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An Incentive-Based Theory of Bank Regulation*

TIM S. CAMPBELL,† YUK-SHEE CHAN,†‡ AND ANTHONY M. MARINO†

†*Graduate School of Business Administration, University of Southern California, Los Angeles, California 90089-1421; and* ‡*School of Business and Management, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong*

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In this paper we analyze how depositors can employ both monitoring and capital requirements to control the risk of bank assets. We also analyze how monitors should be compensated if their actions are not directly observable and if there are binding limits on their liability. Second-best capital and monitoring levels (with unobservable actions) will be distorted away from their respective first-best levels. We derive some results about the nature of these distortions and characterize the optimal incentive scheme for monitors. *Journal of Economic Literature* Classification Number: G21. © 1992 Academic Press, Inc.

I. INTRODUCTION

This paper focuses on the incentive of depository financial intermediaries to undertake excessively risky investments. We approach risk taking by financial intermediaries as a special case of the "asset substitution" problem, analyzed in corporate finance by Gavish and Kalay (1983), Green (1984), Green and Talmor (1985), and Jensen and Meckling (1976), for example. One way to combat this incentive problem in banks is to impose high capital requirements. However, we postulate that, since deposits serve as the medium of exchange and possibly provide liquidity for

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otherwise illiquid assets (Diamond and Dybvig, 1983), they generate social surplus. Therefore, relatively heavy reliance on capital requirements as a substitute for demand deposits is costly because it limits the amount of this surplus. An alternative approach is to directly monitor banks and penalize excessive risk taking.[1] We show that such monitoring will partially substitute for capital requirements in the optimal scheme; i.e., the optimal capital requirements will be lower with regulatory monitoring than without.

Our analysis also focuses on the incentive problems arising from the propensity of monitoring agents to shirk. We follow the lead of Kane (1989, 1990), who has argued that a key problem in recent years has been the adverse incentives of regulators of depository intermediaries. Specifically, it is argued that regulators who are interested in their long-run career earnings have an incentive to delay disclosure of problems by following a "not on my watch" policy. We characterize the problem as arising from an inability to observe the regulatory effort devoted to monitoring bank risk. We concentrate on incentive contracts that provide differential payments to the regulator depending on whether the bank is solvent or insolvent.

Simulations of our model yield several interesting comparative static results on the combination of capital requirements and monitoring in the optimal contract. First, as the underlying exogenous risk of bank assets increases, it is optimal for depositors to increase both capital requirements and monitoring. Second, in the absence of adjustments in the optimal incentive contract and in the capital requirement, monitoring increases insufficiently (relative to the constrained optimum, where capital requirements and incentive contracts are not fixed) as exogenous risk increases. Thus, there is an undersupply of regulatory monitoring if there is sluggishness in adjusting the other regulatory incentives. Third, as incentive problems with monitors become more acute (we will be specific about what we mean by this), depositors should optimally increase capital requirements at the expense of monitoring.

[1] One way to view our approach to the problem of optimal regulation of financial intermediaries is as a parallel to the approach taken by Baron and Myerson (1982), Baron and Besanko (1984), and Demski and Sappington (1987) to the regulation of public utilities. In these papers it is assumed that the regulated firm privately observes a parameter of its cost function. Baron and Myerson show how the regulator can take actions ex ante by designing a contract intended to induce truthful revelation. Baron and Besanko allow the regulator to expend effort to generate a signal which is informative about this parameter and then show how this augments the revelation mechanism derived in Baron and Myerson. Demski and Sappington analyze optimal contracts for a regulator who can learn about a regulated firm's production costs when the regulator is subject to limited liability constraints. Our analysis is also closely related to but independent of the recent paper by Giarmmarino *et al.* (1990), which addresses the optimal design of a deposit insurance scheme when the regulator is less well informed than the bank about the quality of bank assets.

Our paper is organized as follows. Section II presents our model and characterizes the optimal capital structure for banks when there is no opportunity for agents to directly monitor the assets those banks choose. Section III presents the optimal solution when monitoring is allowed but monitors are benevolent. Section IV derives the optimal contract for self-interested monitors and presents the results of simulations of the model. Section V contains a brief conclusion.

II. OPTIMAL CAPITAL STRUCTURE WHEN REGULATORS CANNOT MONITOR BANK ASSETS

A. *Assumptions and Specifications of the Model*

We assume that a representative bank in a competitive banking industry has access to two alternative investment projects. Both projects have the same three possible payoffs in three states (i.e., the payoffs are identical for the two projects): x_1, x_2, and x_3, where $x_3 > x_2 > x_1 \equiv 0$ and where x is expressed per dollar of investment, but the two projects differ by the probabilities of the three payoffs. We assume that project 2 is more risky, in that the probabilities of extreme outcomes (i.e., x_1 and x_3) are higher in project 2 by an amount h. We choose this structure purely for simplicity.[2] Let θ_s be the probability of the payoff s for project 1. The payoffs and their probabilities for the two projects are defined in the following table:

	Probabilities for		
State	Project 1	Project 2	Payoff
1	θ_1	$\theta_1 + h$	$x_1 \equiv 0$
2	θ_2	$\theta_2 - 2h$	x_2
3	θ_3	$\theta_3 + h$	x_3

We also assume that project 2 has a lower expected return than project 1:

$$m_1 \equiv \sum_{i=1}^{3} \theta_i x_i \tag{1}$$

[2] We assume that projects have the same payoffs in order to simplify the computation of the bank's incremental payoff from choosing one project over the other. Given the assumption of a common support, the three-state distribution is the simplest structure which captures the notion of increasing risk and lower expected return in shifting from project 1 to project 2. As suggested by a referee, an alternative simple formulation is a two-state distribution, where the payoffs of the projects differ in the good state, where a higher payoff occurs with a lower probability. Both formulations capture the essential features of the distributions of project payoffs which we wish to model.

and

$$m_2(h) \equiv m_1 + h(x_3 - 2x_2) < m_1 \qquad (\text{i.e., } 2x_2 - x_3 > 0). \tag{2}$$

We assume that all market participants are risk neutral and normalize the required rate of return to zero. Risk neutrality and $m_2 > m_1$ imply that project 1 is socially preferable.

