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An Incentive Approach to Banking Regulation

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ABSTRACT

We examine the optimal design of a risk-adjusted deposit insurance scheme when the regulator has less information than the bank about the inherent risk of the bank's assets (adverse selection), and when the regulator is unable to monitor the extent to which bank resources are being directed away from normal operations toward activities that lower asset quality (moral hazard). Under a socially optimal insurance scheme: (1) asset quality is below the first-best level, (2) higher-quality banks have larger asset bases and face lower capital adequacy requirements than lower-quality banks, and (3) the probability of failure is equated across banks.

PERHAPS THE MOST TROUBLING aspect of the current deposit insurance system is the distortions caused by the pervasive use of an insurance premium that is independent of risk. The undesirable incentives that result when such a system is employed in a world with imperfect information have long been recognized in the literature.[1] Of particular concern is the incentive banks have to increase the risk of their portfolio in order to maximize the value of the deposit insurance provided. In some respects, this problem is similar to the incentives generated by corporate debt. However, the solution to this problem may be different in a banking context because the creditors include the deposit insurer who has the power to regulate the banks. Conceivably, regulation may be able to mitigate the informational problem at hand. In this paper we examine some of the tradeoffs that arise in the design of a regulatory system for banks.

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[1] See for instance Kane (1985).

There are a number of tacks a regulatory authority might take to combat informational problems. For instance, bank investments might be monitored and restricted to limit excessive risk taking. However, in practice, monitoring is only imperfectly informative, and regulators are often unable or unwilling to act on the information they receive. In our analysis, imperfect monitoring and regulatory forbearance play important roles in the regulatory process.

A second course of action that has been advocated is to adjust for risk either the insurance premia that are charged to banks and/or the capital level that is required of insured institutions. Conceptually, if the risk of a bank's assets can be accurately determined, then an adjustment can be made to eliminate any advantage of increasing risk. This reasoning has led to calls for fairly priced deposit insurance where the price of the insurance reflects the bank's capital structure and the risk of its assets. One practical problem with this proposal is that the information required to implement fairly priced deposit insurance is generally not revealed through the monitoring process. Consequently, bank managers generally know more about the riskiness of their loan portfolio than do regulators. A second practical problem with a risk-adjusted deposit insurance system is the change in investment incentives that accompany its implementation.

This paper deals with both the imperfect monitoring problem and incentive effects by explicitly modelling profit-maximizing behavior by banks who have better information about their environment and their activities than do regulators. In our model, the regulator optimally pursues his objective, recognizing the incentive and informational problems he faces.

An example of surprising results that can arise from this sort of approach is provided by Chan, Greenbaum, and Thakor (1992). The authors show that fairly priced deposit insurance and incentive compatibility may not be consistent. Thus, when incentives are taken into account, the optimal scheme may involve the intentional mispricing of deposit insurance. Their finding emphasizes the important regulatory tradeoff between (1) providing informational rents to some banks in order to acquire information with which to better regulate the industry as a whole, and (2) fairly pricing the deposit insurance in a system which is socially inefficient.

Our study extends Chan, Greenbaum, and Thakor's focus on incentive compatibility requirements by analyzing the regulator's concern for social welfare. Campbell, Chan, and Marino (1990) also include a social welfare function, but their focus is on the value of liquidity. We allow bank profits to enter the regulator's objective function and we incorporate explicit costs of bank regulation. Furthermore, we extend the existing literature by enhancing the regulator's policy instruments, giving an important role to imperfect monitoring of the bank's activities.

We focus on the problem of regulatory design taking as given the government's role as a provider of deposit insurance. We take the failure of a bank to be socially costly, and assume that government involvement in the provision of deposit insurance is itself socially costly. Central to our model is an information asymmetry due to the bank's private information about its costs of operation (adverse selection) and about hidden actions that bankers can take to increase their personal well being at the bank's expense (moral hazard).

Employing techniques developed in the agency literature (e.g., Laffont and Tirole (1986)), we derive the properties of the incentive-compatible insurance scheme that maximizes the combined welfare of the depositors, the banks, and the public. In order to highlight the effect of government involvement in deposit insurance, we compare this scheme with one that would arise in a first-best world where government involvement is costless and where information asymmetries do not exist. We find that, relative to the first-best situation, a socially optimal deposit insurance scheme is able to discriminate among banks on the basis of risk but, in so doing, encourages a reduction in the quality of bank assets. In this way we provide a partial explanation of regulatory forbearance: regulators allow a level of quality to prevail which they know can be improved upon.

Our model is built on the assumption that deposits provide liquidity services that are valuable to depositors. Each bank has a given technology that it employs to select and make loans. In addition, the loan portfolio includes a bank-specific innate risk which can be attenuated if the banker devotes personally costly resources to this task. The banker observes the innate quality of the loan portfolio and determines the level of resources that will be devoted to improve this quality. The regulator, on the other hand, only observes the resulting level of quality but does not know whether the observed quality is due to circumstance or neglect. Hence, an important point of departure for our analysis is in recognizing that the objective of the regulator is not to target a specific level of default risk, but rather to manage the tradeoff between the social losses from default and the social costs of avoiding default. Hence, the social planner in our model is explicitly concerned with the impact of the deposit insurance system on the efficiency of the bank's operations, the liquidity value of the deposit insurance, the economic costs of the manager's efforts, the economic cost of bank failure, and the government's cost of bank regulation.

We find that in a socially optimal deposit system: (1) although the optimal insurance scheme is quality adjusted, the extent of adjustment is reduced in order to limit rents that flow to managers of the bank; (2) given the optimal level of induced quality, loan activity and equity financing are not distorted; (3) higher-quality banks are allowed a relatively larger asset base and face lower capital adequacy requirements than lower-quality banks; and (4) despite cross-sectional differences in bank asset quality, the probability of failure is equal across banks.

