© *The Journal of Risk and Insurance*, 2004, Vol. 71, No. 4, 707-735

Deposit Insurance and Forbearance Under Moral Hazard

Jacky So
Jason Z. Wei

Abstract

We study the efficacy of forbearance using a real options approach. Our model endogenizes moral hazard embedded in credit risk undertaken by the bank. The bank's interest rate risk is modeled as duration mismatch. Other modeling improvements over previous studies include such features as stochastic interest rates and deposits, continuous interest payments on an ongoing deposit portfolio, and a stochastic forbearance period. We find that the bank does have an incentive to engage in undue risk taking. Even in the presence of moral hazard, however, forbearance can still be a desirable course of action in reducing the FDIC's expected liability. In addition, the capital ratio plays an extremely important role in determining the fair insurance premium. Finally, using the mismatch of asset and deposit durations as the correct measurement of interest rate risk, our model reveals that an optimal asset variance may exist for a particular bank, contrary to what the contingent claims framework would predict. Therefore, we resolve the puzzle that banks in practice do not increase asset risk to take full advantage of the limited liability.

Introduction

Using a real options approach, this article studies the efficacy of forbearance in insolvency resolutions in the presence of moral hazard. Specifically, we attempt to answer the following questions: Should forbearance be granted under moral hazard? How long should the forbearance period be? How frequently should the bank be monitored during the forbearance period? What is the role of capital requirement? In order to

---

Jacky So works in the College of Business Administration, Texas A&M International University. Jason Z. Wei works in the Division of Management and the Joseph L. Rotman School of Management, University of Toronto. Both authors can be contacted via e-mail: jso@tamiu.edu and wei@rotman.utoronto.ca, respectively. Jacky So thanks the Graduate School of the Southern Illinois University, Edwardsville for providing a summer research grant to support this project. Jason Wei acknowledges financial support from the Social Sciences and Humanities Research Council of Canada. The authors thank James Moser, three anonymous referees, Richard MacMinn (the Editor), and seminar participants at various universities in Canada and the United States for useful comments and suggestions. We also thank Barry Freeman for his professional editorial assistance.

address these questions thoroughly, we build a model that fully captures both the bank's behavior and the FDIC's policy implications. To properly position our work in the literature, we will briefly survey some relevant studies. Broadly speaking, the literature has identified three key issues facing the FDIC: (1) fair pricing of the deposit insurance, (2) optimal closure upon insolvency, and (3) monitoring and regulatory supervision.

The system of risk-based premium levy has been in place since the introduction of the 1991 FDIC Improvement Act (FDICIA). According to Benston and Kaufman (1997), the first 5 years of FDICIA were successful in strengthening the financial conditions of the banking and thrift industries. However, the spread between the premiums charged to the safest and the most risky banks is considerably smaller than that assigned by the market. Therefore, the fairness of the current system is in question, and the misalignment between a bank's risk profile and the levied insurance premium creates an incentive to engage in undue risk taking.[1]

The issue of optimal closure is still in debate. Eisenbeis and Horvitz (1994) provided a review of the main opposing arguments. Kane (1986) has suggested "tougher approaches to insolvency resolutions" based on the Saving and Loans fiasco in the early 1980s. This stance has since been theoretically fortified. For example, Acharya and Dreyfus (1989) found that in a realistic and competitive environment, ailing banks should always be closed promptly. Duan and Yu (1994) showed that capital forbearance can lead to excess risk taking, which in turn can lead to instability in the deposit insurance system. Other authors have attempted to theoretically justify forbearance. Allen and Saunders (1993), for instance, showed that it is sometimes in the best interest of the FDIC to time the closure rather than to always promptly close an ailing bank. Similarly, Dreyfus, Saunders, and Allen (1994) found that forbearance may be warranted if there are liquidation costs. Fries, Mella-Barral, and Perraudin (1997), by assuming a constant interest rate and return on banks' assets, analyzed a series of closure rules and bailout policies to show that under certain conditions, postponing closures is desirable.

Monitoring is an integral part of the deposit insurance system. Close monitoring can uncover problems in a timely fashion and thus minimize losses; but because monitoring is also costly, a trade-off is always desirable. Mazumdar and Yoon (1996) demonstrated that regulatory supervision could be more important than capital regulations when banks' behavior cannot be observed in a costless manner, i.e., when there is asymmetric information or when there is a collusion between the bank and its borrowers for the purpose of extracting regulatory subsidies. Klein and Barth (1995) stressed the importance of solvency monitoring in the insurance sector, and provided a comprehensive overview of monitoring procedures.

[1] Similar disparity exists in the insurance sector, whereby, guaranty funds typically charge an *ex post*, flat premium to member companies. As such, moral hazard can also arise, as documented by Downs and Sommers (1999). Authors such as Feldhaus and Kazenski (1998) have, therefore, studied and proposed risk-based premiums. Nonetheless, as shown by Cooper and Ross (1999), and Babble and Hogan (1992), a flat-rate guaranty fund can still serve a useful role in ensuring market efficiency and moderating moral hazard.

The role of capital requirements in controlling risk taking is also closely studied in the literature. Kahane (1977), Koehn and Santomero (1980), and Kim and Santomero (1988) found that a higher required capital ratio increases asset risk and may lead to a higher probability of bank failures. Furlong and Keeley (1989) and Gennottee and Pyle (1991), however, documented conflicting results. Studies of the fixed-rate system (e.g., Pyle, 1986) recommended that both the leverage and the asset risk of a value-maximizing bank should be regulated when the deposit insurance is subsidized. Bond and Crocker (1993), for their part, showed that capital requirements and deposit insurance are complementary in protecting depositors.

Yet, when addressing the aforementioned issues, previous studies ignored many key phenomena. First, the foremost important factor affecting a financial institution's operation is arguably the interest rate. The results of many studies are based on a constant interest rate, but interest rates can change significantly even in the short term.[2] Some authors (e.g., Duan and Sealey, 1995; Pennacchi, 1987a,b) have attempted to model stochastic interest rates, but they did not incorporate such features as continuous interest payments, credit risk, and endogenous moral hazard, which we consider in the current article.

Second, to the best of our knowledge, our model is the first to incorporate continuous interest payments. Previous studies modeled deposits as a discount bond and assumed that interest is paid only at maturity. Since interest payments represent by far the largest costs for banks and are paid on an ongoing basis, an accurate modeling of interest payments is essential for any analysis to have meaningful policy implications.

Third, previous studies either assumed away moral hazard (e.g., Bond and Crocker, 1993; Mozumdar and Yoon, 1996) or modeled it in a restricting and exogenous fashion. For example, Boyle and Lee (1994), and Duan and Yu (1994) modeled moral hazard as increasing the asset variance upon the asset value dropping below a prespecified level. It is questionable, however, whether excess risk taking should be triggered by declines in asset value, and whether an increase in asset variance represents higher risk. For instance, a bank's financial condition is determined by the difference in value between assets and deposits, or net worth, not by the asset value per se. As we will show later, an increase in asset variance does not always increase a bank's risk profile.

The objective of this study is to answer the questions posed at the beginning while avoid the aforementioned modeling drawbacks. In addition to introducing stochastic interest rates and ongoing interest payments, we will also introduce a new and more realistic way of modeling moral hazard. Unlike previous authors, we model moral hazard by making the level of credit risk *endogenously* dependent on the net worth (i.e., on the difference between the insured institution's assets and liabilities). As for interest rate risk, we assume that financial institutions either completely hedge it or take a calculated position as part of an overall interest rate strategy. In any

[2] Examples include Allen and Saunders (1993), Bond and Crocker (1993), Boyle and Lee (1994), Cummins (1988), Duan and Yu (1994), Fries, Mella-Barral, and Perraudiiin (1997), Mazumdar and Yoon (1996), and Ronn and Verma (1986).

case, financial institutions adverse incentives will only rest on manipulating credit risk.[3]

Within the improved framework, we attempt to determine *when* and *under what conditions* forbearance should be granted to a failing institution, given that insured institutions have a tendency to take excessive risks when their financial condition deteriorates. We also determine *how* forbearance should be carried out, and *what role* capitalization plays in determining the fair insurance premium. We conduct the investigations using a real options approach in light of the fact that most of the FDIC's decisions illustrate the flexibility it enjoys in resolving insolvencies. Options always have a positive value, hence the FDIC could reduce its expected liability by carefully exercising the real options in its decision-making apparatus, as shown by Mason (2002).

In the next section, we model the processes followed by assets and deposits, characterize the bank's behavior due to moral hazard, and outline the FDIC's policies on audits and forbearance. In the section "Theoretical Valuation" we delineate the valuation procedures for equity, charter and deposit insurance and we address the issues of numerical implementation and choice of parameter values. The model setup in the section "Model Development" and the valuation procedures in the section "Theoretical Valuation" are both based on the real options approach. Numerical results are fully examined and discussed in the section "Risk Taking and Forbearance—Numerical Results and Policy Implications." We summarize and conclude the article in the final section.

MODEL DEVELOPMENTS

Our model consists of three building blocks: (1) the stochastic processes followed by assets and deposits, (2) the bank's decisions on undue risk taking, and (3) the FDIC's decisions and policies on forbearance and closures. The intrinsic value of forbearance and the overall valuation of deposit insurance under moral hazard behavior depend on the interplay among these three elements.

This setting makes real options valuation the perfect choice for analysis. As pointed out by Trigeorgis (1996), a real option is basically managerial flexibility or strategy. Many investment decisions involve managerial flexibility and can, as such, be characterized as real options. Examples include decisions to defer, alter, and abandon an investment, or to shut down a project (see Dixit and Pindyck, 1994, for details). In this sense, for a bank, whether and when to take undue risk at the FDIC's expense are the bank's real options. By the same token, the FDIC's decisions on forbearance and closure are

[3] We recognize that, as an application of contingent claims pricing, our article does not treat moral hazard in the same way as the game literature does. Specifically, we are silent on whether the insurer has perfect information or not. One could interpret our setup as one in which the insurer does have perfect information on how the insured agent engages in risk taking, and charges an insurance premium accordingly. Alternatively, the setup could be one in which the insurer does not have perfect information, and is trying to assess the potential impact of moral hazard. The "incentive effect" discussed by Babble and Hogan (1992) is similar to our definition of moral hazard, although they focus on insurance companies while we focus on banks.

also real options. In the next two subsections, we fully characterize both the bank's managerial flexibility (i.e., its option to engage in undue risk taking) and the flexibility of FDIC's policy in forbearance and closure.[4]

Characterization of Deposits, Assets, and Moral Hazard

Assumption 1: All deposits are insured by the FDIC and the face value of the deposits, D_F, grows at a known rate, μ_F:

$$dD_F = \mu_F D_F \, dt. \tag{1}$$

Equation (1) treats the rate of growth μ_F as a policy parameter and is known by virtue of planning. It reflects the net change after the withdrawal of existing deposits and the addition of new ones. If interest rates are stochastic, the market value of the deposits, D_M, will also be stochastic. In order to specify a dynamic for the flow and profile of deposits, the following assumption is made:

Assumption 2: As a policy choice, the bank maintains a constant duration, τ for its deposits by carefully selecting the maturity of newly acquired deposits.