Assume that the bank privately observes h, but that depositors and regulators know only the probability distribution from which h is drawn. Let h be defined on the support $[0, h^+]$, with the cumulative density function $F(h)$ and expected value $\bar{h}$. The distribution for h captures the degree of risk in the banking system as a whole, since banks with relatively high values of h will pursue risky investments in equilibrium.

The sequence of events is described in the following. At the beginning of the period, the depositors choose a level of capital requirement in the amount c per dollar of total investment. The remainder, $1 - c$, is financed with deposits or, equivalently, debt. In return for the deposits, the bank offers a promised payment (par value) to depositors of

$$M \equiv (1 - c)r, \tag{3}$$

where r is one plus the contractual interest rate for depositors. Then, at a later date, the bank privately observes h and selects a project (type 1 or 2). At the end of the period, the payoff of the project is realized and the depositors are paid off in accordance with the debt contract. Also assume that only the bank undertaking an investment costlessly observes, ex post, the actual cash flow generated by that project, x_i. Note that since $x_1 = 0$, deposits are always risky.

Let deposits yield a value to depositors beyond the direct payoff M. This arises because deposits are assumed to serve as the medium of exchange in the economy and thereby lower transactions costs.[3] We refer to this additional value of deposits as its liquidity service. Assume that the liquidity service of each dollar of deposits is worth $\lambda \in (0, 1)$ to depositors. Hence, per dollar of investment in risky assets, a bank which has capital equal to c generates liquidity service equal to $(1 - c)\lambda$. Assume

[3] There have also been some recent suggestions of additional reasons why deposit debt may be socially valuable. For example, Diamond and Dybvig (1983) argue that deposits provide insurance against changes in preferences for depositors in banks that fund illiquid assets. Besanko and Thakor (1992) also assume that deposits provide a liquidity service. Calomiris and Kahn (1991) argue that demand deposits provide an incentive-compatible contract which discourages bank fraud. While our model does not directly coincide with the models employed in any of these papers, they do provide alternative rationales for our assumption that deposits are socially valuable.

that the value of liquidity service is sufficiently large that banks always issue some risky deposits (i.e., $c \in [0, 1)$).

B. *Optimal Capital Structure without Monitoring*

We have thus far precluded direct monitoring of the bank's investment decision. Hence, depositors can control the bank's investment decision only through a specification of a capital structure, c.

The problem facing the bank is to choose the optimal investment, given c, M, and h, where c is chosen by depositors. M is determined by a break-even condition for the banking industry. Recall that h is observed after M is chosen but before the optimal project is chosen. First suppose $x_2 < M \leq x_3$, so that the bank is insolvent in either of the first two states. The expected *gross* payoffs for the bank, given that the bank chooses projects 1 and 2, respectively, are

$$B_1 = \theta_3(x_3 - M) \tag{4}$$

and

$$B_2 = (\theta_3 + h)(x_3 - M). \tag{5}$$

If the bank chooses the project with the highest expected payoff, then project 2 is the choice when $x_2 < M \leq x_3$, since

$$\Delta B \equiv B_2 - B_1 = h(x_3 - M) > 0. \tag{6}$$

Therefore, capital is ineffective as an inducement to the bank to choose project 1 unless $M \leq x_2$. Next suppose that $M \leq x_2$, so that the bank is insolvent only in the first state. Now

$$B_1 = \theta_2(x_2 - M) + \theta_3(x_3 - M) \tag{7}$$

and

$$B_2 = (\theta_2 - 2h)(x_2 - M) + (\theta_3 + h)(x_3 - M), \tag{8}$$

so that

$$\Delta B = h(M - 2x_2 + x_3) \equiv h(M - \psi), \tag{9}$$

where

$$\psi \equiv 2x_2 - x_3 \qquad (\psi > 0 \text{ by assumption}). \tag{10}$$

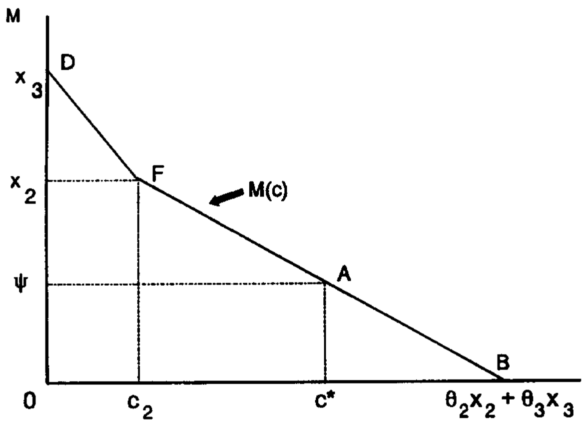

FIG. 1. $c_2 \equiv \theta_3(x_3 - x_2)$ and $c^* \equiv (\theta_2 + 2\theta_3)(x_3 - x_2)$. $M(c) \equiv$ break-even locus with project 1 chosen.

In this case the bank prefers project 2, for any h, as long as $M > \psi$. Thus, combining the two cases, the depositors can induce a choice of project 1 only if $M \leq \psi$ (since $\psi < x_2$) and a choice of project 2 if $M > \psi$.

Next, consider the bank's break-even condition. The specific form of the break-even condition is determined by the subsequent investment decision and by the value of M. Suppose project 1 will be chosen. Then the relevant break-even condition is $B_1 = c$, where

$$B_1 = \theta_2(x_2 - M) + \theta_3(x_3 - M) \qquad \text{if } M \in [0, x_2]. \tag{11}$$

Note that the condition $B_1 = c$ for the bank implies that the break-even promised payment to depositors for given c, $M(c)$, is inversely related to c, *given that project 1 is chosen:* $M(c) = (m_1 - c)/(\theta_2 + \theta_3)$.

