THE JOURNAL OF FINANCE • VOL. XLVII, NO. 1 • MARCH 1992

Is Fairly Priced Deposit Insurance Possible?

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ABSTRACT

We analyze risk-sensitive, incentive-compatible deposit insurance in the presence of private information and moral hazard. Without deposit-linked subsidies it is impossible to implement risk-sensitive, incentive-compatible deposit insurance pricing in a competitive, deregulated environment, except when the deposit insurer is the least risk averse agent in the economy. We establish this formally in the context of an insurance scheme in which privately informed depository institutions are offered deposit insurance premia contingent on reported capital; the result holds for alternative sorting instruments as well. This suggests a contradiction between deregulation and fairly priced, risk-sensitive deposit insurance.

THIS PAPER EXPOSES A conflict between a deregulated, competitive financial services industry on the one hand and fairly priced, risk-sensitive deposit insurance on the other. We show that if depository institutions (DIs) are perfectly competitive, i.e., each makes zero profits on average, then it is impossible to implement incentive-compatible, risk-sensitive deposit insurance pricing.[1]

Recent distress among DIs has fueled debate about reform of the existing deposit insurance system. Many believe that the prevailing risk-insensitive premium structure encourages DIs to choose excessively risky assets, and that it should be replaced by deposit insurance premia linked to the DIs' choices of risk.[2] Risk-sensitive deposit insurance pricing, however, imposes greater informational demands on the deposit insurer, and runs afoul of both

* University of Southern California, J. L. Kellogg Graduate School of Management, Northwestern University, and School of Business, Indiana University, respectively. For their many helpful comments, we wish to express our gratitude to Stephen Buser (the editor), an anonymous referee of this Journal, Arnoud Boot, Lawrence Benveniste, David Besanko, Sudipto Bhattacharya, John Boyd, Mark Flannery, Christopher James, George Kanatas, Edward Kane, Anthony Saunders, Larry Wall, and participants at the 1988 Garn Institute Symposium and workshops at the Federal Reserve Bank of Atlanta, University of Florida, and Tulane University. The usual disclaimer applies.

[1] The only exception is the case in which the provider of deposit insurance enjoys a monopoly in the supply of risk sharing, as would be true if it was strictly less risk averse than any other agent in the economy.

[2] See Black, Miller, and Posner (1978), Chan and Mak (1985), Cummins (1988), Edwards and Scott (1979), Kane (1982), Maisel (1981), Marcus and Shaked (1984), McCulloch (1985), Merton (1977, 1978), Pennachi (1984), Ronn and Verma (1986), and Taggart and Greenbaum (1978).

measurement and implementation problems owing to observability considerations (Pyle (1984)). In particular, a DI's assets normally embody private information, and as a practical matter this precludes conditioning the deposit insurance premium directly on the DI's risk profile (Fama (1985), James (1987), and Lucas and McDonald (1987, 1992)). Of course, the insurer can attempt to learn the riskiness of a DI's asset portfolio through audits and examinations. However, monitoring is costly, especially if it seeks to eliminate all informational asymmetry. Alternatively, the insurer could design an incentive-compatible, risk-sensitive deposit insurance pricing system that elicits voluntary disclosure of each DI's private information. But in administering any such system, the insurer needs to be mindful of the DI's possible incentive to increase asset risk after the deposit insurance terms are fixed.

We focus on the two basic problems facing the deposit insurer: *private information* (the possibility that the DI will misrepresent its asset risk in order to obtain more favorable insurance pricing) and *moral hazard* (the possibility that the DI will skew its asset choice in favor of more risk). To resolve the private information problem, we examine the feasibility of using the DI's readily observable reported capital as the attribute on which to base the deposit insurance premium.[3] An incentive-compatible, risk-sensitive deposit insurance pricing structure may be implemented by requiring each DI to simultaneously choose its capital requirement and its periodic deposit insurance premium per dollar of deposits from a proffered schedule. Imagine two types of privately informed DIs, one with high and the other with low probability of insolvency.[4] Since the capital of an insolvent DI is forfeited, it will be more costly for the high-risk institution to provide capital. Therefore, if the deposit insurer requires a reporting of risk from each DI, accurate information can be elicited if those indicating low risk are offered a lower deposit insurance premium per dollar of insured deposits together with a higher capital requirement. We show that the optimal arrangement will indeed take this form.

Further, we demonstrate that in a competitive environment such a program can succeed only if there are deposit-linked subsidies. Without such subsidies, DIs will be indifferent to capital structure, and if the deposit insurance premium is fairly priced and thus increasing in risk, high-risk DIs will find it profitable to mimic their low-risk peers.[5] This incentive to misrepresent persists unless the insurer requires that a low-risk DI finance itself exclusively with equity, in which case no surplus can be earned from

[3] The recent Treasury proposal for banking reform (1991) recommends that deposit insurance premia be linked to accounting capital. Like the Treasury, we sidestep the many issues of GAAP and RAP accounting. See White (1988).

[4] Throughout the paper, when there is private information, it is the insured DI that is privately informed about its asset risk. Thus, the deposit insurer—private or public—is as informationally disadvantaged as other investors.

[5] Fair pricing in the present context is taken to mean that the insurer will break even on each insured institution, individually. The only other examination of incentive compatible deposit insurance we are aware of is Kanatas' (1986).

mispriced deposit insurance.[6] But then the issue of deposit insurance disappears. Thus, so long as every DI finances itself with deposits, an incentive-compatible, capital-based premium schedule with fairly priced deposit insurance is a contradiction in the context of deregulated, perfectly competitive markets.