This assumption, which is also made by Pennacchi (1987a) and others, implies that deposits are repaid and renewed on a continuous basis. Under this setup, the market value of the deposits can be characterized by the dynamic of a continuum of unit discount bonds whose maturity is equal to the deposit duration.[5]

Assumption 3: The market value of a risk-free discount bond with a face value of \$1 and maturity τ follows a lognormal process:

$$dD = \mu_D D \, dt + \sigma_D D \, dz_D, \tag{2}$$

where z_D is a Wiener process, μ_D is the drift, and σ_D is the instantaneous standard deviation and is assumed to be constant for the same τ.

[4] To our knowledge, the only study that uses a real options approach to analyze the FDIC's flexibility in closing ailing commercial banks is by Mason (2002). He proposed a simple valuation framework in which the FDIC, upon detecting an insolvency, may choose to liquidate the bank's assets at a known loss, or hold until the next period for a possible recovery. The model was supported by empirical evidence.

[5] As pointed out by our referees, banks in general do not get to set the deposit level and deposit duration is most likely to be an endogenous variable. Banks set their deposit rates to compete for deposits. Our model allows banks to set their "monopoly rent," which is essentially the spread between loan rates and deposit rates. Given the overall loan rate, setting the spread will be equivalent to setting the overall deposit rate. Our only assumption is that the bank will set the monopoly rent at such a level that the desired level of deposits can be achieved. As for the duration of deposits, ideally it should be endogenous in the most general framework. Here, since our focus is on the endogenous moral hazard, we make the constant duration assumption mainly for tractability. Given that banks take in and redeem deposits on an ongoing basis, the assumption of a constant duration may not be too far removed from reality.

Equations (1) and (2) imply that $D_M = D_F D$, and by Ito's lemma, the market value of total deposits follows the process below:

$$dD_M = D_M[\mu_F + \mu_D]\,dt + \sigma_D D_M\,dz_D. \tag{3}$$

Since the effective maturity of deposits is kept constant (by tracking a continuum of discount bonds), interest payments would not factor into the above process. Instead, they are deducted from assets, as shown later. When the deposits are modeled as a single discount bond with a fixed maturity date (as most authors have done), the convergence of the bond's market value toward par represents interest earnings. However, as mentioned earlier, assuming a single discount bond fails to acknowledge the ongoing nature of deposits.

Next, we model the bank's assets. We establish the following points before laying out the asset value dynamic: (1) moral hazard is characterized by the bank's taking excessive credit risk when the net worth deteriorates, (2) the moral hazard problem is more pronounced when the bank is either close to, or is already under distress, (3) as the bank's net worth improves, the bank will withdraw from excessive risk taking, (4) the adjustment of risk taking should be gradual, and (5) there are regular expenses other than interests that are paid out of assets. With these points in mind, we propose the following assumption.

Assumption 4: The market value of the bank's assets is described by:

$$dA = [(\mu_A - q)A + (\mu_F - g - p)D_M]\,dt + \sigma_A\left[w\,dz_D + \sqrt{1-w^2}\,dz_A\right]A, \tag{4}$$

where

$$w = \rho \cdot \min\left[1, \left(\frac{A(1-c)}{D_M}\right)^{\beta}\right], \quad \text{and}$$

$\mu_A =$ rate of return on assets,
$q =$ expense payout rate on assets (for such items as loan losses and dividends),
$g =$ interest payout rate on deposits,
$p =$ deposit insurance premium as a percentage of deposits charged by the FDIC,
$\sigma_A =$ standard deviation of asset returns,
$c =$ initial capital ratio defined as $(A^0 - D_M^0)/A^0$ (superscript indicates time zero),
$\rho =$ correlation between returns on assets and deposits in the absence of moral hazard ($\beta = 0$),
$\beta =$ a policy variable for the bank which reflects the extent of moral hazard or undue risk taking ($\beta \geq 0$),
$z_A =$ a Wiener process independent of z_D.

In the asset value process, all parameters are assumed to be constant except for the asset return μ_A and the payout rate on deposits, g, which vary according to the interest rate level. In practice, g is lower than the prevailing interest rate, representing monopoly rents or the spread earned by the bank. Once we assume a constant duration, g can be approximated by the yield on a risk-free discount bond with the same maturity as the aggregate deposits, minus a constant monopoly rent, m.

The bracketed term in front of dt in (4) describes the anticipated changes in the bank's asset value. Per unit of time, the gross increase in asset value is $\mu_A A + \mu_F D_M$, reflecting the dollar return on assets ($\mu_A A$) and new investments from additional deposits ($\mu_F D_M$); the total payout is $qA + (g + p)D_{M.}$ The overall term, which is the difference between the gross increase in asset value and total payout, represents the net increase in asset value per unit of time.

The bracketed term involving the two Wiener processes captures the unanticipated changes in asset value, which are in turn due to interest rate fluctuations (modeled by dz_D) and credit risk changes (modeled by dz_A). It is this term that incorporates the endogenous moral hazard through the definition of w. Before we fully explain the mechanism of endogeneity, we first make the following observations. In a stochastic interest rate environment, the risk profile of a bank is reflected by the variation of its net worth, which itself depends on (1) the correlation between the returns on assets and deposits and (2) the relative magnitudes of the return standard deviations or volatilities. When the assets and deposits have equal volatilities, according to Cox, Ingersoll, and Ross (1979), the asset and liability durations are matched and the bank is fully immune to interest rate risk.[6] The bank may still be exposed to credit risk, however, if the correlation between the asset and liability returns is imperfect (i.e., $\neq 1$). By the same token, if the volatilities are not equal, but the correlation is equal to 1, then the bank faces only interest rate risk (due to unmatched durations) and has no credit risk. Finally, with unequal volatilities and a less-than-one correlation, the bank faces both types of risks. Most banks are in this situation. In other words, they would deliberately maintain a degree of duration mismatch since this is a source of value for the bank; they would also take calculated credit risks to enhance the overall return. The decomposition of risk is illustrated by the following matrix:

	Correlation = 1	**Correlation < 1**
Equal volatilities	No interest rate risk No credit risk	No interest rate risk Only credit risk
Unequal volatilities	Only interest rate risk No credit risk	Both interest rate risk and credit risk

The novel correlation setup in (4) is motivated by these insights. Specifically, the value of w together with the relative magnitudes of σ_D and σ_A determine the relative proportions of interest rate risk and credit risk. When $w = 1$ and $\sigma_D = \sigma_A$, the bank is free of both types of risks, and the equity value is solely derived from the monopoly

[6] As pointed out by a referee, strictly speaking, the bank is fully immunized when $D_A/D_{DM} = D_M/A$, where D_A and D_{DM} stand for the asset and deposit durations, respectively. Matched durations will lead to a perfect immunization only when the net worth is zero. However, since $D_M \approx A$, in the ensuing discussions, we will speak of perfect immunization when $D_A = D_{DM.}$ It should be kept in mind that this approximation is only for ease of exposition. Our numerical analysis in the section "Risk Taking and Forbearance—Numerical Results and Policy Implications" does not rely on this approximation at all.

rent. The fair value of deposit insurance is zero. When $w = 1$ and $\sigma_D \neq \sigma_A$, the change in net worth is solely driven by interest rate variations, and the fair value of deposit insurance depends on the extent of duration mismatch, or volatility mismatch. When $w \neq 1$, regardless of the relative magnitude of σ_D and σ_A, part of the asset return variation is due to factors other than the interest rate. This component is captured by$\sqrt{1 - w^2}\, dz_A$, which we model as credit risk. Clearly, the bank's overall risk will increase if the mismatch between σ_D and σ_A increases, or if w becomes smaller, or both. However, it is the magnitude of w alone that determines the degree of credit risk.

Moral hazard and its inherent real option's value to the bank are embedded in the structure of w. The neutral point is where the bank meets the minimum capital requirement, i.e., $A(1 - c) = D_M$. At his point, the amount of credit risk is determined by $\sqrt{1 - \rho^2}$. As the net worth erodes, i.e., when A decreases or D_M increases or both, the bank will have an incentive to take more credit risk, which is achieved by reducing w. The bank will take less risk when the net worth improves. Regardless, the minimum level of credit risk is $\sqrt{1 - \rho^2}$.[7] It should be pointed out that the neutral point could be set to a value other than $A(1 - c) = D_M$ by adjusting the value of c. Clearly, $\beta = 0$ corresponds to the special case of no moral hazard: the bank does not adjust its risk structure as its net worth varies. With a positive β, the bank is essentially holding a real option to alter the extent of risk taking, which should benefit the equity value.

Note that some authors (e.g., Keely, 1990; Duan and Yu, 1994) have explicitly or implicitly defined moral hazard as the tendency for banks to increase asset risk in order to maximize equity value under limited liabilities. Within the framework of Merton (1977), authors such as Ronn and Verma (1986) made the extreme inference that banks should take as much risk as possible. Several authors (e.g., Keeley and Furlong, 1990; Kwan, 1991) have attempted to explain why, in practice, banks do not increase asset risk without limit. Although this article does not attempt to determine the "optimal" level of σ_A and β, our setup does shed light on the puzzle, as shown later. Meanwhile, we will attempt to answer the following question: given the general level of σ_A, ρ and β, how will the endogenous nature of credit risk affect the deposit insurance pricing and forbearance policy?

