Economic Review

Federal Reserve Bank of San Francisco

Fall 1991 **Number 4**

Have Large Banks Become Riskier? Recent Evidence from Option Markets

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This paper examines trends in risk at the largest U.S. commercial banks during the late 1980s. Prices of exchange-traded options on bank equity are used to derive several measures of banking risk. The results show that the riskiness of bank assets and activities did increase at large banks during the period. However, market capital-asset ratios generally rose, leaving the burden on the deposit insurance fund little changed. Hence, while the results support the notion that banks now engage in a riskier business than previously, the general increase in capital has been sufficient to hold overall banking risk relatively constant.

A series of events during the 1980s generated renewed concern about the condition of large commercial banking firms in the United States. Losses on loans to less-developed countries, energy-related loans, and problems related to real estate markets in various regions reduced the financial strength of many banks. At roughly the same time, large banks expanded their activities in a variety of nontraditional areas—including securities underwriting, trading of interest-rate and foreign-exchange-rate instruments, and financing of highly leveraged transactions—many of which appeared to hold potential for, and in some cases actually caused, significant losses. The combination of reductions in financial strength and expansion into new activities raised the fear that large U.S. banks became significantly riskier during the 1980s.

The riskiness of banks might be of less general interest if not for its impact on federal deposit insurance. The liability borne by the insurance fund roughly depends on expected losses due to bank failures. If banks became riskier during the 1980s, losses may have become more likely, and the liability of the insurance fund may have grown substantially. Large banks are of particular concern, not only because individually they are large components of the banking system, but also because they, more so than smaller banks, have been involved in the nontraditional activities mentioned above. If risk has increased at large banks, then some form of regulatory response—for example, increased bank capital standards, or restrictions on bank activities—may be desirable. Alternatively, the adverse conditions of the 1980s may not have affected risk materially, in which case calls for an active regulatory response to reduce risk are misdirected.

The well-publicized decline in the bank deposit insurance fund, from 1.19 percent of insured deposits at the beginning of 1985 to 0.70 percent at the end of 1989, may seem to constitute clear evidence of an increase in risk. However, Shaffer (1991) has demonstrated a fairly high probability of problems of this magnitude, without any change in the distribution of losses. That is, it is quite likely that the FDIC could experience such losses purely through a series of bad years, random "bad luck," without any change in banking risk. Thus, trends in banking risk cannot be examined simply by observing changes in the reserves of the insurance fund over time.

This paper focuses on the evolution of risk at nine of the largest U.S. bank holding companies. Changes in several measures of banking risk are examined. The primary contribution of the paper is the use of a new type of data: The prices of exchange-listed options on bank stocks. The size of the deposit insurance liability at any point in time depends critically on the prospects of insured banks. Option prices provide a unique source of information on market beliefs regarding both future risk and current financial condition, information that can be used to construct estimates of the risk to the insurance fund.[1] In addition, this paper provides empirical implementation of a relatively new model of insured banks, which is used to link the option price data with stock price and financial data to derive measures of banking risk.

The use of options data restricts the analysis to the second half of the 1980s, when options on most bank stocks began trading. Although some of the events that reduced the financial strength of banks—for example, losses on energy loans and loans to less-developed countries—occurred during the early 1980s, others, such as increased involvement in securities underwriting and trading of relatively exotic financial instruments, also had effects in the second half of the decade. A study by Furlong (1988) provides a useful complement to the present paper: Furlong applied similar methods to analyze changes in the first half of the 1980s.

The first section of this paper defines three measures of banking risk: The volatility of returns on bank asset portfolios, the size of bank capital cushions as reflected in capital ratios, and the overall liability imposed by banks on the deposit insurance fund. Section II presents a contingent-claim model of an insured bank and formalizes the three measures of banking risk. Section III describes a method for computing the market value and volatility of bank assets for use in the contingent-claim model; the section also discusses in detail the reasonable range of values for some key unobservable parameters of the model. Section IV explains the methodology and data used to infer estimates of risk from the market prices of bank stock options and presents the resulting estimates. Section V contains the major results of the paper regarding changes in risk at large banks in the late 1980s. The last section of the paper provides some concluding remarks.

I. Risk in Banking

From an ultimate policy perspective, probably the most important banking-related risk is the risk of losses to the deposit insurance fund. The expected value of these losses at any particular bank depends (1) on the probability that the bank's assets will fall short of its liabilities, thereby exhausting the bank's own capital, and (2) on the size of the shortfall if losses should occur. Of course, payouts from the insurance fund also depend on the degree of coverage offered by the insurer. But under any given coverage policy, the probability that a bank will fail and the size of the necessary insurance payment in the event of failure combine to determine the present value of the liability of the fund.

Both factors in turn reflect two broad types of banking risk. The first is financial risk, which depends on bank capital: The probability that a bank will fail varies inversely with the bank's capitalization for a given combination of bank assets and activities. Capital is defined in this paper as the difference between assets and liabilities, exclusive of deposit insurance. (Equity and capital are not identical in this context; the value of equity *includes* the value of the protection afforded by federal deposit insurance, which limits the liability of stockholders and protects depositors from losses due to unanticipated declines in the value of assets.) Capitalization is expressed most conveniently in terms of the capital ratio (the ratio of capital to total assets), with a higher capital ratio implying lower financial risk, all else equal.

The second broad type of risk is operating risk, which depends on the riskiness of the bank's asset portfolio. This risk is measured most directly by the variability of the rate of return on bank assets, referred to as the "volatility" of the bank's asset portfolio. Volatility is quantified by the statistical standard deviation of percentage changes in the value of bank assets. A bank with higher asset volatility is more likely to fail (and, if it fails, is more likely to impose a larger burden on the insurance fund) for any given capital ratio.

Calculating capital ratios and asset volatilities in order to measure risk is not a simple task. The relevant capital ratios must be computed from the market values of assets and liabilities, but market values often are not observable. Similarly, the relevant volatilities are the volatilities of the actual economic returns on the market value of assets; these returns may be very different from the observable accounting returns on the book value assets. Hence, to measure either financial risk or operating risk, or to combine the two into an estimate of the insurance fund liability, market values somehow must be calculated.

Although the market value of bank assets is not observable, the market value of bank equity *is* observable, since large banks have shares traded on stock exchanges. If the stock market is efficient, then the market value of equity reflects the market value of assets (although it also may depend on other factors, including the value of deposit insurance); hence, a model that correctly specifies the relationship between equity and asset values can be used to infer the latter from the former. In addition, the volatility of equity reflects the unobservable volatility of the underlying assets, again suggesting the possibility of inferring one from the other. The next section describes a model that, in addition to filtering out the effects of deposit insurance on equity values, relates the market value and volatility of bank equity to the market value and volatility of bank assets to permit inferences from observed market data.

