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**Banking Policy and the Pricing of
Deposit Guarantees: A New Approach**

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Abstract

This paper describes a new approach to pricing government deposit guarantees that uses techniques of stochastic process switching employed in the recent literature on exchange rate determination. Our model avoids inconsistent assumptions about the information available to investors and the government common in previous work based on an option pricing approach. We derive actuarially fair deposit insurance premia and optimal financial reorganization rules and examine the role of banking policies such as capital requirements.

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Summary

This paper develops a new framework for studying banking policies and the pricing of deposit guarantees by employing the techniques of stochastic process switching. A unified analysis of financial reorganization rules preferred by the bank shareholders and the government is perhaps the main innovation of the paper.

The model avoids inconsistent assumptions, found in previous work on the pricing of deposit guarantees based on option pricing models, about the information available to investors and regulatory authorities. It also avoids the arbitrary assumptions, common to option models about the frequency of audits and the minimum net worth levels at which banks are closed.

Using this framework, the paper shows the value of deposit guarantees to be the difference between the stock market value of the bank under unlimited liability and the value of the bank's equity with the guarantee in force. It also derives "fair" deposit insurance premia.

The analysis demonstrates that limited liability on the part of shareholders places a lower bound on the earnings level at which the bank's financial reorganization can occur. For various types of reorganization costs, socially optimal reorganization policies are derived. Both the bank and government may seek to manipulate the reorganization rule under certain conditions.

Potential manipulation of the bank's earnings prospects also creates moral hazard problems. An efficient approach to banking regulation that would combat these problems is the use of capital requirements.

I. Introduction

The approach to banking policy and the valuation of deposit guarantees that has generally been followed since the important contributions of Merton (1977, 1978) is to interpret such guarantees as put options written by the government on the value of banks' assets. Assuming that regulatory authorities audit banks according to a given strategy (e.g., either at periodic or randomly determined intervals) and reorganize banks if an audit reveals that their net assets have negative value, the government's deposit insurance liability can be interpreted as a standard option pricing problem, solutions to which are well known. Comparative static analyses of such valuations models then provide some insight into the role of various banking policies in limiting the value of deposit guarantees, such as the frequency of audits, financial reorganization policies, capital requirements, and limits on risk taking.

The above approach has several drawbacks, however. First, the pricing expressions for deposit guarantees derived in this way depend crucially on arbitrary assumptions about the auditing strategy. The government's liability stems, in effect, from the possibility that the bank's net assets will be negative at the date of the next audit. 1/ While it is true that an audit can provide comprehensive information about a bank's financial condition, regulatory authorities also undertake less direct monitoring of individual banks. For example, any unusual behavior in the market price of a bank's shares or subordinate debt can signal potential problems to the authorities. Thus, it is implausible to argue that audits are independent of news about a bank's earnings or the value of underlying assets.

The second problem is the implicit informational asymmetry between investors and bank regulators implied by the assumption that bank closures occur only after audits. 2/ While investors are assumed to have reliable information about banks' asset values which is embodied in share prices, the regulatory authorities' only source of information about the financial condition of banks is their audits. The question of why the authorities do not infer from share prices the value of underlying assets is not generally addressed.

Third, the comparative static properties of the option pricing models only identify what actions can be take by a government to alter the value of the deposit guarantees. These analyses do not necessarily identify efficient banking policies.

The current paper departs from the above literature in that pricing formulae for deposit guarantees are obtained under the assumption of fully

1/ Clearly, if audits were costless and hence could be carried out on a continuous basis, the government's liability would be zero in such models.

2/ The terms closure and financial reorganization are used interchangeably.

symmetric information among bank insiders, stock-market investors, and the regulatory authorities. Moreover, rather than being based on options pricing theory, we use the techniques of stochastic process switching employed in the recent literature on exchange rate determination. ^{1/} In this framework, we identify the socially optimal financial reorganization rule for a bank and assess the cost-effectiveness of certain banking regulations such as capital requirements.

In some respects, our analysis is similar to the perpetual option models of Merton (1978), Pyle (1983, 1984, 1986), and Pennacchi (1987). In these models, the government charges a given bank either a one-time premium or periodically adjusted premia to guarantee all its deposits in perpetuity provided that its net worth is above an arbitrarily specified minimum level (e.g., zero). The presence of audits, though, makes these models fundamentally different from ours. Audits essentially make the deposit guarantee a European put option and rule out the possibility of early exercise by shareholders. As a result, the time path of the bank's net worth between audits does not matter. However, the shareholders' decision on when to petition for the bank's reorganization will depend upon the whole time path of the bank's net worth. Thus, the option pricing approach does not permit a unified analysis of the shareholders' and the authorities' preferred financial reorganization policies or optimal stopping times. An analysis of the latter kind is perhaps the main innovation of this paper.