Characterization of FDIC's Policies

The FDIC is assumed to conduct normal audits at fixed intervals (e.g., annually). Upon detecting insolvency (i.e., negative net worth) on a normal audit, the FDIC will let the bank continue to operate as long as the net worth is not below a threshold level. Otherwise, it will shut the bank down. The closure threshold, as a policy parameter, is measured by a fractional number, α. Specifically, the FDIC forbears if, upon insolvency, $A > \alpha D_M$, and shuts down the bank if $A \leq \alpha D_M$. As extreme cases, $\alpha = 1$ corresponds to prompt closure and $\alpha = 0$ corresponds to complete forbearance. Therefore, whether to forbear (i.e., whether to set $\alpha = 1$) and to what extent to forbear (i.e., at what level to set α) are the first real options that the FDIC has in its decision-making apparatus.

[7] Without the min. operator in (4), the credit risk could be zero or undefined, since the effective correlation w could be equal to or greater than 1. The minimum operator ensures that the credit risk is always well defined.

Similar to Mason (2002), the real option derives its value from the following trade-off: incurring a known immediate cost (by paying off creditors and incurring deadweight loss in asset sales) and avoiding a bigger loss down the road versus forbearing and anticipating a recovery while risking a bigger loss down the road.

Forbearance, if granted, is for a fixed period (e.g., 6 months) during which the bank is audited more frequently. Let n be the number of audits conducted at equal intervals during the forbearance period. At each audit, the closure threshold is checked and a decision is made as to whether the bank should be permitted to continue its operations. If the closure threshold is reached, then the bank is closed; otherwise the bank continues to operate until the end of the forbearance period, at which time a final evaluation is conducted. At that point, the bank is either deemed to be healthy (by which we mean $A > D_M$) and returned to the normal audit schedule, or shut down if the net worth is still negative (i.e., $A < D_M$). The FDIC holds two additional real options after forbearance is granted. The maximum period of forbearance is one, and the audit frequency is another, both of which involve a cost–benefit trade-off. For instance, allowing a longer forbearance period will improve the chance of recovery, but at the same time, will also risk a greater loss.

Upon closing an insolvent bank, the FDIC will incur a deadweight loss expressed as a percentage of the fair market value of the assets, denoted by γ. In the case of "purchase and assumption" where the FDIC auctions or liquidates the assets, this loss represents the "fire sale" loss (Eisenbeis and Horvitz, 1994). In the case of "deposit pay-off" or "deposit transfer" where the FDIC establishes a receivership to manage the assets, the deadweight loss can represent a combination of asset value depression and liquidation costs. James (1991) has documented that "purchase and assumption" is by far the most common approach. Therefore, in this article, we will treat the deadweight loss as the "fire sale" loss.

THEORETICAL VALUATIONS

Valuing Bank Equity

Notations: current time: t, time for next audit: T, final resolution time: $T_1 (T_1 = T + T_f$, where T_f is the maximum forbearance period as defined earlier).

Based on the discussions in the previous section, at the audit time T, there are two possibilities for the net worth:

A: $A(T) > D_M(T) \rightarrow$ positive net worth,

B: $A(T) < D_M(T) \rightarrow$ negative net worth.

If (A) prevails, then the equity value is $E(T) = A(T) - D_M(T) + C(T)$, where $C(T)$ is charter value; if (B) prevails, forbearance of maximum length T_f is granted and the bank is subject to more frequent audits. At any interim audit, if the closure threshold is reached, i.e., $A(t') \leq \alpha D_M(t')$ $(T \leq t' \leq T_1)$, then the bank is closed, the charter is lost, and the equity value becomes zero.

If the asset value is above $\alpha D_M(t')$ for the whole forbearance period $(T \leq t' \leq T_1)$, then the bank is re-evaluated at T_1. There are two possible cases:

BA: $A(T_1) > D_M(T_1) \rightarrow$ positive net worth,

BB: $A(T_1) < D_M(T_1) \rightarrow$ negative net worth.

In accordance with the policy outlined in subsection "Characterization of FDIC's Policies," if (BA) prevails, the equity value is $E(T_1) = A(T_1) - D_M(T_1) + C(T_1)$; if (BB) prevails, the bank is closed, and the equity value is zero.

Note that A (value of bank assets) only covers the asset portfolio (e.g., loans and mortgages), and does not include the charter value. The equity value of the bank derived from A is essentially the value of a call option on the bank's assets. Note also that the value of the deposit guarantee is not considered to be part of the equity value. The treatment of deposits as risk-free instruments automatically accounts for the value of deposit insurance. The fair insurance premium is equivalent to the default risk premium on otherwise risky deposits, as observed by Kaufman (1992).

Valuing Bank Charter

Following Marcus (1984) and Ritchken et al. (1993), we assume that the value of a bank's charter is derived solely from monopoly rents. Based on the discussions in the subsection "Characterization of Deposits, Assets, and Moral Hazard," the charter value for any time period (t_1, t_2), conditional on the bank being solvent at time t_1, is the present value of savings on interest expenses, and can be derived as (detailed derivations are available from the authors upon request)

$$C(t_1) = \theta D_F(t_1) e^{\mu_F (t_2 - t_1)} \frac{D(t, t_1 + \tau)}{D(t, t_1)} \left[1 - e^{-m(t_2 - t_1)}\right], \tag{5}$$

where $D(t_1, t')$ is the time-t_1 value of a unit discount bond maturing at time t', τ is the fixed duration of the bank's deposits, and θ is a scale-down fraction, which represents the probability of bankruptcy and erosion of monopoly rents due to competition.

Prior to the next audit at time T, the charter value is known and can be expressed as

$$C(t) = D_F(t) e^{\mu_F (T - t)} D(t, t + \tau)\left[1 - e^{-m(T - t)}\right]. \tag{6}$$

At a future time, t_1, with a zero deposit growth, the expected perpetual charter value can be obtained by letting t_2 in (5) approach infinity. A formula is given in the subsection "Numerical Implementations" when a particular interest rate process is assumed.

Valuing Deposit Insurance

The valuation of deposit insurance follows the same procedure as in the subsection "Valuing Bank Equity." At time T, if (A) prevails, then the FDIC's liability is zero; if (B) prevails, forbearance is granted, and the FDIC's liability is the expected liability over the forbearance period. If the bank survives the forbearance period and (BA) prevails at the re-evaluation time T_1, then the FDIC's liability is zero; if (BB) prevails, then the FDIC's liability is $D_M(T_1) - (1 - \gamma)A(T_1)$, where γ measures the deadweight loss.

During the forbearance period, if the asset value never drops below $\alpha D_M(t')$, then the FDIC does not face any immediate liability; otherwise, the bank is closed and the

FDIC's liability is $D_M(t') - (1-\gamma)A(t')$. Essentially, the FDIC's overall *ex ante* liability encompasses the many possibilities contingent upon the exercising of the three real options the FDIC possesses.

Numerical Implementations

Our constant duration setup makes the mean-reverting process of Vasicek (1977) a perfect candidate for modeling the interest rate. Specifically, we assume the following spot interest rate process,[8]

$$dr = k[\mu_r - r]\,dt + \sigma_r\,dz_r, \tag{7}$$

where z_r is a Wiener process whose instantaneous correlation with z_D is -1. Assuming a zero market price of risk (without loss of generality), the price of a discount bond can be readily calculated, as shown in Vasicek (1977). In addition, with the process in (7), the expected perpetual charter value at a future time t_1 (with a zero net growth of deposits) is obtained by letting t_2 in (5) approach infinity:

$$\lim_{t_2\to\infty} C(t_1) = \theta D_F(t_1)\frac{D(t, t_1+\tau)}{D(t, t_1)}. \tag{8}$$

This method of modeling charter value is similar to that adopted by Hutchison and Pennacchi (1996).

With (4), (7), and (1), the bond price formula, and the relationship $D_M = D_F D$, we can use the risk-neutral valuation in the spirit of Harrison and Kreps (1979), and Cox, Ingersoll, and Ross (1985b) to simulate the equity value, charter value, and the insurance premium outlined in the three previous subsections.[9] Each value will be based on 10,000 runs augmented with the antithetic variable technique. The stochastic processes are discretized to daily intervals. For convenience, we assume 256 (2^8) days in a year. Unless otherwise specified, the following parameters are used throughout:

$$\begin{array}{lllll}
r = 0.10, & \mu_r = 0.10, & k = 0.18, & \sigma_r = 0.02, & \mu_F = 0.0, \\
\rho = 0.90, & \sigma_A = 0.03, & \beta = 25.0, & q = 0.015, & p = 0.0015, \\
m = 0.01, & \alpha = 0.97, & \gamma = 0.10, & \theta = 0.025, & c = 0.05, \\
\tau = 1.0\,\text{yr}, & T_f = 0.5\,\text{yr}, & T - t = 1.0\,\text{yr}, & n = 8, & D_F = \$110.511, \\
A = \$105.263. & & & &
\end{array}$$

[8] Alternatively, we could assume the square root process proposed by Cox, Ingersoll, and Ross (1985a). However, the local volatility of a discount bond depends on the spot interest rate, which makes the constant duration modeling difficult. Since our focus here is the extent of correlation between assets and deposits which are driven by the same interest rate, we should not expect the qualitative conclusions to be much different when a different interest rate process is assumed.

[9] As pointed out by Trigeorgis (1996), the risk-neutral valuation technique can be applied to real options as long as the nontraded assets can be spanned by traded counterparts. In our case, we assume that spanning assets exist for such items as loans and deposits. This assumption is quite reasonable given that most of the bank's products have securitized counterparts.