II. Model of an Insured Bank

Merton (1974) applied contingent-claim techniques to the general problem of valuing the debt and equity of levered firms; in Merton (1977), the same techniques were applied specifically to insured banks. Following Merton's initial theoretical work, Marcus and Shaked (1984) implemented a similar model to derive empirical estimates of bank capital, asset volatility, and the size of the deposit insurance liability. In these models, banks have market value of assets A_t (excluding the value of deposit insurance), and total liabilities maturing with face value B_T at date T, at which time the bank is examined by regulators and is closed if assets do not equal or exceed liabilities. These assumptions imply a value of equity E at date T of:

$$(1) \qquad E_T = \begin{cases} A_T - B_T & \text{if } A_T \geq B_T \\ 0 & \text{if } A_T < B_T \end{cases} .$$

At any time prior to T, the total market value of a bank's equity is equal to the discounted value of this payoff structure. Equity in the model is a contingent claim (a positive payoff to equity is contingent upon the bank being solvent at T), and its value at any earlier point in time can be calculated using the same valuation techniques used in pricing other contingent claims, such as options.

Levonian (1991) revised this contingent-claim model of insured banks to incorporate both a flexible regulatory closure threshold and positive bank charter value.[2] The inclusion of charter value recognizes the fact that, in practice, banks operate under special charters granted by either state or federal authorities; because the supply of bank charters is limited, the positive value conferred by a charter is not competed away. Charter value is modeled as being a fraction ϕ of liabilities, and as being received by bank equity holders at date T only if the bank is not closed by regulators.[3]

In Merton (1977), banks are closed if they are insolvent at date T. However, in reality regulators have some discretion regarding closure, and the regulatory closure threshold need not be the point of actual insolvency. Banks may be closed while net worth is positive, or may be allowed to continue operating with negative net worth. If the regulatory rule is that a bank is closed if its capital ratio is less than c, then the value of equity at the monitoring date T is

$$(2) \qquad E_T = \begin{cases} A_T - B_T + \phi B_T & \text{if } k_T \geq c \\ 0 & \text{if } k_T < c \end{cases} ,$$

where c is not necessarily equal to zero, and the capital ratio k is defined as

$$(3) \qquad k_T \equiv \frac{A_T - B_T}{A_T} .$$

(A minor difference between this model and (1) is that the closure rule is stated in terms of the capital ratio rather than in terms of the relationship between assets and liabilities. Note that if $c=0$, then $k>c$ implies $A>B$.) Banks that remain open at date T experience a lump-sum increase in value from the rents conferred by a banking charter, where ϕB_T is the value of those rents.[4]

Realistically, E_T can never be negative, since the owners of a bank can always exercise their right of limited liability to walk away from a losing proposition. Thus it must be true that banks are closed at capital ratios above the level at which the charter value would be completely offset by negative net worth; that is, at the point $k=c$, it must also be true that $A-B-\phi B \geq 0$. Rewriting this restriction based on the definition of the capital ratio, the closure threshold must satisfy $c \geq -\phi/(1-\phi)$. If the closure threshold were set lower, regulators would be forced to inject funds—an outright gift, not just a loan—to induce some low-capital banks (those with $c<k<-\phi/(1-\phi)$) not to close voluntarily. The injection would have to be large enough to bring assets, and hence the capital ratio, back up to the minimum level of $-\phi/(1-\phi)$. While the FDIC does sometimes provide so-called open bank assistance, the actual extent of any wealth transfer is not obvious, since the emergency funding generally must be repaid by the surviving institution. In such cases, any net injection of capital comes in the form of FDIC acceptance of a below-market rate on the funds. As an alternative and less complex treatment of this possibility, any assistance anticipated by the market is assumed to be capitalized into ϕ, and c is always no less than $-\phi/(1-\phi)$.

As in most applications of contingent-claim methods, assets are assumed to follow a stochastic process given by

$$(4) \qquad dA = \mu_A A(t)dt + \sigma_A A(t)dz,$$

where μ_A is the expected instantaneous periodic rate of return on assets, t is a time index, dz is the differential of a Wiener process, and σ_A is the instantaneous standard deviation of the rate of return on assets, or asset volatility. Let the date $t=0$ represent the present, and let unsubscripted variables denote present values. Using standard methods for valuing contingent claims (see Smith 1976), the present value of equity with date T payoff as given in (2) is

$$(5) \qquad E = AN(x) - BN(x-\sigma_A\sqrt{T}) + \phi BN(x-\sigma_A\sqrt{T}),$$

where

$$(6) \qquad x \equiv \frac{\ln\left(\frac{(1-c)A}{B}\right) + \frac{\sigma_A^2 T}{2}}{\sigma_A\sqrt{T}}$$

and $N(\bullet)$is the cumulative standard normal distribution function. Equity is essentially a call option on assets, plus an additional lump sum equal to the expected present value of the charter.[5] The first two terms in (5) represent the familiar option value; the third term is the charter value ϕB weighted by a factor that is closely related to the probability that the bank will remain open.[6]

Measures of Banking Risk

Given this theoretical framework, the central issue of this paper can be posed more explicitly. In particular, financial risk has increased at large banks if the market value capital ratio k defined in (3) has decreased; operating risk has increased at large banks if the volatility of assets σ_A has increased.

The deposit insurance liability, which combines the effects of both types of risk, also can be calculated explicitly once values for A and σ_A have been obtained. The deposit insurance contract is another contingent claim and can be evaluated using the same methods. All of the banks in the sample are sufficiently large that the market has good reason to expect that all creditors will be protected from losses in the event of a failure; hence, the contingent deposit insurance liability should be modeled under the assumption that the claim covered by the insurer is B, even though not all liabilities are formally insured. The typical method of resolution when such a large bank fails is to locate a purchaser for the failed institution; the acquirer receives the assets and the charter of the failed bank and assumes all of the liabilities. If the liabilities assumed by the acquirer exceed the value of the assets and charter, the deposit insurer makes up the difference. Thus, the insurance fund pays the acquirer $B-(\phi B + A) = (1-\phi)B - A$ if that difference is positive, and otherwise pays nothing. Formally, the insurer's payout is

$$(7) \qquad V_T = \begin{cases} (1-\phi)B_T - A_T & \text{if } B_T > A_T + \phi B_T \\ 0 & \text{if } B_T \leq A_T + \phi B_T \end{cases}.$$

Again using standard contingent-claim valuation techniques, the value of the contingent payout in (7) is

$$(8) \qquad V = (1-\phi)BN(y+\sigma_A\sqrt{T}) - Ae^{-\gamma T}N(y),$$

where

$$(9) \qquad y \equiv \frac{\ln\left(\frac{(1-\phi)B}{Ae^{-\gamma T}}\right) - \frac{\sigma_A^2 T}{2}}{\sigma_A\sqrt{T}}$$

The dividend rate, γ, appears in (8) and (9) because dividend payments directly reduce the assets available to the deposit insurer in the event of failure. (Note that γ is the rate of dividend payments relative to assets, not equity.) The overall risk to the deposit insurance fund posed by large banks has increased if V has increased.

III. A Method for Computing Asset Values and Asset Volatility

Assuming that the value of bank equity is determined as in (5) it is possible to work backward from the stock market prices of large publicly traded banks to infer the market value of assets and asset volatility. Various realistic values can be assumed for bank liabilities B, the regulatory monitoring interval T, the capital ratio closure threshold c, and the charter value ratio ϕ. The two remaining unknowns in (5) are the value of assets σ_A and the volatility of assets σ_A.

