Deposit Insurance and the Discount Window: Pricing under Asymmetric Information
Author(s): George Kanatas
Source: *The Journal of Finance*, Vol. 41, No. 2 (Jun., 1986), pp. 437-450
Published by: Blackwell Publishing for the American Finance Association
Stable URL: http://www.jstor.org/stable/2328446
Accessed: 26/11/2009 08:28

THE JOURNAL OF FINANCE • VOL. XLI, NO. 2 • JUNE 1986

Deposit Insurance and the Discount Window: Pricing under Asymmetric Information

GEORGE KANATAS*

ABSTRACT

The risk-sensitive pricing of deposit insurance and the discount window is determined in an environment where banks have private information concerning their financial conditions. The two facilities are managed jointly; an incentive-compatible policy is designed such that banks' choice of terms at which they can obtain insurance and access to discount window credit will reveal their asset quality. The function of the discount window is to be a risk-neutral "lender of last resort" to banks in a market dominated by risk-averse depositors.

THE NEED TO REGULATE banks is commonly linked to the risk-independent pricing of deposit insurance in that it provides banks with an incentive to increase their risk-taking activities.[1] Critics of the present system have long advocated risk-sensitive deposit insurance premiums, and a literature is emerging that examines the variety of such pricing schemes.[2] This literature typically assumes that the public insuring agency has the same information as the bank concerning the quality of the bank's assets. This is both implausible and potentially misleading; the bank normally has superior information concerning its assets. A pricing policy that ignores this informational asymmetry is likely to provide banks with similar risk-taking incentives that is associated with the current risk-insensitive pricing arrangement. Kane [6, p. 275], for example, appreciates this aspect of the problem, "[I]t is necessary not only to 'reprice' but also to 'redesign' the existing system. . . . The FDIC and FSLIC must develop *incentive-compatible* [my emphasis] insurance contracts and price them fairly. . . . Contractual incentives must be established that would allow a low-risk institution to lower its premiums by communicating to the insurance agency what its own managers know about the institution's own exposure. . . . " Therefore, as Kane argues, a "redesigned" insurance system is needed that would provide incentives to the banks to truthfully reveal the necessary information and thereby facilitate the efficient pricing of the risk shifted to the public insurer. A variety of pricing policies that involve a bank's choice of capital or asset/liability composition

* Department of Finance, University of Illinois at Chicago. Support from Northwestern University's Banking Research Center is gratefully acknowledged. The comments of Stuart Greenbaum, Kazuhiro Igawa, Paul Kasril, Robert Laurent, and the participants at Wharton's Money and Banking Seminar are appreciated. An earlier draft was written while I was a Visiting Scholar at the Federal Reserve Bank of Chicago. The excellent research environment provided by Karl Scheld is appreciated.

[1] See the July 1983 issue of the *Housing Finance Review*, for example.

[2] See, for example, Bierwag and Kaufman [1], Greenbaum and Ricart i Costa [3], Kareken and Wallace [7], and Merton [8].

could be designed to elicit the needed information. However, our purpose here is not to examine the alternative forms of such pricing policies. Rather, we focus on the neglected link between the government's exposure in providing deposit insurance and that in operating the discount window. A normative model is developed in which the government's exposure in insuring bank deposits and in providing discount window credit is fairly priced in an environment in which banks possess superior information concerning their prospective need to borrow at the discount window.

Although the Federal Reserve's intent is to provide funds to banks that are "illiquid," but not "insolvent," the distinction is unclear. Whereas the former are thought to have sustained only a "temporary" reduction in asset values, the latter have assets reflecting more permanent reductions in value. However, there is no reason to believe that the market will undervalue bank assets; if an asset is expected to increase in value, the current market price should incorporate this expectation. This confusion concerning emergency credit is even more evident when we recognize the discount window as the governmental "lender of last resort." Any bank receiving such emergency funds has presumably been rationed out of the market, i.e., private lenders refuse to lend at any finite price, and therefore such a bank is not readily distinguished from one that is "insolvent." Further confusion regarding the discount window originates from its role under a lagged reserve accounting system. Indeed, the existing literature on the discount window concentrates on its use as a stabilization device (see Goodfriend [2], for example) of monetary policy and ignores allocative issues.

The provision of emergency funds through the discount window is an implicit guarantee of uninsured deposits to the extent that banks experiencing withdrawals are provided funds. If uninsured depositors recognize the availability of such funds, market discipline of banks is weakened, thereby placing a greater burden on either regulation or the pricing of deposit insurance. In fact, if bank access to the discount window is generally available, then the only remaining uninsured depositor at a failed bank would be the Federal Reserve. If risk-sensitive deposit insurance pricing is adopted without change in the current management of the discount window, banks will have an incentive to substitute "uninsured" deposits for insured ones. The pricing of these uninsured deposits will be close to that of insured deposits, given the bank's known access to the discount window and risk-sensitive insurance pricing will shift the bank's expected cost of risk-taking to the Federal Reserve. Thus, if banks are to pay the costs associated with their risk-taking activities, the deposit insurance system must be redesigned to incorporate the management of the discount window.