The interest rate process parameters are chosen according to Chan et al. (1992). The correlation of 0.90 and the asset return standard deviation of 0.03 are based on the empirical evidence of Pennacchi (1987b). The insurance premium as a percentage of the deposits, $p = 0.0015$, is the approximate average premium currently charged by the FDIC. The value of the deadweight loss ratio, $\gamma = 0.1$, is based on the findings of James (1991). The audit interval (1 year) and the forbearance period (6 months) are chosen to reflect the current practice of the FDIC, namely, that most banks are audited once a year and are reviewed every 6 months. The constant maturity of the deposits is set to 1 year so that, with the interest rate parameters, the return standard deviation of deposits (0.0183) is lower than the assets' and is roughly equal to the average observed by Pennacchi (1987b) and others. The face value of deposits ($110.511) corresponds to a market value of $100, which greatly simplifies the interpretation of the insurance premium. The asset value ($105.263) is chosen so that the initial capital ratio, $(A^0 - D_M^0)/A^0$, is exactly 0.05, roughly consistent with the empirical findings of Epps, Pulley, and Humphrey (1996) and Galloway, Lee, and Roden (1997). As for the monopoly rent or spread, Marcus (1984) set it at 0.02, while Hutchison and Pennacchi (1996) found it to be around 0.0101 for MMDA accounts and 0.017 for NOW accounts. To be broadly consistent with previous findings and to reflect the competition-induced narrowing of spreads over time, we set the monopoly rent at 0.01. The closure threshold α and the moral hazard parameter β are policy or strategy variables, and a range of inputs will be examined. The fixed values of α and β, and the value of θ are chosen such that the computed value of insurance premium is in line with the observed average charge (i.e., 0.0015).[10]

RISK TAKING AND FORBEARANCE—NUMERICAL RESULTS AND POLICY IMPLICATIONS

In this section, we will attempt to address the central question of this article: whether and how forbearance should be granted under moral hazard. To facilitate our understanding, we will first examine the implications of the bank's risk-taking behavior, particularly the impacts of the bank's decisions on the asset volatility, σ_A, the initial level of credit risk (captured by the correlation, ρ), and the extent of moral hazard (captured by β). After that, we will turn to the central issue of forbearance.

Bank's Risk-Taking Behavior and Its Implications for FDIC's Liabilities

Among the three risk parameters, σ_A, ρ, and β, σ_A and ρ capture the levels of interest rate risk and credit risk, while β reflects the extent of moral hazard. To examine the impacts of risk-taking behavior, we calculate the equity value and fair insurance premium under different parameter values and summarize the results in Tables 1–3. In each table, we examine three closure rules, namely, $\alpha = 1.0$, 0.98, and 0.96. Again, $\alpha = 1.0$ corresponds to prompt closures (i.e., no forbearance).

Interest Rate Risk. In Table 1, we vary the asset volatility between 0.00 and 0.07. The total equity value (with the heading "Sum") is broken down into "Equity Value" and

[10] Note that our setup calls for an iterative procedure to solve for the insurance premium since it is also an input in the drift of the asset value process. However, experiments show that the iterated value is very close to the approximate value by fixing p at 0.0015 in the drift. To reduce simulation time, we fix the premium at 0.0015 in the drift term of A.

TABLE 1
Impact of Asset Volatility on Equity Value and Fair Insurance Premium Under Alternative Closure Thresholds

Asset	Closure Threshold (α) = 1.0				Closure Threshold (α) = 0.98				Closure Threshold (α) = 0.96			
Volatility (σ_A)	Equity Value ($)	Charter Value ($)	Sum ($)	Fair Premium ($)	Equity Value ($)	Charter Value ($)	Sum ($)	Fair Premium ($)	Equity Value ($)	Charter Value ($)	Sum ($)	Fair Premium ($)
0.00	4.5643	3.2622	7.8265	0.0406	4.5650	3.2649	7.8299	0.0294	4.565	3.2649	7.8299	0.0294
0.01	4.5615	3.2706	7.8321	0.0035	4.5615	3.2708	7.8323	0.0026	4.5615	3.2708	7.8323	0.0026
0.02	4.5665	3.2667	7.8333	0.0202	4.5667	3.2673	7.8340	0.0189	4.5667	3.2673	7.8340	0.0192
0.03	4.5943	3.2266	7.8209	0.1983	4.5993	3.2360	7.8352	0.1643	4.5997	3.2374	7.8370	0.1592
0.04	4.6874	3.1251	7.8125	0.6745	4.7086	3.1537	7.8623	0.5733	4.7141	3.1641	7.8781	0.531
0.05	4.8582	3.0022	7.8604	1.3041	4.8967	3.0408	7.9375	1.1756	4.9111	3.0621	7.9731	1.0945
0.06	5.0873	2.8997	7.9870	1.9052	5.1328	2.9360	8.0688	1.7990	5.1628	2.9680	8.1308	1.6839
0.07	5.3562	2.8080	8.1642	2.4993	5.4126	2.8444	8.2570	2.4055	5.4538	2.8811	8.3348	2.2859

Note: This table reports the impact of the asset volatility. For each closure threshold we report the equity value derived from the bank's asset portfolio (i.e., call option value), the charter value, the sum of the two aforementioned, and the fair insurance premium. The market value of deposits is kept constant at $100, and the fair premium can therefore be interpreted as per $100 deposits. Values of all other parameters are given in the text ("Numerical Implementations" subsection).

TABLE 2
Impact of Initial Level of Credit Risk on Equity Value and Fair Insurance Premium Under Alternative Closure Thresholds

	Closure Threshold (α) = 1.0				Closure Threshold (α) = 0.98				Closure Threshold (α) = 0.96			
ρ	Equity Value ($)	Charter Value ($)	Sum ($)	Fair Premium ($)	Equity Value ($)	Charter Value ($)	Sum ($)	Fair Premium ($)	Equity Value ($)	Charter Value ($)	Sum ($)	Fair Premium ($)
0.95	4.5924	3.2355	7.8279	0.1579	4.5963	3.2431	7.8395	0.1304	4.5966	3.2439	7.8405	0.1285
0.90	4.5943	3.2266	7.8209	0.1983	4.5993	3.2360	7.8352	0.1643	4.5997	3.2374	7.8370	0.1592
0.85	4.5971	3.2174	7.8145	0.2398	4.6040	3.2286	7.8325	0.2000	4.6046	3.2305	7.8351	0.1915
0.80	4.6007	3.2081	7.8088	0.2821	4.6084	3.2205	7.8289	0.2394	4.6090	3.2224	7.8315	0.2296
0.75	4.6050	3.1985	7.8035	0.3262	4.6150	3.2129	7.8279	0.2759	4.6157	3.2149	7.8306	0.2664
0.70	4.6100	3.1901	7.8000	0.3654	4.6212	3.2072	7.8284	0.3043	4.6222	3.2096	7.8317	0.2934
0.65	4.6152	3.1793	7.7945	0.4144	4.6280	3.1981	7.8261	0.3474	4.6292	3.2013	7.8305	0.3341

Note: This table reports the impact of the credit risk parameter, ρ. For each closure threshold we report the equity value derived from the bank's asset portfolio (i.e., call option value), the charter value, the sum of the two aforementioned, and the fair insurance premium. The market value of deposits is kept constant at $100, and the fair premium can therefore be interpreted as per $100 deposits. Values of all other parameters are given in the text ("Numerical Implementations" subsection).

TABLE 3
Impact of Moral Hazard Parameter on Equity Value and Fair Insurance Premium Under Alternative Closure Thresholds

	Closure Threshold (α) = 1.0				Closure Threshold (α) = 0.98				Closure Threshold (α) = 0.96			
β	Equity Value ($)	Charter Value ($)	Sum ($)	Fair Premium ($)	Equity Value ($)	Charter Value ($)	Sum ($)	Fair Premium ($)	Equity Value ($)	Charter Value ($)	Sum ($)	Fair Premium ($)
0.00	4.5625	3.2673	7.8297	0.0165	4.5626	3.2679	7.8305	0.0141	4.5626	3.2679	7.8305	0.0141
5.00	4.5684	3.2599	7.8283	0.0480	4.5692	3.2620	7.8311	0.0408	4.5692	3.2620	7.8311	0.0409
10.00	4.5750	3.2513	7.8263	0.0861	4.5767	3.2559	7.8326	0.0696	4.5768	3.2561	7.8329	0.0690
15.00	4.5818	3.2420	7.8238	0.1278	4.5845	3.2481	7.8326	0.1056	4.5847	3.2487	7.8335	0.1039
20.00	4.5883	3.2338	7.8220	0.1651	4.5921	3.2417	7.8338	0.1364	4.5924	3.2428	7.8352	0.1331
25.00	4.5943	3.2266	7.8209	0.1983	4.5993	3.2360	7.8352	0.1643	4.5997	3.2374	7.8370	0.1592
30.00	4.6001	3.2196	7.8197	0.2305	4.6059	3.2292	7.8351	0.1970	4.6065	3.2310	7.8374	0.1900
35.00	4.6055	3.2128	7.8183	0.2619	4.6124	3.2232	7.8357	0.2262	4.6133	3.2252	7.8385	0.2174
40.00	4.6104	3.2075	7.8179	0.2867	4.6184	3.2190	7.8373	0.2476	4.6195	3.2211	7.8406	0.2377
45.00	4.6148	3.2028	7.8176	0.3089	4.6236	3.2154	7.8389	0.2662	4.6246	3.2177	7.8423	0.2565

Note: This table reports the impact of the moral hazard parameter, β. For each closure threshold we report the equity value derived from the bank's asset portfolio (i.e., call option value), the charter value, the sum of the two aforementioned, and the fair insurance premium. The market value of deposits is kept constant at $100, and the fair premium can therefore be interpreted as per $100 deposits. Values of all other parameters are given in the text ("Numerical Implementations" subsection).

"Charter Value," with the former being derived solely from the asset portfolio, or the value of the call option on the bank's assets. Table 1 reveals some striking patterns. To begin with, the equity value (or the call option value) goes down initially as the asset volatility increases, bottoms when σ_A is between 0.01 and 0.02, and then goes up. The charter value takes an opposite pattern. The effect on total equity is not clear. The fair insurance premium assumes the same pattern as the equity value. These effects are observed under all three closure thresholds.

Why are the equity value and fair insurance premium not monotonic in the asset volatility, contrary to previous studies? The answer lies in a well-known concept that has been largely neglected in the deposit insurance literature, viz., immunization. As discussed earlier, in a broader sense, a bank achieves immunization if the asset duration matches the deposit duration. However, as shown by Cox, Ingersoll, and Ross (1979), the duration of a fixed income instrument is equivalent to its return volatility. In an environment where all instruments depend on the same interest rate, two instruments immunize one another if their instantaneous return volatilities are equal. In our case, the deposit volatility is $\sigma_r(1 - e^{-k\tau})/k$, whose value is 0.0183 based on the parameters in the subsection "Numerical Implementations." Therefore, instantaneous immunization is achieved when σ_A is between 0.01 and 0.02.