Three points deserve emphasis. First, rather than merely illustrating that a particular regulatory instrument (capital) cannot provide sorting, our analysis shows that in a competitive environment, incentive-compatible, risk-sensitive deposit insurance is impossible with any sorting instrument. Second, our results do not depend on the dimensionality of the sorting and attribute spaces. For example, a DI may have private information on more payoff-relevant attributes than there are observable DI choices on which to condition the premium. This might itself preclude incentive-compatible insurance premia that accurately reflect risk. Our point, however, is that even when sorting instruments exceed privately known attributes, separation by risk is impossible in a competitive environment. Third, taxes do not invalidate our conclusion. A DI need not be indifferent between deposits and equity, as in Modigliani and Miller (1958), for our conclusion to be sustained. With perfectly competitive credit markets, subsidies are necessary for sorting, even when interest payments are tax-deductible and dividends are not.

Resolving the problem of moral hazard requires multi-period contracting as well as rents. The moral hazard can be controlled only if the insurer can credibly threaten a DI operating with excessive risk, and this requires that the DI's license has value. Only when the deposit insurer is less risk averse than any other agent in the economy will subsidies prove to be unnecessary. The insurer then can break even while preserving a positive surplus associated with deposits due to the standard risk-sharing argument. This will make deposits special relative to DI equity, and will permit the design of incentive-compatible deposit insurance.

Our analysis assumes that the deposit insurer is an agency of the government. This has two implications. First, default by the insurer is not an issue. Second, the governmental insurer has the authority to tax, so that it is able to subsidize the insured. With a private insurer, subsidies are unavailable, default is an issue, and the supply of deposits is imperfectly elastic.[7] Implementing an incentive-compatible, risk-sensitive deposit insurance pricing scheme therefore is impossible.

Our analysis relates to Buser, Chen, and Kane (BCK) (1981) wherein deposit insurance includes both an explicit and an implicit price. The explicit price is a subsidized risk-insensitive insurance premium. The implicit price derives from regulatory restrictions and monitoring aimed at mitigating

[6] As we point out later, our results are sustained even if regulatory subsidies are transmitted through channels other than underpriced insurance, provided that the subsidies remain deposit-linked.

[7] We assume that private insurers are not subsidized by the government, so that they must price deposit insurance fairly, although not necessarily on each DI.

moral hazard. BCK's subsidies permit the insurer to influence the DI, and thereby address the moral hazard arising from risk-insensitive deposit insurance pricing. We show that subsidies are needed to resolve private information and moral hazard problems, even when deposit insurance pricing is risk-sensitive. In addition, whereas BCK explain the sufficiency of subsidies in controlling incentives, we explain their necessity. Our analysis also relates to Bhattacharya's (1982), which shows that deposit interest rate ceilings and entry restrictions are necessary to control moral hazard relating to asset risk.[8]

Section I describes the model. Section II analyzes incentive-compatible deposit insurance pricing with private information. Moral hazard is considered in Section III. Section IV discusses the robustness of the analysis, and Section V summarizes.

I. The Model

Consider a representative DI with access to insured deposits provided in infinitely elastic supply at the riskless interest rate. For simplicity, the DI is viewed as lending to a single borrower.[9], We take the loan size, I, to be fixed, and the DI therefore chooses a mix of deposits, D, and equity, E, to satisfy the balance sheet constraint, $D + E = I$. All of the formal analysis assumes pervasive risk neutrality, but alternative preferences are discussed in Section IV.

The borrower uses the loan to finance a single-period project with a two-state probability distribution.[10] The project returns $R > 0$ with probability (w.p.) θ, and zero w.p. $1 - \theta$. The return is observable by the DI and the borrower, but not by the deposit insurer. Since all agents are risk neutral, a necessary and sufficient condition for the borrower's project to be socially optimal is

$$\theta R - Ir_f > 0,$$

where r_f is the riskless interest factor (one plus the riskless interest rate). This condition is assumed to be satisfied throughout.

Since depositors earn the riskless interest rate—a yield consistent with other competitively priced financial instruments—the surplus available from the borrower's project will be shared by the DI and the borrower, and the competitive structure of the market will determine the sharing. If the credit market is perfectly competitive, the standard Bertrand undercutting logic will dictate that all of the surplus accrues to the borrower. With an imper-

[8] In a paper that came to our attention while revising this one, Giammarino, Lewis, and Sappington (1990) show that if the DI is a monopoly, an incentive-compatible deposit insurance pricing scheme is possible, but that the distortions necessary to achieve incentive compatibility may not make it worthwhile.

[9] Multiple borrowers are considered in Section IV.

[10] The results generalize to multiple-state or continuous distributions, as discussed in Section IV.

fectly competitive credit market, a more complex distribution of the surplus obtains.[11] To avoid tying our results to a particular market structure, we assume that a fraction, $\alpha \in [0, 1]$, of the project surplus accrues to the DI.[12]

Let $p \in (0, 1)$ represent the periodic deposit insurance premium per dollar of deposits. We can either treat p as a constant, as under prevailing arrangements, or make it a function of some observable instrument of DI choice (e.g., capital) and/or some ex post outcome (e.g., default).[13] For simplicity, we abstract from all regulatory restrictions other than capital requirements.

II. Optimal Risk-Sensitive Pricing with Private Information

Assume that each DI lends to one borrower, and that each DI can be one of two types.[14] Type "H" lends to a borrower with success probability θ_H and return R_H in the successful state. Type "L" lends to a borrower with success probability θ_L and return R_L in the successful state. The returns are zero in unsuccessful states with probabilities $1 - \theta_H$ and $1 - \theta_L$, respectively. Let $\theta_H < \theta_L$, and $R_H > R_L$. Since we wish to focus on the private information aspect, we assume that the DI does not choose its borrower and that its knowledge of the borrower's payoff distribution is not available to either the deposit insurer or any other DI. The assumption that the DI knows its own borrower's payoff distribution is not intended to suggest that informational problems between the DI and its borrower are trivial. Rather, it is made to focus on the informational asymmetry between the DI and the deposit insurer. Pre-contract private information therefore is the sole problem. Moral hazard issues will be addressed in Section III.