Obviously, a single equation cannot be solved for two unknowns; a second independent equation is needed. Merton (1974) suggests applying Itô's Lemma to the expression for the value of equity, to yield a second equation relating the volatility of equity and the volatility of assets. Merton derives the relationship[7]

$$\sigma_E = \sigma_A \frac{\partial E}{\partial A}\frac{A}{E} \tag{10}$$

An intuitive grasp of (10) follows from considering the case in which bank stockholders do not have limited liability for the debts of the bank. In that case, the contingent aspect that makes equity behave like a call option on assets disappears, and the value of equity changes one-for-one with the value of assets.[8] Then $\partial E/\partial A = 1$, and (10) reduces to $\sigma_E = \sigma_A(A/E)$, with the straightforward interpretation that the volatility of equity is simply the "levered-up" volatility of the underlying assets. However, with limited corporate liability, equity becomes somewhat less sensitive to changes in asset values, as gains and losses are shared partially with debtholders. Then $\partial E/\partial A<1$, and σ_E falls relative to σ_A.

In the present case, differentiation of (5) yields

$$\frac{\partial E}{\partial A} = N(x) + \frac{\Theta B N'(x-\sigma_A\sqrt{T})}{A\sigma_A\sqrt{T}}, \tag{11}$$

where $N'(\bullet)$ is the standard normal density function and $\Theta = 1/(1-c)-(1-\phi)$. Using (11), the expression in (10) can be rewritten as

$$\sigma_E = \frac{AN(x)\sigma_A\sqrt{T} + \Theta B N'(x-\sigma_A\sqrt{T})}{E\sqrt{T}}. \tag{12}$$

Equation (12) depends on all of the same variables as equation (5). If σ_E is observable, then under identical assumptions regarding the parameters of the model, this equation also has A and σ_A as the only unknowns, and (5) and (12) can be solved simultaneously for values of the two unknown variables.[9]

As noted above, solving these two equations to obtain market assets and volatility requires making assumptions about the other parameters: bank liabilities B, the regulatory monitoring interval T, the capital ratio closure threshold c, and the charter value ratio ϕ. The market value of bank liabilities is assumed to be approximately equal to book value, since the bulk of bank liabilities are short term. The monitoring interval is assumed to be one year; this corresponds roughly to bank examination frequency. Assumptions regarding the charter value and closure threshold assumptions require more detailed explanation.

The Charter Value Ratio

Previous approaches to estimating bank charter value are inappropriate for this analysis. For example, Keeley (1990) divides the sum of book value liabilities and market value equity by book value of assets, and uses this ratio as a proxy for Tobin's q to examine changes in charter value; Kwan (1991) applies a similar approach based on q. Such estimates based on the market value of bank equity cannot capture the concept of charter value as defined in this paper, because they do not separate the effect of deposit insurance from other components of measured charter value. Some other method must be used to define a reasonable value for ϕ.

In practice, the value of a bank charter is likely to manifest itself in nonmarket interest rate spreads: either a rate of return on bank loans in excess of the required rate for that level of risk, or a below-market rate of interest on deposits, or some combination of the two. Hence, information on deposit and loan spreads can be used to develop an estimate of ϕ.

On the deposit side, if the bank charter gives the bank the ability to set $r_d<r_f$ and still attract federally insured deposits, the basic contingent claim model of bank equity must be modified; without the lump-sum charter value, equation (5) becomes

$$E = AN(x') - Be^{(r_d - r_f)}N(x'-\sigma), \tag{5'}$$

where T = 1 without loss of generality and

$$x' = \frac{\ln(A/B) + (r_f - r_d + \sigma^2/2)}{\sigma}. \tag{6'}$$

This can be viewed as an alternative formulation of the basic model presented in (5), in which the charter value is received as a flow over time in the form of a rate spread rather than as a lump sum ϕB at the end of the period. Comparing the two forms of the model, if the relatively small effect of $(r_d - r_f)$ on x' is ignored, then $(1-\phi)=e^{(r_d - r_f)}$. In this case, the charter value ratio can be approximated by the deposit interest rate spread, $\phi \approx r_f - r_d$, since for realistic spreads it will be true that $e^{(r_d - r_f)} \approx 1-(r_f - r_d)$.

If instead the charter allows the bank to earn an above-market rate of return on assets, a variant of the contingent claim model is appropriate. McDonald and Siegel (1984) consider the case of a contingent claim on an asset earning a rate of return different from the appropriate risk-adjusted rate. If Δ is the loan spread—the rate of return on loans held by the bank minus the required rate of return for assets of comparable risk—then the value of bank equity can be expressed as

$$(5'') \qquad E = Ae^{\Delta}N(x'') - BN(x''-\sigma),$$

where again $T=1$ and

$$(6'') \qquad x'' = \frac{\ln(A/B)+(\Delta+\sigma^2/2)}{\sigma}.$$

This version of the model, with A multiplied by a factor e^{Δ} which is positively related to charter value, suggests that the charter value should be modeled as being proportional to assets rather than liabilities in this case. However, recognizing that $A=B/(1-k)$, that for most banks $N(x'') \approx N(x''-\sigma)$, and that $e^{\Delta} \approx 1+\Delta$ for realistic values of Δ, and ignoring the trivial effect of Δ on x'', a value of Δ greater than zero increases the value of bank equity by an amount equal to

$$(13) \qquad \Delta AN(x'') \approx \frac{\Delta B}{1-k} N(x''-\sigma).$$

Thus, in the context of the model presented above in (5), the effect on bank equity is roughly equivalent to setting $(1-\phi) = -\Delta/(1-k)$.

If a chartered bank has positive spreads on both the deposit and the loan side of the business, the joint effect can be approximated as

$$(14) \qquad (1-\phi) \approx 1-(r_f - r_d) - \frac{\Delta}{1-k},$$

where

$$(15) \qquad \phi \approx \frac{\Delta}{1-k} + (r_f - r_d).$$

The approximation in (15) was combined with data on interest rates to provide a sense of reasonable values for ϕ. The deposit rate spread was proxied by the difference between the rate on six-month certificates of deposit (the national average from *Bank Rate Monitor*) and the secondary market yield on six-month U.S. Treasury bills. The loan spread was proxied by the difference between the weighted average interest rate on short-term commercial and industrial bank loans (from the Federal Reserve's survey of terms of bank lending) and the rate on one-month commercial paper. (One-month commercial paper was used because it was closest to the average maturity of bank loans reported in the terms-of-lending survey.) Combining the average values of the interest rate spreads (based on quarterly data for the sample period) with values of k between 0 and 10 percent produced estimates of the value of ϕ in the relatively narrow range of 0.016 to 0.018. Since substantial approximation error is likely, these estimates should be taken only as indicative of the neighborhood of the charter value ratio; values for ϕ of 0.01 and 0.02 are used in Section V to bracket a reasonable range.

In the model, the charter value ratio is assumed to be constant over time. In reality, interest rate spreads fluctuate, and a systematic trend might cause calculations based on the assumption of constant ϕ to be biased. To test for the existence of a trend, the sum of the interest rate spreads was regressed on a time variable, with a correction for first order autocorrelation. The trend coefficient was positive but insignificant (at the 5 percent level) during the sample period. Thus, the assumption that ϕ is constant over time probably is innocuous.

The charter value ratio also is assumed to be identical for all banks in the sample. It is possible that differences in managerial ability, location, and other factors might cause different banks to reap different benefits from their charters. However, the nine banks in this sample are sufficiently similar in size and character that interbank differences in ϕ are unlikely to be major, despite some variation in business strategy among the sample firms.