Now we are in a position to explain the patterns. First of all, when the bank pursues immunization or hedges its interest rate risk, the values of assets and deposits move in sync, and the net worth (or equity value) remains more or less constant. As the asset and deposit durations deviate from one another, interest rate risk increases, which benefits the equity as a call option. This explains why the "Equity Value" is U-shaped with respect to asset volatility. As for the charter value, it is secure when the bank is immunized to interest rate risk, and at risk when durations are mismatched. This explains the humped pattern of charter value with respect to asset volatility. The case for the fair insurance premium is straightforward. When the bank completely hedges its interest rate risk by immunization, the FDIC's liability is the lowest because only the credit risk matters. As duration mismatch becomes more pronounced, the chance of insolvency increases, which in turn increases the FDIC's expected liability.

We have thus provided a potential explanation as to why banks do not take excessive risk in their asset portfolios; a question that has puzzled many researchers. As shown above, when the bank strives to maximize the equity value derived from both the asset portfolio and the charter value, a simple pursuit of higher asset volatility may actually be counterproductive. Depending on the risk management policies (i.e., duration policies) and the bank's perception of FDIC's forbearance practices, an optimal asset volatility may exist. This leads to a very important policy implication. Currently, the FDIC assesses and charges premiums based on risk classes. If "risk" is mainly defined as the asset return volatility, then significant over- or undercharge can occur. As Table 1 shows, a "low risk" bank (with an asset volatility close to zero) commands a higher premium than a relatively "risky" bank (with an asset volatility of 0.02).

Credit Risk. As discussed in the subsection "Characterization of Deposits, Assets, and Moral Hazard," the correlation between the asset and deposit returns captures the extent of credit risk. Specifically, the higher the correlation, the lower the credit risk. We vary ρ between 0.65 and 0.95, and report the results in Table 2.

It is observed that as the correlation moves away from unity (i.e., as credit risk increases), FDIC's expected liability increases under all closure thresholds. Naturally, as the bank takes more credit risk, the bank is seeking potentially higher returns while leaving potentially larger losses to the FDIC, owing to limited liability. As Table 2 shows, the increase in expected liability is substantial when credit risk increases.

As for the equity value, the call-option-like part of the equity (based on the asset portfolio) goes up and the charter value part goes down as the credit risk increases, which is what we would expect. The net result depends on the trade-off. When the charter value is small as part of the overall equity, banks will have an incentive to take higher credit risks.

Moral Hazard. Recalling from the subsection "Characterization of Deposits, Assets, and Moral Hazard," the moral hazard parameter β serves the purpose of "amplifying" the credit risk when the bank's net worth erodes. It follows that a higher β will have the same qualitative effect as a higher correlation, ρ. The results in Table 3 confirm this statement. We vary β between 0 and 45 and calculate similar quantities as in the previous two tables. When β is zero, moral hazard is absent.

It is seen that taking excessive credit risk may benefit the equity value due to limited liability, but will impair the charter value. When prompt closure is effected (i.e., $\alpha = 1.0$), a higher moral hazard parameter leads to a lower overall equity value. But, under other closure rules, a higher β is associated with a higher overall equity value due to the dominance of the asset portfolio's contribution. Conceivably, an optimal moral hazard position may exist for an individual bank, depending on both the trade-off between the call-option-like equity value and the charter value, and the overall risk taking policy of the bank.

It is interesting to observe that the impact of the moral hazard parameter on the fair insurance premium is far more significant than that on the equity value and charter value. This suggests that even if the bank engages in very light undue risk taking (by the bank's own standard), the potential liability for the FDIC can increase significantly.

Taken together, the results so far suggest that it is in the bank's interest to engage in undue risk taking. The next question is, given the bank's risk-taking behavior, how should the FDIC formulate its forbearance and capital requirement policies? We will turn to this question in the next section.

FDIC's Forbearance Policies and Fair Insurance Premium

Should the FDIC forbear at all, given the bank's risk-taking behavior? If the answer is yes, then additional questions need to be addressed. For example, when forbearance is granted, at what level should the FDIC set the closure threshold? How frequent should the interim audits be during forbearance? How long should the FDIC allow the bank to operate? How sensitive is the FDIC's expected liability to the bank's capital position?

Optimal Closure Rules. Here we attempt to answer two questions: (1) Should forbearance be granted? (2) When should forbearance be granted? Many studies have examined the merit of forbearance but very few give guidelines as to *when* forbearance should be granted. Although it is implied in some studies (e.g., Fries, Mella-Barral, and Perraudin, 1997) that the existence of deadweight loss may justify forbearance, it is not known what level of deadweight loss warrants forbearance. Moreover, when banks are found to be insolvent, it is conceivable that the degree of insolvency will vary. Some banks may have a net worth very close to zero while others' may be significantly negative. Meanwhile, one aspect of the FDICIA is to set a positive capital level as the trigger for prompt corrective actions. It would be extremely useful for the FDIC to have some guidance when relating forbearance decisions to insolvency or undercapitalization conditions.

To shed some light on the above issues, we perform the following simulations. We set the current time to the time at which a regular audit has just been conducted, and assume that the bank is found to be either insolvent or critically undercapitalized. The FDIC must decide at this point whether to grant forbearance. When the capital ratio c is positive and higher than or equal to the deadweight loss rate, γ, the decision is obvious: close the bank. For all other cases, if the bank is closed promptly, then the FDIC's immediate liability is $D_M - A + \gamma A$, where γA represents the deadweight loss; if forbearance is granted, then the FDIC does not face any immediate liability, but does face the expected liability of a potential closure during the forbearance period. If the bank recovers, then the FDIC will have avoided both the deadweight loss and the refund to depositors. Clearly, the decision should be based on the comparison between the immediate liability and the expected liability. We assume that the maximum forbearance period is always 6 months with eight interim audits. We compare the liabilities for different levels of deadweight losses and capital ratios. For brevity, we report what is called "percentage cost savings due to forbearance," which is calculated as $[(p_c - p_f)/p_c] \times 100\%$, where p_c and p_f are the immediate and expected liabilities, respectively. In addition, we set the closure threshold during the forbearance period at 0.90, so that a severely insolvent bank (with, say, a capital ratio of -0.10) will not be closed right away when forbearance is granted. The results are summarized in Table 4.[11]

As expected, when the deadweight loss is very low (0.00 or 0.01), the FDIC is best to close distressed banks regardless of the degree of insolvency. However, as the deadweight loss goes up, interesting patterns start to emerge. With a deadweight loss rate of 0.02, the FDIC is still better off by closing distressed banks, except when the net worth is zero. With a deadweight loss rate of 0.03 or 0.04, the FDIC is better off by closing only those insolvent banks with a capital ratio lower than -0.01. The above results make intuitive sense. For insolvent banks, the chance of recovery is higher when the insolvency is not severe; for undercapitalized banks, forbearance is desirable (except for the combination of $c = 0.01$ and $\gamma = 0.02$) not only because the chance of recovery is better, but also because the immediate "fire sale" loss is high (if foreclosure is imposed) due to a larger asset base.

[11] Please note that when the bank is found to be undercapitalized (with a capital ratio of 0.01 or 0.02), the resolution at the end of the forbearance period is different from that when the bank is insolvent. The latter follows the criterion ($A > D_M$) set out in the subsection "Valuing Bank Equity." For the former case, the criterion is $A > (1 + c)D_M$, in order to be consistent with the notion that c is the critical capitalization level.

TABLE 4
Optimal Closure Rule for Different Combinations of Capital Ratio and Deadweight Loss

Deadweight Loss Ratio (γ)	Percentage Cost Savings (%) Due to Forbearance for Different Capital Ratios												
	0.02	0.01	0.00	−0.01	−0.02	−0.03	−0.04	−0.05	−0.06	−0.07	−0.08	−0.09	−0.1
0.00	$-\infty$	$-\infty$	$-\infty$	−37.61	−15.75	−10.13	−7.48	−5.90	−4.85	−4.09	−3.49	−2.90	−2.09
0.01	$-\infty$	$-\infty$	−17.07	−10.17	−8.15	−6.24	−4.91	−4.01	−3.38	−2.89	−2.50	−2.09	−1.51
0.02	$-\infty$	−12.22	14.87	−1.02	−4.35	−3.90	−3.20	−2.67	−2.27	−1.96	−1.71	−1.43	−1.02
0.03	6.41	18.06	25.51	3.56	−2.06	−2.35	−1.98	−1.66	−1.42	−1.22	−1.06	−0.88	−0.61
0.04	22.25	28.15	30.84	6.30	−0.54	−1.23	−1.06	−0.88	−0.73	−0.61	−0.52	−0.41	−0.26
0.05	31.80	33.20	34.03	8.13	0.54	−0.40	−0.35	−0.25	−0.17	−0.11	−0.06	−0.01	0.04
0.06	36.57	36.22	36.16	9.44	1.36	0.25	0.22	0.27	0.30	0.32	0.33	0.33	0.31
0.07	39.44	38.24	37.68	10.42	1.99	0.77	0.69	0.69	0.69	0.69	0.67	0.64	0.54
0.08	41.35	39.68	38.82	11.18	2.50	1.19	1.08	1.06	1.03	1.01	0.97	0.90	0.75
0.09	42.71	40.76	39.71	11.79	2.91	1.55	1.41	1.37	1.33	1.29	1.23	1.14	0.94
0.10	43.74	41.60	40.42	12.29	3.26	1.85	1.69	1.64	1.58	1.53	1.47	1.35	1.11
0.11	44.53	42.28	41.00	12.70	3.55	2.10	1.93	1.87	1.81	1.75	1.67	1.54	1.26
0.12	45.17	42.83	41.48	13.06	3.80	2.33	2.15	2.08	2.01	1.95	1.86	1.72	1.4
0.13	45.69	43.29	41.89	13.36	4.02	2.52	2.34	2.26	2.19	2.12	2.03	1.87	1.52
0.14	46.12	43.67	42.24	13.62	4.21	2.69	2.51	2.43	2.36	2.28	2.19	2.02	1.64
0.15	46.49	44.01	42.55	13.85	4.38	2.85	2.66	2.58	2.5	2.43	2.33	2.15	1.74
0.20	47.72	45.15	43.61	14.66	4.99	3.41	3.22	3.14	3.07	2.99	2.88	2.67	2.17
0.25	48.41	45.81	44.25	15.17	5.37	3.77	3.59	3.52	3.45	3.38	3.27	3.04	2.47
0.3	48.85	46.24	44.68	15.51	5.64	4.03	3.85	3.79	3.73	3.66	3.55	3.31	2.7
Asset	102.04	101.01	100.000	99.010	98.039	97.087	96.154	95.238	94.34	93.458	92.593	91.743	90.909

Note: This table illustrates the optimal closure rule for distressed banks under different combinations of capital ratio and the deadweight loss rate. The capital ratio is measured by the proxy, $(A - D_M)/A$, where A and D_M stand for, respectively, the market values of assets and deposits. The percentage cost savings is calculated as follows. First, for each combination of the capital position and deadweight loss rate, we calculate the total liability of immediate closure, which is the sum of the negative net worth and the deadweight loss. Denote this sum by p_c. Then for the same combination, we calculate the expected liability or fair premium if forbearance of 6-month (with eight times of monitoring) is granted. Denote this quantity by p_f. The percentage cost savings is $100\% * (p_c - p_f)/p_c$. A positive entry indicates that forbearance would lead to savings for the FDIC. When varying the capital ratio, we keep D_M at \$100 and adjust A whose values are reported in the last row. The closure threshold is set at 0.90 for all cases. Values of all other parameters are given in the text ("Numerical Implementations" subsection).