We will view the deposit insurance agency (FDIC) and the Federal Reserve as acting in concert in providing banks with deposit insurance and access to emergency funds. Furthermore, we will assume that the regulator is a true "lender of last resort" in the sense that discount window borrowing will imply that banks have been rationed by the credit market. Consequently, the discount rate can be viewed as a "subsidy" rate. The regulator in our model serves two purposes. First, the policy adopted in pricing the deposit insurance and the access to emergency credit allows the market to infer the banks' private information, i.e., their loan quality. This information is then available to uninsured depositors enabling them to correctly price the banks' debt. The regulator's policy is thereby complemented by the market's discipline. The second function of the regulator is to serve as a risk-neutral lender to banks operating in a market dominated by risk-averse depositors. Thus, in addition to an initial quality standard that must be met by all banks, a further constraint must be satisfied whenever emergency funding is required. The regulator will provide credit to banks that experience fallen asset values and face withdrawals by their risk-averse uninsured depositors but not to those banks that are so severely impaired that even risk-neutral depositors would attempt to withdraw their funds. This distinction differs from that usually made between borrowing at the discount window for "liquidity" and "solvency" reasons. If emergency credit were to be provided to a bank that loses even risk-neutral uninsured depositors, then the regulator would clearly be supporting an insolvent institution. However, if it is the risk aversion of depositors that results in their attempt to withdraw their funds, then the regulator in providing credit is merely sustituting for a risk-neutral private lender and this can be viewed as a temporary facility.

I. The Model

The bank and regulator are risk-neutral whereas depositors are risk-averse. The bank's balance sheet is predetermined, consisting of two types of liabilities, insured and uninsured deposits, and one risky asset, loans. There is no loanable bank capital. Deposits mature at the end of each of two periods. Loans have a maturity of two periods and are worthless if called before the end of the second period. At the end of the second period, the bank's borrowers will either default *in toto* or repay in full. The initial quality, or default risk, of loans is known by the bank but not by the depositors nor the regulator. All know that at the end of the first period, information concerning the new probability of loan default will be received by the market. If the new information indicates that a bank's loans will "probably" be repaid ("good news"), the deposit interest rate is adjusted to reflect the new information and the uninsured depositors renew their deposits. If the new information indicates that the loans will "probably" default ("bad news"), the uninsured depositors attempt to withdraw their funds. In this case, the bank may be provided a discount window loan to replace its uninsured depositors.[3] If the bank is not provided with funding, it is terminated and the regulator pays off the insured depositors, the bank's loans are sold and any proceeds are divided between the uninsured depositors and the regulator according to the relative size of their claims.[4]

Before the beginning of the first period, the bank's prospective balance sheet is determined, and the bank applies for a charter and, therefore, for deposit insurance and access to the discount window. If the regulator grants the charter, the initial insurance fee is determined and the regulator informs banks of their

[3] Collateral is not considered; the bank's loans, given their possible payoffs, can obviously not serve as collateral. Furthermore, given our assumption that the discount window serves as a "lender of last resort," the banks would only be given access to funds after their collateral had been exhausted.

[4] Our qualitative results would be unchanged if we assumed that the regulator has priority over the uninsured depositors, but the algebraic manipulations would be somewhat more cumbersome.

future discount window borrowing rate in the event they need emergency funds and satisfy the predetermined quality standard.[5] This assumption merely formalizes one aspect of the present environment; banks typically have a good short-term estimate of their discount rate, at least relative to the risk-free rate. However, while there is little current variation in the discount rate across banks, in our model the discount rate is bank-specific. Recognizing its informational disadvantage, the regulator formulates a charter-granting policy that will permit the sorting of banks according to their asset quality. We know from the revelation principle (Myerson [9], Harris and Townsend [4]) that direct revelation mechanisms cannot be dominated; there is no policy superior to the one that is incentive-compatible and in which the bank is asked to reveal its asset quality. Thus, we can view the regulator's policy instruments, consisting of the prior probability of granting a charter, the insurance premium, and the discount rate, as being functions of the bank's report of its private information. Truthfulness is assured by the incentive compatibility restriction.

A. Loan Quality

There are three dates, $t = 0$, 1, and 2; bank loans are made at $t = 0$ and mature at $t = 2$. The bank is in one of three possible states at $t = 1$. Letting g and b denote a "good" and "bad" condition, respectively, for the bank at $t = 1$, we have

$$i = \begin{cases} g \\ b \end{cases} \text{with probability } \begin{matrix} q \\ 1-q \end{matrix} \text{ and } q \in [q_0, q_1],\ q_1 > q_0 > 0 \tag{1}$$

where the probability, q, is public information at $t = 0$. We further distinguish between banks that are in a "bad" condition ($i = b$) at $t = 1$ by letting $k = g$ describe those that are only "somewhat" impaired and denoting those that are "severely" impaired by $k = b$. At $t = 0$, the conditional probability that the bank will be in state $k = g$ at $t = 1$ (given $i = b$), is denoted by j,

$$\text{Prob}\{k = g \mid i = b\} = j \tag{2}$$

with $j \in [j_0, j_1]$ and $j_1 > j_0 > 0$, and j is the bank's private information.