In the next section we set out the structure of our model. Our main findings are recorded in Section II. A summary and concluding remarks are contained in Section III.

I. The Model

We are concerned with the following general problem. There are investors who have wealth that can be allocated either to illiquid equity or to liquid deposits. Liquidity is valued by investors.[2] There are also a fixed number of banks in the economy that can provide two socially valuable services. First, they can issue deposit accounts that are completely liquid. (For simplicity we assume each bank can issue a fixed, finite amount of liquid deposits at zero marginal cost.) Second, they can employ the deposits they receive to make risky corporate loans or to purchase risk-free securities. By employing resources that would otherwise be used to increase the welfare of the bank managers, the bank can identify the more promising loan opportunities, and can reduce the risk associated with its loan portfolio. This reduction in risk has social value. There are also social gains to avoiding the bankruptcy costs that are incurred when the bank is unable to repay depositors.[3]

This relatively simple scenario is complicated by the presence of regulation. By assumption, bank deposits are fully insured by the government. Conceivably, this insurance can distort the incentives of the banks to make prudent loans. Given that the regulator cannot monitor the activities of the banks perfectly, questions arise concerning the restrictions that should be imposed on bank operations. For instance, the regulator could ensure the solvency of all banks by requiring that they invest only in risk-free securities or securities for which market values can be easily ascertained.[4] Doing so, however, would entail a social loss since banks would be unable to exploit their ability to discern high-quality loan opportunities and create lower-risk portfolios. In addition, some projects that would have been financed in the absence of this severe regulatory policy will not receive funding.

This general problem guides our model construction. The specific details of our model are as follows. There are four classes of risk-neutral actors: (1) investors who have wealth that can be invested or loaned, (2) companies that seek loans to finance projects, (3) banks that provide intermediation services, and (4) a regulator who is required to insure deposits issued by the banks. We now provide more detail on these parties.

[2] We simply assume that liquidity is valuable without modelling the imperfection that would make it so. In doing this we are following the banking literature (see, for instance, Campbell, Chan, and Marino (1990), and Besanko and Kanatas (1989)). Also see Diamond and Dybvig (1986) and Freeman (1988) for examples of models where the need for liquidity is based on uncertainty about intertemporal consumption needs.

[3] The problem described is in some ways similar to the classic capital structure problem. Banks can issue debt which has a liquidity advantage (as opposed to the usual tax advantage). But if the proceeds are invested in risky loans, expected bankruptcy costs arise. In an unregulated environment, there would be an equilibrium capital structure for each bank and for the economy as a whole. Under some parameter values, the equilibrium would imply "narrow" banks that invest all deposit proceeds in risk-free securities. More generally, however, banks would invest in both risk-free and risky securities.

[4] See Karaken and Wallace (1978), for an example of this line of argument.

A. Investors / Depositors

To capture the preference of investors for liquidity most simply, we assume investors are indifferent between illiquid securities offering a rate of return of $r^e > 1$ and liquid assets offering a rate of return of 1.

B. Companies

We assume that each company has access to an investment project. The company is unable to finance the project alone and thus requires an outside source of funding. For simplicity, we assume that banks are the only source of funds, perhaps reflecting an overriding advantage in providing intermediation services. Although each investment project requires the same amount of funding from the bank, projects differ in their expected returns. We denote by r the average rate of return on all projects financed by the bank. We discuss the determination of r in greater detail below.

For simplicity, we imagine that banks have all the bargaining power in negotiating financing with the companies.[5] (For example, each company may be forced to borrow from the local bank, whose knowledge of the local economy gives it local monopoly power.[6]) Consequently, the bank can capture as profit all the expected surplus from the loan. Thus, if the bank lends a total of L dollars to companies who collectively generate an average return of r, the bank earns an overall return of rL.

C. Banks

At the start of our model, just prior to time t_0, the bank has one outstanding share and has no outstanding deposits. The bank's only asset at this point is monopoly access to a segment of the risky loan market. The objective of the bank is to maximize the value of its initial equity share, which will henceforth be referred to as the bank's initial wealth. At t_0, provided it has complied with the rules established by the regulator, the bank can attract the funds it needs to finance projects by issuing both equity and fully insured deposits. The cash flows generated by the bank's assets are collected at time t_1 and distributed to the claimants of the bank in a manner specified below.

At t_0, the bank issues D of deposits and sells a fraction of the equity, denoted by z, to new shareholders. It then invests R of the proceeds in risk-free assets and L in risky loans used to finance the projects of selected companies. The investment in the risk-free asset returns R at time t_1 with certainty. (Thus we normalize the risk-free rate of interest to zero.) The investment in the risky loans provides an average gross return of rL. The net return on risky loans is influenced by the operating economies achieved

[5] This assumption is for convenience only. It allows us to capture all of the social surplus from risky investment in the expression for the bank's profit. Our analysis would not change significantly, however, if the bank and the companies were assumed to divide the surplus from investment in some other way according to their relative bargaining strengths.

[6] See Besanko and Thakor (1991) for a model that features spatial competition in banking.

by the bank. We denote by $\gamma(L)$, an increasing, strictly convex function, the cost of processing L of risky loans. Hence the net return on risky loans is $rL - \gamma(L)$.

A central feature of our model is the bank's private information about its influence on the return it receives from the risky projects it finances. By undertaking careful analysis and selection of the projects it finances, the bank can enhance the distribution of returns from its loan portfolio. The enhancement can take the form of a reduction in the variance of the gross return or an increase in its mean. Formally, the average gross rate of return, r, on the bank's portfolio is modelled as a random variable with smooth distribution function $G(r|q)$. q is the quality of the bank's loan portfolio. Higher levels of q will be assumed to shift the distribution of returns in the sense of either first-order stochastic dominance (FOSD) (i.e., reduce the likelihood of low returns) or second-order stochastic dominance (SOSD) (i.e., reduce the variance of returns). The two assumptions lead to qualitative results that are very similar. Since both types of shifts capture important aspects of moral hazard, we allow for both types in our analysis.