With a loss rate of 0.05, we observe even more interesting patterns. In this case, the benefit of forbearance becomes smaller as the negative net worth worsens; when the capital ratio is between −0.03 and −0.09, the benefit of forbearance completely disappears, and prompt closure is preferred; but when the capital ratio goes beyond −0.09, forbearance is again preferred. This is due to the trade-off of two opposing effects. On one hand, as the capital ratio becomes more negative, the total liability in dollar terms increases, leading to a bigger savings potential from forbearance. On the other hand, a more negative capital ratio or larger negative net worth makes recovery less likely. It so happens that this trade-off creates a roughly U-shaped pattern for the percentage cost savings. Similar patterns also exist for a loss rate of 0.06, although forbearance is preferred for all capital ratios. For deadweight loss rates higher than 0.06, forbearance is again desirable for all capital ratios. Furthermore, the percentage savings go down as the capital position becomes worse. It is seen that when the deadweight loss rate is above 0.1 (the empirical observation by James, 1991), the percentage savings are more than 12 percent as long as the capital ratio is no less than −0.01.

Table 4 clearly demonstrates that forbearance is indeed desirable in certain situations. It is definitely advisable for undercapitalized banks. For insolvent banks, it is desirable when the deadweight loss rate is high or when the insolvency is less severe, or both. Given the significant asset losses associated with bank closures documented by James (1991), and given that a failing bank's capital ratio is unlikely to be too low, thanks to the 1991 FDICIA policy of prompt actions, Table 4 suggests that forbearance is a desirable course of action most of the time.

Having established the usefulness of forbearance, we now turn to the secondary question of how forbearance should be granted. From this point on, we will assume the regular settings as outlined in the subsection "Numerical Implementations." In other words, we assume that the bank has just passed the last audit, and that the next audit is 1 year from now. If the bank is found to be insolvent in a year's time, a 6-month forbearance period will be granted.

Closure Threshold and Monitoring Frequency During Forbearance. Here we vary the closure threshold between 0.88 and 1.00 and the monitoring frequency between 1 and 32 times during the 6-month forbearance period. The results are summarized in Table 5. Hereafter, we will report only the sum of the charter value and the equity value due to the asset portfolio or the call option value. We will call the sum "equity value."

To begin with, we observe that the fair premium under a closure threshold of 1 is higher than those under other closure thresholds for all monitoring frequencies. This simply corroborates our findings in Table 4 that forbearance is indeed desirable. In addition, we observe that, for all monitoring frequencies, there appears to be an optimal closure threshold between 0.94 and 0.96. At that optimal forbearance level, the FDIC's expected liability is the lowest. To understand this, realize that, at a particular monitoring frequency and as the closure threshold is relaxed, the bank will have a better chance to recover, allowing the FDIC to avoid paying liabilities. But, as the closure threshold is further relaxed, the chance of recovery will not improve dramatically since the asset value may have dropped significantly below that of the deposits, yet the FDIC's liability will be greater if closure occurs. When the closure threshold

TABLE 5
Fair Insurance Premium and Equity Value Under Alternative Combinations of Closure Threshold and Monitoring Frequency During Forbearance

Monitoring Frequency (n)	Closure Threshold (α) 1	0.99	0.98	0.96	0.94	0.92	0.90	0.88
				Fair Premium ($)				
1	0.1983	0.1666	0.1619	0.1593	0.1595	0.1595	0.1595	0.1595
2	0.1983	0.1709	0.1628	0.1598	0.1594	0.1596	0.1595	0.1595
4	0.1983	0.1745	0.1641	0.1593	0.1594	0.1596	0.1595	0.1595
8	0.1983	0.1780	0.1643	0.1592	0.1594	0.1596	0.1595	0.1595
16	0.1983	0.1814	0.1654	0.1591	0.1593	0.1596	0.1595	0.1595
32	0.1983	0.1843	0.1673	0.1590	0.1592	0.1596	0.1595	0.1595
				Equity Value ($)				
1	7.8209	7.8340	7.8361	7.8372	7.8372	7.8372	7.8372	7.8372
2	7.8209	7.8327	7.8357	7.8370	7.8372	7.8372	7.8372	7.8372
4	7.8209	7.8314	7.8353	7.8370	7.8372	7.8372	7.8372	7.8372
8	7.8209	7.8303	7.8352	7.8370	7.8372	7.8372	7.8372	7.8372
16	7.8209	7.8288	7.8350	7.8370	7.8372	7.8372	7.8372	7.8372
32	7.8209	7.8277	7.8344	7.8370	7.8372	7.8372	7.8372	7.8372

Note: This table reports the impact of the FDIC's decision variables, namely, the closure threshold and monitoring frequency during the forbearance period. For each combination of the two variables, we report the fair insurance premium per $100 deposits and the total equity value (i.e., the sum of the charter value and the equity value derived from the asset portfolio or the call option value). Values of all other parameters are given in the text ("Numerical Implementations" subsection). Note that a closure threshold of 1.0 corresponds to prompt closure.

is below a critical level (e.g., 0.88), lowering the threshold further will not have any material impact on the equity value and the insurance premium, since the probability of the asset value dropping below the critical level is virtually zero. This suggests that if the FDIC decides to forbear, it should carefully choose a closure threshold. Too high a threshold will unnecessarily increase the expected liability, while too low a threshold is either meaningless or equivalent to having no threshold.

Equity value increases as more lenient forbearance is granted. However, when the closure threshold is 0.94 or lower, the equity value ceases to respond. When the assets start off five per cent above the deposits and when the average asset volatility is not very high (0.03), there is little chance for the asset value to drop far below that of the deposits. A closure threshold of, say, 0.88 is as lenient as a threshold of zero.

As for the monitoring frequency, frequent audits increase the expected liability and decrease the equity value in most cases. This is to be expected. When the bank is under more frequent monitoring, the chance of being closed before reaching the end of the forbearance period increases, which is detrimental to the equity value. For the FDIC's expected liabilities, the impact of having frequent audits and enforcing early closures is a result of subtle trade-offs. On the one hand, a higher monitoring frequency has the advantage of avoiding disasters by detecting problems early; on the other hand, early closures also take away the chance for a distressed bank to recover, causing the FDIC to face liabilities, which it may otherwise avoid. Whether frequent monitoring will reduce FDIC's expected liability depends on the trade-off of the two opposing effects. Apparently, when the closure threshold is high, the latter effect always outweighs the former. With a closure threshold of 0.96, the former seems to outweigh the latter in most cases. Had we assumed an audit cost, a higher monitoring frequency would clearly have been unsupported.

We can conclude from Table 5 that, as long as the deadweight loss is not negligible, forbearance will be a Pareto optimal decision. Once forbearance is granted, an aggressive re-enforcement of closures will not necessarily save potential liabilities, although frequent monitoring can still benefit the FDIC in terms of supervision and risk control.

Maximum Length of Forbearance. As has been discussed, our framework utilizes a stochastic forbearance period in that the bank is closed whenever the asset value drops below a fraction of the deposit value. The FDIC must nonetheless specify a maximum forbearance period during which the bank is allowed to recover. It is of interest to analyze if and to what extent the maximum length is related to the expected liability. To this end, we vary the forbearance length, T_f, while keeping the length of interim audits constant, which is achieved by varying the monitoring frequency accordingly. The regular audit is always a year from now, as in previous tables. To conserve space, we will omit the table and only report the key results below.

It turns out that for all closure thresholds, there exists an optimal length of forbearance: 0.5 year. The expected liability is the lowest when the forbearance period is 0.5 year. This finding could help the FDIC to develop a meaningful policy regarding the length of forbearance.

As far as the equity value is concerned, 0.5 year also appears to benefit the bank the most. For a given closure threshold, the hump-shaped relationship between the equity value and the forbearance period is due to a complex trade-off between the impacts of a longer forbearance period and more interim audits. As the forbearance period increases, the equity value due to the asset portfolio would benefit since it behaves like a call option. However, because we are keeping a constant monitoring interval, a longer forbearance period means more interim audits and potentially early closures, which will hurt both the option-like equity value and the charter value. When forbearance period initially increases from zero, the benefit of having a longer maturity for the call option outweighs the drawback of more audits, hence the total equity value increases. But when the forbearance period is longer than 0.5 year, the drawback from more audits outweights the benefit of a longer maturity for the call option, hence the total equity value decreases.

Capital Adequacy. It has been realized in the literature (e.g., Pyle, 1986; Ronn and Verma, 1989) that capital regulation and the charging of fair insurance premiums should be integrated endeavors. In our framework, we need to examine two issues: (1) How sensitive is the fair premium to the capital ratio defined as the net worth over the asset value $(A - D_M)/A$? (2) Is capital requirement an effective measure to mitigate the effect of moral hazard?