Given the bank's observable state at $t = 1$, depositors, regulator, and bank all assign the same probability to loan repayment at $t = 2$. Letting $\theta = 1$ denote the state at $t = 2$ in which all loans are repaid, and $\theta = 0$ loan defaults, the conditional probabilities for the three states are given by

$$\begin{aligned} &\text{Prob}\{\theta = 1 \mid i = g\} = p_0 \\ &\text{Prob}\{\theta = 1 \mid i = b,\ k = g\} = p_1 \\ &\text{Prob}\{\theta = 1 \mid i = b,\ k = b\} = p_2 \end{aligned} \tag{3}$$

where $p_0 > p_1 > p_2 > 0$. Thus, the informational asymmetry is eliminated at $t = 1$, and the probabilities for loan repayments at $t = 2$ are known by all.

We can interpret the observable probability, q (or $1 - q$), that the bank will be in a "good" (or "bad" condition) at $t = 1$ along with the unobservable

[5] This standard can also be described as the bank's expected asset value at $t = 1$ being at least as great as the value of its liabilities as determined in a market dominated by *risk-neutral* depositors.

conditional probability, j, as differing across banks. Such an interpretation would imply that certain gross characteristics of each bank's loan portfolio are observable and the probability of realizing conditions that would result in a deterioration is also known. However, the magnitude of the likely quality deterioration (indicated by j) is unobservable.

An alternative interpretation of q, however, views the states $i = g$ or b at $t = 1$ as descriptions of the economy, with the probability of "prosperity" ($i = g$) or of "recession" ($i = b$) initially known by all. A "recession" would lead to widespread business failures, and bank asset values would plummet. The bank's private information at $t = 0$ is the conditional probability that describes the likely magnitude of the "recession's" effect on the bank. Either interpretation is acceptable.

The bank's loan proceeds after two periods are denoted by θR where θ has already been described as being either one or zero. We assume that R is independent of the loan quality parameters. Although this assumption may appear artificial since we would expect that riskier loans should carry a higher interest rate, our analysis requires only that the regulator cannot infer the loan's quality from the observed loan rate. We could have assumed that R is decreasing in j (but expected R is increasing) and that due to the bank's unknown monopoly power in the loan market, the regulator (and depositors) cannot infer j from R. Since our results would be qualitatively unchanged, we therefore simply assume independence between R and j.

B. Deposit Interest Rates and Withdrawals

We want to now discuss the determination of the various deposit interest rates and the conditions that result in uninsured depositor withdrawals at $t = 1$.

Each bank has one unit of deposits, of which α is insured. All deposits have a one-period maturity. Deposit interest rates are set in a competitive market dominated by risk-averse depositors; insured depositors receive the one-period risk-free rate, r_f, (one plus the interest rate) each period. If the bank's loan proceeds, R, were sufficient to repay all depositors at $t = 2$ if $\theta = 1$, there would be no deposit withdrawals at $t = 1$, and the interest rates demanded by uninsured depositors for the second period corresponding to the conditional probabilities in (3) would be

$$r_2 = \begin{cases} r_{20} & \text{if} \quad i = g \\ r_{21} & \text{if} \quad i = b, \quad k = g \\ r_{22} & \text{if} \quad i = b, \quad k = b \end{cases} \tag{4}$$

and

$$r_{20} \leq r_{21} \leq r_{22}.$$

That is, regardless of the bank's state at $t = 1$, there would exist a market-determined deposit rate that will compensate the uninsured depositors for their risk and would, therefore, induce them to "roll over" their deposits. With the probabilities given by (3) unchanged, consider a reduction in R until

$$R = \alpha r_f^2 + (1 - \alpha) r_1 r_{22} \equiv R^*$$

where r_1 is the first-period uninsured deposit rate, and r_{22} is the second-period deposit rate from (4) in the event that the bank at $t = 1$ realizes the worst possible outcome $\{i = b, k = b\}$. In this case, if the bank's loans are repaid at $t = 2$, i.e., $\theta = 1$, the proceeds would just cover the bank's cost of funds. However, we assume that R is below R^*; for each bank, there is some value of R, conditional probability, p_2, and associated deposit rate, r_{22}, such that $R < R^*$. Thus, if the bank realizes $i = b$, $k = b$, at $t = 1$ all know that the bank cannot possibly pay the rate r_{22} at $t = 2$. Since a deposit rate lower than r_{22} will not compensate depositors for their risk, given p_2, no new uninsured depositor would provide funds to the bank. If the bank were given access to the discount window, the bank's existing uninsured depositors would certainly withdraw their funds. Without emergency credit from the regulator, the bank's uninsured depositors could allow it to "reschedule" its debt and thereby continue to operate until $t = 2$ or force the bank's termination at $t = 1$ by attempting to withdraw their funds. In the latter case, the regulator immediately pays off the insured depositors and subsequently liquidates the bank. The bank's assets are assumed to be sold in a competitive market dominated by risk-neutral buyers and thereby providing revenue of p_2R/r_f. Given that the claims of the regulator and uninsured depositors are assumed to have equal seniority, the depositors would receive

