3

Good regulators will audit all applicants for licences. They will allocate a licence to every sound agent and will not allocate licences to other agents. They will then allow banks to assume the maximum size which is consistent with bank investment by other agents as this will maximise the productivity of the economy. Suppose that a bad regulator deviates from this policy and thus signals her type. Then by proposition 7, we need to consider two cases: where $a^{MH} = 0$ and where $a^{MH} > 0$.

If $a^{MH} = 0$ then a bad regulator has two alternatives: she can set bank size equal to $k_{\underline{\eta}}$, in which case every agent will apply for a banking licence; and she can reduce bank size sufficiently far to ensure that only good agents apply for a banking licence. In the former case, the size of the banking sector is reduced but, as all agents apply for a licence, its quality has not been increased and this cannot dominate the pooling equilibrium; in the latter case, the largest banking sector which he can hope for has μ banks of k^O, all of which are sound. If $a^{MH} > 0$ then the best the regulator can hope for is a banking sector containing μ sound banks of size k^O. It is therefore sufficient to demonstrate that the pooling equilibrium is never dominated for the bad regulator by the economy containing only sound banks of size k^O.

Firstly, note that $k^O = \frac{CIp_L}{CIp_L - (R\Delta p - C)p_H}$, where $I = \frac{N}{\mu}$ (for a proof of this identity, see the proof of proposition 9). The maximum level of monitored investment in the separating equilibrium is μk^O. It follows from the proof of proposition 4 that the probability that any bank is sound in the pooling equilibrium is $\frac{\mu}{N}$ and hence that the expected level of monitored investment is $\frac{\mu}{N}\mu k_\eta + \left(1 - \frac{\mu}{N}\right)\mu = \mu\left(\frac{k_\eta - 1}{I} + 1\right)$. The result is therefore proved if and only if $k^O \leq \frac{k_\eta - 1}{I} + 1$, which is equivalent to

$$\frac{CIp_L}{CIp_L - (R\Delta p - C)\,p_H} \leq \frac{(R\Delta p - C)\,\eta + I}{I\left[C\eta - R\Delta p\,(\eta - p_L)\right]}.$$

Cross multiplying and simplifying reduces this to the following:

$$I \geq \frac{R\Delta p - C}{Cp_L} p_H. \tag{10}$$

Note that $(R\Delta p - C)\, p_H = (Rp_H - C)\, \Delta p - Cp_L < (Rp_H - C)\, \Delta p$, so the right hand side of equation 10 is less than k^B. By assumption, $I > k^B$ in regulated economies and we are done.

Proof of Lemma 8

Rewrite DBUDG as $\rho \{N\eta R + \mu (1-\eta)(k-1)\mathcal{P}\} = \mu (1-\eta)(k-1)\mathcal{P}$ and differentiate with respect to ρ to obtain

$$\frac{\partial \rho}{\partial k} \{N\eta R + \mu (1-\eta)(1-k)\mathcal{P}\} + \rho \left\{\mu (1-\eta)\mathcal{P} + \mu (1-\eta)(k-1)\frac{\partial \mathcal{P}}{\partial k}\right\}$$
$$= \mu (1-\eta)\mathcal{P} + \mu (1-\eta)(k-1)\frac{\partial \mathcal{P}}{\partial k}.$$

Since DQIR binds, $\frac{\partial \mathcal{P}}{\partial k} = \frac{\eta}{1-\eta}\frac{\partial Q}{\partial k}$. When $\rho = 0$ DBUDG implies that $\mathcal{P} = 0$ and hence

$$\left.\frac{\partial \rho}{\partial k}\right|_{k=0} = \frac{\mu (k-1)}{NR} \left.\frac{\partial Q}{\partial k}\right|_{\rho=0}$$

If MIC binds then $\left.\frac{\partial Q}{\partial k}\right|_{\rho=0} = \frac{R\Delta p - C}{\Delta p (k-1)^2}$ and the result follows immediately.

Proof of Proposition 9

We consider in turn the cases where $a \geq a^{MH}$ so that MIC binds and all agents apply for a licence, and where $a < a^{MH}$ so that BIC binds and only sound agents apply for a licence.