Table 6
Impact of Capital Ratio on Fair Insurance Premium Under Alternative Closure Thresholds

Closure	Capital Ratio: $(A - D_M)/A$									
Threshold (α)	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
Panel A: Fair Premium ($) With Moral Hazard										
1.00	3.6333	1.9857	1.0243	0.4705	0.1983	0.0729	0.0293	0.0114	0.0039	0.0014
0.99	3.3400	1.7999	0.9232	0.4174	0.1780	0.0663	0.0267	0.0113	0.0031	0.0015
0.98	3.1414	1.6700	0.8383	0.3816	0.1643	0.0606	0.0263	0.0106	0.0032	0.0015
0.96	3.0601	1.6052	0.8037	0.3703	0.1592	0.0602	0.0255	0.0108	0.0033	0.0015
0.94	3.0463	1.5982	0.8021	0.3710	0.1594	0.0606	0.0255	0.0107	0.0033	0.0015
Panel B: Fair Premium ($) Without Moral Hazard										
1.00	4.0543	1.7633	0.5467	0.1118	0.0165	0.0009	0.0000	0.0000	0.0000	0.0000
0.99	3.7099	1.5643	0.4670	0.0968	0.0146	0.0004	0.0000	0.0000	0.0000	0.0000
0.98	3.5815	1.5107	0.4474	0.0949	0.0141	0.0004	0.0000	0.0000	0.0000	0.0000
0.96	3.5528	1.4994	0.4454	0.0945	0.0141	0.0004	0.0000	0.0000	0.0000	0.0000
0.94	3.5500	1.4985	0.4453	0.0945	0.0141	0.0004	0.0000	0.0000	0.0000	0.0000

Note: This table reports how capital ratio affects the fair insurance premium under different closure thresholds. We report the fair insurance premium per $100 deposits. The capital ratio is measured by the proxy, $(A - D_M)/A$, where A and D_M stand for, respectively, the market values of assets and deposits. Values of all other parameters are given in the text ("Numerical Implementations" subsection). Note that a closure threshold of 1.0 corresponds to prompt closure. The variation of capital ratio is achieved by varying A while keeping D_M constant at $100. The moral hazard parameter β is set to 25 in Panel A and 0 in Panel B.

The insurance premium's sensitivity to the capital ratio directly determines the effectiveness of capital requirements in reducing FDIC's overall liabilities. If the sensitivity is low, the FDIC should focus on policy instruments other than capital regulations. If the sensitivity is extremely high, then capital regulation should be the foremost focus. To shed light on this issue, we calculate the fair insurance premium for a wide range of capital ratios (i.e., $0.01 \sim 0.10$) and different closure thresholds. We investigate two separate cases: with moral hazard and without moral hazard. The results are summarized in Table 6. We first examine Panel A for the case with moral hazard.

To begin with, lower premiums are associated with higher capital ratios, and a low closure threshold generally leads to lower premiums. More importantly, the fair insurance premium is extremely sensitive to the capital ratio, and it can be very high even when the capital ratio is not very low. With a closure threshold of 0.94, for instance, a one-percentage-point drop in the capital ratio from an initial position of 0.05 will more than double the premium (from 15.94¢ to 37.10¢). To see the significant size of fair premiums, for a capital ratio of 0.03, the fair premium is 102.43¢ for every $100 deposits assuming the absence of forbearance.

The above observations have some profound policy implications for the FDIC. For one thing, the FDIC should not simply focus on banks' asset portfolio risk in setting the insurance premium. If we compare the results in Panel A of Table 6 with those in

Tables 2 and 3, we would infer that capital ratio is at least as important as, if not more important than, the asset risk.

Another implication concerns the fair pricing of deposit insurance. If the prevailing average capital ratio is indeed around 0.05, then we can easily determine if the current premium schedule is adequate or justifiable. Based on our model parameters, we see that the premium ranges from 15.94¢ to 19.83¢ per $100 deposits when the capital ratio is 0.05. Assuming the absence of forbearance ($\alpha = 1.0$), the fair premium would be 19.83¢, lower than the highest charge currently in place (27¢). On the surface, the range is compatible with the current premium range of 0¢ to 27¢. But it should be realized that the vast majority of the banks in the United States are currently paying an annual premium close to zero. The average premium levy across the banking sector is much lower than, say 19.83¢. We could then argue that FDIC is undercharging members of the Bank Insurance Fund. Additionally, we must also consider the impact of potential variations in the capital ratio between audits. To again use the above illustration, if the capital ratio of a particular bank is 0.05 at the time of audit, but changes to 0.04 subsequently, then the fair levy should have been 47.05¢ instead of 19.83¢—twice more than the levied amount. Had we set the asset volatility higher than 0.03 (which is used for Table 6), this result would have been even more dramatic, suggesting that the schedule currently employed by the FDIC is far from being adequate; it at least does not have a wide enough range. In this regard, our results are perfectly consistent with those in Benston and Kaufman (1997).

The results in Panel A of Table 6 also indicate that the FDIC should exercise care when estimating the capital ratio of a bank for the purpose of assessing deposit insurance premiums. As illustrated above, a 1 percent misestimation of the capital ratio can lead to significant premium errors.[12] Our findings corroborate those of some previous studies. For example, Gjerde and Seman (1995) studied the relationship between risk-based capital and bank portfolio risk after the enactment of the 1991 FDICA. They found that risk-based capital is a superior mechanism only when equity is constrained and the risk weights are optimal. Relying on the risk-based capital standard, Jones and King (1995) found that the vast majority of insolvent banks from 1984 through 1989 would not have been considered undercapitalized and, therefore, would not have been subject to mandatory corrective actions. They recommended the inclusion of loan loss reserves and credit risk of problem assets in determining the risk weights. These studies indicate that capital must be estimated and measured with extreme care.

We now turn to the issue of capital requirements versus moral hazard. Specifically, we would like to know if capital requirements can adequately compensate the additional liability that the FDIC faces as a result of banks' excessive risk taking. To this end, we repeat the calculations in Panel A by setting the moral hazard parameter, β to zero, and report the results in Panel B of Table 6. (Recall that $\beta = 0$ corresponds to

[12] Please note that the FDIC classifies banks into three capital categories according to their capitalization. Given that certain assets have either a zero weight (such as cash and marketable securities) or a fractional weight (such as mortgages), and given that our definition of capital ratio covers more or less only tier-one capital, a capital ratio of 0.05 is quite close to reality, and a capital ratio of 0.04 is probable.

the absence of moral hazard.) Comparing the results in the two panels, it is seen that the presence of moral hazard can substantially increase the potential liability for the FDIC. The increase becomes less pronounced as the capital ratio decreases.[13] The impact of moral hazard is striking for capital ratios around 0.05. When moral hazard is absent, for example, the premium is between 1.41¢ and 1.65¢ per $100 deposits with a capital ratio of 0.05 (Panel B). With moral hazard, to keep the same magnitude of premiums, the capital ratio would have to be close to 0.08 (Panel A). An immediate implication is that, the FDIC must increase the capital requirement substantially in order to compensate itself for bearing the additional risk brought on by moral hazard. Given that banks' risk-weighted capital tends to vary within only a narrow range (to comply with the minimum 8 percent requirement per the Basle Accord), it appears that using capital requirements to combat moral hazard may be difficult to implement. Other measures like asset portfolio restrictions may be more effective. This is consistent with the findings of Mazumdar and Yoon (1996).

SUMMARY AND CONCLUSIONS

We use the real options approach to study the efficacy of forbearance under the assumption that insured banks can engage in undue risk taking. Our study contributes to the literature in both theoretical modeling and policy implications.

On the theoretical level, the key contribution lies in the innovative modeling of moral hazard. Specifically, using the insights of duration and immunization, we model a bank's overall interest rate risk as duration mismatch. Realizing that banks tend to hedge most of the interest rate risk, we treat credit risk as the main focus in risk taking. We then postulate a novel setup of the correlation between the assets and the deposits such that the level of risk taking is linked to the net worth of the bank. This setup amounts to endogenous moral hazard. In modeling stochastic interest rates and stochastic deposits, we avoid the commonly employed and restrictive assumption that all deposits mature at the next audit. Instead, we allow the total amount of deposits to grow or shrink with a constant, rolling maturity. We also allow interest to be paid on a continuous basis. In modeling forbearance, we allow a stochastic forbearance period in that the FDIC has the option to close the bank whenever the capital ratio (as opposed to the asset value per se) reaches a predetermined level. In our model, the FDIC has several policy variables to manipulate: the closure threshold or minimum capital ratio, the monitoring frequency, and the maximum length of forbearance. These variables represent the FDIC's flexibility in implementing closure rules. Insofar as flexibility represents real options, our setup makes the real options approach a perfect choice for analysis.

On the practical level, our numerical analyses lead to several useful insights and policy implications. First, we demonstrate that it is indeed in the bank's interest to engage in undue risk taking. Even in the presence of moral hazard, forbearance can still be

[13] As a matter of fact, when the capital ratio is 0.01, the presence of moral hazard helps reduce the fair insurance premium. Intuitively, when the capital ratio is low or when the bank's net worth is close to zero, "doing nothing" will unlikely revive the banks and prompt closure will surely lead to an immediate liability due to the 10 percent "fire sale" loss. However, when the asset portfolio's credit risk is increased, the chance of recovery is enhanced, which leads to the expected savings in FDIC's liabilities.

a desirable course of action upon detecting undercapitalization or insolvency as long as there are nonnegligible costs in closure such as a loss in asset value due to "fire sales." James (1991) reported a direct closure cost of around 10 percent of fair assets value. In our model, with realistic parameter values we find that forbearance becomes desirable when the closure cost is higher than 6 percent of fair asset value. The less severe the insolvency, the more preferred is the choice to forbear. As far as we know, this is the first study that numerically demonstrates when forbearance is warranted.

Second, we find that choosing the right closure threshold is very important. Too stringent a closure threshold will lead to a higher expected liability while too low a threshold will not serve any purpose. Generally, a more lenient forbearance will lead to a lower expected liability, although based on our parameter values, an optimal threshold between 0.94 and 0.96 seems to exist for most monitoring frequencies (recalling that a closure threshold is defined as the ratio of the assets value over the deposits value). As for monitoring frequency, it is found that more frequent audits together with re-enforced early closures generally lead to a higher liability, especially when the closure threshold is high. If audit costs are considered, more frequent audits will lead to an even higher liability. The maximum length of forbearance has an interesting implication for the fair premium: for almost all closure thresholds, there exists an optimal forbearance period of 6 months. This in turn has some important implications for the FDIC. Too short or too long a forbearance period will be counterproductive.