$$\left[\frac{(1-\alpha)r_1}{\alpha r_f + (1-\alpha)r_1}\right]\frac{p_2R}{r_f} \tag{5}$$

from the liquidation based on the size of their claim relative to the aggregate claims on the bank. If depositors allow the bank to "reschedule" its debt, they have the expected payoff given by

$$\frac{(1-\alpha)r_1r_{22}}{[\alpha r_f^2 + (1-\alpha)r_1r_{22}]}\cdot p_2R \tag{6}$$

where uninsured depositors again receive the fraction of the total proceeds represented by their claim. Allowing the bank to "reschedule" its debt and continue to operate is equivalent to the depositors investing their certain proceeds, given by (5), from a liquidation for an expected payoff given by (6). Depositors will choose to "reschedule" only if they can obtain at least the market return, r_{22}, from their new investment. From (6), however, their expected payoff is clearly insufficient and depositors will demand the closing of the bank in this state.

We will assume that R is sufficiently small so that not only is $R < R^*$, but in fact

$$R < \alpha r_f^2 + (1-\alpha)r_1r_{21} \tag{7}$$

where r_{21} is the deposit rate given in (4) when the bank is in state $i = b$, $k = g$ and is only somewhat less impaired. Thus, uninsured depositors would choose to withdraw their funds in both states denoted by $i = b$.

All banks that realize the states $i = b$, $k = g$, b at $t = 1$ are known from (7) to be unable to pay depositors the market rate at $t = 2$. However, we assume that banks in the less impaired state, $i = b$, $k = g$, could have paid off depositors if

$\theta = 1$ at $t = 2$, had depositors been risk-neutral and consequently required the interest rate factor r_f/p_1 rather than r_{21}, i.e., $R \geqslant \alpha r_f^2 + (1 - \alpha) r_1 r_f/p_1$. This inequality, together with (7), indicates that the bank's reduced asset values at $t = 1$ in the less impaired state $i = b$, $k = g$, would have led to a higher deposit cost in the second period but not to deposit withdrawals *provided depositors had been risk-neutral.* The attempted withdrawals in this state result from the risk aversion of depositors. However, banks in the state $i = b$, $k = b$, could not have repaid depositors even if they had been risk-neutral and therefore required r_f/p_2, i.e., $R < \alpha r_f^2 + (1 - \alpha) r_1 r_f/p_2$. In this state, the bank's loan quality is so low or equivalently r_f/p_2 is so high that even risk-neutral depositors would not have chosen to lend to the bank.

We assume that the regulator provides credit through the discount window at $t = 1$ only to banks that realize $i = b$, $k = g$, i.e., only to those banks that could have retained their uninsured depositors if the latter had been risk-neutral and closes banks that realize $i = b$, $k = b$. Each bank, therefore, has an initial probability, $(1 - q)j$, of facing deposit withdrawals at $t = 1$ and receiving funds from the discount window. Hence, with probability $q + (1 - q)j$, first-period uninsured depositors will be able to withdraw their funds at $t = 1$ and with probability $(1 - q)(1 - j)$ the bank will be liquidated at $t = 1$. Consequently, the first-period deposit rate, r_1, demanded by the risk-averse uninsured depositors must satisfy

$$[q + (1 - q)j]r_1 + \frac{(1 - q)(1 - j)(1 - \alpha)}{[\alpha r_f + (1 - \alpha)r_1]} \frac{p_2 R}{r_f} \geq r_f \tag{8}$$

where the second term on the lefthand side denotes the uninsured depositors' expected share of the proceeds from liquidating the bank's assets at $t = 1$.

