Risk and Capital Adequacy in Banks

Sherman J. Maisel*

Financial markets have become more volatile and more competitive. The scopes of banks and bank holding companies have expanded. Management decisions have become more vital and more complex. Modern theories of risk and capital can aid bank decision-making. With a better understanding of potential trade-offs, banks may choose a desired level of risks with a minimum waste of capital. Unnecessary risks can be avoided.

Complaints are widespread that government regulations reduce productivity and raise costs of borrowing and lending. Bank regulations are specifically accused of reducing competition while giving birth to a plethora of wasteful nonprice competitive practices. Bankers' decisions are said to be warped as they shape their operations and lending to circumvent regulatory constraints. Risk-taking is artificially reduced even as capital is wasted.

Existing regulations and the bank examination system attempt to control capital, liquidity, diversification, and risks while promoting sound management. However, controls are based on tradition, industry norms, and subjective evaluations. How to measure risks and what is adequate capital have not been formulated in objective terms. The ratio of capital to assets has declined steadily. It is unclear whether this is due to market forces or to weaknesses in the regulatory system. In critical cases, problem banks have ignored regulatory constraints because suggestions for change could not be formulated in an enforceable manner.

Yet the need for some regulation is widely recognized. Without regulations, an undue percent of financial institutions are likely to take excessive risks. Because of the large amount of leverage, the difficulty of depositors' policing of risk levels, the high cost of information, and the number of small, uninformed depositors, an institution can profit by raising its risk ratio. Moral hazards are also high; it is hard to protect against conflicts of interest and self-dealing.

The introduction of federal deposit insurance was a major reform. It reduced fear among depositors, ended bank runs, and strengthened the stability of the economy. It also potentially increased competition and choice among borrowers and lenders by making entry easier. Depositors do not have to seek size to insure the safety of their claims.

*Sherman Maisel is a Professor of Business Administration at the University of California at Berkeley. This research was supported by a grant to the National Bureau of Economic Research from NSF-RANN (grant #APR 76-02511). The views expressed herein do not necessarily reflect those of the NSF or the NBER. This paper has not undergone the review accorded official NBER publications.

However, the existing system has several actual and potential flaws. Because insurance premiums are fixed and flat at all levels of risk or capital adequacy, bank managers and stockholders can profit by increasing their risks at the expense of the FDIC and uninsured depositors. As a result, to curtail excessive risks, detailed regulations and examinations are necessary. Many observers believe it would be more efficient to protect the public by greater use of the market and through insurance properly priced to reflect risks rather than through regulations. (Scott and Mayer, 1971; Barnett, 1976)

Another potential danger is the ambiguous position of uninsured depositors. Those in large banks have been insured *de facto*, while those in small banks have suffered losses. Moreover, since protection is not a matter of law, in critical periods all banks may become suspect. Unless changes are made, the future may witness major runs, together with all the problems that the deposit insurance is supposed to avoid. Even if such a point is not reached, fear may bring about concentration of funds in only a few large banks, causing critical problems for the smaller banks.

It is also claimed that the system penalized the well-managed bank. Poor managers are protected by the umbrella of the FDIC. Only in extreme situations will the stockholders and management be forced into bankruptcy. In most cases the FDIC helps bail them out of bad decisions. Many banks have been carried for long periods by the forebearance of the FDIC. When the economy was shaken in 1973 and 1974, a number of banks, including several large ones, turned out to have assumed excessive risks. The examination process did not protect the public against bad or unscrupulous managements.

The object of our study was to examine various implications of the modern theory of finance in order to compare their basic thrusts to the existing procedures of regulation with enforcement by examination. The theories contain a number of simplifying assumptions. What problems arise when they are applied to specific institutional problems?

On the whole, we believe that the regulatory process has not shifted rapidly enough to an emphasis on use of market information in place of detailed examination of individual loans and procedures. While adjustments must be made in application to individual cases because of lags, transactions costs, and poor information, the assumption that the market can solve most problems may well be a better starting point than the existing emphasis.

The primary risks are those of interest rate risk, mal-diversification, and moral hazard. Risks also arise from poor management. The question must be asked as to whether the current system has not established a pattern of subsidies to bad management with a resulting regulatory structure needed to keep the subsidies within bounds.

Our approach has been to emphasize the costs to the FDIC if banks become insolvent, on the assumption that deposit insurance has removed most of the original reasons for regulation. If depositors and borrowers can be guaranteed against loss, what do other regulations accomplish? Many seem to have arisen because entry into the banking market has been restricted because of a fear of competition. In contrast, if banks are required to maintain adequate capital or

are offered a choice of paying insurance penalties if their capital becomes inadequate, more use could be made of the competitive system.