Deposit insurance premia are assumed to be paid in advance.[15] At the end of the period, if the borrower's project succeeds, the loan is repaid and the DI compensates its depositors. If the project fails, the borrower defaults and the deposit insurer repays depositors.[16]

Consider a risk-sensitive deposit insurance pricing scheme designed by the insurer to elicit the DI's private information. If the deposit insurer wishes to

[11] Besanko and Thakor (1990) show how the surplus from investment projects is shared in imperfectly competitive credit markets.

[12] We assume that there are alternative risky investments available that yield an expected return of r_f. Therefore, a DI will not invest in a loan with $\alpha < 0$. The implicit loan rate is $(1 - \alpha)(r_f/\theta) + \alpha(R/I)$, and when $\alpha = 0$ the borrower is charged the risk-adjusted, risk-free loan rate. This point will be revisited later.

[13] Note that the premium charged in the past has varied from year to year because of rebates. Nevertheless, every DI was charged the same premium per dollar of deposits, before and after the rebate. That is, the premium did not depend on the individual DI's choice of risk.

[14] Each type may have numerous members.

[15] The deposit insurance premium presumably is paid from the DI's retained earnings prior to the receipt of deposits and equity. Remaining retained earnings are paid out as dividends. An alternative would be to assume that $D + E$ equals I plus the deposit insurance premium. This makes the algebra messier without altering the results.

[16] Loans are assumed to be unsecured; secured lending is examined in Besanko and Thakor (1987).

avoid cross-subsidization of a riskier by a safer DI, linking capital requirements to the deposit insurance premia offers one possibility. The deposit insurer can offer each DI a choice between combinations of insurance premia and capital requirements, $\{p_H, E_H\}$ and $\{p_L, E_L\}$, whereby each type of DI selects a distinct pair that maximizes its own welfare and thereby reveals its type. Since the revelation principle (Myerson (1981)) indicates that the optimal scheme is equivalent to one that induces truthful revelation, an alternative is for the DI to report its risk parameter to the insurer, which then charges a premium and specifies a capital requirement based on the report.

The expected payoff to a DI of type i choosing $\{p_j, E_j\}$ is

$$\alpha_i(\theta_i R_i - Ir_f) + D_j r_f(1 - \theta_i - p_j), \tag{1}$$

where D_j is determined residually from the budget constraint, given E_j. The first term in (1) is that portion of the project surplus that accrues to the DI. The second is the subsidy from deposit insurance. Incentive compatibility requires that the following non-mimicry constraints be satisfied:

$$\alpha_H(\theta_H R_H - Ir_f) + D_H r_f(1 - \theta_H - p_H) \geq \alpha_H(\theta_H R_H - Ir_f) + D_L r_f(1 - \theta_H - p_L),$$

or

$$D_H(1 - \theta_H - p_H) \geq D_L(1 - \theta_H - p_L); \tag{2}$$

and similarly

$$D_L(1 - \theta_L - p_L) \geq D_H(1 - \theta_L - p_H). \tag{3}$$

Conditions (2) and (3) ensure that each type of DI will select the contract intended for it.[17] In (2), the left-hand side (LHS) is the expected payoff to the high-risk DI if it reports its type truthfully and the right-hand side (RHS) is its expected payoff if it misrepresents; thus, when (2) holds, the high-risk DI (weakly) prefers truth telling. Similarly, in (3), the LHS is the expected payoff if the low-risk DI reports truthfully and the RHS is its expected payoff if it misrepresents.

Although we have not yet specified a regulatory objective function, a standard result is that the non-mimicry constraint for the potential mimic, (2) in our case, holds tightly in equilibrium. Now suppose that deposit insurance is fairly priced for each type, so that $P_H = 1 - \theta_H$ and $P_L = 1 - \theta_L$. With (2) as an equality, we see that the constraint becomes

$$D_L(\theta_L - \theta_H) = 0.$$

[17] Note that (2) and (3) constrain strategies to those that induce truth-telling by the DIs. Assuming that a Nash equilibrium exists in any general reporting game (possibly without these constraints), the revelation principle asserts that without loss of generality the same Nash equilibrium outcomes can be implemented in a game with truth-telling constraints.

The only way that this constraint can hold is with $D_L = 0$. Thus, incentive compatibility requires that the low-risk institution fund itself entirely with equity, in which case it is no longer a DI. Note that this result obtains because the DI is indifferent between deposits and capital. Thus, it will prefer a lower deposit insurance premium for any positive level of deposits. Consequently, the high-risk DI will always prefer the premium and capital requirement choice of the low-risk DI, as long as the low-risk DI has any deposits.[18] Since this conclusion holds for all $\alpha_i \geq 0$, the conflict between fairly priced deposit insurance linked to capital requirements and incentive compatibility remains, regardless of the competitive structure of the credit market.