Technically, we assume the underlying density function has positive support on $[\underline{r}, \bar{r}]$ and:

(FOSD) $\quad G_q(r|q) \leq 0 \; \forall r \in [\underline{r}, \bar{r}]$ with strict inequality for some r; or

(SOSD) $\quad \int_{\underline{r}}^{y} G_q(r|q)\, dr \leq 0 \; \forall y \in [\underline{r}, \bar{r}]$ with strict inequality for some y.

Furthermore, we assume $G_{qq}(r|q) < 0 \; \forall r, q$ implying diminishing effects of improved loan quality.

The realized quality of the bank's portfolio is the sum of two influences: (1) the innate quality of the available lending opportunities, and (2) the extent to which the bank devotes resources to the enhancement of its loan quality. Innate quality, q_0, captures factors that influence the bank's operations but are beyond the bank's control. These factors include local economic conditions and the managerial abilities of the bank's customers. We assume the bank's day-to-day interactions with borrowers provide it with better information about innate loan quality than the regulator has. Formally, we assume the bank knows the exact level of innate quality, while the regulator views innate quality as a random variable on the interval $[\underline{q}, \bar{q}]$ with density function $f(q_0)$. $F(q_0)$ denotes the corresponding distribution function. To avoid uninteresting technical problems, we assume $\frac{d}{dq_0}\left\{\frac{1 - F(q_0)}{f(q_0)}\right\} \leq 0 \; \forall q_0 \in [\underline{q}, \bar{q}]$. This simplifying assumption is satisfied, for example, by the uniform distribution.

The bank is able to raise the quality of its loan portfolio e units above q_0 if it devotes resources to this purpose with a cost of $C(e)$. We assume that these costs directly reduce the bank's initial wealth. One interpretation of e is that it represents the personal effort devoted to the affairs of the bank by its manager and $C(e)$ is the disutility of this effort. While this interpretation is quite natural for a small institution, it may be less germane for a larger institution. For larger banks, e can be thought of as corporate resources over which the bank managers have discretion. For instance, e might be the corporate resources that the manager is able to consume in the form of perquisites without being detected. To devote these same resources to, say, additional audit staff might increase the quality of the bank's loans, but would be costly to the manager. Alternatively, it may be possible for the manager to grant ill-advised loans to a company over which it has control and from which the manager would receive considerations. In this case, e is the diminution of the bank's loan portfolio from the ill-advised loans, and $-C(e)$ is the value of the considerations that flow to the bank manager.[7] Formally, the level of quality achieved by the bank is $q = q_0 + e$.

At t_1 the cash flows of the bank are collected and distributed to the claimants. If the cash flow exceeds total deposits D, then D is repaid to depositors and the residual is paid to equity holders as a dividend. The fraction $(1 - z)$ of the dividend is paid to the initial shareholders and the balance is paid to the holders of the newly issued shares. If the cash flow is less than D, the regulator pays D to the depositors and gains title to the assets of the bank. All shares of the firm are extinguished through bankruptcy, and the equity holders of the firm receive nothing.

Therefore, for a given portfolio of loans (L) and risk-free investment (R), and a given level of deposits outstanding (D), the equity raised (E) must satisfy

$$r^e E = z \int_{r^b}^{\bar{r}} [rL - \gamma(L) + R - D] \, dG(r|q), \tag{1}$$

where $G(r|q)$ is the conditional cumulative density function for r, $r^e > 1$ is the required expected return on bank equity, and r^b is the "breakeven" return level below which default occurs.[8] Thus r^b satisfies

$$r^b = \frac{D + \gamma(L) - R}{L}. \tag{2}$$

[7] A recent example can be found in the Lincoln Savings and Loan case. The Office of Thrift Supervision issued a $40 million claim against a group led by Charles Keating, who previously controlled Lincoln. The claim is based on: (1) Lincoln's backing of a hotel purchase by a group that included Keating and which generated a $24 million loss for Lincoln, (2) losses on loans made by Lincoln that allowed a stock ownership plan to purchase shares from Keating, and (3) land sales at artificial prices that temporarily boosted profits for Lincoln and allowed it to continue paying generous salaries. In addition, Keating was the target of a $1.1 billion federal suit under the Racketeer Influence and Corrupt Organizations Act.

[8] Notice the assumption here that the cost of equity to the bank does not vary with the level of equity raised. This simplifying assumption follows from the presumed indifference of investors between liquid assets and illiquid securities with rate of return r^e. More generally, investors might wish to hold some mixture of liquid and illiquid assets. In this case, investors would supply more funds to the bank the higher the promised return, causing the bank's marginal cost of equity to rise with the level of equity raised from investors. Consequently, changes in the equilibrium level of equity will change the marginal cost of equity, which in turn influences the bank's demand for equity funding. The simplifying assumption that r^e is constant allows us to avoid these general equilibrium considerations in our analysis of the banking sector. We comment below on the qualitative changes in our conclusions that would arise from these general equilibrium considerations.

Note that reserves held by the bank in the risk-free asset act as a buffer in the sense that, for a given level of loans, the breakeven return decreases as deposits are reduced and reserves are increased.[9]

Given the investment and financing opportunities available to the bank, we can define the initial wealth of the bank for a given set of financial decisions as

$$(1 - z)\int_{r^b}^{\bar{r}}[rL - \gamma(L) + R - D]\, dG(r|q) - C(q - q_0) - P. \qquad (3)$$

The first term in (3) is the value of the residual claim retained by the original owners of the bank. The second term is the cost of achieving the quality level q, given innate quality level q_0. The last term in (3) is the premium charged to the bank at time t_0 for the deposit insurance. Notice that the bank's profit reflects the social surplus from risky loans and the value of liquidity services.[10]

Initial wealth also reflects the operating efficiency of the bank and the net benefit of quality provision.