It is assumed that risk-neutral buyers dominate the market for the assets of banks that are closed at $t = 1$. This assumption is consistent with our earlier one of risk-neutral behavior for the bank. However, if potential buyers for the loans of these failed banks are risk-averse, the competitive price for the loans will be less than p_2R/r_f and consequently the uninsured depositors' payoff from the bank's liquidation would also be lower. Given a sufficient degree of buyer risk aversion relative to that of depositors, the uninsured depositors' payoff at $t = 1$ could be so low that allowing the bank to "reschedule" and operate until $t = 2$ with an expected depositor payoff given by (6) provides them with at least the market return. In these circumstances, the uninsured depositors would agree to maintain the bank for the final period. Likewise, if the bank in the other (less) impaired state, $i = b$, $k = g$, were not provided with discount window credit, depositors could prefer to "reschedule" the bank's debt rather than forcing its liquidation. However, given the regulator's policy of providing emergency credit to banks if they can possibly pay at $t = 2$ the competitive risk-neutral deposit rate, uninsured depositors would certainly choose to withdraw their funds at $t = 1$ if $i = b$, $k = g$. Under these circumstances, the less impaired banks would face deposit withdrawals financed by the discount window while the more impaired banks would be denied any new credit and would "reschedule" their debt with the approval of their creditors. No bank would be terminated at $t = 1$. We will, however, retain our risk-neutrality assumption for potential buyers of assets of troubled banks, thereby leading to the liquidation of banks at $t = 1$ in state $i = b$, $k = b$.

C. Bank Profits and Policy Constraints

With probability qp_0, the bank will be in a "good" condition at $t = 1$ and subsequently realize revenue R and pay αr_f^2 and $(1 - \alpha)r_1 r_{20}$ to the insured and uninsured depositors, respectively, at $t = 2$. With probability $(1 - q)j$, the bank will be in a "somewhat" impaired state at $t = 1$ and borrow from the discount window at the interest rate, s, to finance uninsured depositor withdrawals; subsequently, with probability p_1, the bank will realize revenue, R, and pay αr_f^2 and $(1 - \alpha)r_1 s$ to the insured depositors and regulator, respectively. Let $Z \in [0, 1]$ be the probability that the bank will be granted a charter if it reports j to the regulator, and let I be the initial deposit insurance fee with the bank's cost of obtaining these funds being c. Just prior to applying for the charter, the bank's profit expectation, discounted at the risk-free rate, is

$$\Pi(j) = \{-I(1 + c) + qp_0[R - \alpha r_f^2 - (1 - \alpha)r_1 r_{20}] + (1 - q)jp_1[R - \alpha r_f^2 - (1 - \alpha)r_1 s]\}r_f^{-2}. \quad (9)$$

Rather than assuming the bank pays $I(j)$ out of deposits, we have assumed that the bank issues sufficient equity shares, at a cost c, to cover the deposit insurance fee. The transactions cost, c, is included to capture the difference between the regulator and the bank in their rate of substitution of the initial fee and the borrowing rate. If the fee had been paid out of deposits, then this difference would have the bank's cost of deposits as its origin; our basic qualitative results are expected to be the same in either case. The advantage of not paying the fee out of deposits is that the regulator's pricing policy will then not affect the bank's probability of being in any specific future state. While the present discussion of risk-sensitive insurance pricing has indicated some concern that such pricing will further damage already impaired banks, incorporation of this aspect of the regulator's policy would only complicate our model to no apparent end.

The regulator's policy, denoted by $\{Z(j), I(j), s(j)\}$, must induce the bank to be truthful. That is, $\{Z(j), I(j), s(j)\}$ must satisfy the incentive compatibility constraint

$$\Pi(j) \equiv \Pi(j, j) \geq \Pi(\hat{j}, j) \quad \text{for all} \quad j, \hat{j} \quad \text{in} \quad [j_0, j_1] \quad (10)$$

where the first argument in Π denotes the bank's reported quality and the second is its true quality. This constraint ensures that the bank cannot gain by misrepresenting its true value of j by reporting $\hat{j}$. Furthermore, the deposit insurance fee, I, is set equal to the present value of the regulator's expected net cash outflows, or

$$I(j) + [(1 - \alpha)(1 - q)jp_1 r_1(j)/r_f^2][s(j) - (r_f/p_1)] - \alpha[(1 - q)(1 - j)(1 - p_2 R/(\alpha r_f + (1 - \alpha)r_1))] - \alpha[q(1 - p_0) + (1 - q)j(1 - p_1)] = 0. \quad (11)$$

The second term in (11) is the expected cash flows associated with borrowings at the discount window; the third term is the expected repayment of insured depositors minus the regulator's share of the proceeds if the bank's assets are liquidated at $t = 1$. The last term is the regulator's expected losses on insured deposits if the bank continues until $t = 2$. To avoid cross-subsidization of banks, (11) requires that the regulator expect to break even on each bank.