We have just established that, *for given c*, the bank will choose project 1, for all h, if and only if $M \leq \psi$. Since $M'(c) < 0$, depositors can maximize depository liquidity service and completely deter bank risk taking, by choosing the c satisfying the break-even condition, when M is set equal to ψ (see Fig. 1). Let c^* be this critical value of c; that is, $M(c^*) = \psi$. We can see intuitively that values of c other than zero and c^* will never be optimal for depositors. To see this, note that given that M is chosen to enable the bank to just break even, any $c > c^*$ reduces the liquidity service benefits of deposits without any risk-reduction benefit, since the bank prefers project 1 over project 2. Likewise, at any value of $c < c^*$, the bank prefers project 2, so that capital should be set at zero.

III. OPTIMAL CONTRACTING WITH BENEVOLENT MONITORS

A. *The Role of the Monitor*

Consider a possible role for direct monitoring of a bank's project choice. The monitor can expend effort to observe a signal about the bank's project choice. The greater the effort, the greater the probability that the signal will reveal the bank's project choice. Define β as the probability that the monitor observes a signal which reveals the bank's project choice; hence, with probability $1 - \beta$ no information is obtained. Also define $V(\beta)$ as the monitor's personal cost in generating a probability β of observing the signal. Let $V'(\beta) > 0$, $V''(\beta) > 0$, $V' \to 0$ as $\beta \to 0$, $V' \to \infty$ as $\beta \to 1$, and $V(0) = 0$. Also assume that the monitor has a reservation utility of $\overline{U}$.

The benevolent monitoring process will proceed as follows. Ex ante, the monitor chooses the level of monitoring, β, and depositors choose the capital requirement, c. Second, the bank observes β and c and offers its promised payment, M, to depositors. Finally, the bank privately observes h and selects project 1 or 2. In selecting β and c, account is taken of their impact on the bank's decisions.

Since the critical gain from direct monitoring accruing to depositors is the increased liquidity service of deposits generated by lower capital requirements, it follows immediately that $c < c^*$ if monitors are employed. Furthermore, if the bank is revealed by the signal to be pursuing project 2, then we assume two actions are taken. First, the bank is compelled to "cease and desist" the inappropriate investment activity and switch to project 1.[4] Second, a penalty is imposed on the bank's equity holders. The most severe penalty that can be imposed is to confiscate all of the equity holders' capital. Hence, the maximum penalty is c. However, to encompass the prospect of a less severe penalty, we assume a more general form for the penalty, but require that it be an increasing function of c: $\phi(c)$. Let $\phi(c) \leq c$ and $\phi'(c) \geq 0$, so that the bank's liability cannot exceed its capital. We refer to the combination of both actions as penalizing the bank.

Next, we need to describe how the bank chooses M, given c, and makes its optimal project choice in the presence of a monitor. Consider M first. Define the break-even condition for the bank, given that project 1 is chosen, as

[4] The qualitative results of the paper will not change as long as the bank can be compelled to improve upon its portfolio choice, when it is found to have pursued project 2. Our choice of the assumption that project 1 will be implemented with certainty is made to simplify the exposition.

$$M(c) = \begin{cases} \text{(i)} \quad (m_1 - c)/(\theta_2 + \theta_3) & \text{for } c \geq c_2 \equiv \theta_3(x_3 - x_2), \\ \text{(ii)} \quad (m_1 - c - \theta_2 x_2)/\theta_3 & \text{for } c \in [0, c_2). \end{cases} \tag{12}$$

In case (i), $M(c) \leq x_2$. In case (ii), $x_2 < M(c) \leq x_3$ (see Fig. 1).

First, note that the existence of the monitor implies that no bank will offer $M > M(c)$, since this implies that project 2 will be chosen (with $M > M(c)$, the bank will suffer a loss with project 1), so that the bank should be penalized. On the other hand, competition will force the bank to offer the highest M conditional on *project 1* being chosen such that the bank breaks even ex ante. Thus, given c, the bank offers $M = M(c)$.

Next consider the bank's project choice. The bank makes its choice cognizant of the decisions of the monitor and depositors, i.e., with knowledge of β and c, and the penalty $\phi(c)$.[5] Given these variables, the bank compares the expected net gain from choosing project 2 over project 1. If a bank chooses project 2 without being detected, then its expected marginal gain, $\Delta B = B_2 - B_1$, for a given h, is represented by Eq. (9):

$$\Delta B = h(M(c) - \psi).$$

If the monitor chooses β and depositors set c, then the bank will prefer project 2 if

$$(1 - \beta)\{h[M(c) - \psi]\} - \beta\phi(c) > 0. \tag{13}$$

This is equal to the direct gain from project 2 over project 1, if the choice were not detected, weighted by the probability that its choice will not be detected, minus the penalty if it is detected, weighted by the probability of detection.

[5] We assume that the benevolent monitor chooses the level of monitoring ex ante, i.e., before the bank makes its project choice. Thus, we think of monitoring choice as the choice of a fixed investigation technology that cannot be changed once it is chosen. This would then be consistent with the notion that β is chosen ex ante even though the physical process of monitoring the project choice may occur after the project is chosen. It is important to note that if β is chosen ex post, there is a potential time inconsistency problem in that the level of monitoring committed ex ante may not be optimal ex post, once the bank has made the investment decision. This problem can be resolved if the depositors can choose a contract where, ex ante, they deposit funds with a trustee and instruct the trustee to pay the funds solely to the monitor if and only if the monitor chooses the desired β. This forcing contract precommits both the depositors and the monitor to the ex ante optimal β. Alternatively, it might be assumed that the monitor can precommit by hiring bank examiners and investing in monitoring technology in such a way that the ex ante optimal β will be ex post optimal. If no precommitment mechanism were available, then an additional sequential rationality constraint would have to be imposed on β in the problem.