Third, the level of expected liability or fair insurance premium is very sensitive to the capital ratio, which implies that the FDIC should ensure that banks meet their capital requirements. Any slight deficiency can impose a significant amount of excess liability on the FDIC. Meanwhile, due to the strong impact of moral hazard, a wide range of capital requirements may be necessary should the FDIC use capital as the only tool to compensate for the risk it bears. Given that the risk-weighted capital of most banks tends to be within a narrow range (in the upper neighborhood of 8 percent in accordance with the Basle Accord), it may be difficult to dramatically increase capital requirements. Other measures such as portfolio restrictions may be desirable.

Fourth, thanks to a key feature of our model—measuring a bank's interest rate risk by its duration mismatch instead of the asset variance per se—we have offered an explanation as to why banks do not maximize their asset portfolio's risk to take advantage of limited liabilities, as early studies (e.g., Merton, 1977; Ronn and Verma, 1986) have predicted. We find that, depending on the bank's duration policy, it is sometimes even in the bank's best interest to lower the asset return volatility. The key to the puzzle is the degree of immunization and the trade-off between the equity value and the charter value. Charter value is maximized when the bank is perfectly immunized, but the part of the equity resembling a call option has the lowest value at the prefect immunization point. Since banks are never perfectly immunized and operate with different strategies, it is conceivable that each bank has its own "optimal" level of average asset variance.

In summary, by introducing several key elements, our study extends and supplements the existing studies by making the model more realistic. In addition to having justified forbearance under moral hazard from an economic point of view (i.e., cost saving), we have also drawn other conclusions that bear policy implications for both the FDIC and the administration of the insurance guaranty funds.

REFERENCES

Acharya, S., and J.-F. Dreyfus, 1989, Optimal Bank Reorganization Policies and the Pricing of Federal Deposit Insurance, *Journal of Finance*, 54(5): 1313-1333.

Allen, L., and A. Saunders, 1993, Forbearance and Valuation of Deposit Insurance as a Callable Put, *Journal of Banking and Finance*, 17: 629-643.

Babble, D. F., and A. M. B. Hogan, 1992, Incentive Conflicts and Portfolio Choice in the Insurance Industry, *Journal of Risk and Insurance*, 59(4): 645-654.

Benston, G., and G. Kaufman, 1997, FDICIA After Five Years: A Review and Evaluation, Federal Reserve Bank of Chicago, Working paper series (WP97-1).

Bond, E. W., and K. J. Crocker, 1993, Bank Capitalization, Deposit Insurance, and Risk Categorization, *Journal of Risk and Insurance*, 60(4): 547-569.

Boyle, P., and I. Lee, 1994, Deposit Insurance With Changing Volatility: An Application of Exotic Options, *Journal of Financial Engineering*, 3(3/4): 205-227.

Chan, K. C., A. Karolyi, F. Longstaff, and A. Sanders, 1992, An Empirical Comparison of Alternative Models of the Short-Term Interest Rates, *Journal of Finance*, 47(3): 1209-1227.

Cooper, R., and T. W. Ross, 1999, Public and Private Guarantee Funds With Market Fragility, *Journal of Risk and Insurance*, 66(2): 163-184.

Cox, J. C., J. E. Ingersoll Jr., and S. Ross, 1979, Duration and the Measurement of Basis Risk, *Journal of Business*, 52(1): 51-61.

Cox, J., J. Ingersoll, and S. Ross, 1985a, A Theory of the Term Structure of Interest Rates, *Econometrica*, 53: 385-408.

Cox, J., J. Ingersoll, and S. Ross, 1985b, An Intertemporal General Equilibrium Model of Asset Prices, *Econometrica*, 53(March): 363-384.

Dixit, A. K., and R. S. Pindyck, 1994, *Investment Under Uncertainty* (Princeton, NJ: Princeton University Press).

Downs, D. H., and D. W. Sommer, 1999, Monitoring, Ownership, and Risk-Taking: The Impact of Guaranty Funds, *Journal of Risk and Insurance*, 66(3): 477-497.

Dreyfus, J.-F., A. Saunders, and L. Allen, 1994, Deposit Insurance and Regulatory Forbearance: Are Caps on Insured Deposits Optimal?, *Journal of Money, Credit, and Banking*, 26(3): 412-438.

Duan, J.-C., and J. W. Sealey, 1995, Deposit Insurance and Bank Interest Rate Risk: Pricing and Regulatory Implications, *Journal of Banking and Finance*, 19(6): 1091-1108.

Duan, J.-C., and M.-T. Yu, 1994, Forbearance and Pricing Deposit Insurance in a Multiperiod Framework, *Journal of Risk and Insurance*, 61(4): 575-591.

Eisenbeis, R. A., and P. M. Horvitz, 1994, The Role of Forbearance and Its Costs in Handling Troubled and Failed Depository Institutions, in: G. G. Kaufman, ed., *Reforming Financial Institutions and Markets in the United States* (Boston: Kluwer Academic Publishers).

Epps, T. W., L. B. Pulley, and D. B. Humphrey, 1996, Assessing the FDIC's Premium and Examination Policies Using 'Soviet' Put Options, *Journal of Banking and Finance*, 20: 699-721.

Feldhaus, W. R., and P. M. Kazenski, 1998, Risk-Based Guaranty Fund Assessments, *Journal of Insurance Regulations*, 17: 42-63.

Fries, S., P. Mella-Barral, and W. Perraudin, 1997, Optimal Bank Reorganization and the Fair Pricing of Deposit Guarantees, *Journal of Banking and Finance*, 21: 441-468.

Furlong, F. T., and M. C. Keeley, 1989, Capital Regulation and Bank Risk Taking: A Note, *Journal of Banking and Finance*, 13: 883-891.

Galloway, T. M., W. B. Lee, and D. M. Roden, 1997, Bank's Changing Incentives and Opportunities for Risk Taking, *Journal of Banking and Finance*, 21: 509-527.

Gennotte, G., and D. Pyle, 1991, Capital Controls and Bank Risk, *Journal of Banking and Finance*, 15: 805-824.

Gjerde, O., and K. Semmen, 1995, Risk Based Capital Regulation and Bank Portfolio Risk, *Journal of Banking and Finance*, 19: 1159-1173.

Harrison, J. M., and D. M. Kreps, 1979, Martingales and Arbitrage in Multiperiod Securities Markets, *Journal of Economic Theory*, 20: 381-408.

Hutchison, D. E., and G. G. Pennacchi, 1996, Measuring Rents and Interest Rate Risk in Imperfect Financial Markets: The Case of Retail Bank Deposits, *Journal of Financial and Quantitative Analysis*, 31(3): 399-417.

James, C., 1991, The Losses Realized in Bank Failures, *Journal of Finance*, 46: 1223-1242.

Jones, D., and K. King, 1995, The Implementation of Prompt Corrective Action: An Assessment, *Journal of Banking and Finance*, 19(3-4): 491-510.

Kahane, Y., 1977, Capital Adequacy and the Regulation of Financial Intermediaries, *Journal of Banking and Finance*, 1: 207-218.

Kane, E. J., 1986, Appearance and Reality in Deposit Insurance Reform: The Case for Reform, *Journal of Banking and Finance*, 10: 175-188.

Kaufman, G. G., 1992, Some Shortcomings of Analyzing Deposit Insurance as a Put Option: A Communication, *Journal of Financial Engineering*, 1(3): 376-383.

Keeley, M. C., 1990, Deposit Insurance, Risk, and Market Power in Banking, *American Economic Review*, 80: 1183-1200.

Keeley, M. C., and F. T. Furlong, 1990, A Reexamination of Mean-variance Analysis of Bank Capital Regulation, *Journal of Banking and Finance*, 14(1): 69-84.

Kim, D., and A. M. Santomero, 1988, Risk in Banking and Capital Regulation, *Journal of Finance*, 35: 1219-1233.

Klein, R. W., and M. M. Barth, 1995, Solvency Monitoring in the Twenty-First Century, *Journal of Insurance Regulation*, 13: 256-301.

Koehnm, M., and A. M. Santomero, 1980, Regulation of Bank Capital and Portfolio Risk, *Journal of Finance*, 35: 1235-1244.

Kwan, S., 1991, Re-examination of Interest Rate Sensitivity of Commercial Bank Stock Returns Using a Random Coefficient Model, *Journal of Financial Services Research*, 5(1): 61-76.

Marcus, A. J., 1984, Deregulation and Bank Financial Policy, *Journal of Banking and Finance*, 8: 557-565.

Mason, J., 2002, A real Options Appraoch to Bankruptcy Costs: Evidence From Failed Commercial Banks During the 1990s, Drexel University Working Paper.

Mazumdar, S. C., and S. H. Yoon, 1996, Loan Monitoring, Competition, and Socially Optimal Bank Capital Regulations, *Journal of Risk and Insurance*, 63(2): 279-312.

Merton, R., 1977, An Analytic Derivation of the Cost of Deposit Insurance and Loan Guarantees, *Journal of Banking and Finance*, 1: 3-11.

Pennacchi, G. G., 1987a, Alternative Forms of Deposit Insurance, Pricing and Bank Incentive Issues, *Journal of Banking and Finance*, 11: 291-312.

Pennacchi, G. G., 1987b, A Reexamination of the Over- (or Under-) Pricing of Deposit Insurance, *Journal of Money, Credit, and Banking*, 19(3): 340-360.

Pyle, D. H., 1986, Capital Regulation and Deposit Insurance, *Journal of Banking and Finance*, 10: 189-201.

Ritchken, P., J. B. Thomson, R. P. DeGennaro, and A. Li, 1993, On Flexibility, Capital Structure and Investment Decisions for the Insured Bank, *Journal of Banking and Finance*, 17(6): 1133-1146.

Ronn, E. I., and A. K. Verma, 1986, Pricing Risk-Adjusted Deposit Insurance: An Option-Based Model, *Journal of Finance*, 41(4): 871-895.

Ronn, E. I., and A. K. Verma, 1989, Risk-Based Capital Adequacy Standards for a Sample of 43 Major Banks, *Journal of Banking and Finance*, 13: 21-29.

Trigeorgis, L., 1996, *Real Options, Managerial Flexibility and Strategy in Resource Allocation* (Cambridge, MA; London, England: The MIT Press).

Vasicek, O., 1977, An Equilibrium Characterization of the Term Structure, *Journal of Financial and Economics*, 5: 177-188.