Other problems with the perpetual option models are the arbitrary assumptions about the frequency of audits and the minimum net worth level at which banks are closed. Moreover, these models depend on the ability of investors to construct a hedging portfolio that would require continuous trading in the bank's assets, which are generally illiquid. The construction of such a portfolio is necessary to derive an option valuation formula that is independent of investors' utility functions.

II. The Model

Suppose that a given bank holds a portfolio that is long in risky loans yielding a flow of income, k_t , and short in deposits. Total deposits equal D_t and total bank earnings are

$$e_t = k_t - (r + \gamma)D_t, \quad (1)$$

where r is the constant, risk-free interest rate and γ is the deposit insurance premium paid by the bank to the government. We assume that k_t and D_t are Brownian motions of the form

$$dk_t = \mu_k dt + \sigma_k d\omega_{1t} \quad (2)$$

^{1/} See Froot and Obstfeld (1991a, 1991b), and Smith (1991).

$$dD_t = \mu_D dt + \sigma_D d\omega_{2t}, \quad (3)$$

where $d\omega_{1t}d\omega_{2t} = \rho dt$. It follows that

$$\begin{aligned} de_t &= [\mu_k - (r + \gamma)\mu_D]dt + [\sigma_k^2 + (r + \gamma)^2\sigma_D^2 - 2(r + \gamma)\rho\sigma_k\sigma_D]^{1/2}d\omega_t \\ &= \mu dt + \sigma d\omega_t, \end{aligned} \quad (4)$$

where $d\omega_t$ is a standard Brownian motion and μ and σ are constants.

For expositional simplicity, suppose that total cash distributions (including dividends and share repurchases) less receipts from new share issues, equal the earnings stream, e_t . The drawback to this approach is the implausible assumption that net distributions have continuous sample paths almost surely as we implicitly do by modeling them as Brownian motions. Empirical implementation of the model requires that we relax this assumption by explicitly modeling the retention of earnings. 1/

To derive valuation formulae for the deposit guarantee and equity of the bank, consider the equilibrium condition that, under risk neutrality, links the stochastic process for the bank's stock market value to the process for its net distributions. Since, in our case, net payouts equal earnings, this yields

$$rV_t = e_t + d/d\Delta E_t V_{t+\Delta} \big|_{\Delta=0}, \quad (5)$$

where V_t is the bank's stock market value. Section VI discusses how this equation and our subsequent analysis can be generalized to allow for risk aversion.

If $V_t = V(e_t)$, where $V(\cdot)$ is a twice-continuously differentiable function, one may apply Itô's lemma inside the expectations operator in (5) to obtain

$$rV(e_t) = e_t + \mu V'(e_t) + (\sigma^2/2)V''(e_t). \quad (6)$$

This second-order ODE characterizes the relationship between the bank's stock market value and the current level of its net earnings. The equation has

$$V(e_t) = A_0 + A_1 e_t + A_2 \exp(\lambda_1 e_t) + A_3 \exp(\lambda_2 e_t) \quad (7)$$

as its general solution.

Taking the derivatives of (7) and substituting in (6), we obtain an equation with a constant and terms involving e_t , $\exp(\lambda_1 e_t)$, and $\exp(\lambda_2 e_t)$.

1/ Such modeling is undertaken in Fries and Perraudin (1991).

Equating coefficients on like terms leads to the following system of equations:

$$A_0 = \mu/r^2 \quad (8)$$

$$A_1 = 1/r \quad (9)$$

$$-rA_2 = \mu\lambda_1 A_2 + (\sigma^2/2)\lambda_1^2 A_2 \quad (10)$$

$$-rA_3 = \mu\lambda_2 A_3 + (\sigma^2/2)\lambda_2^2 A_3, \quad (11)$$

which determines A_0 , A_1 , λ_1 , and λ_2 . To tie down the remaining two parameters, A_2 and A_3 , we shall assume, first, that the bank undergoes a financial reorganization when its earnings fall to a given level and, second, that the bank's stock market value is free of bubbles.