How can the incentive compatibility of a risk-sensitive pricing structure be restored? In the absence of deposit-related rents, stemming from either subsidies or monopsonistic pricing in the deposit market, incentive-compatible pricing that links deposit insurance premia to capital levels is impossible. However, if the credit market is imperfectly competitive, so that $\alpha_i > 0$, there will be other possibilities for restoring incentive compatibility. The most emphatic may be to use the threat of charter revocation as a sorting instrument. That is, suppose the charter value of a DI of type i at the end of the period is V_i; for simplicity, let V_i be independent of the first-period state realization. This charter value can be thought of as the present value of all prospective rents expected to accrue to the DI due to $\alpha_i > 0$. Now the insurer can ask each DI to report its type. A DI indicating high risk is charged $p_H = 1 - \theta_H$ per dollar of deposits and is assured that its charter is inviolate. A DI indicating low risk is charged $p_L = 1 - \theta_L$ per dollar of deposits, but the DI's charter will be revoked with probability β if the deposit insurer is forced to repay depositors at the end of the period. This scheme will be incentive-compatible with $\beta = Dr_f(\theta_L - \theta_H)/V_H(1 - \theta_H)$, for a given D.[19] If V_H is sufficiently high, β can be a probability, i.e., take a value in $[0, 1]$. Note that this arrangement does not require that capital requirements vary across DIs. However, if each DI is perfectly competitive and $\alpha_i = 0$, sorting based on threat of charter revocation will not succeed. More generally, incentive-compatible risk-sensitive deposit insurance pricing is impossible even with

[18] With an arbitrarily large number of DI types, our analysis implies that without subsidies the only type allowed to fund with deposits will be that with the highest risk. Kareken (1983) and Niehans (1982), among others, have suggested that the deposit contract be replaced with mutual funds which could provide most of the services of deposits. Runs would be unlikely (Chari and Jagannathan (1988) and Diamond and Dybvig (1983)), but the claims would not be riskless. This raises the question of whether the pervasive availability of a risk-free claim is socially important, if at a cost (Kareken and Wallace (1978)). We do not attempt to settle that issue here. Our objective is limited to explaining that if insured deposits are socially desirable, then risk-sensitive deposit insurance may be impossible in a setting without subsidies.

[19] To see this, note that β is determined by the incentive compatibility constraint that the high-risk DI does not envy the allocation of the low-risk DI; this constraint holds tightly in a Pareto efficient equilibrium. Thus, we solve $\alpha_H[\theta_H R_H - Ir_f] + Dr_f[1 - \theta_H - p_H] + V_H = \alpha_H[\theta_H R_H - Ir_f] + Dr_f[1 - \theta_H - p_L] + \{\theta_H + [1 - \theta_H][1 - \beta]\}V_H$, with $p_H = 1 - \theta_H$ and $p_L = 1 - \theta_L$.

other sorting instruments, given perfectly competitive factor and output markets.

We now examine the role of subsidized deposit insurance in resolving the incentive compatibility problem for a competitive DI. Assume that $p_H = 1 - \theta_H - \varepsilon$ and $p_L = 1 - \theta_L - \varepsilon$, where the subsidy ε is a positive scalar. Since ε is risk-insensitive, the subsidies are invariant across DI types. Note again that the subsidy need not be embedded in the deposit insurance, but some kind of deposit-linked subsidy is essential. For example, the subsidy could arise from a deposit interest rate ceiling.[20]

The insurer's task is to minimize the cost of the deposit subsidy,

$$S \equiv \textstyle\sum_i \lambda_i\{\varepsilon D_i\} = \varepsilon\{\lambda_H D_H + \lambda_L D_L\}, \tag{4}$$

where the λ's are scalar weighting factors, subject to the fixed-subsidy insurance premium pricing conditions

$$p_i = 1 - \theta_i - \varepsilon, \qquad i = H, L,$$

and the constraints (2) and (3). Treating (2) as an equality in equilibrium, substituting $p_H = 1 - \theta_H - \varepsilon$ and $p_L = 1 - \theta_L - \varepsilon$, and rearranging yields

$$\varepsilon[I - E_H] = [I - E_L][\theta_L - \theta_H + \varepsilon], \tag{5}$$

or equivalently,

$$\varepsilon(D_H - D_L) = D_L(\theta_L - \theta_H). \tag{5'}$$

Since $\theta_H < \theta_L$ and $\varepsilon > 0$, (5) implies that $D_H > D_L$. This means that $E_L > E_H$, since $D_H + E_H = D_L + E_L = I$. Thus, the incentive-compatible scheme has the deposit insurer offering the low-risk DI a lower periodic insurance premium ($p_L < p_H$) per dollar of deposits coupled with a higher capital requirement ($E_L > E_H$). To verify that this necessary condition for incentive compatibility is also sufficient, we need to check whether (3) is satisfied. Proving that (3) holds reduces to showing that

$$D_H(\theta_L - \theta_H) \geq \varepsilon(D_H - D_L). \tag{6}$$

Since $D_H > D_L$ and $\theta_L - \theta_H > 0$, (5′) implies that (6) holds as a strict inequality. The intuition is as follows. With a subsidy that is invariant across DIs, fairness requires that the insurance premium be positively related to DI risk. However, such a schedule would not be incentive-compatible since all DIs would be encouraged to describe themselves as low risk. Incentive compatibility is retrieved, however, by linking capital requirements to the insurance premia. In order to persuade the high-risk DI to truthfully reveal its type, it

[20] In the case of private information, the value of α does not affect the ability to design an incentive-compatible deposit insurance pricing scheme that uses the capital requirement as a sorting variable; the deposit-linked subsidy is the essential element. However, a positive α may be a necessary precondition for using an alternative sorting instrument such as the bank's loan volume. Note also that either $\alpha > 0$ or positive subsidies will be needed in the moral hazard case.

can be subjected to a lower capital requirement. Recall that a higher capital requirement is less onerous for a low-risk DI. Thus, the optimal risk-sensitive insurance pricing structure relates capital requirements inversely to deposit insurance premia.[21]

To verify the need for subsidies, note that if $\varepsilon = 0$, (5) can hold only if $E_L = I$. Moreover, the cost (defined as the amount of subsidies) of eliciting truthful revelation will increase in the volume of deposits that the regulator wants the low-risk DI to maintain.[22]

Thus far we have assumed that deposit-linked subsidies accrue entirely to the DI. But in a competitive credit market these subsidies might be shared with the borrower, and this could affect our conclusion. For example, incentive compatibility would be jeopardized if DIs were to compete away *all* deposit-linked subsidies. However, a DI can be expected to retain deposit-linked subsidies, perfect competition notwithstanding. To see this, recall that the DI can invest in marketable securities as well as loans. Provided that the markets offer investment opportunities with payoff distributions that span the payoff distributions of loans, no DI will have an incentive to offer a loan with a repayment obligation of less than r_f/θ per dollar.[23] Consequently, the DI can be expected to retain deposit-linked subsidies.