The Closure Threshold

It is unlikely that regulators would seize any of the large banks in the sample at positive market value capital ratios. Hence, the assumed value of c almost certainly should be zero or less. However, as noted in Section II, a credible closure point cannot be so low that the charter value is completely exhausted before the bank is closed; that is the threshold must satisfy $c \geqslant -\phi/(1-\phi)$. Since the charter value ratio is assumed to be in the range of 0.01 to 0.02, the closure threshold cannot be less than about 0.01 if ϕ is on the low side at 0.01, or 0.02 if ϕ is 0.02.

As with the charter value ratio, there is some possibility that c varies either over time, or across banks in the sample, or both. Substantial interbank variation within this sample seems unlikely, for the same reasons given above in the discussion of ϕ. As for variation over time, if closure policy changed during the period, there should be some evidence of a change in the loss experience of the deposit insurance fund. To examine this possibility, FDIC losses resulting from bank closures (deposit payoffs, deposit transfers, and purchase and assistance transactions) were computed from the FDIC's *Annual Report* and divided by the deposits of closed banks to construct a loss ratio. This ratio was roughly the same at the end of the sample period as at the beginning, and a regression of the ratio on a time variable revealed no significant trend during the 1980s. Thus, the assumption of constant c probably is a reasonable approximation.[10]

IV. Equity Volatility From Traded Option Prices

The two-equation approach to deriving estimates of A and σ_A for a sample of banks has been used previously by Marcus and Shaked (1984), Ronn and Verma (1986), Furlong (1988), and Kendall and Levonian (1991), among others. All of these earlier studies used the standard deviation of historically observed stock returns for equity volatility σ_E. But conceptually, the relevant volatility is the *expected* volatility over the period from $t=0$ to $t=T$. Use of historical volatility assumes that expectations at each point in time are formed adaptively, and therefore reflect realizations over some recent interval. If traders form their expectations of σ_E using information in addition to historical returns, then the historical standard deviation may be a poor proxy for the expected volatility required in the contingent-claim framework.

A more direct measure of expected volatility is both desirable and available. Options on bank stocks trade on several U.S. options exchanges; the prices of stock options are known to depend in part on the expected volatility of the underlying stocks. Using an option pricing model, values of expected σ_E can be inferred from traded option prices.[11] Because exchange-traded stock options in the United States have American terms (meaning that the holder may choose to exercise prior to expiration), expected volatilities are inferred from an American option pricing model developed by Barone-Adesi and Whaley (1987) given by

$$C = Se^{-\delta\tau}N(z) - Xe^{-r\tau}N(z-\sigma_E\sqrt{\tau}) + P(S,X,\tau,\sigma_E,r,\delta), \tag{16}$$

where C is the value of a τ-period American call option with exercise price X on a stock with price S and continuous dividend rate δ (dividends relative to equity), r is the risk-free interest rate, and z is defined as

$$z \equiv \frac{\ln\left(\frac{S}{X}\right) + \tau(r-\delta) + \frac{\tau\sigma_E^2}{2}}{\sigma_E\sqrt{T}} \tag{17}$$

The first two terms in (16) give the value of a European option, which cannot be exercised prior to the expiration date. The function $P(S, X, \tau, \sigma_E, r, \delta)$ is an approximation of the early exercise premium (the difference in value between an American option and a European option due to the possibility of early exercise), the exact form of which is derived by Barone-Adesi and Whaley. They demonstrate that their approximation works well for the range of expirations used in this paper.

All of the variables in (16) are observable in the financial press or elsewhere, with the exception of σ_E. Although (16) cannot be inverted for σ_E, standard numerical techniques can be used to find the unique value of σ_E satisfying (16), which is referred to as the "implied volatility" of the stock. This implied volatility can then be used in (12) to solve for σ_A and A.

Levonian (1988) showed that implied volatilities of bank stocks differ substantially from volatilities calculated using historical stock returns. Both Black and Scholes (1972) and Latané and Rendleman (1976) used tests based on observed option prices to show that historical volatility is inferior to implied volatility as a predictor of future volatility; Schmalensee and Trippi (1978) obtained similar results. Hence, volatilities implied by option prices should provide better information about the riskiness of bank stocks, and consequently about the various types of banking risk, than would volatility estimates based on historical stock returns.

However, the use of implied volatility is not without cost. Since far fewer banks have traded options than have traded stock, the sample size is reduced substantially. As always in empirical research, small sample size may bias the results. Thus, it is possible that the results may fail to represent adequately the riskiness of the banking industry as a whole, even though the volatility estimates for each individual bank are likely to be superior.

Options Sample

The sample for this paper consists of listed call options from the various options exchanges in the United States, sampled at the ends of the second and fourth quarters of the five years 1985 through 1989, for nine large banking firms: BankAmerica, Bankers Trust, Chase Manhattan, Chemical, Citicorp, First Chicago, J.P.Morgan, Manufacturers

Hanover, and Security Pacific. This group comprised nine of the top ten U.S. banks at the beginning of 1985, ranked by assets. (The tenth, First Interstate, also has exchange-listed options, but trading was too infrequent to allow construction of a reliable time series.) These are options on the common stocks of bank holding companies, not banks; however, to the extent that the predominant assets of holding companies are banking-related, the implied volatilities provide information on bank asset risk. The term "bank" is used to refer to these firms throughout the paper.

The interest rates used in the option pricing model were the yields-to-maturity on the U.S. Treasury bills maturing closest to the expiration date of each option. The dividend rates were computed by assuming that expected dividends during the life of each option were identical to dividends actually paid and then calculating equivalent continuous rates.[12] Last-trade-of-the-week call option prices and stock prices for the nine banks were collected from published listings in *The Wall Street Journal*.

Day and Lewis (1988) describe two sources of potential bias in the use of published prices. One is the problem of nonsynchronous trading, that the last option trade for any given bank may not have occurred at the last observed stock price; the option valuation model in (16) requires the use of a contemporaneous stock price. The other is that stocks and options trade with a spread between the bid price and the ask price, and reported trades may occur at either the bid or the ask or at prices in between, making it impossible to observe a precise estimate of value. Day and Lewis argue that estimates of implied volatility should incorporate information from the prices of several different options on the same stock in order to minimize the potential bias. Studies of option volatility have used a variety of methods for combining different options on a single underlying security (for example, compare Day and Lewis to Latané and Rendleman or Schmalensee and Trippi.

To deal with these problems, for each bank only the two options with exercise prices closest to the current stock price are used. That is, for all of the options with exercise prices above the current stock price, the option with the lowest exercise price is selected; in addition, for all of the options with exercise prices below the stock price, only the one with the highest exercise price is selected, for each bank. Day and Lewis show that trading volume is concentrated in these "near-the-money" options; for the index options they examine, about 70 to 90 percent of the volume is in options with exercise prices just above and just below the current stock price. Even a cursory review of published options sales data confirms that this relationship is true in general. As Day and Lewis point out, any lack of synchronization between the closing stock price and the closing option price will be minimized for these options. They also note that the percentage bid-ask spread is less for these options, reducing the second source of bias as well. (Feinstein 1988 provides a discussion of other desirable properties of near-the-money options for the purpose of inferring volatilities from prices.)