Suppose that the regulatory authorities undertake the bank's financial reorganization when its level of earnings falls to some level, \underline{e} . Note that a financial reorganization rule based on the discounted value of the bank's earnings flow could be rewritten as a rule based on the earnings level, e_t , as this value equals $e_t/r + \mu/r^2$. Since in a financial reorganization the bank's shareholders relinquish their claim to the bank's earnings, it must be the case that $V(\underline{e}) = 0$ given their limited liability. Otherwise, the stock market value of the bank would jump at the moment of financial reorganization, creating the possibility of arbitrage profits for speculators.

The above "value matching" condition is similar to the boundary conditions obtained in the exchange rate determination literature when a government announces that its freely-floating exchange rate will be fixed after it hits a given level for the first time. ^{1/} The only difference is that in the exchange rate models both the driving process and the exchange rate are "absorbed" when they hit the relevant barriers, but in our case the value of the bank is absorbed, while the earnings process, when it reaches \underline{e} for the first time, jumps from \underline{e} to zero, where it remains thereafter. ^{2/}

To rule out bubbles, we assume that there is an upper absorbing barrier for the earnings process at an arbitrary earnings level, \bar{e} . The discounted value of the earnings absorbed at \bar{e} is \bar{e}/r . Thus, to avoid arbitrage possibilities, it must be the case that $V(\bar{e}) = \bar{e}/r$. We then evaluate A_2 and A_3 by taking their limits as $\bar{e} \rightarrow \infty$.

^{1/} See Froot and Obstfeld (1991a) and Smith (1991).

^{2/} Note that this description of absorption is from the point of view of the shareholders who lose any claim to the earnings stream after it hits \underline{e} for the first time.

The two boundary conditions yield a system of two equations with two unknown variables. Solving for A_2 and A_3 , we obtain

$$A_2 = [\exp(\lambda_2 \bar{e})(A_0 + A_1 \underline{e}) + \exp(\lambda_1 \bar{e})A_0] / [\exp(\lambda_1 \underline{e} + \lambda_2 \bar{e}) - \exp(\lambda_1 \bar{e} + \lambda_2 \underline{e})] \quad (12)$$

$$A_3 = [\exp(\lambda_1 \bar{e})(A_0 + A_1 \underline{e}) - \exp(\lambda_1 \bar{e})A_0] / [\exp(\lambda_1 \underline{e} + \lambda_2 \bar{e}) - \exp(\lambda_1 \bar{e} + \lambda_2 \underline{e})]. \quad (13)$$

Assume without loss of generality that $\lambda_2 < 0 < \lambda_1$. 1/ Letting $\bar{e} \rightarrow \infty$, we obtain

$$A_2 = 0 \quad (14)$$

$$A_3 = -(A_0 + A_1 \underline{e}) \exp(-\lambda_2 \underline{e}). \quad (15)$$

The parameter A_2 approaches zero as \bar{e} approaches infinity because we require the bank to have a finite value at the upper boundary condition. Thus, the bank's stock market value is given by

$$V(e_t) = A_0 + A_1 e_t - (A_0 + A_1 \underline{e}) \exp[\lambda(e_t - \underline{e})], \quad (16)$$

where

$$\lambda = \sigma^{-2} [-\mu - (\mu^2 + 2r\sigma^2)^{1/2}] \quad (17)$$

is the negative root of (10).

The first part of the above expression, $V_1(e_t) = A_0 + A_1 e_t$, represents the discounted value of the earnings stream in the absence of any financial reorganization rule. An evaluation of the integral

$$V_1(e_t) = E_t \left\{ \int_t^{\infty} \exp[-(s-t)r] e_s ds \right\} \quad (18)$$

confirms the point. $V_1(e_t)$ is essentially the stochastic version of the valuation formula for an annuity with payments that grow arithmetically.

To interpret the second, non-linear part of $V(e_t)$, $V_2(e_t) = (A_0 + A_1 \underline{e}) \exp[\lambda(e_t - \underline{e})]$, note that the moment, T , at which the earnings process hits \underline{e} for the first time has the conditional density

1/ Equations (10) and (11) have one positive and one negative root.

$$f(T|e_t, \underline{e}, t) = (e_t - \underline{e})[2\pi\sigma^2(T - t)^3]^{-\frac{1}{2}} \exp\{[e_t - \underline{e} + \mu(T - t)]^2/2\sigma^2(T - t)\}. \quad (19)$$

The Laplace transform of $f(T)$ is defined as

$$\mathcal{L}(q) = \int_t^{\infty} \exp[-q(T - t)]f(T)dT, \quad (20)$$

for $q \in \mathbb{R}$. If $q = r$, then from (20), $\mathcal{L}(r)$ is an average discount factor weighted by the probability that T is the first passage time. In this case, Karlin and Taylor (1975, p. 362) show that

$$\mathcal{L}(r) = \exp[\lambda(e_t - \underline{e})]. \quad (21)$$

Therefore, $V_2(e_t)$ is negative the expected discounted value of a claim to the bank's earnings stream when it first reaches \underline{e} given that earnings currently equal e_t . In other words, $-V_2(e_t)$ is the value of the government's deposit guarantee.