In addition to incorporating the financing constraint (1), the maximization of (3) by the bank must also satisfy the cash flow constraint

$$R + L + P = D + E.$$

We can, without loss of generality, simplify our analysis by assuming that $D = L$. Intuitively, this assumption standardizes the regulator's problem. Banks create social value by issuing low-cost liquid deposits and investing in illiquid high-return assets. Illiquid equity can also be used to finance illiquid investments but at lower social value. Hence, equity financing is used only to adjust the probability of default.[11]

D. The Regulator's Problem

The regulator's task is to provide deposit insurance while maximizing social welfare. Social welfare reflects bank profits less the social cost of

[9] Notice the presumed unique role of banks in providing intermediation services. The assumption that r^e is constant implies funds are available to banks in perfectly elastic supply. If the companies who seek financing for their projects could access these funds directly, the need for intermediated banking would be diminished. We presume companies have no other direct access to funds, which provides the bank with its monopoly power. The ensuing monopoly rents can be viewed as returns to unique skills to distinguish between "good" and "bad" projects, even though there is variation in the returns to good projects. The possibility of introducing competition among intermediaries to better control the activities of banks is beyond the scope of this research, but is treated in related nonfinancial settings by, for example, Demski *et al.* (1987) and Laffont and Tirole (1988).

[10] Recall that the social surplus from liquidity and risky investment are fully captured by the bank in the form of profits.

[11] Conceivably, equity and reserves might have separate incentive effects in some settings, but it is useful to effectively focus on a single policy instrument.

government involvement in the industry and any social costs generated by financial distress.[12]

The critical informational asymmetry in our model centers on the costs of enhancing the quality of the bank's loan portfolio. We assume that the regulator knows the functional form of $C(e)$ and the relationship between quality and the bank's efforts ($q = q_0 + e$), but cannot observe the realization of q_0 nor can the regulator monitor the level of discretionary resources that the manager devotes to quality enhancement. However, the regulator is able to evaluate the realized total quality of the loan portfolio q. This assumption is consistent with the periodic inspection of bank assets and operations that regulators undertake in practice. Of course, actual inspections are multi-faceted and imperfect. For our purposes, though, it is helpful to simplify by assuming the regulator is able to accurately determine the realized quality of the bank's loan portfolio.[13]

The regulator uses the following instruments to deal with the informational problem: (1) the insurance premium it charges to the bank (P); (2) the level of equity financing required (E) and thus the level of risk-free reserves that must be held (R); and (3) the amount of loans (L) that the bank can issue. The regulator can tie the level of each of these policy variables to the total realized quality (q) of the bank's loan portfolio. Thus, for example, the regulator may allow the bank to issue more loans, pay a smaller insurance premium and/or maintain a lower level of equity financing as a proportion of loans provided that the manager achieves a higher level of loan quality.

Without loss of generality, we model the regulator as presenting a menu of linked options $\{q(\cdot), P(\cdot), L(\cdot), R(\cdot)\}$ to the bank. The bank is permitted to choose one of these options after observing the environment in which it is operating, i.e., after observing the realization of its innate quality, q_0. We will denote by $\{q(q_0), P(q_0), L(q_0), R(q_0)\}$ the particular option that the bank will select in equilibrium when q_0 is the realized level of its innate quality. After announcing the option it has selected, the bank raises the required amount of equity and issues deposits. The funds raised are used to pay the required insurance premium, invest in risk-free securities, and make loans. The regulator monitors this procedure and prevents the bank from operating if the specified quality level is not achieved. If the quality level is achieved,

[12] In addition, there is the social value of the liquidity services supported by deposit insurance. This is reflected in our model through the differential costs of deposits relative to equity and the impact of this difference on the bank's profits.

[13] A great deal of research has been devoted to the development of indicator systems based on accounting data (see Putnam (1983) for a review of the indicators being used in the United States). More recently, market-based measures have also been suggested (see Giammarino, Schwartz, and Zechner (1989)). Despite these efforts, however, inspection and supervisory procedures provide only imperfect measures of asset quality. Although it is more tedious to incorporate imperfect monitoring into the model, doing so would not alter our main qualitative insights. For details of a related model with imperfect monitoring of realized quality, see Lewis and Sappington (1989). On the other hand, see Lucas and McDonald (1987) and Flannery (1991) for studies in which the unobservable component of quality is critical to the regulator's problem.

the bank remains in operation until t_1, at which time the realized cash flows are collected and distributed in the manner described above. The interaction between the regulator and the bank is not repeated.

The cost of government involvement in bank regulation is captured by the assumption that the social cost of a dollar of public funds used to finance the insurance program is $(1 + \lambda) > 1$. This cost reflects the social losses that occur when distortionary taxes are imposed in one sector to finance other sectors of the economy.[14]

In equilibrium, the expected net payoff to the government from providing deposit insurance to a bank with innate quality q_0 is given by

$$S(q_0) \equiv r^e P(q_0) - [1 + b]\int_{\underline{r}}^{r^b} [rL(q_0) - \gamma(L(q_0)) - L(q_0) + R(q_0)]\, dG(r|q(q_0)). \tag{4}$$

The first term is the (positive) future value of the insurance premium collected from the bank. The second term is the (negative) expected payout during financial distress plus the social costs of financial distress which are assumed to be proportional to these losses.[15] The social cost factor b is assumed to be positive due to the negative externalities and deadweight costs associated with bank failure.[16]

To measure the equilibrium initial value of the bank, first consider

$$\pi(\hat{q}_0|q_0) \equiv \int_{r^b}^{\bar{r}} [rL(\hat{q}_0)) - \gamma(L(\hat{q}_0)) - L(\hat{q}_0) + R(\hat{q}_0)]\, dG(r|q(\hat{q}_0)) - r^e[R(\hat{q}_0) + P(\hat{q}_0)] - C(q - q_0). \tag{5}$$

$\pi(\hat{q}_0|q_0)$ is the bank's initial value when its innate quality is actually q_0 but the bank chooses the insurance terms that, in equilibrium, will be chosen by a bank with an innate quality level $\hat{q}_0$. The expression in (5) follows directly from (3) using the fact that the bank's operations must be consistent with the insurance terms chosen.