In addition to private information, the deposit insurer must address moral hazard.

III. Moral Hazard

A. *Motivation*

We have thus far assumed that the DI's payoff distribution is not an instrument of choice. If the DI can make unobservable asset choices, however, the deposit insurer must be concerned about moral hazard. In the case of a perfectly competitive DI, subsidies will be shown to serve an essential role in coping with moral hazard. However, in contrast with the private information case, even with subsidies it is impossible to control moral hazard in a single-period setting. With both private information and moral hazard, subsidy-based, risk-sensitive deposit insurance pricing linked to capital requirements could be incentive-compatible in a static setting, in the sense that each DI would truthfully reveal its risk. However, each DI would choose excessive risk relative to the first best. To discourage excessive risk, the deposit insurer must contract over more than one period. We show that in a two-period setting, second-period subsidies can motivate the appropriate

[21] Note that the incentive-compatible schedule, unlike the prevailing arrangement, generates total premium income to the insurer, pD, which is nonlinear in D. Also, given the assumed payoff distribution, the liability of the deposit insurer is independent of the DI's capital, *conditional* on the failure of the DI.

[22] Solving for ε from (5) and substituting into (4), we can see that S is increasing in D_L.

[23] With risk-neutral investors, θ is the actual probability of success. If investors are risk averse, θ can be viewed as the risk-neutral version of the probability, derived through the equivalent martingale representation argument of Harrison and Kreps (1979).

first-period asset choice by a perfectly competitive DI. Although our formal analysis assumes away pre-contract private information, we indicate how the results would be affected by modeling private information and moral hazard jointly.

B. Single-Period Model

To focus on moral hazard, we assume only one type of DI, but it chooses assets from a continuum of investment opportunities. Each is a single-period loan used to purchase a single-period project returning $R(\theta)$ if successful, and nothing otherwise; θ is the probability of success. Cross-sectionally, $\theta \in [\underline{\theta}, \bar{\theta}] \subset (0,1)$. We assume $R'(\theta) < 0$ and consider two cases: (1) θR is constant, and (2) θR is concave in θ with a unique maximizer at $\theta^0 \in (\underline{\theta}, \bar{\theta})$.

The deposit insurer's problem is to design a pair (p, D), where p is the periodic deposit insurance premium per dollar of deposits and D is the amount of permissible deposits. As indicated earlier, the deposit limit is equivalent to a capital requirement. Since there is no private information, p is a scalar and any DI with deposits in the amount D must pay a premium of pD at the start of the period. Moreover, as we will show in the following discussion, p can be defined so that the deposit insurer breaks even. We assume that the DI's asset choice cannot be observed by the insurer, and likewise cannot be verified ex post. The insurer can only observe whether it must settle depositors' claims; it cannot observe the project outcome (payoff). This establishes preconditions for moral hazard.

For a given (p, D), the DI chooses θ so as to maximize

$$\pi = \alpha(\theta R - I r_f) + D r_f [1 - \theta - p]. \tag{7}$$

The maximizing value of θ is given by the first-order condition

$$\partial \pi / \partial \theta = \alpha \, \partial(\theta R)/\partial \theta - D r_f = 0. \tag{8}$$

Let the θ satisfying (8) be θ^*. Then we see from (8) that for Case 1, $\theta^* = \underline{\theta}$ unless $D = 0$. That is, for any (p, D), the DI chooses the riskiest project. The insurer can set its breakeven (zero subsidy) policy as follows: (i) fix some D and assume $\theta^* = \underline{\theta}$, and then (ii) set $p = 1 - \theta^* = 1 - \underline{\theta}$. This will be a breakeven pricing policy since the DI will choose the riskiest project when faced with this (p, D) combination.

For Case 2, we see from (8) that $\theta^* < \theta^0$ unless $D = 0$. Once again, the deposit insurer can set its breakeven policy as in Case 1. Thus, we find that distortions induced by moral hazard are unavoidable in a single-period setting with insured deposits. The DI chooses higher asset risk than the (socially optimal) first best because the choice of θ is independent of the insurance premium p.[24]

[24] The moral hazard and private information problems are not isomorphic. In the private information case, we want the deposit insurance premium to accurately reflect each DI's risk. In the moral hazard case, we want to coax each DI to choose a risk in a desired proximity of the social optimum.

If two a priori indistinguishable types of DI can choose assets from a continuum of investment opportunities, then the deposit insurer confronts both private information and moral hazard. We could think of the high-risk DI choosing θ from $[\underline{\theta}_H, \bar{\theta}_H]$ and the low-risk DI choosing from $[\underline{\theta}_L, \bar{\theta}_L]$, with $\bar{\theta}_H < \underline{\theta}_L$. To induce each DI to truthfully reveal its type, the deposit insurer can offer a choice between $\{p_H, D_H\}$ and $\{p_L, D_L\}$, as in the private information case. If the deposit insurance premium is appropriately subsidized, this will resolve the private information problem. However, each DI will choose the highest risk. In anticipation of this, the insurer must set $p_H = 1 - \underline{\theta}_H - \varepsilon$ and $p_L = 1 - \underline{\theta}_L - \varepsilon$. We will now examine the resolution of moral hazard with multiperiod contracting.