Before any report from the bank, the regulator must establish its policy using prior expectations of the bank's asset quality. Let these expectations be described by the cumulative distribution function, $F(j)$, and density, $f(j)$, which is continuous and strictly positive for all j in $[j_0, j_1]$. The optimal policy maximizes the regulator's expectation of the bank's profits, i.e.,

$$\operatorname*{Max}_{\{Z,I,s\}} \int_{j_0}^{j_1} \Pi(j)\, dF(j) \tag{12}$$

and satisfies (10), (11), and

$$0 \leq Z(j) \leq 1$$

$$s \leq \bar{s}$$

where $\bar{s}$ is the maximum discount rate that the bank is able to pay if its own loans are repaid.[6]

II. The Optimal Policy

Before determining the regulator's optimal policy, it will be useful to replace the global incentive-compatibility condition, (10), by a local representation. It is shown in the Appendix that (10) is equivalent to

$$\Pi'(j) = Z(j)(1 - q)p_1 r_f^{-2}[R - \alpha r_f^2 - (1 - \alpha)r_1 s(j)]. \tag{13}$$

The term in brackets is the bank's *ex post* profits if $\theta = 1$ and after it has realized $i = b$, $k = g$, i.e., after having borrowed at the discount window. Since this term must be non-negative (otherwise, the regulator would be certain of never being repaid), the incentive-compatibility conditions requires that expected profit be nonconcave in j, i.e., $\Pi'(j) \geq 0$ and from the Appendix, $\Pi''(j) \geq 0$.

The regulator's optimal policy is the solution to (12) with the incentive-compatibility constraint, (10), replaced by (13) and $\Pi''(j) \geq 0$.

Substituting the regulator's zero profit condition (11) into the bank's profit function (9) results in an expression for the discount rate that we will use later,

$$s(j) = \frac{1}{(1 - \alpha)(1 - q)jp_1 r_1 c}$$

$$\left\{\frac{r_f^2 \Pi}{Z} - R[qp_0 + (1 - q)jp_1 + (1 - q)(1 - j)(1 + c)p_2 \alpha r_f^2/(\alpha r_f + (1 - \alpha)r_1)]\right.$$

$$\left. + \alpha r_f^2[1 + c - c(qp_0 + (1 - q)jp_1)] + (1 - \alpha)r_1[qp_0 r_{20} + (1 + c)(1 - q)jr_f]\right\}. \tag{14}$$

[6] If the constraint provided by $\bar{s}$ is binding, the regulator may be unable to construct an incentive-compatible policy; in that case, alternative sorting instruments will be needed.

Using (14) and the incentive-compatibility constraint, (13), gives

$$\Pi' = \frac{-\Pi}{jc} + \frac{Z}{jc}\left\{\frac{R}{r_f^2}\,[qp_0 + (1-q)jp_1(1+c) + (1-q)(1-j)(1+c)p_2\alpha r_f^2/(\alpha r_f + (1-\alpha)r_1)] - \alpha[1 + c(1-qp_0)] - \frac{(1-\alpha)r_1}{r_f^2}\,[qp_0r_{20} + (1+c)(1-q)jr_f]\right\}. \tag{15}$$

Denoting the expression in braces by $A(j) \gtreqless 0$, we can express (15) as

$$\Pi'(j) = \frac{-\Pi(j)}{jc} + \frac{Z(j)A(j)}{jc}. \tag{16}$$

Thus, the optimization problem in (12) becomes,

$$\text{Max} \int_{j_0}^{j_1} \Pi(j)\, dF(j) \text{ subject to (16), } Z \in [0, 1], \text{ and } \Pi(j_0) = 0,$$

where the expected profits of the lowest quality bank (for given q) applying for a charter has been arbitrarily taken as zero. The Hamiltonian is given by

$$H = f\Pi + \lambda\mu \tag{17}$$

where Π and λ are the state and costate variables, respectively, Z is the control, and the equation of motion of the state variable is

$$\mu = \frac{-\Pi}{jc} + \frac{ZA}{jc}. \tag{18}$$

The first-order necessary conditions are given by

$$\frac{\partial H}{\partial \Pi} = -\lambda' = f - \frac{\lambda}{jc} \tag{19}$$

with the transversality condition $\lambda(m_1) = 0$,

$$Z = \text{argmax}\{H\} \tag{20}$$

and the state of motion equation

$$\Pi' = \frac{-\Pi}{jc} + \frac{ZA}{jc} \tag{21}$$

and are obviously also sufficient for a maximum (Kamien and Schwartz [5, p. 120]).

The solution to (19) is

$$\lambda^*(j) = c^{1/j} \int_j^{j_1} f(x)c^{-1/x}\, dx \geq 0.$$

Now, since H is linear in Z, and $\lambda^* \geq 0$, the optimal probability function for allowing the bank to operate, $Z^*(j)$, is determined by the sign of $A(j)$. That is,

$$Z^*(j) = \begin{cases} 1 \\ 0 \end{cases} \text{if } A(j) \gtreqless 0 \tag{22}$$

meaning that a bank having the unobservable parameter, j, knows that the regulator will definitely grant (refuse) the charter if $A(j)$ is non-negative (negative).

Differentiating $A(j)$, we find that $A'(j) \geq 0$, meaning that banks with higher values of j are more likely to be considered acceptable, i.e., (22) can be written as

$$Z^*(j) = \begin{cases} 1 \\ 0 \end{cases} \text{if } j \gtreqless \bar{j}$$

where $\bar{j}$ is defined by $A(\bar{j}) = 0$.