[14] Empirical estimates of the value of λ can be found in Ballard, Shoven, and Whalley (1985). They estimate λ to be in the range [0.17, 0.56]. Alternatively, λ can be thought of as a Lagrange multiplier associated with a constraint which limits the deficit the government can accrue in the banking industry.

[15] Note that in this statement of the financial distress costs we have employed the cash flow constraint to substitute $L(q_0)$ for $D(q_0)$.

[16] Alternative formulations of the bankruptcy costs are possible although they seem unlikely to affect the qualitative conclusions drawn below. For example, the costs of bankruptcy might be proportional to the magnitude of the bank's outstanding loans, reflecting the idea that direct and indirect bankruptcy costs vary with the absolute size of the bank.

This notation allows a formal statement of the regulator's problem, [RP]:

$$\max_{q, P, L, R} \int_{\underline{q}}^{\overline{q}} \{[1 + \lambda] S(q_0) + \pi(q_0)\}\, dF(q_0) \tag{6}$$

subject to, $\forall q_0, \hat{q}_0, \in [\underline{q}, \overline{q}]$:

$$\pi(q_0) \equiv \pi(q_0 | q_0) \geq 0; \quad \text{and} \tag{7}$$

$$\pi(q_0) \geq \pi(\hat{q}_0 | q_0). \tag{8}$$

The individual rationality constraints (7) ensure that, for all realizations of innate quality, the bank expects to have nonnegative initial wealth. The incentive compatibility constraints (8) identify $\{q(q_0), P(q_0), L(q_0), R(q_0)\}$ as the option the bank will select when its innate quality level is q_0. The revelation principle (e.g., Myerson (1979)) ensures there is no loss of generality in representing the bank's choice in this manner.

II. Findings

As a benchmark against which the solution to [RP] can be compared, consider the first-best solution to the regulator's problem.[17] This is the policy that the regulator would implement if he shared the bank's private knowledge of its innate quality level (so that the incentive compatibility constraints were not relevant), and if $\lambda = 0$ so that no additional costs arise from government provision of deposit insurance.

Definition: Assume [FOSD] or [SOSD]. At the first-best solution to the regulator's problem, $\forall q_0 \in [\underline{q}, \overline{q}]$:

(i)

$$\int_{\underline{r}}^{\overline{r}} \delta(rL^*(q_0) - \gamma(L^*(q_0)) - L^*(q_0) + R^*(q_0))\, dG_q(r | q^*(q_0)) - C'(q^*(q_0) - q_0) = 0; \tag{9}$$

(ii)

$$\int_{\underline{r}}^{\overline{r}} \delta'(rL^*(q_0) - \gamma(L^*(q_0)) - L^*(q_0) + R^*(q_0)) \cdot [r - \gamma'(L^*(q_0)) - 1]\, dG_q(r | q^*(q_0)) = 0; \quad \text{and} \tag{10}$$

(iii)

$$[1 + b] G(r^{b^*} | q^*(q_0)) + \left[1 - G(r^{b^*} | q^*(q_0))\right] - r^e = 0, \tag{11}$$

[17] Actually this is a "constrained first-best" solution in that bankruptcy costs are present.

where

$$\delta(x) = \begin{cases} [1+b]x & \text{for } x \le 0 \\ x & \text{for } x > 0, \end{cases}$$

and $r^{b^*}L^* - \gamma(L^*) - L^* + R^* = 0$. Equations (9), (10), and (11) are obtained by differentiating (6) with respect to q, L, and R, respectively.[18]

Equation (9) identifies the first-best level of quality for the bank's loan portfolio. Increases in quality increase the expected cash flows of the bank and reduce the probability of failure. At the first-best level of quality, these marginal gains are equal to the marginal costs of additional quality $C'(\cdot)$. The first-best capital structure of the bank is set out in (10) and (11). The optimal level of loan activity reflects the usual tradeoff between the expected benefits from debt and the (social) costs of bankruptcy. The benefits from debt reflect the bank's increased ability to fund projects at a cost that reflects the social value of the liquidity services provided by deposits. Similarly, the first-best level of equity financing occurs where the marginal reduction in bankruptcy costs is equal to the marginal cost of equity financing, $r^e - 1$. Hence, the first-best capital structure of the bank is similar to that of any other type of firm, except for exogenous differences in the costs of debt, equity, and financial distress.

Proposition 1 reports how the information asymmetry and the social cost of government financing combine to induce departures from the first-best solution. These departures are designed to limit any gains the bank might anticipate from "understating" its innate quality level by choosing from the menu of options one that, in equilibrium, will be selected by the bank when a smaller value of q_0 is realized. The regulator is concerned with limiting the bank's information rents because these rents are paid with the costly dollars that are raised through the distortionary tax system.

The primary deviation from the first-best solution that the regulator implements is a reduction in the final level of quality that the bank will achieve for all but the bank with the highest realization of innate quality. (See equation (12) below.) The reduced quality limits the gains to the bank from understating its innate quality q_0 and profiting from devoting fewer resources to enhancing asset quality.[19] Hence, the deposit insurance system is, to some extent, quality adjusted. However, the quality adjustment is blunted somewhat to offset the bank's incentive to misrepresent its true situation.