It is possible that at any point in time market traders anticipate that volatility will change in some predictable way over time. In that case, the options from which the stock volatility is inferred should have expirations identical to the regulatory monitoring interval for banks, assumed to be one year in this paper. However, until very recently exchange-traded stock options were restricted to expirations of less than a year; moreover, the most active trading generally occurs in options with short expirations. Thus, short-term options are likely to yield superior estimates of expected σ_E, and these estimates can be used in the bank equity model provided that volatility is not expected to change drastically between the expiration date of the option and the end of the regulatory monitoring period. However, using the shortest expirations may introduce other problems; Day and Lewis document a statistically significant increase in implied volatility for options as the expiration date approaches, especially in the last few trading days. They attribute this effect to technical factors related to the unwinding of hedged positions. To achieve a balance between both types of distortions, the options sample for this study consists of the shortest-term options for each bank, but with a minimum time to expiration of one month. This sample selection process is similar in spirit to that used by Schmalensee and Trippi (1978).

An additional complicating factor is that unusual events or changes in option market liquidity might cause option prices from a single week to be unrepresentative of the true riskiness of banks. To minimize this problem, prices were sampled for three consecutive weeks surrounding each semiannual sample point: The week of the financial reporting date, one week before that date, and one week after. For each bank in each of the weeks, prices of the two call options with exercise prices nearest to the underlying stock price and with shortest time to expiration (but exceeding one month) were collected. Implied stock volatility was calculated for each option, and all six options averaged for each bank at each semiannual date. The procedure produced 90 estimates of volatility (ten semiannual observations for nine banks).[13]

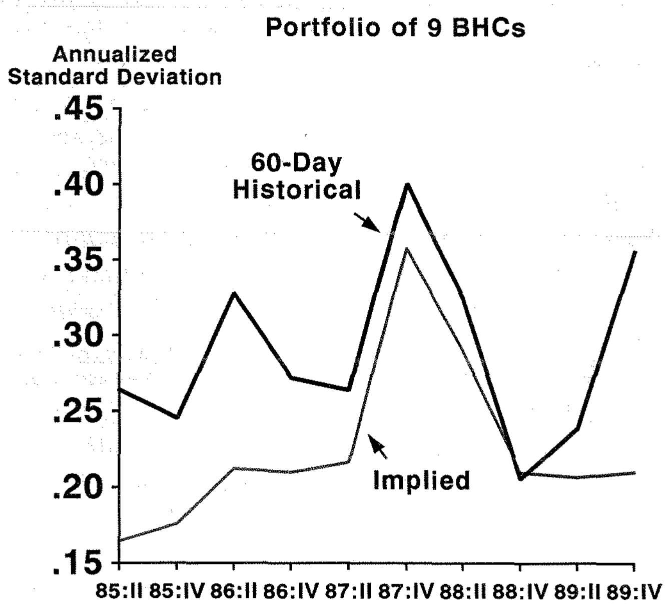
Stock Volatility Estimates

A weighted average of the nine banks was computed for each time period to summarize the resulting implied stock volatilities and to present the pattern of changes during the late 1980s. The weights for the observations were the market value of each bank's equity (stock price multiplied by number of shares) divided by the total market value of equity of all nine banks for that date. The resulting weighted average can be viewed as an index of implied bank stock volatility, with heavier emphasis given to banks that are larger components of total bank stock market value. (Alternatively, if returns on bank stocks were perfectly correlated, this average would equal the volatility of a stock portfolio consisting of equal percentages of each bank's equity, for example 5 percent of Bank A, 5 percent of Bank B, etc.) The results are presented in Chart 1, with volatility stated in annual terms (that is, the figures can be interpreted as standard deviations of annual percentage changes in the prices of the stocks). A similarly constructed index of historical volatility is presented for comparison. Historical volatility was computed as the annualized standard deviation of stock returns for the 60 trading days (roughly three months) preceding the end of the quarter.

One notable feature of Chart 1 is the upward spike in both implied and historical volatility in the fourth quarter of 1987. Implied volatility rose from 22 percent to 36 percent, and historical from 26 percent to 40 percent. This spike corresponds to the period immediately following the stock market crash of October 1987. Over the following year, volatility returned to levels similar to those preceding the crash. This pattern was not unique to bank stocks: Schwert (1990) documents similar effects for implied and historical volatility for the overall stock market as measured by the S&P500 stock index.

While the patterns of historical and implied volatility around the time of the crash are similar, there are noticeable differences in the rest of the sample period. Historical is almost always higher than implied for this sample, and three of the nine quarter-to-quarter changes are opposite in sign. The fourth quarter of 1989, in which the divergence is especially pronounced, provides an excellent example of the primary drawback of historical volatility. The high standard deviation of realized returns for the fourth quarter of 1989 is due to stock price movements on two dates,

Chart 1
Stock Return Volatility



Friday October 13 and Monday October 16. On Friday, the failure of UAL Corp. to obtain financing for a leveraged buyout precipitated a large decline in the overall stock market. Stocks of large banks were hit especially hard, apparently because the news was taken as a signal of a fundamental change in a major line of business. (Citicorp had the largest percentage single-day drop at 16 percent, and J.P. Morgan had the smallest at 5.5 percent.) On Monday, stock prices increased, recovering a portion of the value lost on the preceding Friday. A 60-day historical volatility calculation treats returns from these days equally with the other 58 days in the period. In reality, it is likely that traders viewed these two days as extreme events, and that by the end of December traders gave them little weight in formulating expectations of bank stock volatilities. The lower implied volatilities from option markets for 89:IV are direct reflections of expectations at that date, automatically discounting any information that is irrelevant to future returns.

V. Changes in Banking Risk, 1985-1989

The stock volatility results hold some intrinsic interest, and are roughly comparable to the bank stock volatility results presented by Jonathan Neuberger in another article in this *Review*. (Neuberger examines changes in bank stock risk during the 1980s in greater detail, and investigates the relationship between bank stock returns and returns in the bond market and the overall stock market.) However, the main purpose of the preceding stock volatility computations is to provide the raw material for other calculations related to banking risk. In this section, estimates of the three measures of banking risk are presented for the second half of the 1980s. Asset volatilities are obtained from the simultaneous solution of equations (5) and (12), using the implied σ_E for each bank in each period as the input to (12).

The solutions for market asset values from (5) and (12) are used to compute market value capital ratios from equation (3). Finally, the liability of the insurance fund is calculated from (8), also using the two-equation solution values of σ_A and A.

As discussed in Section III, the market value of bank liabilities is assumed to be equal to book value, and the monitoring interval is set equal to one year. The actual dividends paid by each bank during each year are used to compute the dividend rate γ in (8), under an assumption that dividends were paid as expected. The earlier discussion of realistic ranges for the charter value ratio and the closure threshold concluded that $\phi = 0.01$ and $\phi = 0.02$ would provide a reasonable bracket for charter value, and that c should be less than or equal to zero, but no larger in absolute value than ϕ. Thus, four cases are considered for combinations of these two parameters:

C1: $c = 0.00$, $\phi = 0.01$ Charters have low value, and banks are closed when they are insolvent in market value, that is, when $A<B$.

C2: $c = 0.01$, $\phi = 0.01$ Charters have low value, and banks are closed when charter value is exhausted.