Improvements can be made through a better understanding of how risks arise and how they can be measured. The modeling of risks shows that it is the entire portfolio, including its level of capital, that determines the danger of insolvency. A proper emphasis on the portfolio could bring about a reduction in specific constraints.

Measuring Adequate Capital

The use of a portfolio approach enables us to define capital adequacy. We would like to be able to measure adequate capital in a way that could be used by managers, insurers, and regulators. Such a task is not simple; if it were, no special studies would be needed. Our experience shows that modern theories of finance enable us to define and model capital adequacy. The measurement problem, while not easy, does not appear more difficult than those solved elsewhere. Applications of known techniques allow us to clarify many problems and to arrive at preliminary estimates of the magnitudes of some of the key parameters.

What constitutes adequate capital depends upon the amount of risk assumed by a firm. Capital is adequate either when it reduces risk of future insolvency to some predetermined level or when the premium paid by the bank to an insurer is "fair"; that is, it covers the expected losses of the insurer, given the risk and capital of the firm and the terms of insurance with respect to when insolvency will be determined and what losses will be paid.

Portfolio theory supplies the necessary tools for measuring the risks of insolvency. A bank selects a portfolio consisting of a variety of particular activities, including assets, liabilities, commitments, nonbalance-sheet operations, and net worth (capital and reserves). The expected changes in these activities, their rate of return, and the bank's capital policy give an expected end-of-period net worth. However, expectations are unlikely to be realized exactly. Because of economic events, total income (including changes in capital values) will exceed or fall short of expected levels. (Markowitz, 1959; Sharpe, 1964; Lintner, 1965; Mossin, 1966; Merton, 1974, 1977)

Measuring the risk of a portfolio requires a calculation of its expected end-of-period net worth and of the probable distribution of possible net worths around this level. The bank will become insolvent if events cause its income to be so negative as to more than offset its initial capital plus any contributions less any dividends paid during the period. Risk depends on both the probability of insolvency and the expected losses in case of such failure.

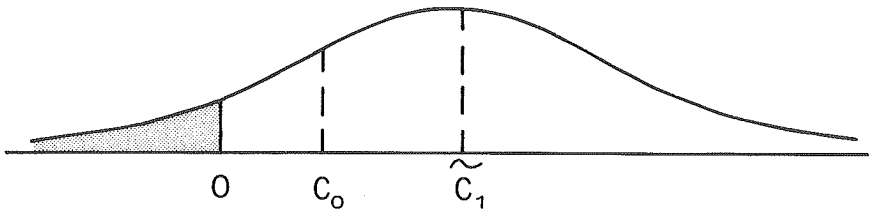
A Model of Insolvency

A bank is theoretically insolvent either (a) when its liquidity is so low that it cannot pay its debts, i.e., a negative cash flow cannot be met, or (b) when the market value of its liabilities exceeds that of its assets reduced by the costs of

bankruptcy. Because of gains and losses on intangibles not shown on a bank's books, the determination of insolvency is complex. Not infrequently, regulators delay bankruptcy procedures beyond the economic occurrence of insolvency. In an attempt to avoid the costs of liquidation, regulators close banks only with reluctance. In the interim, the FDIC or debenture-holders or noninsured depositors bear the cost of future potential losses.

Figure 1 diagrams this risk of insolvency. The bank's assets have a present value of A_0 and liabilities of L_0. Its net worth is $A_0 - L_0 = C_0$. Between the present and the next evaluations, events will cause unanticipated changes in the asset and liability values. The bank's expected value at the next evaluation is $\tilde{C}_1$. The difference between C_0 and $\tilde{C}_1$ is the expected return, $\tilde{R}_Z$, adjusted to correct for dividends or capital contributions. The total expected return, $\tilde{R}_Z$, depends on projected income, payments on liabilities, operating costs, loan losses, and the forward interest rate used to discount expected assets at the next evaluation.

Figure 1



The curve illustrated is the distribution function of $\tilde{R}_Z$ centered on the expected end-of-period net worth. To the left of the zero point in the diagram, net worth is negative, and the bank insolvent. The solid area under the curve indicates the probability of insolvency. To determine risk requires measuring the bank's initial net worth (C_0); the expected return in the period ($\tilde{R}_Z$); and the probability distribution or variance of the expected return [$\text{Var}(\tilde{R}_Z)$].

A Model of Variances

To measure risks, individual assets and liabilities can be grouped into a limited number of activities, such as consumer loans, real estate loans, bonds with three-year maturities, certificates of deposit. The banks' expected return and its variance depends on the weight of the individual activities, their expected returns, and their variances and co-variances. The returns on individual assets and liabilities will vary with movements in net yields and the rate of which the net yields are discounted.