C. Two-Period Model

Again assume that there is only one type of DI and consider Case 1 where θR = constant. At $t = 0$, the DI lends against a project that at $t = 1$ yields $R(\theta_1)$ w.p. θ_1, and zero w.p. $1 - \theta_1$. If the project fails, the borrower defaults at $t = 1$, yielding the DI nothing. The deposit insurer then repays the depositors, and the DI expires. If the project succeeds, the loan is repaid and the DI compensates depositors and continues in business for another period. At $t = 1$, new deposits are obtained and a new loan is made. At $t = 2$, the second loan yields $R(\theta_2)$ w.p. θ_2, and zero w.p. $1 - \theta_2$. For simplicity, we assume that α is invariant from period to period. We also assume that it is not feasible for the DI to operate with a negative expected profit in any period.[25]

The deposit insurer's problem is to design $((p_1, D_1), (p_2, D_2))$, where (p_i, D_i) is the combination of a premium per dollar of deposits and deposits for period i. Of course, (p_2, D_2) is offered conditional on first-period success. The DI's expected return for period i is

$$\pi_i(p_i, D_i) = \alpha\left[\theta_i R(\theta_i) - I r_f\right] + D_i r_f[1 - \theta_i - p_i]. \tag{9}$$

The DI's objective at $t = 0$ is to maximize.

$$\tilde{\pi} = \pi_1(p_1, D_1) + \theta_1 r_f^{-1} \pi_2(p_2, D_2), \tag{10}$$

where all returns are normalized in time $t = 1$ dollars. The first-order condition governing the optimal choice of θ_1 is

$$\partial\tilde{\pi}/\partial\theta_1 = \alpha\partial\left(\theta_1 R(\theta_1)\right)/\partial\theta_1 - D_1 r_f + r_f^{-1}\left[\pi_2(p_2, D_2)\right] = 0. \tag{11}$$

Note that π_2 may include a subsidy for the second-period deposit insurance.

[25] If it were possible for the DI to operate with negative expected profit, then we could design a pricing scheme that taxes the DI heavily in the first period (which, in the absence of subsidies, would mean negative expected profit for the DI), and promises success-contingent second-period subsidies sufficient to resolve the moral hazard problem.

The deposit insurer can select (D_1, p_2, D_2) so that

$$D_1 r_f \leq r_f^{-1}[\pi_2(p_2, D_2)]. \tag{12}$$

Since $\partial\{\theta_1 R(\theta_1)\}/\partial\theta_1 = 0$ by assumption of Case 1, (11) implies that the insurer can induce a choice of $\theta^* = \bar{\theta}$ (the project with the lowest risk) if (12) is satisfied. That is, in the first period, first-best project choice incentives can be enforced with the appropriate choices of D_1, D_2, and p_2. To further analyze (12), write

$$\pi_2 = \alpha[\theta_2 R_2 - I r_f] + D_2 r_f[1 - \theta_2 - p_2],$$

and defining

$$\Delta(\theta_2) \equiv \alpha[\theta_2 R_2 - I r_f],$$

we have

$$\pi_2 = \Delta(\theta_2) + D_2 r_f[1 - \theta_2 - p_2]. \tag{13}$$

Substituting (13) into (12), we obtain

$$\Delta r_f^{-1} + D_2[1 - \theta_2 - p_2] \geq D_1 r_f. \tag{14}$$

Note that in the second period, the DI will choose $\theta_2 = \underline{\theta}$ for any $D_2 > 0$. That is, the end-game problem precludes a resolution of the moral hazard in the second period. Thus, we can write (14) as

$$D_2[1 - \underline{\theta} - p_2] \geq D_1 r_f - \Delta r_f^{-1}. \tag{15}$$

Suppose $\Delta(\theta_2) = 0$; i.e., the credit market is perfectly competitive and $\alpha = 0$. Then, (15) implies that a subsidy in the second period is necessary to ensure that the DI will choose the low-risk project in the first period, provided that $D_1 > 0$. With $\Delta(\theta_2) > 0$, a second-period subsidy will be necessary to control the first-period moral hazard when the contractual payout on the first-period deposits exceeds the discounted value of the surplus accruing to the DI from the second-period project evaluated at time 1.

For Case 2, from the results of the single-period model, the DI will choose $\theta_2^* < \theta^0$ in the second period unless $D_2 = 0$. The DI's first-period asset choice, θ_1^*, is determined by the first-order condition, (11). Substituting (13) into (11), we see that $\theta_1^* = \theta^0$ if and only if

$$D_1 r_f - \Delta(\theta_2^*) r_f^{-1} = D_2(1 - \theta_2^* - p_2).$$

The interpretation is similar to that for Case 1. If $\Delta(\theta_2^*) = 0$, a subsidy in the second period is necessary to assure first best in the first period as long as $D_1 > 0$. In general, with $\Delta(\theta_2^*) > 0$, a second-period subsidy is necessary when the contractual return on the first-period deposits exceeds the surplus accruing to the DI from the second-period project evaluated at time 1.

Thus, we find that a deposit insurance premium linked to a capital requirement will not solve the moral hazard problem in a one-period setting.[26] In a two-period setting, the moral hazard problem can be resolved only with restrictions on D_1 and D_2, and possibly with a second-period deposit-linked subsidy. A longer time horizon than two periods provides yet greater flexibility in addressing the moral hazard since subsidies can be strung out to create appropriate asset choice incentives.