When MIC binds total welfare is given by $\mathcal{W}^P$ and it is a consequence of lemma 8 that $\frac{\partial \mathcal{W}^P}{\partial \rho}$ and $\frac{\partial \mathcal{W}^P}{\partial k}$ have the same sign. We therefore consider the value of $\frac{\partial \mathcal{W}^P}{\partial k}$ when $\rho = 0$.

$$\frac{\partial \mathcal{W}^P}{\partial k} = \frac{\mu (R\Delta p - C)}{\Delta p} \left[(1-\rho)(\eta - p_L) - \frac{\partial \rho}{\partial k}\{(\eta - p_L k + p_H - \eta)\}\right], \text{ so}$$

$$
\begin{aligned}
\frac{\Delta p}{\mu\left(R\Delta p-C\right)}\left.\frac{\partial\mathcal{W}^P}{\partial k}\right|_{\rho=0} &= \left(\eta-p_L\right)\left(1-k\left.\frac{\partial\rho}{\partial k}\right|_{\rho=0}\right)-\left.\frac{\partial\rho}{\partial k}\right|_{\rho=0}\left(p_H-\eta\right) \\
&= \left(\eta-p_L\right)\left(1-\frac{k\mu\left(R\Delta p-C\right)}{NR\Delta p\left(k-1\right)}\right)-\frac{\mu\left(R\Delta p-C\right)}{NR\Delta p\left(k-1\right)}\left(p_H-\eta\right),
\end{aligned}
$$

using lemma 8. This expression is greater than or equal to 0 iff and only if

$$k\geq k^*\equiv\frac{\left(p_H-\eta\right)\left(R\Delta p-C\right)+\left(\eta-p_L\right)IR\Delta p}{\left(\eta-p_L\right)\left[R\Delta p\left(I-1\right)+C\right]},$$

where $I\equiv\frac{N}{\mu}$. When MIC binds proposition 7 states that k will be set equal to $k_{\eta(a)}$ when $C\eta>R\Delta p\left(\eta-p_L\right)$ and to $\frac{N}{\mu}$ otherwise. Since $\frac{N}{\mu}>k^*$ it is therefore sufficient to demonstrate that $k^*\leq k_\eta$ when $C\eta>R\Delta p\left(\eta-p_L\right)$. Algebraic manipulation yields the following:

$$k_\eta-k^*=\frac{\left(R\Delta p-C\right)\left\{R\Delta p\left(\eta-p_L\right)\left(\Delta p+\left(I-1\right)\eta\right)-C\left(p_H-\eta\right)\right\}}{\left(\eta-p_L\right)\left(R\Delta p\left(I-1\right)+C\right)\left(C\eta-R\Delta p\left(\eta-p_L\right)\right)}.$$

The denominator of this expression is positive and the numerator is increasing in η. The minimum value for η when MIC binds is obtained by setting BIC equal to QIR and solving for η: it is $\frac{Rp_Lp_H}{Rp_H-C}$. Inserting this into the numerator in the above expression yields the following expression:

$$\frac{C\left(R\Delta p-C\right)\left\{Rp_L\Delta p\left(\left(I-1\right)\eta+\Delta p\right)-p_H\eta\left(R\Delta p-C\right)\right\}}{Rp_H-C} \tag{11}$$

Recall that by assumption, in the regulated economy, $I\geq k^U>k^B=\frac{\left(Rp_H-C\right)\Delta p}{Cp_L}$. It follows that

$$Rp_L\Delta p\left(I-1\right)\eta>\frac{R\Delta p}{C}\frac{p_L}{p_L}\left(R-C\right)p_H\eta\geq\left(R-C\right)p_H\eta$$

and hence that the contents of the curly brackets in equation 11 are bounded below by

$$R\left(1-\Delta p\right)p_H\eta+Rp_L\Delta p^2>0,$$

so for every ability a, $k_{\eta(a)}-k^*>0$ and hence $\left.\frac{\partial\mathcal{W}^P}{\partial k}\right|_{\rho=0}>0$.