C3: $c = 0.01$, $\phi = 0.02$ Charters have high value, and banks are closed before charter value is exhausted.

C4: $c = 0.02$, $\phi = 0.02$ Charters have high value, and banks are closed when charter value is exhausted.

Comparing the results from the four cases provides insight into the sensitivity to changes in the assumptions. Three pairwise comparisons are most interesting:

C1 vs. C2: impact of a lower closure threshold when charter value is low.

C3 vs. C4: impact of a lower closure threshold when charter value is high.

C2 vs. C3: impact of higher charter value with a fixed closure threshold.

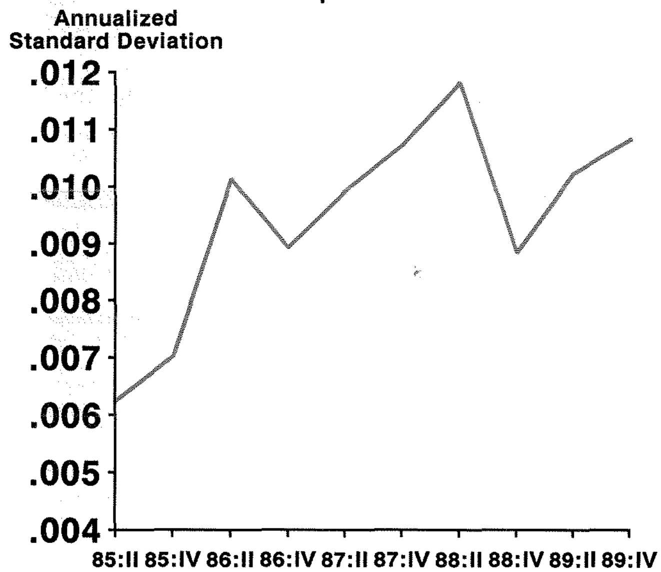
Operating Risk

Weighted averages are constructed to summarize the individual bank results for each time period, with each bank weighted by liabilities relative to total liabilities of the nine banks for that date. The individual banks could instead have been weighted by equity (as with the stock volatilities above) or by assets. Other weightings produced very similar results.

Chart 2 shows the evolution of bank operating risk as reflected in annualized figures for asset volatility. Only case C4 is presented, because alternative assumptions about c and ϕ had very little effect on the estimates of σ_A. The general upward trend shows that operating risk did indeed increase at large banks during the late 1980s: The level of asset volatility in 89:IV was about 80 percent higher than in 85:II. At least in part, this increase may have been due to the expanded range of activities conducted by banks. The rate of increase in operating risk is consistent with that found by Furlong (1988) for the early 1980s, implying that bank assets became progressively more volatile across the entire decade. Interestingly, the increase in average asset volatility in the fourth quarter of 1987 was not dramatically different from adjacent periods. Hence, the significant jump in stock volatility in that period was *not* due to any great increase in the riskiness of bank assets as perceived by the market.

Chart 2
Asset Volatility

Assumptions: Case C4

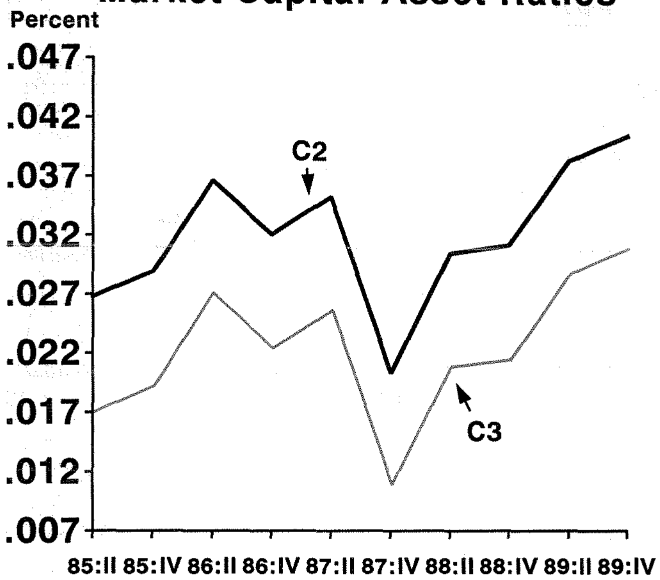


The pattern of asset volatility during the period is most heavily influenced by the larger banks in the sample, such as Citicorp, because of the use of a weighted average. The patterns for individual banks differ somewhat, although for each of the nine banks asset volatility was higher at the end of the sample period than at the beginning.

Financial Risk

Chart 3 shows weighted-average market capital ratio results for two illustrative cases, C2 and C3. Capital ratios were higher at the end of the sample period than at the beginning, implying that financial risk decreased at large

Chart 3
Market Capital-Asset Ratios



banks. (The pattern also is representative of the banks individually, except that several banks show slight declines in capital ratios in the fourth quarter of 1989.) However, market capital ratios suffered a tremendous hit in the stock market crash, from which they only gradually recovered over the next one-and-a-half to two years.

In the two cases omitted from Chart 3, C1 was essentially the same as C2, and C4 was little different from C3, demonstrating that variations in the assumed closure threshold have a trivial impact on the resulting capital ratio estimates. The only major distinction among the four alternative sets of assumptions was that variations in the assumed charter value produced capital ratios that differed by roughly the magnitude of the difference in the charter value ratio. The reason is straightforward. Recall that the capital ratio k is based on assets exclusive of the charter value; since a higher charter value should make bank stock more valuable all else equal, a *given* market value of equity can only be consistent with a *lower* market value of assets, and hence a lower market value of bank capital. Except for this charter value difference, the pattern over time is very similar in all four cases.

The decline in the market capitalization of banks resulting from the October 1987 crash evident in Chart 3 explains the pattern of implied stock volatility observed in Chart 1. Although Chart 2 showed that the riskiness of bank assets did not increase, the market value of equity fell as stock prices collapsed, and large banks suddenly became much more highly levered. The higher volatility of bank stock returns reflected in call option prices stemmed from traders' recognition that any given percentage change in the return on bank assets would translate into a much larger percentage change in return on the stock, when viewed relative to the lower base value of equity. (In terms of equation (10), the ratio A/E increased; for a given σ_A, this leverage increase caused σ_E to rise.) An interesting implication of the results presented here is that, at least for banks, the increase in volatility was of roughly the magnitude that should be expected after a decline in market equity-to-asset ratios of the extent experienced in the October crash.

The Deposit Insurance Liability

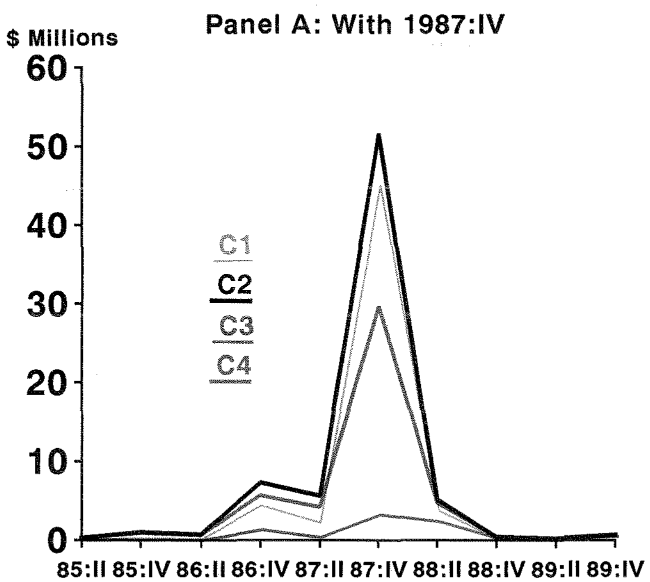
Chart 4 shows the path of the estimated deposit insurance liability over the sample period. Because the overwhelming impact of the stock market crash makes it hard to see the pattern of changes in the deposit insurance liability for other periods, Panel B displays the same results as Panel A, but with the 87:IV data omitted.