[18] Throughout, our focus is on interior solutions in both the first- and second-best problems. Thus, we assume $\underline{q}$ is sufficiently large that it is socially optimal to have all banks, even the bank with the lowest innate quality, make loans. In practice, the government will only provide deposit insurance to banks who achieve a minimum quality threshold, q_m. For simplicity, we assume $q(\underline{q}) \ge q_m$ in the solution to [RP]. Absent this assumption, there would be an interval of the lower innate quality realizations for which the bank would be shut down. (For the analytic details in a related analysis, see Baron and Myerson (1982).)

[19] Quality distortions are common in incentive problems of this type. See, for example, Laffont and Tirole (1986).

Given the quality of the loan portfolio that is induced in equilibrium, the capital structure decision of the firm is efficient. (Compare equation (13) and (14) below with equations (10) and (11), respectively.) Given the quality of the loan portfolio, the expected profits of the bank are not affected differentially according to its innate quality level by changes in capital structure. Therefore, since distortions in capital structure play no role in limiting the rents that the bank commands from its private knowledge of q_0, capital structure will be determined as in the first-best calculations described above.[20, 21]

Of course, the rents of the bank cannot be completely eliminated when the bank has private knowledge of q_0, as is evident in (15).

PROPOSITION 1: *Suppose* [FOSD] *or* [SOSD] *hold. Then at the solution to* [RP].[22]

$$\text{(i)}\quad \int_{\underline{r}}^{\bar{r}} \delta(rL(q_0) - \gamma(L(q_0)) - L(q_0) + R(q_0))\, dG_q(r|q(q_0)) - C'(q(q_0) - q_0) = \frac{\lambda}{1+\lambda} C''(q(q_0) - q_0)\frac{1 - F(q_0)}{f(q_0)}; \tag{12}$$

$$\text{(ii)}\quad \int_{\underline{r}}^{\bar{r}} \delta'(rL(q_0) - \gamma(L(q_0)) - L(q_0) + R(q_0)) \cdot [r - \gamma'(L(q_0)) - 1]\, dG_q(r|q(q_0)) = 0; \tag{13}$$

$$\text{(iii)}\quad [1 + b]G(r^b|q(q_0)) + \left[1 - G(r^b|q(q_0))\right] - r^e = 0; \quad \textit{and} \tag{14}$$

$$\text{(iv)}\quad \pi(q_0) = \int_{\underline{q}}^{q_0} C'(q(\tilde{q}) - \tilde{q})\, d\tilde{q}. \tag{15}$$

[20] Similar qualitative conclusions arise in Laffont and Tirole's (1986) model.

[21] As a referee has observed, this conclusion depends on our simplifying assumption that r^e is a constant. Because the induced quality levels in the solution to [RP] differ from first-best levels, the magnitude of the equity raised by the bank in the solution to [RP] will generally differ from the corresponding magnitude in the first-best setting. Consequently, if the required return to equity varies with its equilibrium supply, the r^e in equation (14) below will differ from the r^e in equation (11). In this regard, capital structures will differ in the first- and second-best solutions. Nevertheless, in this setting, it is still true that given the portfolio quality which is induced in equilibrium, the bank's choice of capital structure will be efficient. We abstract from these general equilibrium complications to better focus on the key incentive issues in our analysis. However, it is not difficult to determine how our main qualitative conclusions would change in the expanded general equilibrium setting. (See footnote 23 below.)

[22] Throughout we assume that the second-order conditions for a maximum are satisfied and the solution to [RP] is interior. Using standard techniques, it is straightforward to show that the second-order conditions will be satisfied if $q(\cdot)$ is an increasing function of q_0 at the identified solution. This will be the case, for example, if $G_q(r^b|q(q_0))$ is sufficiently small $\forall q_0 \in [\underline{q}, \bar{q}]$, as indicated in Proposition 2.

The proof of Proposition 1 (like the the proof of Proposition 2 below) is in the Appendix. Notice equation (14) can be simplified to

$$bG(r^b|q(q_0)) - [r_e - 1] = 0, \tag{16}$$

which implicitly determines the equilibrium probability of bankruptcy, $G(r^b|q(q_0))$. The first term in (16) measures the expected savings in bankruptcy cost from increasing reserves by one dollar. The second term represents the marginal cost of financing an extra dollar of reserves. In equilibrium these two quantities are always equated. This means the capital structure of each bank is determined so that the probability of bankruptcy is the same for all banks, independent of their initial quality, q_0. This may seem surprising. One might expect high-quality banks to experience bankruptcy less often than low-quality banks. However, reserves are a substitute for quality in reducing bankruptcy; and, whatever the starting quality level, reserves will be added until their marginal cost (which is identical for all banks) equals their marginal benefit (which is also the same for all banks).[23] The following corollary follows directly from equation (16).

COROLLARY 1: *Given [FOSD] or [SOSD], at the solution to [RP], the probability of bank failure is the same for all realizations of innate quality, i.e.,*

$$G(r^b|q(q_0)) = \frac{(r^e - 1)}{b} \qquad \forall q_0 \in \left[\underline{q}, \bar{q}\right]. \tag{17}$$

The following observation is also apparent from equation (16).

COROLLARY 2: *The equilibrium probability of bankruptcy increases with the cost of equity, r^e, and decreases with the social cost of bankruptcy, b, under [FOSD] or [SOSD], i.e.,*

$$\frac{d}{dr^e}\left\{G(r^b|q(q_0))\right\} > 0 \quad \textit{and} \quad \frac{d}{db}\left\{G(r^b|q(q_0))\right\} < 0 \qquad \forall q_0 \in \left[\underline{q}, \bar{q}\right]$$

at the solution to [*RP*].