In contrast to the base case solution with no monitoring, the bank does not prefer project 1 for every value of h. Instead, there is a critical value of h, h^*, such that the gain from choosing project 2 over project 1 is exactly zero: $(1 - \beta)\{h^*[M(c) - \psi]\} = \beta\phi(c)$.[6] We can express h^* as a function of the two decision variables in our analysis, β and c, as

$$h^*(\beta, c) = \frac{\beta\phi(c)}{(1 - \beta)(M(c) - \psi)}, \tag{14}$$

where

$$\frac{\partial h^*}{\partial \beta} = \frac{\phi(c)}{(1 - \beta)^2(M(c) - \psi)} > 0 \tag{15}$$

and

$$\frac{\partial h^*}{\partial c} = \frac{\beta[\phi'(c)(M(c) - \psi) - M'(c)\phi(c)]}{(1 - \beta)(M(c) - \psi)^2} > 0. \tag{16}$$

Thus, higher monitoring effort and capital requirements will provide greater deterrence to risk taking by banks.

B. *Optimal Contracting*

The possible gains from directly monitoring the bank's project choice are as follows. First, capital requirements may be lowered, enabling greater liquidity service to be provided by deposits. This gain amounts to $\lambda(c^* - c^o)$, where c^o is the optimal value of c, when there is direct monitoring. Second, depositors directly gain from the penalty, ϕ, that they impose on a bank that is revealed to have chosen project 2. This occurs with probability $\beta\{1 - F(h^*(\beta, c))\}$, since $1 - F(h^*(\beta, c))$ is the probability that the bank will not be deterred from choosing project 2 and β is the probability that the bank's choice of project 2 will be detected.

The costs of monitoring include the direct cost of compensating the monitor for β, $V(\beta) + \overline{U}$, and an indirect cost due to incomplete deterrence. This indirect effect arises from the fact that if a bank has a value of $h > h^*$, then the optimal project choice (project 2) entails a deadweight loss.

[6] We assume that monitoring is equally effective for high and low h's. If monitoring is more effective for high h's (i.e., a riskier project is more likely to be detected, given monitoring effort), then the bank may have the incentive to choose project 2 only if h is not too small or too large.

The depositors' problem is formally defined as the solution to

$$\max_{\{\beta,c\}} J(\beta, c) - V(\beta) - \overline{U},$$

where

$$\begin{aligned} J(\beta, c) &= (1 - \theta_1)M(c) + \int_{h^*}^{h^+} [\beta\phi(c) - (1 - \beta)(m_1 - m_2 + B_2 - c)] \\ &\quad \times f(h)dh - (1 - c)(1 - \lambda) \\ &= (1 - \theta_1)M(c) + \int_{h^*}^{h^+} [\beta\phi(c) - (1 - \beta)hM(c)] \\ &\quad \times f(h)dh - (1 - c)(1 - \lambda). \end{aligned}$$

The first-order conditions for the first-best β and c and the interpretation of $J(\cdot)$ are developed in the Appendix. We denote this solution as (β^o, c^o).

IV. OPTIMAL CONTRACTING WITH SELF-INTERESTED MONITORS

A. *The Monitor's Problem*

In the previous section the monitor's choice of β was assumed to be directly observable and contractible. In this section we assume that β is unobservable (and hence not contractible) and that monitors are self-interested. We focus on the depositors' decision problem when they must devise incentive contracts for monitors and simultaneously choose capital requirements for banks. We assume that the monitor has a personal resource constraint that limits the penalty that can be imposed upon him. This is a surrogate for risk aversion and we use it because of its greater potential to shed light on the nature of the optimal incentive scheme. Demski and Sappington (1987) employ a similar assumption.

The assumption of a personal resource constaint means that a monitor who has a greater capacity to absorb losses may be more valuable, since it will be less likely that this constraint will be binding. This may make private monitors preferable to government regulators, if we assume that the former have greater personal resources. However, it is possible that a government regulator might be less self-interested than a private monitor, measured by a lower $V(\beta)$ for any β. Such a difference would create an advantage for a government regulator. While we do not dwell on which form of organization for monitoring will be preferable, it is useful to note that the structure of *feasible* penalties is of relevance to the optimal design of the monitoring cum capital requirement scheme.

Let the compensation package available to monitors be composed of two payments which are contingent on whether the bank is solvent or insolvent (since the actual payoffs of the project are not observable). If the bank is insolvent (i.e., if the payoff on the project is zero), then the monitor receives W; if the bank is solvent (i.e., if the payoff on the project is x_2 or x_3), then the monitor receives S.

Since the monitor's choice of β and the bank's project choice (project 2 if and only if h exceeds some value h^*) are not publicly verifiable ex post, we model the equilibrium strategies, if they exist, in a Nash game. First, the monitor does not observe h, but for given values of W and S and a conjectured value for $h^* = h'$, the monitor chooses β so as to[7]

$$\max_{\{\beta\}} [\theta_1 W + (1 - \theta_1)S] - \int_{h'}^{h+} (1 - \beta)(S - W)hf(h)dh - V(\beta). \quad (17)$$

The first-order necessary condition,

$$\int_{h'}^{h^+} (S - W)hf(h)dh \leq V'(\beta), \quad (18)$$

determines the monitor's choice as $\beta(h', S, W)$. It is obvious from (18) and the conditions regarding the derivatives of $V(\beta)$ that there is an interior solution $\beta \in (0, 1)$ satisfying (18) with equality if and only if $S > W$.

Second, the bank does not observe the monitor's actual choice of β, which in turn determines h^* from (14), for a given c. For any conjectured value of the monitor's choice of β, say β', a bank can compute $h^*(\beta', c)$. The bank's and the monitor's conjectures will be consistent if there exists a Nash equilibrium (β', h') solving (14) and the equality version of (18). In Lemma 1 we show that such a Nash equilibrium exists and is unique. (See the Appendix for all proofs.)

LEMMA 1. *Given c, S, and W such that $S - W > 0$, there exists a unique Nash equilibrium (β', h') which satisfies Eqs.* (14) *and* (18).