We now consider economies where $a < a^{MH}$. In this case, we cannot rely as above upon lemma 8. Instead, differentiate equation 6 with respect to ρ to obtain:

$$\left.\frac{\partial \mathcal{W}^O}{\partial \rho}\right|_{\rho=0} = \left(\left.\frac{\partial k}{\partial \rho}\right|_{\rho=0} - k\right)\mu\left(R\Delta p - C\right).$$

It is therefore sufficient to demonstrate that $\frac{\partial k}{\partial \rho} > k$ when $\rho = 0$. There are two cases to consider: economies with optimistic expectations that DOPIC binds; and those with pessimistic expectations so that DPESSIC binds.

When DOPIC binds, equilibrium is attained where $B^{DO}(k)$ and BIC intersect: in other words, at the solution to equation 12:

$$CN\left(k-1\right)p_L + Ck\mu p_H = Rk\mu p_H \Delta p + \mathcal{P}kp_H\mu\left(1-p_H\right). \tag{12}$$

When only sound agents apply for licences, DBUDG becomes

$$\left(1-p_H\right)\left(1-\rho\right)\mu\left(k-1\right)\mathcal{P} = N\rho\eta R,$$

whence

$$\left.\frac{\partial \mathcal{P}}{\partial \rho}\right|_{\rho=0} = \frac{Np_H R}{\left(1-p_H\right)\mu\left(k-1\right)}. \tag{13}$$

Differentiating equation 12 with respect to ρ and setting $\rho = 0$ yields

$$\begin{aligned}\left[CNp_L - \left(R\Delta p - C\right)\mu p_L\right]\left.\frac{\partial k}{\partial \rho}\right|_{\rho=0} &= \left.\frac{\partial \mathcal{P}}{\partial \rho}\right|_{\rho=0} kp_H\mu\left(1-p_H\right) \\ &= Np_H^2 R\left.\frac{k}{k-1}\right|_{\rho=0}.\end{aligned}$$

Since $\frac{N}{\mu} > k^B$, the square bracketted term in the above expression is bounded below by $\mu\left\{\left(Rp_H - C\right)\Delta p - \left(R\Delta p - C\right)p_H\right\} = C\mu p_L > 0$, so

$$\left.\frac{\partial k}{\partial \rho}\right|_{\rho=0} = \frac{Ip_H^2 R\frac{k}{k-1}}{CIp_L - \left(R\Delta p - C\right)p_H} > 0,$$

where again $I = \frac{N}{\mu}$. The value of k when $\rho = 0$ (i.e. k^O) is obtained by solving 12 for k with $\mathcal{P} = 0$:

$$k_{\rho=0} = k^O = \frac{CIp_L}{CIp_L - \left(R\Delta p - C\right)p_H},$$

so that

$$\begin{aligned}
\left.\frac{\partial k}{\partial \rho}\right|_{\rho=0} &= \frac{I^2 p_H^2 p_L RC}{(R\Delta p - C)\, p_H\, (CIp_L - (R\Delta p - C)\, p_H)} \\
&= k\left(\frac{IRp_H^2}{(R\Delta p - C)\, p_H}\right) \\
&\geq k\frac{Rp_H - C}{R\Delta p - C}\frac{p_H}{p_L}\frac{R\Delta p}{C}, \text{ since } I \geq k^B \\
&> k,
\end{aligned}$$

which concludes the proof for the optimistic case.

For the pessimistic case, we proceed in an identical fashion. Setting BIC equal to $B^{DP}(k)$ yields the following equations in a similar way to the above:

$$\begin{aligned}
\left.\frac{\partial k}{\partial \rho}\right|_{\rho=0} &= \frac{Ip_H^2 R\left(\frac{1-\eta}{1-p_H}\right)\left(\frac{k}{k-1}\right)}{CIp_L - R(\eta - p_L)\, p_H + C\eta} > 0 \\
k_{\rho=0} &= k^P = \frac{CIp_L}{CIp_L - R(\eta - p_L)\, p_H + c\eta}.
\end{aligned}$$

Substituting the second of these equations into the first and proceding as in the optimistic case yields

$$\begin{aligned}
\left.\frac{\partial k}{\partial \rho}\right|_{\rho=0} &= k\left(\frac{IRp_H^2\left(\frac{1-\eta}{1-p_H}\right)}{R(\eta - p_L)\, p_H - C\eta}\right) \\
&\geq k\frac{Rp_H - C}{R(\eta - p_L) - C}\frac{p_H^2}{\eta p_L}\frac{R\Delta p}{C} \\
&> k.
\end{aligned}$$

This concludes the proof.