By linking insurance premia and capital requirements in the way suggested, the insurer can achieve ex ante efficiency with respect to first-period asset choice. Ex post inferences by the deposit insurer are not required. Thus, the insurer need not verify the DI's asset selection.[27] Because of ex ante efficiency, the insurer knows that a rational DI will choose the socially optimal risk when offered appropriate premia/capital alternatives.

Were the insurer to design a policy to address both private information and moral hazard, each DI could be asked to choose a schedule from the pair $\{p_1(H), D_1(H); p_2(H), D_2(H)\}$ and $\{p_1(L), D_1(L); p_2(L), D_2(L)\}$. Schedules would be designed so that both the first- and the second-period deposit insurance premia are subsidized, and continued operation of the DI in the second period would be conditional on first-period success. Each DI would truthfully reveal its type and first-period moral hazard would be restrained. For a perfectly competitive DI, our conclusion regarding the essentiality of subsidies remains unchanged.

IV. Robustness of Results

A. Taxes

Capital structure is irrelevant in our model without taxes and deposit-linked subsidies. This suggests that with taxes the finding that subsidies are necessary for sorting may be vitiated. Leverage signaling requires that it must be costly for the high-risk DI to mimic. This, in turn, requires that the costs of debt and equity differ so that capital structure can affect the cost of capital.[28]

[26] Kim and Santomero (1988) consider deposit insurance designed to control asset choices and show that by tying future insurance premia to ex post asset returns, the insurer can induce the DI to undertake less risky projects. Our model differs in that we assume that the asset return cannot be verifiably deduced ex post; all that the regulator knows is whether or not it is required to settle depositors' claims.

[27] This is just as well since knowing only whether or not it is required to settle depositors' claims will not generally permit the regulator to infer the probability distribution from which the outcome was drawn.

[28] The intuition is akin to that in Shah and Thakor (1987) where incentive-compatible capital structure contracts can be designed to induce a perfectly separating equilibrium in which firms with levels of risk that vary along a continuum choose distinct debt-equity ratios. In that model, it is essential that interest payments be tax-deductible; the tax advantage of debt permits separation.

This intuition, however, is misleading in the present context. We will show that, with perfectly competitive credit markets, subsidies are necessary for sorting, even with taxes.[29] Consider the model in Section II with corporate taxes and let T denote the tax rate. Since both the interest expenses (when paid) and the insurance premium are tax-deductible, the expected return to a DI of type i choosing the pair $\{p_j, E_j\}$ will be

$$(1 - T)\{\alpha_i[\theta_i R_i - Ir_f] + D_j r_f(1 - \theta_i - p_j)\} - TE_j r_f. \tag{16}$$

If the credit market is perfectly competitive, $\alpha_i = 0$, and the DI's expected return is

$$D_j r_f(1 - \theta_i - p_j)(1 - T) - TE_j r_f.$$

Note that the first term reflects the value of the deposit insurance subsidy and the second indicates that bank equity, since it allows for no tax benefit, is a dominated instrument. Hence, unless E_j is set to zero for every DI, fairly priced deposit insurance will not be viable since it violates the DI's participation constraint (zero profits). In the Modigliani and Miller setting with taxes, extreme leverage is the optimal capital structure. In our perfectly competitive credit market, extreme leverage is the *only* feasible capital structure with taxes and without deposit-linked subsidies. Therefore, with fairly priced deposit insurance, every DI will choose extreme leverage, but then sorting becomes impossible. Thus, subsidies are necessary to restore sorting incentives.

To see how the premium/capital combinations sort DIs, consider the incentive compatibility conditions. Substituting for $p_i = 1 - \theta_i - \varepsilon$ and $E_i = I - D_i$, the conditions analogous to (2) and (3) are:

$$\varepsilon(1 - T)D_H + TD_H \geq (1 - T)D_L[\theta_L - \theta_H + \varepsilon] + TD_L, \tag{17}$$

and

$$\varepsilon(1 - T)D_L + TD_L \geq (1 - T)D_H[\theta_H - \theta_L + \varepsilon] + TD_H. \tag{18}$$

As is standard in such analyses, (17) can be shown to hold tightly in equilibrium, and therefore

$$D_H/D_L = \{1 + (1 - T)(\theta_L - \theta_H)/[T + (1 - T)\varepsilon]\}, \tag{19}$$

and $D_H > D_L$. Thus, the incentive-compatible premium/capital contracts must satisfy $E_L > E_H$ and $p_H > p_L$. As in the asymmetric information case without taxes, an incentive-compatible design inversely relates capital requirements to deposit insurance premia. Moreover, arguments similar to

[29] Note that the tax deductibility of deposit interest payments does not necessarily permit separation in the present setting. Taxes only make deposits different from shareholders' equity, but not from debt claims subordinated to deposits. Within limits, these latter claims satisfy the regulatory definition of capital. Thus, we again have indifference between deposits and capital in the absence of subsidies. Since our basic model assumes that taxes are zero, without loss of generality, capital can be defined as equity exclusively.

those made previously establish that deposit-linked subsidies are retained, even by perfectly competitive DIs.

B. Multiple DI Types and Arbitrary Return Distributions

We assumed only two DI types in the private information case. Suppose instead a continuum of types capable of being ranked according to risk. Then only the riskiest will have deposits in the absence of deposit-linked subsidies. All others will be required to fund exclusively with capital, since the riskiest will covet the lower deposit insurance premium offered to the less risky that have any deposits. Thus, subsidies are necessary in this more general case.

Subsidies also are necessary when each borrower's payoff is described by an arbitrary probability distribution. To see this, suppose returns are described by a continuous density function and borrowers can be ranked on the basis of first- or second-order stochastic dominance. Then the deposit insurer's liability per dollar of insured deposits will be greater for riskier DIs, implying a higher periodic premium per dollar of deposits. Subsidies will once again be required for incentive-compatible, risk-sensitive deposit insurance pricing that permits DIs, other than just the riskiest, to use deposits.