When the cost of equity rises relative to the cost of debt, it becomes more costly to avoid bankruptcy. Consequently, bankruptcy is permitted to occur with greater frequency in equilibrium. On the other hand, when the social losses from bankruptcy increase, the regulator will optimally ensure a reduced incidence of bankruptcy.

[23] It is apparent from (16) that with r^e constant, the optimal bankruptcy probability is independent of q_0 under both [FOSD] and [SOSD]. If the marginal cost of equity were strictly increasing, however, high-quality banks would have a lower probability of bankruptcy in equilibrium.

To derive additional results in the case of [SOSD] it is convenient to impose the following condition, which is sometimes referred to as the single crossing property (SCP).[24]

(SCP): There exists $\hat{r} \in (\underline{r}, \bar{r})$ such that $G_q(r|q) \lesseqqgtr 0$ as $r \lesseqqgtr \hat{r}$.

Intuitively, the SCP states that an increase in the quality of the bank's loan portfolio makes all returns below some level ($\hat{r}$) less likely, and all higher returns more likely.

Although the equilibrium probability of bankruptcy does not vary with the induced level of the bank's assets, the equilibrium levels of debt and equity do vary systematically with quality.

COROLLARY 3: *Suppose [FOSD] holds, or [SOSD] and (SCP) hold with $r^b < \hat{r}$.*[25] *Then the higher the quality of the bank's portfolio, the more loans the bank is permitted to make and the fewer reserves it is required to hold, i.e., $dL/dq > 0$ and $dR/dq < 0$ at the solution to [RP].*

Proof: From equations (2) and (17), $G\left(\dfrac{L + \gamma(L) - R}{L}\bigg| q\right) = \dfrac{r^e - 1}{b}$. Therefore

$$\frac{dR}{dL} = \frac{G_q(\cdot)L}{g(\cdot)} < 0.$$

Furthermore,

$$\begin{aligned}\frac{dL}{dq} &= -\frac{G_q(\cdot)L^2}{L\gamma'(L) - \gamma(L) - R} \overset{s}{=} L\gamma'(L) - \gamma(L) - R \\ &> L\gamma'(L) - \gamma(L) > 0.\end{aligned}$$

The last inequality follows from the strict convexity of $\gamma(L)$. □

To obtain additional insight into the optimal regulatory policy, a comparative static analysis is useful. The results of this analysis are recorded in Proposition 2. The statement of the Proposition includes a sufficient condition for the second-order conditions to be satisfied in [RP]. This condition requires a change in the quality of the bank's assets to have a small impact on the equilibrium probability of financial distress. This will be the case, for example, if $g(\cdot)$ is continuously differentiable everywhere and the equilibrium probability of bankruptcy is sufficiently small.

[24] The (SCP) is further described and characterized in Keeton (1979).

[25] The restriction that $r^b < \hat{r}$ will be satisfied whenever the equilibrium probability of bankruptcy is sufficiently small. This assumption is also utilized in Proposition 2.

PROPOSITION 2: *Suppose [FOSD] or [SOSD] with (SCP) holds. Also suppose $G_q(r^b|q(q_0))$ is sufficiently small $\forall q_0 \in [\underline{q}, \bar{q}]$. Then at the solution to [RP]:*

(i) *higher levels of innate quality are associated with loan portfolios of higher realized quality, more loans, and greater equity-financed reserves, i.e.,*

$$\frac{dq}{dq_0} > 0, \qquad \frac{dL}{dq_0} > 0, \quad \text{and} \quad \frac{dR}{dq_0} > 0;$$

(ii) *as the cost of government involvement in regulation goes up, achieved levels of quality, loan levels, and reserve levels all decline, i.e.,*

$$\frac{dq(q_0)}{d\lambda} < 0, \frac{dL(q_0)}{d\lambda} < 0, \text{ and } \frac{dR(q_0)}{d\lambda} < 0, \forall q_0 \in [\underline{q}, \bar{q}); \text{ and}$$

(iii) *as the cost of equity increases, the quality of the bank's assets, loan levels, and reserve levels all decline, i.e.,*

$$\frac{dg(q_0)}{dr^e} < 0, \frac{dl(q_0)}{dr^e} < 0 \text{ and } \frac{dR(q_0)}{dr^e} < 0\, \forall q_0 \in [\underline{q}, \bar{q}).$$

Because any level of quality is less costly for the bank to provide the larger the realization of q_0, loan portfolios of higher quality are induced from the bank the higher its innate quality level. A higher-quality portfolio increases the expected returns from additional loans, so more loans are induced. To maintain the optimal probability of financial distress (as indicated in Corollary 1), equity financing of reserves is increased to counteract the larger outstanding loan balance, as reported in (i) of Proposition 2. However, it can be shown that although equity financing increases with quality, loan levels increase by even more, so the equity/debt or capital adequacy requirement decreases as the size of the bank's loan portfolio increases.

The greater the cost of government involvement in the provision of deposit insurance, the more severely will the regulator limit the rents that accrue to the bank. The bank's profits are restricted by reducing the induced quality of the bank's assets. With a loan portfolio of lower quality in place, fewer loans are permitted, thereby allowing a reduction in the bank's reserves, as recorded in (ii) of Proposition 2.

An increase in the cost of equity makes it more costly to provide an equity buffer which reduces the probability of financial distress. Consequently, the bank is required to use less equity financing (and hold fewer reserves), so the probability of financial distress increases. To reduce the expected bankruptcy costs, the number of loans the bank is allowed to make is reduced. With fewer loans being made, quality is less valuable on the margin, so a lower-quality portfolio is induced from the bank, as indicated in (iii) of Proposition 2. Notice that if an increase in quality would reduce the probability of bankruptcy by a sufficient amount (contrary to the hypothesis of

Proposition 2), the optimal regulatory policy could involve an increase in quality (and loans) when reserves are reduced due to an increase in r^e.