B. *The Depositors' Problem*

The self-interested monitoring process can be thought of as either a two- or one-stage procedure. Under two stages, the depositors choose (S, W, c) ex ante so as to maximize their utility subject to the relevant con-

[7] The first term in (17) is the expected payment to the regulator if project 1 is chosen by all banks. The second term represents the incremental loss of expected payment to the regulator due to higher insolvency of banks taking project 2 and not being detected.

straints. Next, the triple (S, W, c) determines a Nash equilibrium $\beta(S, W, c)$ and $h(S, W, c)$ as described in Lemma 1. Equivalently, this two-stage problem can be solved in one stage by assuming that depositors choose (S, W, c, β) subject to conditions (14) and (18) and the relevant constraints. We employ the one-stage technique in our analysis.[8]

The reformulated depositors' problem is to choose the optimal values of S, W, c, and β, subject to constraints (14) and (18) and two participation constraints. The first constraint is the same as that specified above, i.e., that total expected compensation, net of the disutility of effort, must exceed $\overline{U}$. The second constraint is that compensation *in any state* must exceed Z; i.e., $S, W \geq Z$. We assume that $Z \leq \overline{U}$ (i.e., the depositors are not required to give the monitor a surplus in the absence of monitoring.) We refer to this as the limited liability constraint, to distinguish it from the first participation constraint. One implication is that prospective monitors who bring greater capacity to absorb penalties (or have lower reservation wages) are potentially more valuable. Note that since $S > W$ in equilibrium, limited liability constraints on W and S would never both be binding in equilibrium. Also let γ, δ, and ζ be Lagrangian multipliers on, respectively, the incentive compatibility constraint, the monitor's participation constraint, and the limited liability constraint on W.

Now we can write the depositors' problem as

$$\begin{aligned}\max_{\{\beta,c,W,S\}} D = {} & J(\beta, c) - R(\beta, S, W, c) \\ & + \gamma\left[\int_{h^*(\beta,c)}^{h^+} (S - W)hf(h)dh - V'(\beta)\right] \\ & + \delta(R - V(\beta) - \overline{U}) + \zeta(W - Z),\end{aligned} \tag{19}$$

where

$$R(\beta, S, W, c) \equiv [\theta_1 W + (1 - \theta_1)S] - \int_{h^*(\beta,c)}^{h^+} (1 - \beta)(S - W)hf(h)dh,$$

and $h^*(\beta, c)$ is given by (14).

It is helpful to divide the characterization of the equilibrium contract for the monitor and the resulting values of c and β into two cases, where the cases depend on whether the limited liability constraint, Z, is binding on

[8] Unlike the case of the benevolent regulator, β and h^* are chosen simultaneously in the Nash game. Hence, the Nash game is equivalent to imposing time consistency or sequential rationality, since it requires that the β conjectured by the bank be equal to the β chosen by the monitor and the h^* conjectured by the monitor be the one actually assumed by the bank when it chooses a project, for a given c, S, and W.

W. If the constraint is not binding ($\zeta = 0$), then it is feasible for the depositors to choose a contract which induces the regulatory to choose the first-best value of β, β^o, and the first-best c, c^o. However, if the limited liability constraint is binding ($\zeta > 0$), then, while it is feasible to choose a contract which induces the regulator to choose β^o, it is not optimal to do so. The reason is that the contract involves a transfer of surplus from the depositors to the regulator. In this case, since it is too costly to implement the first-best solution, the depositors optimally trade off the value of monitoring against the cost of inducing the monitor to exert effort.

When the limited liability constraint is not binding, the first-best combination of monitoring and capital requirements is attainable. But the optimal compensation contract requires that the regulator be penalized if the bank is insolvent, in the sense that his compensation in that state must be less than his aggregate reservation compensation, $\overline{U}$. We state this in Proposition 1.

PROPOSITION 1. *If the limited liability constraint is not binding and if monitoring is used at all, then depositors choose $S > W$, $W < \overline{U}$, $\beta = \beta^o$ and $c = c^o$.*

For example, if $\overline{U} = 0$, so that the expected monetary compensation is equal to $V(\beta)$, then this implies $W < 0$. Hence, under the optimal contract, depositors will penalize the monitor if the bank becomes insolvent. This penalty retrieves, for the depositors, the surplus which would otherwise be transferred to the monitor, at any higher level of W. (Note that if $W = Z$, then $W \leq \overline{U}$, since $Z \leq \overline{U}$ by assumption.)

Since the optimal contract for the monitor involves a penalty (or a lack of reward) in the insolvent state, this solution may violate the limited liability constraint. Since the ability of the monitor to sustain a penalty is so important, it will be useful to derive a condition which determines when the constraint is binding. Lemma 2 defines the minimum liability, Z^o, that the monitor has to assume to permit implementation of the first-best solution.

LEMMA 2. *The limited liability constraint is binding if and only if $Z > Z^o$, where*

$$Z^o = \overline{U} + V(\beta^o) - \left\{\frac{1-\theta_1}{H(h^o)} - (1-\beta^o)\right\} V'(\beta^o)$$

and $\qquad h^o \equiv h^*(\beta^o, c^o).$

It can be verified that Z^o is decreasing in β^o; that is, the liability requirement is more constraining when more monitoring effort is to be implemented at the first-best solution. On the other hand, Z^o is increasing in $\overline{U}$, which implies that the limited liability requirement is less severe if the monitor's participation constraint calls for a higher expected wage.

Next, suppose the monitor cannot commit sufficient resources and the limited liability constraint is binding. We can then establish two results about the resulting distortion in the optimal level of monitoring and the capital requirement. First, in Proposition 2 we show that if either the capital requirement or the level of monitoring is set at its first-best level, then the second best calls for setting the other variable below its first best. Also, when the constraint is binding, depositors are forced to pay the monitor some of the surplus they would otherwise retain to induce him to monitor.