Another way to see that the nonlinear part of $V(e_t)$ equals negative the expected discounted value of the government guarantee consists of noting that the value of the shareholders' claim to the bank's earnings stream in the absence of a government guarantee and corresponding premium but with unlimited shareholder liability is the integral on the right-hand-side of (13). Evaluating this integral, we obtain the linear part of $V(e_t)$, i.e. $V_1(e_t)$, which is independent of \underline{e} . The gain to shareholders and the loss to the government in going from the unlimited liability case to limited liability with a government guarantee of deposits is thus $V_2(e_t)$, assuming that γ equals zero.

Of course, bank shareholders do not have unlimited liability, but the above "thought experiment" is the relevant one to infer the value of the government guarantee, because under any form of limited liability without a guarantee, depositors would bear some risk associated with the possibility of default by the bank. Deposit interest rates, in this case, would involve a risk premium, altering the stochastic process for earnings from what it would be in a situation without risk for depositors. Only by comparing the case in which shareholders' liability is unlimited with the case in which the government guarantees deposits can we plausibly assume that the stochastic process for the earnings stream is the same in both cases. 1/

Chart 1 illustrates the above results by showing the value of the bank as a function of earnings under unlimited liability and with a closure rule at $\underline{e} = -0.5$. The solution with this reorganization policy lies above the

1/ We assume that the bank's shareholders would have sufficient net worth to satisfy any claim against them under unlimited liability.

unlimited liability solution for all feasible earnings levels, reflecting the positive value of the guarantee to shareholders. Note that for earnings levels just above the shutdown point, earnings are negative and, hence, equity-holders are injecting funds into the bank. The reason that they are willing to do this despite the positive yield available on the safe asset is that the curvature of the nonlinear part of the equity claim increases the likelihood that the price will appreciate in value more and more as earnings fall toward \underline{e} .

III. "Fair" Deposit Insurance Premia

In the above discussion, we assumed that the government charges the bank's shareholders at a rate of γ per dollar of deposits, but there was no presumption that this rate reflected an actuarially fair premium. Suppose that at some given moment in time, t_0 , earnings are e_{t_0} . The actuarially fair premium rate, γ^* , can then be obtained by solving the implicit equation:

$$\begin{aligned} V(e_{t_0}, \gamma^*) + C(\underline{e}) \exp[\lambda(e - \underline{e}_{t_0})] &= V_1(e_{t_0}, 0) \\ &= (u_k - r\mu_D)/r^2 + (e_{t_0} + \mu^* D_{t_0})/r, \end{aligned} \quad (22)$$

where $V(\dots)$ and $V_1(\dots)$ are written so as to stress their dependence on both e_{t_0} and γ^* . $C(\underline{e})$ represents administrative and legal costs incurred by the regulatory authorities in reorganizing the bank. Equation (22) says that, abstracting from reorganization costs, the fair premium rate is that rate which equates the value of the bank at t_0 to the value it would have under unlimited shareholder liability and a zero premium rate. In other words, shareholders do not gain from the introduction of deposit guarantees compared with a situation of unlimited liability in which shareholders would in effect guarantee the deposits. Canceling terms in (22), we obtain

$$\begin{aligned} \gamma^* \mu_D / r^2 + \gamma^* D_{t_0} / r + \{[\mu_k - (r + \gamma^*) \mu_D] / r^2 + \underline{e} / r - C(\underline{e})\} \exp[\lambda(e_{t_0} - \underline{e})] \\ = 0. \end{aligned} \quad (23)$$

Equation (23) is the gain to the government from providing the deposit guarantee at a premium of γ^* per dollar of deposits. The first part of the above expression is the discounted value of the perpetual stream of deposit insurance premiums. The second, nonlinear part of equation (23) is the discounted value of a claim to the bank's earnings stream at time T (including an allowance for future deposit insurance premia) multiplied by a weighted average discount factor. The second part also includes the expected discounted value of reorganization costs.