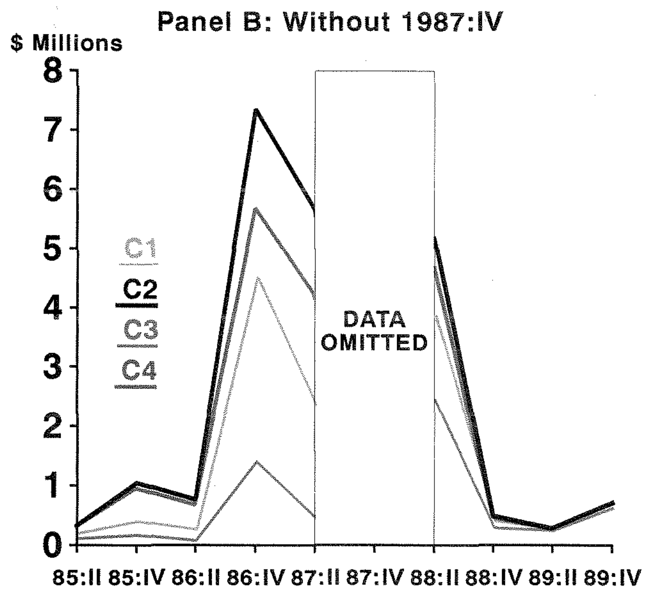
Panel A displays the total value of the liability at each date, summed across banks, for each of the four parameter cases. The stock market crash had a temporary but dramatic impact on the computed liability of the insurance fund. In case C1, for example, the liability rises from \$2.4 million in 87:II to \$45.3 million in 87:IV, then falls back to near the year-earlier level by 88:II. The reason is clear from Chart 3: The fall in market capital ratios associated with the decline in bank stock prices caused a large increase in financial risk at these banks, and the ensuing recovery in market value reversed the change. Each bank in the sample exhibits roughly the same pattern.

In all four cases in Panel B, the liability is only slightly higher at the end of the sample period than at the beginning. This conclusion would hold even if the correct values of c and ϕ changed during the period. For example, if regulators began allowing more poorly capitalized banks to remain open as time passed, so that C3 was most realistic at first and C4 was most realistic at the end, the 89:IV liability in case C4 is still little greater than the 85:II liability in case C3.

However, it is also true that the deposit insurance liability increased substantially during the middle part of the sample period, and that the increase predated the stock market crash. The change in risk was driven by the general increase in financial risk that began in 86:II, during a period of rising operating risk. The increase in market capital ratios toward the end of the sample period (assisted by the relatively large drop in asset volatility in 88:II)

Chart 4
Deposit Insurance Liability





brought the deposit insurance liability down to near its earlier level.[14]

Comparison of the various cases reveals that assumptions about the closure threshold and the charter value ratio have some impact on the computed deposit insurance liability at each point in time, although not a major impact. Comparing C1 to C2 and C3 to C4 shows that an earlier closure assumption reduces the total liability. The magnitude of the effect is roughly the same under either charter value assumption. (Note that this result does *not* demonstrate that instituting a policy of earlier closure would reduce risk to the deposit insurance fund. These derived results are conditional on the observed prices of bank stocks; an explicit policy change probably would generate a behavioral response by banks, and would alter the market value of bank equity, thus complicating any evaluation of a change in regulatory policy. This point is similar to the "Lucas critique" in macroeconomics.)

Comparing C2 to C3, different assumptions about the value of bank charters have a somewhat larger impact on the computed liability, for a given closure threshold assumption: The higher value of ϕ implies a smaller deposit insurance liability. This effect stems from the assumption that the deposit insurer uses the charters of failed banks to offset at least partially any required transfer from the insurance fund. It is interesting also to compare C2 to C4 in this regard. In both cases, the closure threshold is set so that the bank is closed as late as possible, when the charter value is completely exhausted by losses on bank assets. Even with this extreme closure assumption, higher charter value reduces risk to the insurance fund.

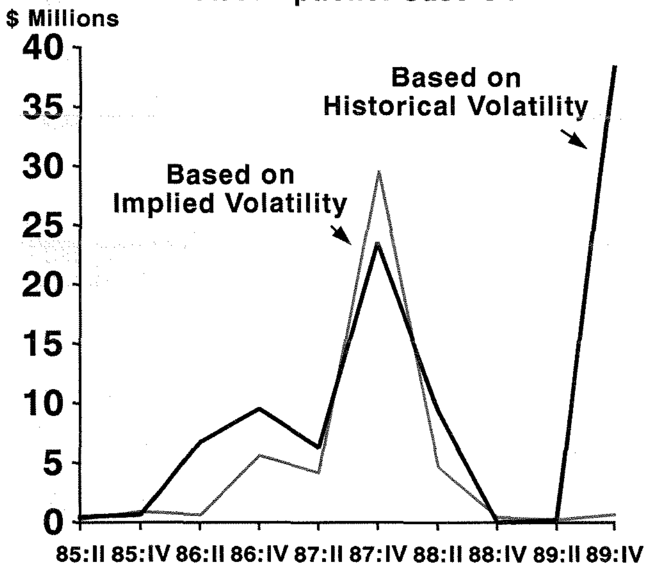
The inverse relationship between assumed charter value and the deposit insurance liability might seem to be at odds with the conclusion from Chart 3, which showed that higher assumed charter value increases financial risk. The apparent conflict can be resolved by recognizing that while higher charter values reduce measured capital ratios, the additional value is captured by the insurer in the event of a bank seizure, leaving little net effect on the insurance liability from changes in this parameter.

The moderate sensitivity of the deposit insurance results to alternative assumptions about the unobservable parameters makes it inappropriate to attach great weight to the specific dollar amounts of the liability; it is the general secular trends that are the important features for the aims of this paper. The overall pattern is clear, using any of the four parameter combinations: Despite a large increase in risk to the deposit insurance fund during the middle of the sample period, risk from these nine large banks was back down to a relatively low level by the end of the decade.

It is interesting to return to the comparison of historical stock volatility and implied stock volatility, and examine whether the difference between the two would affect the conclusions in this section. Chart 5 compares estimates of the total deposit insurance liability based on implied and historical σ_E, using C4 assumptions. The difference in the fourth quarter of 1989 is huge. Using historical volatility, the risk to the deposit insurance fund appears to be much

Chart 5
Effects of Implied and Historical Volatility on Deposit Insurance Liability

Assumptions: Case C4



higher at the end of the sample period than at the beginning. However, as noted in Section IV, the difference between historical and implied volatility in 89:IV is due almost entirely to stock price movements on two consecutive trading days, probably related to the collapse of the UAL leveraged buyout. In this case, implied and historical volatility lead to significantly different conclusions, and the results based on historical clearly are questionable.