PROPOSITION 2. *If the limited liability constraint is binding, then the first-best solution to the depositors' problem with benevolent regulation, c^o and β^o, will not be optimal, and in a neighborhood of the first-best solution, the depositors prefer a lower value of β or c, holding the other variable at its first-best level.*

Second, in Proposition 3 we show that, for a given level of deterrence for risk taking, more capital and less monitoring will be used with a self-interested (as opposed to a benevolent) monitor. This result follows from the fact that monitoring and capital requirements are substitutes. As monitoring becomes more costly with a self-interested monitor, it pays to substitute capital for monitoring, given any desirable level of deterrence.

PROPOSITION 3. *Suppose that the limited liability constraint is binding on W, but depositors wish to have the same level of deterrence against a bank choosing investment 2 as prevails when $\beta = \beta^o$ and $c = c^o$, i.e., $h^* = h^o = h^*(\beta^o, c^o)$. The solution to the depositors' problem will then entail higher capital requirements and a lower level of monitoring, $\beta < \beta^o$ and $c > c^o$, in a neighborhood of β^o and c^o.*

C. *Simulations of Comparative Statics and Policy Issues*

Because the solution to the depositors' problem yields a complex system of nonlinear equations which are not amenable to direct comparative static analysis, we have chosen to simulate the behavior of this system for alternative parameters of the model. We determine the optimal values of β, c, S, W, Z^o, and the expected utility of depositors (EUD) for different levels of riskiness and different values of $\overline{U}$. For the purposes of the simulation, we assume that h is uniformly distributed over the interval $[0, \nu]$, so that $f(h) = 1/\nu$, and we assume that $V(\beta) = -\{\beta + \ln \beta\}$. The results of the simulation, for the parametric values $\lambda = 0.1$, $\theta_1 = 0.25$, $\theta_2 = 0.5$, $\theta_3 = 0.25$, $x_2 = 2.1$, $x_3 = 3$, and $Z = 0$, are presented in Table I. The three right-hand columns in the table present the first-best values of β, c,

TABLE I
COMPARATIVE STATIC ANALYSIS OF FIRST- AND SECOND-BEST SOLUTIONS TO DEPOSITOR'S PROBLEM

		Self interest regulators: β noncontractible ($W = Z = 0$)			Direct monitoring: β contractible		
$\bar{U}$		$\nu = 0.15$	$\nu = 0.20$	$\nu = 0.25$	$\nu = 0.15$	$\nu = 0.20$	$\nu = 0.25$
0.38	β	0.0375	0.0501	0.0629	0.3073	0.3390	0.3647
	c	0.5161	0.5331	0.5439	0.2443	0.2654	0.2819
	S	0.5576	0.5752	0.5933	—	—	—
	Z^o	−13.25	−10.10	−8.17	—	—	—
	EUD	0.3669	0.3372	0.3096	0.4146	0.3883	0.3633
0.42	β	0.0412	0.0550	0.0689	0.3073	0.3390	0.3647
	c	0.4956	0.5135	0.5249	0.2443	0.2654	0.2819
	S	0.6161	0.6354	0.6552	—	—	—
	Z^o	−13.21	−10.06	−8.13	—	—	—
	EUD	0.3282	0.2987	0.2712	0.3746	0.3483	0.3233
0.46	β	0.0449	0.0598	0.0748	0.3073	0.3390	0.3647
	c	0.4770	0.4955	0.5075	0.2443	0.2654	0.2819
	S	0.6746	0.6956	0.7170	—	—	—
	Z^o	−13.17	−10.01	−8.09	—	—	—
	EUD	0.2895	0.2600	0.2326	0.3346	0.3083	0.2833

and EUD corresponding to the specified values of ν and $\bar{U}$. The middle three columns present the corresponding second-best values of the same variables, plus the values of Z^o and S. The table contains several interesting results regarding the nature of the second-best optimum.

First, consider the implications of a change in the riskiness of bank investments captured by a shift in ν. The table shows that, for both the first-best and the second-best solutions, both β and c are increasing in ν. That is, as the asset substitution problem becomes more acute, both monitoring and capital requirements should be increased. Therefore, we would expect that if there were an increase in underlying risk and the intensity of monitoring and capital requirements were not enhanced, there would be an even larger increase in subsequent bank failures than would otherwise be anticipated. The table also shows that the percentage change in β, in response to a change in ν, is much larger than the change in c. Hence, monitoring becomes relatively more important than capital requirements as risk increases. We believe that the historical record of the 1980s suggests that regulation during this period was not cognizant of the trade-offs between these alternative mechanisms.

The simulation results assume that the optimal incentive contract is adjusted as ν increases. Historically, it seems reasonable to posit that, in the United States, incentive contracts for regulators did not adjust to perceived changes in exogenous risk. Hence, we also evaluated the optimal reaction of β to changes in perceived risk, holding fixed both the incentive contract and c. For all values of $\bar{U}$ shown in Table I, we found that this "third-best" β did not rise as much as the second-best β with increases in risk. This implies an undersupply of regulatory monitoring due to sluggishness in adjusting the other regulatory incentives. This observation seems to be consistent with casual empiricism about the savings and loan debacle, and it suggests one explanation for the higher incidence of bank failures.[9]

Another possibility is that rather than riskiness itself changing, it may become more difficult to distinguish safe from risky investments. This is an alternative way to characterize the underlying changes which took place during the 1970s and 1980s in the United States. This can be interpreted as an increase in the level of $V(\beta)$ as well as possible increases in V' and V''. If this occurs, a monitor would have to work harder to get the same quality signal as before. This immediately implies that β will decline, even if the optimal contract is adjusted.

It is also useful to consider the effects of changes in $\bar{U}$. The required value Z such that the first-best solution can be implemented, Z^{o}, is quite insensitive to changes in $\bar{U}$, for a given value of ν; but it is decreasing in ν, for any given level of $\bar{U}$. The relationship between Z^{o} and ν may seem puzzling at first glance. It implies that as the underlying level of risk increases, there is a decrease in the penalty-absorption capability of regulators needed to implement the first-best solution. This result reflects the fact that when ν is small, the regulator faces a relatively small variance in his compensation, for fixed S and W. Since increases in ν cause the variance in compensation to increase, for a given S and W, it is easier to induce the monitor to exert a given level of effort with higher ν. Hence, a lower level of Z^{o} is required, for high values of ν, to implement a value of W that is low enough to provide the necessary inducement to achieve the first-best level of effort.