Since depositors are indifferent to a switch from a situation with unlimited liability to one with a government guarantee, and since

shareholders gain nothing from such a switch if there are no reorganization costs, it must be the case that the government loses nothing if $\gamma = \gamma^*$. This is in fact the condition given in equation (23). Note also that equation (23) is a complicated nonlinear function of γ^* , since λ is a function of γ .

An alternative way of charging shareholders for the deposit guarantee is to set γ equal to zero but to demand a lump-sum payment at the inception of the insurance scheme. If this payment is $V_2(e_{t_0}, 0)$ plus the expected discounted value of reorganization costs, the payment is an actuarially fair recompense for the guarantee.

Several points emerge from this analysis. First, as others have noted, there are numerous ways in which the government can charge banks for their deposit guarantees on an actuarially fair basis. Combinations of lump-sum and per dollar of deposit fees are the most obvious.

A second and perhaps less obvious point is that it may be quite difficult to evaluate empirically whether a particular charging scheme is actuarially fair since it is possible to view the "contract" between the bank and government as having commenced at different points in time. Whether or not a premium is "fair" depends on the level of earnings at the moment one chooses to regard as the inception of the scheme.

In other words, a deposit guarantee scheme that appears to be currently "unfair" may, in fact, be no more unfair than an insurance contract between an insurance company and client when new information concerning the risks involved has reached the parties after the signing of the contract.

IV. Financial Reorganization Policies

Up to this point, the financial reorganization policy, \underline{e} , has been exogenously given. We now consider the choice of a financial reorganization rule, assuming that when a bank is closed the government liquidates enough deposits so that it can be sold to the private sector as a going concern. Suppose also that the reorganization of the bank costs the regulatory authorities a sum, $C(\underline{e})$. $C(\underline{e})$ may be thought of as deadweight costs, such as administrative and legal expenses, the incurrence of which do not improve the bank's earnings prospects. Given this assumption, the financial reorganization rule preferred by a social planner is that \underline{e} which minimizes the expected discounted value of $C(\underline{e})$. If, for example, any financial reorganization rule were feasible and, if $C(\underline{e}) > 0 \forall \underline{e}$, $\underline{e} = -\infty$ would minimize the expected discounted value of reorganization costs by eliminating the possibility of a financial reorganization.

Not all financial reorganization policies are feasible, however. To see this, consider the solution for a reorganization rule of $\underline{e} = -3.5$ depicted in Chart 2. This solution is incompatible with the limited

liability of shareholders, since it implies that the value of the bank will be negative for attainable levels of earnings. With limited liability, shareholders have the right to discharge the bank's liabilities by assigning to the government their claim to the bank's earnings, with the government protecting depositors from any losses. Shareholders would thus petition to reorganize the bank the moment its stock market value reaches zero.

To ascertain the range of financial reorganization policies that is consistent with limited liability, consider the rule $\underline{e}^* = 1/\lambda - \mu/r$. It is straightforward to show that, for any $\underline{e} \geq \underline{e}^*$, $V'(e_t) \geq 0 \forall e_t \geq \underline{e}$. Thus, for any reorganization policy satisfying $\underline{e} \geq \underline{e}^*$, the value-matching condition (i.e., $V(\underline{e}) = 0$) and the continuity of $V(e_t)$ imply that the bank's stock market value is positive for all feasible earnings levels. Thus, any rule satisfying $\underline{e} \geq \underline{e}^*$ is consistent with limited liability.

Conversely, for any $\underline{e} < \underline{e}^*$, one may show that $V'(\underline{e}) < 0$. Again, given the value-matching condition and the continuity of $V(e_t)$ at \underline{e} , it follows that such a reorganization policy yields negative stock market values for feasible earnings levels. Hence, \underline{e} is consistent with limited liability if and only if $\underline{e} \geq \underline{e}^*$.

So far, we have demonstrated the important role of \underline{e}^* without providing any economic explanation of from where it comes. In fact, \underline{e}^* is the maximizing argument to the problem

$$\max V(e_t, \underline{e}) = A_0 + A_1 e_t - (A_0 + A_1 \underline{e}) \exp[\lambda(e_t - \underline{e})], \quad (24)$$

where $V(\dots)$ is written so as to emphasize its dependence on both e_t and \underline{e} . In other words, \underline{e}^* is the reorganization rule that maximizes the bank's stock market value for any given deposit insurance premium rate. The problem has an interior solution because, as the closure point declines, the gains to shareholders in the event that they exercise their right to limited liability are eventually more than offset by reductions in the weighted average discount factor.