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Figure 1

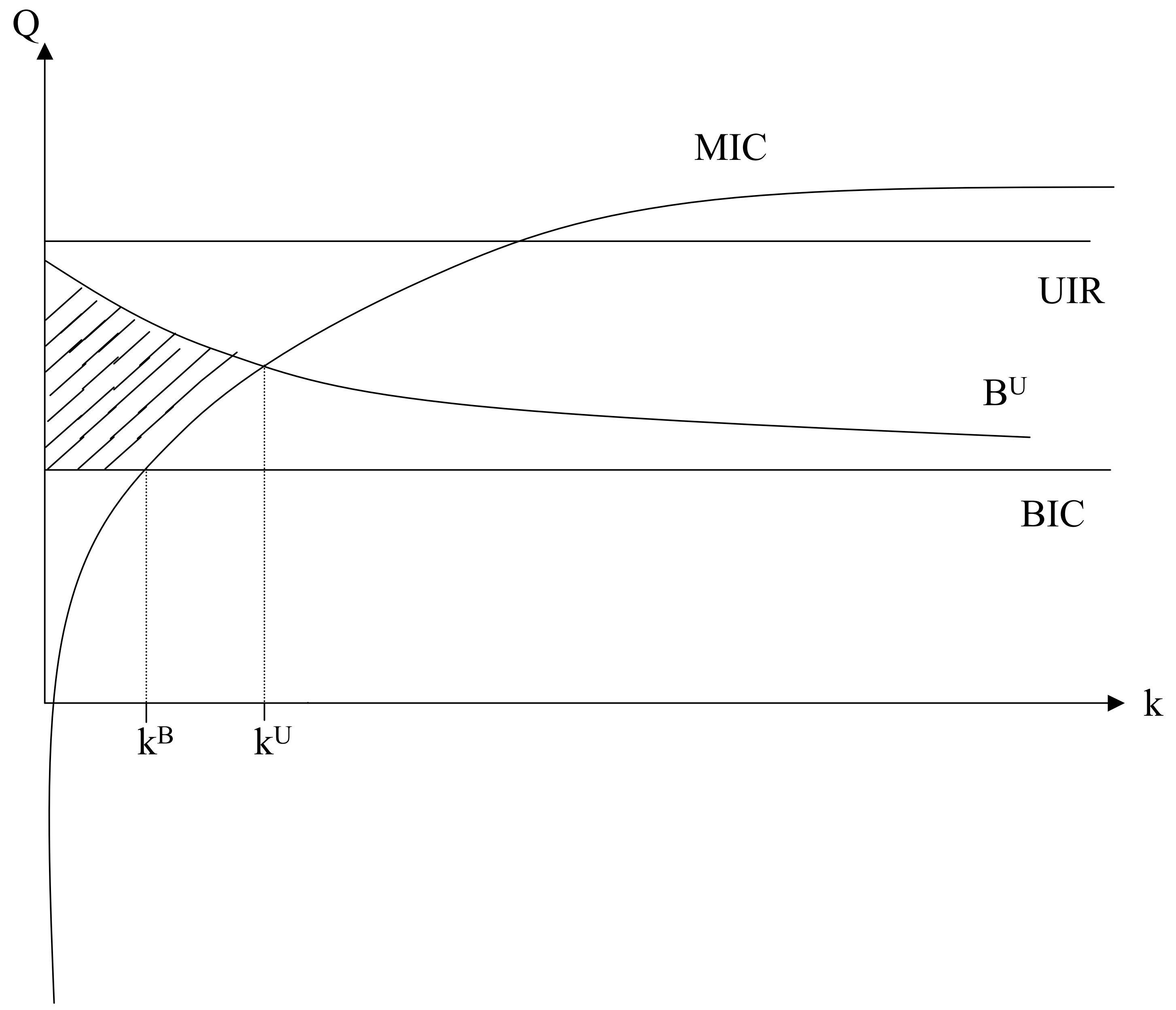
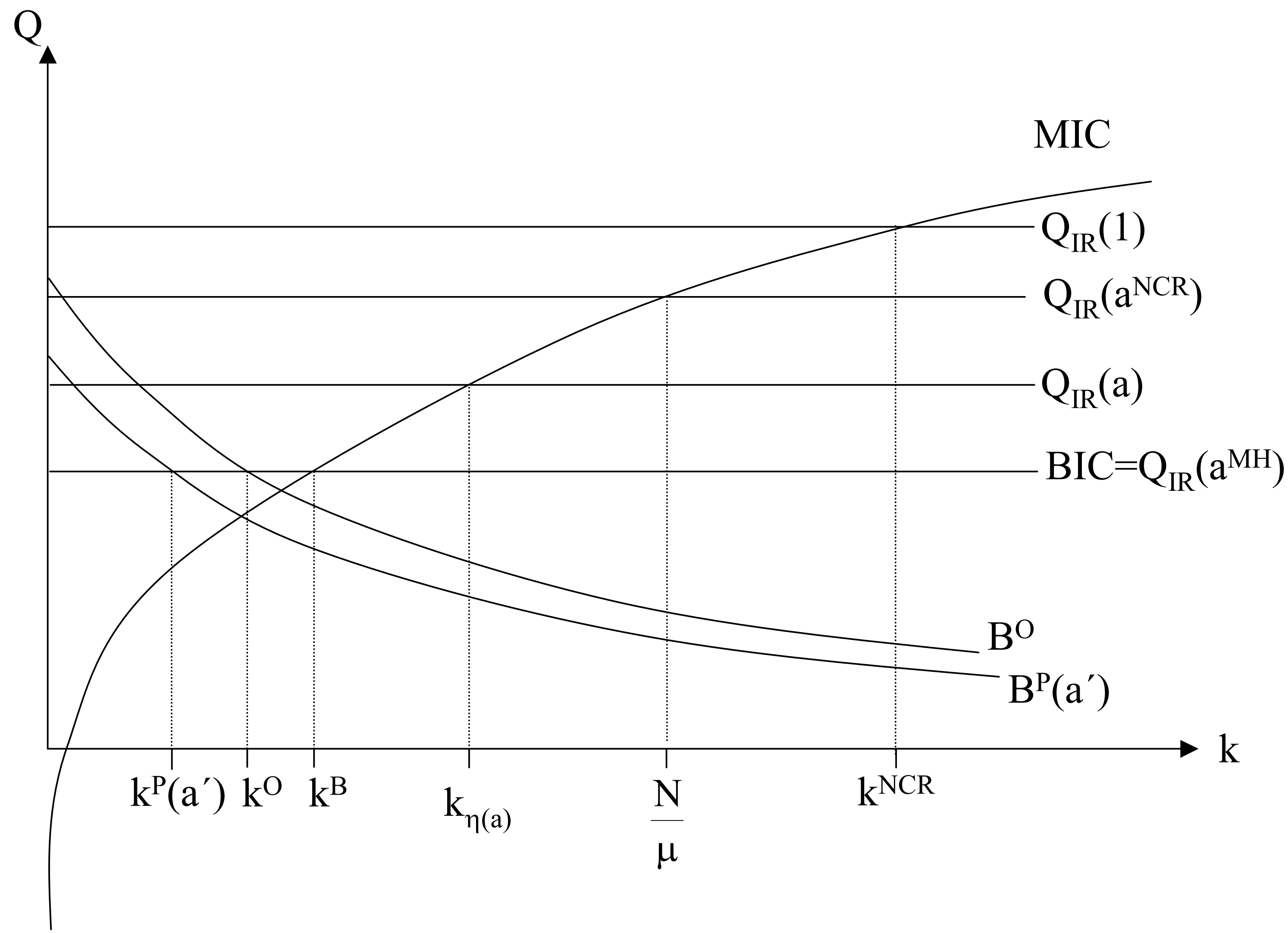


Figure 2



Q
MIC
$Q_{IR}(1)$
$Q_{IR}(a^{NCR})$
$Q_{IR}(a)$
$BIC=Q_{IR}(a^{MH})$
B^O
$B^P(a')$
k
$k^P(a')$
k^O
k^B
$k_{\eta(a)}$
$\frac{N}{\mu}$
k^{NCR}

Figure 3