Finally, comparing the first-best and second-best solutions (for given $\bar{U}$ and ν), the depositors rely more on capital requirements than on monitoring when there is an incentive problem with monitors. Put another way, it is optimal for depositors to substitute capital requirements for monitoring when the incentive problem pertaining to monitors becomes more severe. In the second-best solution, increases in $\bar{U}$ cause depositors to optimally substitute β for c. This is because, with the limited liability constraint

[9] For example, with $\bar{U} = 0.38$, the third-best β at $\nu = 0.20$ is 0.0494 as compared to 0.0501 at the second best, and the third-best β at $\nu = 0.25$ is 0.0610 as compared to 0.0629 at the second best. In these computations, the incentive contract and c were fixed at the second-best values for $\nu = 0.15$. Analogous results were obtained for $\bar{U} = 0.42$ and $\bar{U} = 0.46$.

binding ($W = Z$ is binding at 0 in the simulations), higher β can be induced only with a higher payment of S and that may yield a larger surplus to the monitor. However, with higher $\overline{U}$, higher β can be induced without giving the regulator a surplus.

V. CONCLUSION

In this paper we have analyzed how depositors can hire agents to directly monitor the asset choices of banks. The monitors in our analysis expend effort in order to receive a signal which is informative about banks' investment decisions. This direct monitoring is an alternative to bank capital requirements in limiting banks' risk-taking incentives. As a result, the capital structure which is socially optimal for banks is jointly determined with the optimal expenditure on direct monitoring of banks.

We have analyzed how monitors should be compensated if their actions are not directly observable. If there are binding limits on the liability of monitors, then the second-best capital and monitoring levels (with unobservable actions) will be distorted away from their respective first-best levels. We have derived some results about the nature of these distortions and characterized the dependence of the optimal solution on the underlying risk of bank investments and the exogenous cost characteristics of monitors. Our paper suggests that, within some limits, it is useful to view capital requirements and regulatory monitoring as substitutes and complements in controlling risk taking by banks.

APPENDIX

A.1. *Characterization of the Optimum with Benevolent Monitors*

If the depositors can employ direct monitoring, then their objective function is as above:

$$\max_{\{\beta, c\}} J(\beta, c) - V(\beta) - \overline{U},$$

$$\begin{aligned} J(\beta, c) &= (1 - \theta_1)M(c) + \int_{h^*}^{h^+} [\beta\phi(c) - (1 - \beta)(m_1 - m_2 + B_2 - c)] \\ &\quad \times f(h)dh - (1 - c)(1 - \lambda) \\ &= (1 - \theta_1)M(c) + \int_{h^*}^{h^+} [\beta\phi(c) - (1 - \beta)hM(c)] \\ &\quad \times f(h)dh - (1 - c)(1 - \lambda). \end{aligned} \tag{20}$$

$J(\beta, c)$ can be interpreted as follows. The first term represents the expected payment to depositors from the bank, given that it has chosen project 1, while the second term represents the incremental expected payment, given that the bank has chosen project 2. If $h > h^*$, then the bank will choose project 2. Then, with probability β, the penalty is paid to depositors. With probability $1 - \beta$, the bank's choice of project 2 goes undetected. In that event, the depositors lose the difference in the expected values of the two projects, $m_1 - m_2$, as well as the excess return anticipated by the bank from choosing project 2, $B_2 - c$. The third term represents the net cost of deposits to the depositors.

The first-order necessary conditions are (we assume that the second-order conditions are satisfied at the optimum)

$$\beta: \quad J_\beta = V'(\beta),$$

and

$$c: \quad J_c = 0,$$

where

$$J_\beta = \int_{h^*}^{h^+} (\phi(c) + hM(c))f(h)dh - f(h^*)[\beta\phi(c) - (1 - \beta)h^*M(c)] \frac{\partial h^*}{\partial \beta}, \tag{21}$$

and, recalling that $M' = -1/(1 - \theta_1)$,

$$\begin{aligned} J_c = \int_{h^*}^{h^+} &[\beta\phi'(c) - (1 - \beta)hM'(c)]f(h)dh \\ &- f(h^*)[\beta\phi(c) - (1 - \beta)h^*M(c)] \frac{\partial h^*}{\partial c} - \lambda. \end{aligned} \tag{22}$$

The first-order condition for β simply implies that depositors should equate the marginal cost of compensating the regulator for effort expended in direct monitoring ($V'(\beta)$) to the net gain from the direct and indirect effects of increasing β. The net gain is composed of two terms (see Eq. (21)). The first term is the direct gain generated by increased probability of detection of riskier project choice while the second term is simply the indirect cost of an incremental change in h^* resulting from the increase in β. Both terms include components which pertain to the extraction of a penalty from the bank and the prospect that a loss will result from riskier project choice. The first-order condition for c has an analogous interpretation.

A.2. *Characterization of Optimum with Self-Interested Regulators*

Proof of Lemma 1. (i) From (14), $h^*(\beta', c)$ denotes the bank's computation of the critical value h^* given any conjectured value of $\beta = \beta'$. Define $\beta^+ \equiv h^+[M(c) - \psi]/\{\phi(c) + h^+[M(c) - \psi]\}$. From (14), $h^*(0, c) = 0$, $h^*(\beta^+, c) = h^+$, and $\partial h^*(\beta, c)/\partial\beta > 0$.

(ii) $\beta(h', S, W)$ denotes the regulator's choice of β given any conjectured value of $h^* = h'$. From the equality version of (18), $\beta(0, S, W) > 0$, $\beta(h^+, S, W) = 0$, and $\partial\beta(h, S, W))/\partial h < 0$.