The maximizing argument, \underline{e}^* , has several noteworthy properties. First, it is independent of the current level of e_t and is thus time invariant. Second, since λ is negative, \underline{e}^* is less than that earnings level at which the bank's earnings stream has a zero discounted value. Third, \underline{e}^* satisfies the "smooth pasting" condition

$$\partial V(\underline{e}^*, \underline{e}^*) / \partial e_t = \partial V(\underline{e}^*, \underline{e}^*) / \partial \underline{e} = 0. \quad (25)$$

As Dixit (1991) discusses, in absorbing barrier problems, smooth pasting is a necessary condition for an optimal stopping rule, of which the above shutdown policy is an example. ^{1/}

Having established the class of financial reorganization rules that are consistent with shareholders' limited liability, we now consider the choice of such rules by a social planner. The objective of such a planner is simply to minimize the expected discounted costs of financial reorganization, i.e.,

$$\min -C(\underline{e})\exp[\lambda(e_t - \underline{e})] \quad (26)$$

$$\text{s.t. } \underline{e} \geq \underline{e}^*, \quad (27)$$

Note as a special case that, if the reorganization costs are independent of \underline{e} , the social planner would choose the reorganization rule that shareholders prefer, \underline{e}^* . The social optimum, in this case, would involve postponing reorganization of the bank as long as possible which, in turn, implies choosing the lowest possible reorganization policy that is consistent with limited liability.

Now suppose that reorganization costs depend on \underline{e} and that (26) and (27) have an interior solution \underline{e} such that $\underline{e} > \underline{e}^*$. In this case, the social planner's and shareholders' choice of reorganization rule will coincide only at the inception of the deposit insurance scheme, assuming that the deposit insurance premium is set at an actuarially fair rate. With the implementation of actuarially fair pricing, shareholders will effectively internalize the expected reorganization costs in their calculation of a preferred reorganization policy.

Immediately after the beginning of the scheme, however, the bank's shareholders will have an incentive to resist implementation of the reorganization rule since they will then prefer the rule that maximizes the stock market value of the bank, \underline{e}^* . This fact could be important under circumstances in which banks have political or legal means to resist the authorities' implementation of the reorganization policy.

Note that the above analysis presumes that the objectives of the government are those of a social planner; however, a government could act to maximize its own financial gain, as would a private insurance company. In such a circumstance, the government, like the shareholders, would prefer one reorganization rule at the beginning of the insurance scheme, assuming

^{1/} In problems with reflecting barriers, as in the band exchange rate models of Froot and Obstfeld (1991b) and Perraudin (1991), smooth pasting conditions hold even without optimally chosen barriers. In such cases, optimality generally implies additional conditions upon the second derivatives of the solution evaluated at the barriers. For a discussion, see Dixit (1991).

actuarially fair pricing; but after that moment, the government would face an incentive to renege upon the agreed policy and to raise the reorganization point to reduce the value of the guarantee.

As a final point, the above analysis also provides some guidance on how the government should implement the bank's financial reorganization. If the reorganized bank is charged an actuarially fair deposit insurance premium after it is sold to the private sector, the government will not be able to recoup the expected discounted value of future reorganization costs. In this case, the bank's stock market value is given by equation (22) and is equal to that value it would have under unlimited liability and $\gamma = 0$ less $C(\underline{e})\exp[\lambda(e_{t_0} - \underline{e})]$. Thus, to minimize its exposure to losses, the government should liquidate enough deposits so that the discounted value of the reorganization costs is negligible. Under an actuarially fair premium, any reduction in the bank's deposits boosts its stock market value at the moment it is sold back to the private sector by an equal amount.

V. Banking Regulation

Just as in some circumstances the bank has an incentive to manipulate the reorganization policy after the deposit insurance premium has been fixed, it faces a similar incentive to alter the distribution of its earnings process. One view of banking regulation is that it serves to combat these incentives.

To facilitate our discussion of banking regulation, we somewhat arbitrarily distinguish between two ways in which the bank's earnings prospects can be altered. First, the bank's managers, acting on behalf of shareholders, may attempt to influence the parameters μ and σ of the basic earnings process. Second, by selling assets and distributing the proceeds to shareholders, the bank may alter its level of capital. In our model, such actions would alter the level of the earnings process discretely at a moment in time. ^{1/} We begin with the first type of moral hazard problem.