The equation of motion for Π, (21), can be solved for $j \geq \bar{j}$, yielding

$$\Pi^*(j) = \begin{cases} \dfrac{1}{c} \displaystyle\int_{j_0}^{j} \frac{A(x)}{x} \left(\frac{x}{j}\right)^{1/c} dx & j \geq \bar{j} \\ & \text{if} \\ 0 & j < \bar{j} \end{cases}$$

Given $\Pi^*(j)$ and $Z^*(j)$, the optimal discount rate, $s^*(j)$, can be obtained from (14); then $I^*(j)$ can be determined from the regulator's zero profit condition (11). The optimal discount rate, $s^*(j)$, must be below r_{21} [given in (4)], but it may, however, be above or below r_f/p_1, the competitive rate with risk-neutral depositors. Depending on $s^*(j)$, the optimal fee, $I^*(j)$, may be above, equal, or below the "pure" insurance component given by

$$\alpha[(1 - q)(1 - j)(1 - p_2 R/(\alpha r_f + (1 - \alpha) r_1)) + q(1 - p_0) + (1 - q)j(1 - p_1)]. \quad (23)$$

Any deviation of $s^*(j)$ from the competitive, risk-neutral deposit rate (r_f/p_1) is offset by the initial fee. Of special interest is the dependence of s^* and I^* on the banks' private information. After some manipulation, we find that $s^{*\prime}(j) \leq 0$ and $I^{*\prime}(j) \geq 0$; banks having larger values of j will be offered lower future borrowing rates and higher initial fees. This pricing policy is obviously incentive-compatible since banks with greater values of j recognize their higher probability of being able to borrow emergency funds at the discount window and are willing to pay a greater initial fee to obtain a lower discount loan rate.

A. Symmetric Information

Since discount window access is available only to banks that experience fallen asset values, but who would not need the emergency credit if their depositors had been risk-neutral, the *symmetric* information policy calls for a uniform discount rate of r_f/p_1 and the initial fee at the "pure" insurance level, Equation (23). Banks that suffer withdrawals and are so impaired that they cannot pay even the risk-neutral rate are terminated.

III. Conclusions

The pricing policy of a bank regulator that provides both deposit insurance and a "lender of last resort" function to banks is formalized. Our analysis is the first to consider the joint pricing of deposit insurance and discount window advances in a setting with private information.

Although interest rate risk is not explicit, the bank's possible deterioration could be taken to reflect unexpected interest rate changes; the bank's private information would be the elasticity of its assets' value to interest rates.

The paper makes three basic points. Deposit insurance pricing policies that ignore informational asymmetries between regulators and bankers are unlikely to be incentive-compatible and, therefore, may prove no more useful in limiting bank risk-taking than risk-insensitive premia. Second, whereas alternative incentive compatible risk-sensitive deposit insurance pricing policies are possible, the incorporation of the discount window is necessary if the government's exposure to bank risk-taking is to be priced. Any policy that prices the banks' deposit insurance but maintains the current discount window arrangements will prompt banks to substitute "uninsured" deposits for insured ones and thereby escape the discipline of both the market and the insurance pricing policy. Our final point relates to management of the discount window. The intent of the discount window, or "lender of last resort," is to provide credit to illiquid but not insolvent banks. However, given the ambiguities of the distinction between illiquidity and insolvency, the appropriateness of lending funds to a given bank may be questionable. An alternative distinction is developed in our paper; the role of the government is to provide funds only to banks that require a "lender of last resort" because of depositor risk aversion. Banks that could not borrow from even risk-neutral depositors are refused credit and terminated. Thus, the discount window is managed as a risk-neutral lender to banks, and by implication for a temporary period of time, until private lending by less risk-averse depositors can be arranged.

The integration of deposit insurance pricing with discount window policy is seen as central to any regulatory reform aimed at risk abatement. Moreover, borrower eligibility for discount window credit must be addressed in any such policy examination unless ambiguity is seen as a virtue. In addition, any analysis of public policy remains incomplete without consideration of informational disparities between regulators and those regulated.

Appendix

Incentive-Compatibility

To show that (10) implies (13) and $\Pi''(j) \geq 0$.