Summary

The results in this section indicate that there was no significant overall increase in the riskiness of large banks during the late 1980s. The riskiness of bank assets and activities did increase at large banks over the five-year period studied, but concurrent with this increase in operating risk, financial risk fell as market capital ratios rose. The increase in market capital ratios was sufficient to prevent a large secular rise in the burden on the insurer. By the end of the sample period, these large banks posed little more risk to the deposit insurance fund than at the beginning of the period.

It is not surprising that capital increased as asset volatility rose, since the regulatory guidelines in effect during this period explicitly required banks engaged in riskier activities to maintain higher capital ratios (Board of Governors 1985). The positive relationship is evident in Table 1, which shows a high positive correlation between asset volatility and capital across the sample within each period. (If the results for individual banks were assumed to be drawn from normal distributions for each variable, the 5 percent critical level for a null hypothesis of $\rho = 0$ would be 0.666; the correlation coefficients would be judged to be significantly greater than zero, except in 1985). The rise in market value capital ratios does not reflect simply a passive increase as bank stock prices increased along with the overall stock market. The book value of bank equity also rose, both absolutely and relative to the market value of bank assets, with much of the rise due to earnings retention and new equity issuance. Thus, the reduction in financial risk probably was an active response to a perceived need for greater capital.

Table 1
Correlation Between Risk and Capital

85:II	0.575	87:IV	0.948
85:IV	0.506	88:II	0.924
86:II	0.859	88:IV	0.724
86:IV	0.796	89:II	0.716
87:II	0.920	89:IV	0.714

Note: Coefficient of correlation between σ_A and k across banks, using case C1 assumptions.

VI. Conclusions

This paper considers the evolution of bank risk during the late 1980s, with a focus on nine large U.S. banking firms. The unusual element of this study is the use of exchange-traded options on bank holding company stocks to infer the volatility of bank assets and activities. The results show that operating risk increased by about 80 percent during the period. However, with the exception of the period around the 1987 stock market crash, financial risk generally declined. When the two separate changes are combined to examine overall risk to the deposit insurance fund, it appears that the burden imposed by large banks on the deposit insurer was little different at the end of the sample period than at the beginning.

Hence, while the data do support the notion that banks now engage in generally riskier activities than they did previously, market capital ratios have on average kept pace with the evolving mix of banking services and products, thus preventing deterioration in the degree of protection provided by bank capital. Large banks did not become substantially riskier in what is probably the most important public policy sense, the risk imposed on the deposit insurance fund. Additional regulatory actions to force reductions in bank risk-taking appear neither necessary nor warranted, at least on the strength of changes in risk at large banks during the late 1980s.

ENDNOTES

1. The only known previous use of these data (Levonian 1988) examined a shorter time period and used a simple but not strictly appropriate option pricing model.

2. The model presented by Levonian is a generalization of Merton's and two others, Marcus (1984) and Ronn and Verma (1986). The differences among the various models are summarized in Levonian (1991).

3. The main motivation for assuming that charter value is proportional to liabilities is modeling convenience; however, the assumption also is appropriate to the extent that franchise value is related to the size of a bank's "core" deposit base.

4. In a multiperiod setting, ϕB would reflect the discounted value of the future stream of rents as well.

5. This formulation differs slightly from Levonian (1991). In the present version, any regulatory costs are capitalized into the value of bank assets. Note that the dividend rate does not appear in (5) or (6). Equity is essentially a "dividend-protected" call option, in which the option holder receives the benefits of the dividend cash flow that otherwise would reduce the value of assets and hence equity.

6. The factor $N(x-\sigma_A\sqrt{T})$ is actually the probability that the bank would remain open in a world of risk-neutral investors, that is, a world in which the assets of the bank earn the risk-free rate of return.

7. According to Itô's Lemma, if $A(t)$ is determined by the stochastic process in equation (4), and equity is a function of $A(t)$ and t, then the differential of $E(A(t), t)$ is given by

$$dE = \frac{\partial E}{\partial A}\, dA + \frac{\partial E}{\partial t}\, dt + \frac{\partial^2 E}{\partial A^2}\, (dA)^2,$$

which is essentially a Taylor series expansion of E, with all higher-order terms vanishing as dt approaches zero (that is, in continuous time). Substituting for dA from (4), regrouping terms, and recognizing that $(dt)^2=0$, $dtdz=0$, and $(dz)^2=dt$ yields

$$dE = \left[\frac{\partial E}{\partial A}\,\mu_A A + \frac{\partial E}{\partial t} + \frac{\partial^2 E}{\partial A^2}\,\sigma_A{}^2 A^2\right] dt + \sigma_A A\,\frac{\partial E}{\partial A}\, dz.$$

The term in parentheses is the expected drift of the process. Defining μ_E as the expected drift term divided by E (to create a percentage rate of change), the differential dE can be written as

$$dE = \mu_E E dt + \sigma_E E dz,$$

where σ_E is given by (10). For a relatively simple discussion of Itô's Lemma and the associated stochastic calculus, see Haley and Schall (1979), Chapter 10. For a more rigorous but still accessible treatment, see Merton (1982).

8. This also is approximately true if the bank is very well-capitalized, so that the probability of closure is insignificant. As a bank moves closer to the point of closure, the contingent element becomes more important.

9. Again, if the contingent element of equity is trivial, then $N(x)\approx 1$ and $N'(x-\sigma_A\sqrt{T})\approx 0$, so that $\sigma_E\approx\sigma_A(A/E)$.

10. Linear regression analysis cannot rule out the possibility that c and vary in some nonlinear but known way during the sample period. Neither direct nor anecdotal evidence suggests that changes in either parameter are a major problem for the period studied, although King and O'Brien (1991) argue that regulators might systematically vary the threshold (and the monitoring interval) with the condition of each bank. Since this possibility cannot be ruled out, some degree of caution is appropriate in interpreting the results. Most previous studies using similar contingent-claim models have implicitly held both the closure threshold and the charter value ratio constant over time and across banks, often without the critical examination given to these assumptions in this paper; Furlong (1988) is an exception.

11. Schellhorn and Spellman (1991) calculate implicit volatilities from the prices of subordinated debt issued by bank holding companies, using the fact that risky debt can be valued as riskless debt minus a put option on the assets of the issuer. The spirit of the Schellhorn-Spellman approach is very similar to the present analysis. One drawback to their use of subordinated debt is that the sample size is smaller, because so few banks have regularly traded subordinated debt outstanding.

12. Day and Lewis (1988) make identical assumptions regarding interest rates and dividends.

13. Other methods for computing implied volatility typically involve weighted averages of observed option volatilities; see Bodurtha and Courtadon (1987, pages 28-30)

for a discussion. All of the methods give heavier weight to near-the-money options, and therefore in practice are likely to yield results close to those obtained through the simpler approach used here (arithmetically averaging only the nearest-the-money options).

14. The relatively small estimated insurance liability in Chart 5 is a result of the assumption that the FDIC sells the charters of failed banks to defray the cost of covering deposits; only the liability net of the charter value, as developed in equation (8), is presented.

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