Within the simple risk-neutral investor model developed above, it is straightforward to show that the bank can increase the wealth of its shareholders at the expense of the government by increasing the variance of its earnings process. Raising σ has no impact on the linear part of $V(e_t)$, whereas λ and, hence, the value of the nonlinear part depend positively on σ . Moreover, this dependence increases as e_t nears \underline{e} . If the risk neutrality assumption is relaxed, an increase in the instantaneous standard deviation would not necessarily translate into a higher stock market value for the bank, since the risk premium may also rise. However, if the

^{1/} These two phenomena are not completely distinct since, for example, changing dividend policies so as to increase the portion of earnings that is reinvested, could be regarded as increasing μ at the same time as cutting the current level of earnings, e_t .

instantaneous variability is increased by raising idiosyncratic, diversifiable risk that is not "priced" (see Section VI below), the bank's stock market value would unambiguously increase even with risk averse investors. Charts 3 and 4 illustrate the sensitivity of the stock market value of a typical, large U.S. bank and of the value of its deposit guarantee to changes in σ , assuming risk neutral investors.

Turning now to the second type of moral hazard problem mentioned above, we start by noting that within our model a change in the bank's capital structure would affect how its total value is allocated between shareholders and the government. For example, suppose that shareholders withdraw a unit of capital from the bank while attracting an additional unit of deposits. The stock market value of the bank after the distribution to shareholders would decline by

$$\partial V(e_t)/\partial D_t = -1 - \gamma/r + (A_0 + A_1 e)\lambda(r + \gamma)\exp[\lambda(e_t - e)]. \quad (28)$$

The increase in deposits has two opposing effects on $V(e_t)$. First, it cuts earnings because of the increased interest and deposit insurance premium expenses. Second, it boosts the nonlinear part of $V(e_t)$ since it increases the likelihood of financial reorganization. The net change in the bank's stock market value after the distribution to shareholders would exceed or fall short of minus unity depending on whether the deposit guarantee scheme subsidizes or taxes the incremental deposits at the current level of earnings.

How should the regulatory authorities respond to the potential for wealth transfers from government to shareholders that they create? ^{1/} Essentially, a government faces the same problems as those of a private lender after the terms of the loan have been fixed. Black, Miller, and Posner (1978) develop this analogy at some length and argue that private lending practices, including capital requirements and loan covenants, provide guidelines for efficient banking regulations.

Typical private loan contracts contain many more provisions than simply an interest rate and maturity date. For example, such contracts generally impose initial capital requirements by limiting the value of loans to a fraction of the borrowers' total funding requirements, restrict the use of the borrowers' assets and their payment of dividends, and provide for the direct supervision of the borrowers' businesses by lenders, so as to prevent acts that would benefit borrowers at the expense of lenders.

Enforcement of many provisions in private loan contracts entails costs on the part of lenders, which will be reflected in the terms of the loan. A borrower and lender thus have incentives to take actions at the inception of a loan to minimize these costs. One such act is to accept an initial

^{1/} The transfers may also be to managers or other employees of the bank in the case of malfeasance.

capital requirement; another is to assign some of the borrower's assets as collateral for the loan. A high initial capital requirement reduces the incentive of the borrower to increase its business risk once the loan agreement is signed. By taking a lien on an asset, the lender limits the ability of the borrower to sell assets and pay out the proceeds as dividends.

Banking regulations are essentially actions taken by the government standing in the place of private lenders to a bank (i.e., its depositors) to prevent the transfer of wealth to its shareholders or managers. Typically, a government imposes at least initial capital requirements on banks and places restrictions on entry to the banking industry. In addition, many governments restrict the activities permissible to banks and impose (or threaten to impose) additional capital requirements when banks seek to alter their activities in a way that increases risk. Governments also restrict bank dividend payments and audit banks to prevent actions that transfer wealth.

Capital requirements imposed at the beginning of the deposit insurance scheme appear to provide an efficient means of protecting against both the types of moral hazard problems discussed above. First, by boosting the bank's earnings level, a high initial capital requirement, reduces the incentive that exists after the inception of the scheme to increase the riskiness of the bank's assets (see Charts 3 and 4), although some restraints on risk-taking would still be required. Second, equation (28) indicates that a high initial capital requirement lowers the incentive to substitute deposits for equity in funding the bank's assets. ^{1/}

The main practical drawback to high initial capital requirements is the opposition of bank shareholders who generally regard equity as a more expensive funding source than deposits. However, under an actuarially fair deposit insurance premium, this would not necessarily be the case. In fact, from the definition of a fair premium given by equation (22), a high initial capital requirement would raise the stock market value of the bank by lowering the expected discounted value of the reorganization costs, although the tax treatment of interest payments in many countries could offset the benefits of equity financing.