Using (9), we can express (10) as

$$\begin{aligned}\Pi(j) &\equiv \Pi(j, j) \geq \Pi(\hat{j}, j)\\ &= Z(\hat{j})\{-I(\hat{j})(1 + c) + [(R - \alpha\, r_f^2)/r_f^2][qp_0 + (1 - q)jp_1]\\ &\quad -[(1 - \alpha)r_1(\hat{j})/r_f^2][qp_0r_{20} + (1 - q)jp_1s(\hat{j})]\}\\ &= \Pi(\hat{j}) + Z(\hat{j})(\hat{j} - j)(1 - q)p_1r_f^{-2}\{(R - \alpha\, r_f^2) - (1 - \alpha)r_1(\hat{j})s(\hat{j})\} \qquad \text{(A1)}\end{aligned}$$

where $\hat{j}$ is the bank's reported value, and j is its true value. Reversing the roles of $\hat{j}$ and j, we find

$$\Pi(\hat{j}) \equiv \Pi(\hat{j}, \hat{j}) \geq \Pi(j, \hat{j})$$
$$= \Pi(j) + Z(j)(\hat{j} - j)(1-q)p_1 r_f^{-2}\{(R - \alpha r_f^2) - (1-\alpha)r_1(j)s(j)\}. \quad \text{(A2)}$$

Thus, we have,

$$\frac{Z(\hat{j})(j - \hat{j})(1 - q)p_1}{r_f^2}\{(R - \alpha r_f^2) - (1 - \alpha)r_1(\hat{j})s(\hat{j})\} \leq \Pi(j) - \Pi(\hat{j})$$
$$\leq \frac{Z(j)(j - \hat{j})(1 - q)p_1}{r_f^2}\{(R - \alpha r_f^2) - (1 - \alpha)r_1(j)s(j)\}. \quad \text{(A3)}$$

For $j \geq \hat{j}$, we see that

$$Z(\hat{j})(1 - q)p_1 r_f^{-2}[(R - \alpha r_f^2) - (1 - \alpha)r_1(\hat{j})]$$
$$\leq Z(j)(1 - q)p_1 r_f^{-2}[(R - \alpha r_f^2) - (1 - \alpha)r_1(j)s(j)]$$

and therefore

$$\frac{Z(j)(1 - q)p_1}{r_f^2}\{R - \alpha r_f^2 - (1 - \alpha)r_1(j)s(j)\}$$

is nondecreasing in j, ensuring continuity and differentiability (almost everywhere) in $[j_0, j_1]$. Dividing (A3) by $(j - \hat{j})$ and taking the limit as $\hat{j} \to j$ we have

$$\Pi'(j) = \frac{Z(j)(1 - q)p_1}{r_f^2}[R - \alpha r_f^2 - (1 - \alpha)r_1(j)s(j)] \quad \text{(A4)}$$

and since $\Pi'(j)$ is nondecreasing in j, we also have $\Pi''(j) \geq 0$.

To show that (13) and $\Pi''(j) \geq 0$ imply (10):

$$\Pi(j) - \Pi(\hat{j}, j)$$
$$= \Pi(j) - Z(\hat{j})(1 - q)p_1 r_f^{-2}\{(R - \alpha r_f^2) - (1 - \alpha)r_1(\hat{j})s(\hat{j})\}$$
$$= \Pi(j) - \Pi(\hat{j}) - (j - \hat{j})Z(\hat{j})(1 - q)p_1 r_f^{-2}\{(R - \alpha r_f^2) - (1 - \alpha)r_1(\hat{j})s(\hat{j})\}$$
$$= \int_{\hat{j}}^{j} \Pi'(X)\, dX - (j - \hat{j})\Pi'(\hat{j}).$$

Since $\Pi''(j) \geq 0$, we have

$$\int_{\hat{j}}^{j} \Pi'(X)\, dX \geq (j - \hat{j})\Pi'(\hat{j})$$

and therefore $\Pi(j) - \Pi(\hat{j}, j) \geq 0$.

REFERENCES

1. G. Bierwag and G. Kaufman. "A Proposal for Federal Deposit Insurance with Risk Sensitive Premiums." Staff Memorandum No. 833, Federal Reserve Bank of Chicago, 1983.

2. M. Goodfriend. "Discount Window Borrowing, Monetary Policy, and the Post-October 6, 1979 Federal Reserve Operating Procedure." *Journal of Monetary Economics* 12 (September 1983), 343–56.
3. S. Greenbaum and J. Ricart i Costa. "Pricing Deposit Insurance." Banking Research Center Working Paper, Northwestern University, 1983.
4. M. Harris and P. Townsend. "Resource Allocation Under Asymmetric Information." *Econometrica* 49 (January 1981), 33–64.
5. M. Kamien and N. Schwartz. *Dynamic Optimization.* NY: North-Holland, 1981.
6. E. Kane. "A Six-Point Program for Deposit-Insurance Reform." *Housing Finance Review* 2 (July 1983), 269–278.
7. J. Kareken and N. Wallace. "Deposit Insurance Bank Regulation: A Partial Equilibrium Exposition." *Journal of Business* 51 (July 1978), 413–38.
8. R. Merton. "An Analytic Derivation of the Cost of Deposit Insurance and Loan Guarantees: An Application of Modern Option Pricing Theory." *Journal of Banking and Finance* 1 (June 1977), 3–11.
9. R. Myerson. "Incentive Compatibility and the Bargaining Problem." *Econometrica* 47 (January 1979), 61–74.