Even with the strong restrictions imposed in Proposition 2, it is not possible to sign unambiguously the comparative static derivatives associated with changes in the cost of bankruptcy, b. Increases in b cause the regulator to reduce the equilibrium probability of bankruptcy. But this reduced probability can result either from fewer loans (and an associated reduction in the quality of the bank's loan portfolio) or from a higher level of quality (and an associated increase in loans).

III. Concluding Remarks

The heart of the debate over the value of bank regulation centers on a comparison of the benefits and costs of government intervention in the financial marketplace. Although we did not directly address the important question of whether government-sponsored deposit insurance should be provided, we did explicitly account for the costs of government involvement in the banking sector.[26] We also recognized the social cost of bank failure, the value of the liquidity services provided by the bank, and the managerial costs of enhancing the quality of a bank's assets.

We showed how a regulator who recognizes these costs should optimally employ capital adequacy restrictions, monitoring, and restrictions on lending activity to best motivate banks to improve their loan portfolios. To limit the magnitude of government subsidies to the banking sector, though, quality below the first-best level is induced under the optimal regulatory policy. However, capital adequacy restrictions are consistent with optimal capital structure given the induced level of quality. Our analysis also indicates that the level of loan activity is optimal given the level of induced quality.[27]

Appendix

Proof of Proposition 1: Using standard techniques (e.g., Laffont and Tirole (1986)), it is straightforward to verify that the incentive compatibility con-

[26] Again, though, our analysis could be readily extended to identify the minimal level of quality a bank must achieve before it is allowed to operate (and receive government-sponsored deposit insurance). This minimal level in the solution to [RP] will generally exceed the corresponding level in the first-best setting.

[27] Although the interaction between regulator and bank is not repeated in our formal model, our qualitative conclusions will continue to hold in many settings with repeated play. For example, if the bank's innate quality realization is identical across periods, the regulator's optimal policy is to commit ex ante to carry out the policy described in Proposition 1 in every period. In essence, the regulator optimally commits to "ignore" the information about q_0, that becomes available from observing the bank's actions. With positive but imperfect correlation of innate quality realizations over time, the optimal regulatory policy will vary over time, but the same qualitative distortions identified above will persist. (See Baron and Besanko (1984) for a careful proof of these conclusions in a related setting.)

straints (7) require

$$\pi'(q_0) = C'(q(q_0) - q_0) \quad \text{a.e.} \tag{A1.1}$$

(A1.1), together with $q'(q_0) \geq 0 \; \forall q_0 \epsilon [\underline{q}, \overline{q}]$ and $\pi(\underline{q}) = 0$, are sufficient for (7) and (8) to hold.

Using (A1.1), integration by parts reveals

$$\int_{\underline{q}}^{\overline{q}} \pi(q_0)\, dF(q_0) = \int_{\underline{q}}^{\overline{q}} C'(q(q_0) - q_0)[1 - F(q_0)]\, dq_0. \tag{A1.2}$$

Substituting from (5) and (6), and using (A1.2), the regulator's problem can be rewritten as

$$\text{Maximize} \quad \int_{\underline{q}}^{\overline{q}} \left\{ \int_{\underline{r}}^{\overline{r}} \delta(rL(q_0) - \gamma(L(q_0)) - L(q_0) + R(q_0) \right\} dG(r|q(q_0))$$
$$- r^e R(q_0) - C(q(q_0) - q_0)$$
$$\left. - \frac{\lambda}{1+\lambda} C'(q(q_0) - q_0) \frac{1 - F(q_0)}{f(q_0)} \right\} dF(q_0). \tag{A1.3}$$

Pointwise maximization of (A1.3) with respect to q, L, and R yields equations (12), (13), and (14) respectively. Equation (15) follows directly from (A1.1).

Proof of Proposition 2: From (A1.3), define

$$Z(L, q) \equiv \int_{\underline{r}}^{\overline{r}} \delta(rL - \gamma(L)L + R)\, dG(r|q)$$
$$- r^e R - C(q - q_0) - \frac{\lambda}{1+\lambda} C'(q - q_0) \frac{1 - F(q_0)}{f(q_0)}. \tag{A2.1}$$

R and r^b are now treated as functions of L and q, where

$$r^b = \frac{L + \gamma(L) - R}{L}, \quad \text{and} \tag{A2.2}$$

$$G(r^b|q) = \frac{r^e - 1}{b}. \tag{A2.3}$$

(A2.2) and (A2.3) then provide

$$\frac{dr^b}{dL} = [\gamma'(L)L - (\gamma(L) - R)]/L^2 > 0; \tag{A2.4}$$

$$\frac{dr^b}{dq} = -\frac{G_q(r^b|q)}{g(r^b|q)} > 0; \tag{A2.5}$$

$$\frac{dR}{dL} = -\frac{dr^B/dL}{dr^b/dr} = \frac{dr^b}{dL} > 0; \quad \text{and} \tag{A2.6}$$

$$\frac{dR}{dq} = \frac{G_q}{gdr^b/dR} > 0. \tag{A2.7}$$

Total differentiation of the necessary conditions for an interior maximum of (A2.1) provides

$$\begin{bmatrix} Z_{qq} & Z_{qL} \\ Z_{Lq} & Z_{LL} \end{bmatrix} \begin{bmatrix} dq \\ dL \end{bmatrix} = -\begin{bmatrix} Z_{qq_0} & Z_{qc} & Z_{q\lambda} & Z_{qb} \\ Z_{Lq_0} & Z_{Lc} & Z_{L\lambda} & Z_{Lb} \end{bmatrix} \begin{bmatrix} dq_0 \\ dc \\ d\lambda \\ db \end{bmatrix}. \tag{A2.8}$$

It is straightforward although tedious to verify that application of Cramer's Rule to (A2.8), using (12) to (15) and (A2.2) to (A2.7), provides the reported comparative static results.

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