The imposition of capital requirements after the beginning of the deposit insurance scheme is somewhat more difficult to analyze than initial capital requirements. The regulatory authorities would need to distinguish between adverse developments beyond the control of the bank and deliberate attempts to manipulate the bank's earnings prospects. If, for example, the authorities were to seek an increase in the bank's capital after a deterioration in its earnings due to exogenous factors, they would be in

^{1/} Note also that a deposit insurance premium levied on a per dollar of deposit basis lowers the incentive to substitute at the margin deposits for equity, whereas a lump-sum premium does not.

effect reneging on part of the deposit guarantee which may initially have been priced according to an actuarially fair formula. Conversely, if the authorities failed to adjust the terms of the deposit guarantee following the manipulation of the bank's earnings prospects (e.g., through the payment of excessive dividends), the bank's shareholders would be unfairly enriched. In such circumstances, the regulatory authorities could encourage the bank's recapitalization by threatening an increase in the premium if the recapitalization does not occur. The auditing of the bank's activities is clearly an important way to distinguish between these two types of developments.

While a detailed analysis of the many types of banking regulation is beyond the scope of this paper, we have emphasized the role of capital requirements because of their apparent efficiency in combating certain moral hazard problems and audits because of their potential for uncovering such problems. Other devices that are frequently employed by governments and private lenders alike include restrictions on dividends.

VI. Risk Aversion

In the above analysis, agents were assumed to be risk neutral. Relaxing this assumption is reasonably straightforward and we do no more than sketch the arguments involved, providing references to other papers than can supply the details. Harrison and Kreps (1979) show that under general conditions, the absence of arbitrage in a financial market implies the existence of a probability measure, Q , such that gain processes (i.e. prices processes plus compounded accumulated dividends) are martingales under Q . If agents are risk neutral then an example of such a Q will be the measure, P , that represents the actual probabilities. If we interpret the expectations operator in the equilibrium condition (5) as taken with respect to Q , this relation will hold even if investor are risk averse.

Since any empirical exercise uses data generated under the actual probabilities P , it is important to know how to map our results back into a world with P probabilities. To do this, one may follow the argument of Chamberlain (1988). Chamberlain shows that in the presence of a representative agent, 1/ if aggregate consumption at some terminal date T can be written as a stochastic integral with respect to a vector of M Brownian motions representing nondiversifiable risk, then the Radon-Nykodym derivative of the martingale measure Q with respect to the actual probability measure P may be written as a stochastic integral with respect to the M Brownian motions. By an application of Girsanov's theorem, it is then possible to show that expectations of the kind in equation (5) with respect to the martingale measure Q may be solved by adjusting the drift

1/ His analysis is actually more general and does not require the existence of a representative agent but it is simpler to think in these terms.

terms of the driving process, e_t , and then solving as though the correct probabilities were P . The drift term adjustment involves including up to J linear terms where J is the number of the M nondiversifiable risk Brownian motions that are instantaneously correlated with e_t . These terms are the continuous time equivalents of the risk adjustments that one finds in mean asset returns in a discrete time arbitrage pricing model.

To take a concrete example, Ho, Perraudin and Sorensen (1990) extend Chamberlain's arguments to the case in which the information-generating factors include both Brownian motions and random jump-size Poisson processes and show that if the representative agent's utility function is logarithmic and the logarithm of consumption at some terminal date, T , is linearly related to the terminal levels of the "factors", then, the implied risk adjustments are a set of constants, equal in number to the factors.

VII. Conclusion

This paper provides a new framework within which one may analyze banking policies and the pricing of deposit guarantees provided by the government. Fair deposit insurance premia and socially optimal financial reorganization policies are derived and interpreted. Many of our results are valid not just for banks but for any corporation with bondholders and limited liability. The main difference is that the bank's liabilities to depositors are backed by the government in the present model, while bondholders are in effect self-insured; however, this distinction does not affect the basic pricing problem. 1/

Priorities for future research are, first, empirical implementation of the model developed in this paper and, second, further work on developing the implications of our analysis for capital structure and nonlinearities in asset pricing both for debt and equity securities.

1/ One complication is that bond contracts, especially for private sector borrowers, are generally fairly short maturity.

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