C. Risk Aversion

Since we assume risk neutrality, one might reasonably question the need for deposit insurance. We can imagine, however, that depositors are risk averse and investments embody systematic as well as unsystematic risks. Since DI equity will be priced as if shareholders are well-diversified, only the systematic component of risk will require a premium. Completely insured depositors will require a return equal to the riskless interest rate. Fairly priced deposit insurance will require that the insurance premium compensate the insurer for the difference between the yield on uninsured deposits and the riskless interest rate (Merton (1977)). Given fair pricing, however, the effective risk-adjusted yield on deposits will equal that on DI equity, and capital structure is again irrelevant.[30] Anything less than such a premium should be viewed as a deposit insurance subsidy. Our main result is then sustained in this more general framework.

Incentive-compatible, risk-sensitive deposit insurance pricing seems possible in a competitive milieu without insurer losses only if the insurer is less risk averse than all other agents. Deposit insurance priced to enable the insurer to just break even then can generate a surplus for the DI due to risk-sharing benefits. Deposits would be special relative to (uninsured) equity, and a risk-sensitive pricing structure that overcomes private information problems would be attainable. However, the deposit insurer must be the most efficient risk absorber in the economy. If others in the private sector were equally efficient, they could provide competitively priced insurance

[30] In this framework, governmental deposit insurance may arise because diversified shareholders are unable to provide a credible commitment to make the stipulated depositor payoffs.

with as much risk-sharing surplus for *shareholders* as governmental deposit insurance provides for depositors. Once again, DI capital structure becomes irrelevant.

D. Monitoring

In practice, deposit insurers rely on monitoring to address private information and moral hazard problems. Could risk-sensitive deposit insurance pricing be designed to exploit monitoring in lieu of direct reporting by DIs? Without subsidies, monitoring is likely to be inadequate for two reasons. First, it should be more costly than direct reporting and the deposit insurer therefore will need to gross up the premium. Unless deposits provide a surplus relative to equity, DIs will prefer to fund entirely with equity or uninsured debt rather than pay the monitoring cost of insured deposits. Second, monitoring can be effective only if the insurer can credibly threaten to punish excessive risk taking. However, in a competitive environment without subsidies, charter termination, arguably the most severe sanction available, imposes no loss on the DI and thus would not deter risk taking.

E. Private Deposit Insurance

We have assumed thus far that deposit insurance is governmental. Because of the demonstrated role of subsidies in resolving private information and moral hazard problems, private deposit insurance would not be able to implement incentive-compatible, risk-sensitive insurance pricing. Even if the DI earns monopoly rents so that subsidies are unnecessary, depositors would be concerned about the possible default of the insurer.[31] The deposit interest rate that an individual DI would need to offer depositors would then be increasing in the total of insured deposits as well as in the deposits of the individual DI. Depositors would need to monitor the insurer, and the monitoring cost would be reflected in a mark-up of the deposit interest rate. A DI therefore would find private deposit insurance inferior to governmentally provided deposit insurance.

V. Summary Remarks

This paper considers the problem of designing an incentive-compatible, risk-sensitive deposit insurance pricing scheme when the insurer confronts private information and moral hazard problems. It is shown that the insurer can elicit truthful disclosure regarding asset portfolio risk from each DI, without intrusive regulatory monitoring. This is achieved by offering DIs a schedule of capital requirements that are inversely related to deposit insurance premia and each DI is permitted to choose its most preferred combination. We show that deposit-linked subsidies are necessary if such a system is to succeed in a competitive banking industry. Since even perfectly

[31] We thank the referee for pointing this out to us.

competitive DIs do not completely dissipate deposit subsidies in pricing loans, positive charter values are maintained, making incentive compatibility feasible. Subsidies are also shown to be necessary to cope with the moral hazard associated with deposit insurance. Thus, fairly priced deposit insurance and, by implication, competitive private-sector insurance of deposits is impossible in a competitive banking system in which private information and moral hazard distort equilibria.

Risk-sensitive deposit insurance pricing might have been possible earlier when DIs enjoyed greater deposit-linked rents.[32] Moral hazard was less of a problem when deposit rents discouraged high-risk strategies. The value of the DI charter served as bankruptcy cost, conditioning asset selection as well as capital structure (Chan, Greenbaum, and Thakor (1986)). With the erosion of deposit rents, however, DIs had less incentive to avoid risky assets. The variety of DIs' assets expanded, increasing the informational burden of the deposit insurer, and thereby making risk-sensitive premia more compelling. But without subsidies to replace previously available deposit rents, fairly priced deposit insurance is impossible. Thus, deregulation and risk-sensitive deposit insurance pricing may be incompatible, and we confront the nice irony that risk-sensitive premia are most compelling when they are least attainable.

Recent increases, and the prospect for further increases in insurance premia, indicate continued erosion of deposit subsidies. Growing global competition together with the momentum of deregulation suggest that any future implementation of risk-sensitive deposit insurance pricing faces serious impediments. To the extent that incentive compatibility is jeopardized, more intrusive and costly supervision may become necessary with negative implications for DI competitiveness. To be sure, there are alternatives such as the narrow bank, but the restoration of a system with minimal failures, benign regulation, and risk-insensitive premia seems increasingly unlikely.

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[32] This is one explanation offered for the recent growth of securitization. When deposits provided greater rents, it was advantageous for DIs to unify the origination and funding functions of credit transactions. Dissipation of these rents, however, has eroded the DI's funding advantage, leading to the separation of the two credit functions with DIs concentrating on origination (Greenbaum and Thakor (1987)).

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