(i) and (ii) establish the existence of a unique Nash Equilibrium. ■

Properties of the Solution to the Depositors' Problem. Define

$$H(h^*) \equiv \int_{h^*}^{h^+} hf(h)dh > 0, \tag{23}$$

$$R_W \equiv \partial R/\partial W = \theta_1 + (1 - \beta)H(h^*) > 0, \tag{24}$$

$$R_S \equiv \partial R/\partial S = (1 - \theta_1) - (1 - \beta)H(h^*) = 1 - R_W > 0. \tag{25}$$

The first-order necessary conditions for the depositors problem stated in (19) can be written, after some simplification (once again, we assume that the second-order conditions are satisfied) as

$$\beta:\quad J_\beta - V'(\beta) - \left[\frac{\partial h^*}{\partial\beta} h^*f(h^*)(S - W)\right][(1 - \delta)(1 - \beta) + \gamma] - \gamma V''(\beta) = 0, \tag{26}$$

$$c:\quad J_c - \left[\frac{\partial h^*}{\partial c}(S - W)h^*f(h^*)\right][(1 - \delta)(1 - \beta) + \gamma] = 0, \tag{27}$$

$$W:\quad -(1 - \delta)R_W - \gamma H(h^*) + \zeta = 0, \tag{28}$$

$$S:\quad -(1 - \delta)R_S + \gamma H(h^*) = 0. \tag{29}$$

The properties of the Lagrangian multipliers in the depositors' problem are summarized in the following: At an optimum for the depositors' problem, the Lagrangian multipliers satisfy (i) $\delta = 1 - \zeta$, (ii) $0 \le \zeta \le 1$, (iii) $0 \le \delta \le 1$, and (iv) $\gamma \ge 0$ if and only if $\zeta \ge 0$. To see this note that $1 - R_S = R_W$. Equations (28) and (29) directly imply (i). (ii) then follows from $\delta \ge 0$ and from (i). (iii) then follows from (ii). (iv) follows directly from Eq. (28), (i), and $H(h^*) > 0$.

Proof of Proposition 1. $S > W$ follows directly from (18). If the limited liability constraint is not binding, then $\zeta = 0$ and Proposition 1(iv) implies $\gamma = 0$. Then (26) and (27) directly imply that c^o and β^o are optimal. To prove $W < \overline{U}$, first recall that the participation constraint for the regulator is binding (with $\delta = 1 - \zeta = 1$); thus

$$\overline{U} = (1 - \theta_1)S + \theta_1 W - (1 - \beta)(S - W)H(h^*) - V(\beta).$$

Subtracting W from both sides and substituting $V'(\beta) = (S - W)H(h^*)$ from the incentive compatibility constraint to the depositors' problem yields

$$\overline{U} - W = [(1 - \theta_1)/H(h^*) - 1]V'(\beta) + \beta V'(\beta) - V(\beta).$$

$V(0) = 0$ and $V(\beta)$ is convex by assumption, which implies $\beta V'(\beta) > V(\beta)$ for all $\beta > 0$. Also $(1 - \theta_1) = \theta_2 + \theta_3$ and $\theta_2 > 2h$, for all h, by assumption. This implies $1 - \theta_1 > \theta_2 > 2\overline{h}$. Since $\overline{h} > H(h^*)$, $(1 - \theta_1)/H(h^*) > 1$. Hence, $\overline{U} - W > 0$. ■

Proof of Lemma 2. The proof involves identifying the parametric restriction on Z under which the solution (β^o, c^o) is implementable with the regulator just breaking even. Recall that the incentive compatibility condition requires that at β^o and c^o

$$S - W = V'(\beta^o)/H(h^o).$$

If the regulator just breaks even at an optimum we also have

$$W + (S - W)\{(1 - \theta_1) - (1 - \beta^o)H(h^o)\} = V(\beta^o) + \overline{U}.$$

Substituting for $S - W$ and solving for W from above yield the value of Z^o defined above. Therefore, implementation of the first best, β^o and c^o, with the regulator just breaking even requires $W = Z^o$. Hence, if $Z < Z^o$, then the solution with $W = Z^o$ is feasible. If $Z > Z^o$, then (β^o, c^o) cannot be implemented with the regulator just breaking even. ■

Proof of Proposition 2. The proposition follows directly by applying Proposition 1, with $\zeta > 0$, to first-order conditions (26) and (27). ■

Proof of Proposition 3. The restriction on β and c such that $h^*(\beta, c) = h^o$ adds a further constraint to the optimization problem. Let η be the multiplier for the constraint $h^*(\beta, c) = h^o$ and D' be the depositors' modified objective function. Then the first-order conditions are

$$\begin{aligned}\frac{\partial D'}{\partial \beta} &= J_\beta - V'(\beta) - [h^*_\beta h^* f(h^*)(S - W)][(1 - \delta)(1 - \beta) + \gamma] \\ &\quad - \gamma V''(\beta) - \eta h^*_\beta = 0,\end{aligned} \tag{30}$$

$$\frac{\partial D'}{\partial c} = J_c - [h_c^* h^* f(h^*)(S - W)][(1 - \delta)(1 - \beta) + \gamma] - \eta h_c^* = 0. \quad (31)$$

Solving for η from (31) and substituting for it in (30), we have

$$\frac{\partial D'}{\partial \beta} = J_\beta - V' - J_c \left(\frac{h_\beta^*}{h_c^*}\right) - \gamma V'' = 0.$$

Evaluating $\partial D'/\partial\beta$ at (β^o, c^o), and noting that $J_\beta = V'$ and $J_c = 0$ at (β^o, c^o), we have

$$\left.\frac{\partial D'}{\partial \beta}\right|_{(\beta^o, c^o)} = -\gamma V'' < 0.$$

Since it is clear that

$$\left.\frac{d\beta}{dc}\right|_{h^* = h^o} < 0,$$

a decline in β immediately implies an increase in c. ■

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