The present expected value of an asset depends on three factors:

1. Its net yield. This will differ from its promised gross return by the amount of operating expenses and a provision for loss.

2. The rate at which net returns are translated into certainty equivalents (risk-free returns). This depends on the variance of the expected returns and their co-variance with the market.
3. The discount rate applied to the risk-free returns. This will vary with the time to maturity of the risk-free flow from the asset.

Changes in any of these items will cause the total return to differ from that originally expected. Predictions of risk require estimating possible changes in each of these factors: operating expenses and losses, to obtain an estimate of net yields; the market's discount for risk; and the risk-free interest rate.

For example, a mortgage may carry a face interest rate of 11 percent. The estimated risk-free return will be the 11 percent less allowances for each of these factors. Compared with government bonds, mortgages will have larger expenses and losses. The mortgage returns must be further discounted because they vary more than returns on risk-free securities. Finally, the value of their expected yield is reduced because risk-free long-term yields are higher and vary more than do short-term ones. On the average, these three forces may reduce the expected rate of return on a mortgage with a face yield of 11 percent by 250 basis points, or to 8.5 percent. The factors causing these reductions of promised returns compared to actual returns vary over time. Experience shows that, as a result, the average rate at which expected future mortgage cash flows are discounted will vary so that the 250 basis point reduction is merely the center of a range between 150 and 350 basis points. The expected return of an 11 percent mortgage over time has ranged from 7.25 percent to 9.5 percent around the average expected return of 8.5 percent.

In any period, the yield from an activity is its net cash flow plus the change in its capital value between the start and the end of the period. Changes in capital values, in turn, depend on how the discount factors move. Thus, in recent years, actual returns on mortgages have been as low as -3 percent, while in others they have been as high as 13 percent. The risk of an activity depends on the expected variance of such returns. [Var(r)].[1]

The expected return for the bank ($\tilde{R}_z$) is the sum of the present values of the positive and negative expected returns from each activity. A vector, Y_z, contains each activity's relative share of the next period's expected return. A covariance matrix is formed of the expected returns from each activity:

$$D = \mathrm{Cov}(r_{it}, r_{jt})$$

[1]A bank has a set of activities, "i" (K activities, with assets 1 . . . J and liabilities J + 1 . . . K). Each activity has an expected cash flow in the future: $\tilde{m}_{i1} \ldots \tilde{m}_{iT}$ for the years 1 . . . T. Each of these cash flows has an adjusted certainty equivalent market value in future years: $\tilde{F}_{i1} \ldots \tilde{F}_{iT}$. The present value, c, of activity i is the sum of these future market values each discounted by the market-wide discount factors expected to prevail. $c_i = \tilde{q}_1 \tilde{F}_{iT} + \tilde{q}_2 \tilde{F}_{i2} + \ldots \tilde{q}_T \tilde{F}_{iT}$ where $\tilde{q}_t = \frac{1}{\tilde{r}_{ft}}$ and $\tilde{r}_{ft}$ is a risk-free rate of return in period t. The actual return on an activity in a holding period will be: $\tilde{r}_{it} = m_{it} + \tilde{c}_{i,t+1} - c_{it}$ dependent on m_{it}, the cash flow actually received, plus the change in value of the activity which depends on $\tilde{r}$, the changes in $\tilde{F}_{it}$ and $\tilde{q}_1$, the future values of the certainty equivalent and the applicable discount rates for each. The risk in the activity [Var($\tilde{r}_{it}$)] depends on how the total return varies with events (Lanstein-Sharpe, 1978; Boquist, Racette, and Schlarbaum, 1975).

Given this co-variance matrix, the total expected variance of the bank's return is:

$$\text{Var}(\tilde{R}_Z) = Y_Z D Y_Z'$$

One of the major tasks of measuring capital adequacy is finding this expected variance. In thinking about the factors causing a bank's variance and risk, a useful background is the extensive literature based on portfolio theory and the Capital Asset Pricing Model (CAPM). This literature generally classified risks under three heads. Most important are market risks (also called systematic risks). These depend on those movements of the firm's returns which are correlated with movements of returns for the market portfolio (a combination of all securities, each in proportion to market value outstanding). Some of the bank's activities, such as defaults, shifts in operating expenses, and changes in the overall price of risk, are likely to react to the same events that cause movements in the value of the market portfolio. Depending on the particular set of activities the bank has chosen, the reaction of the bank's returns to these events may exceed or fall below those of the market as a whole.

In addition, however, because they may react in a unique manner to such factors as interest rates, foreign exchanges, localized depressions, or over-expansion in the real estate market, the returns of a bank may move quite differently from the overall market. Some movements lead to nonmarket, or nonsystematic, risks. These movements may be further subdivided into factors likely to cause banks as a group to move more or less together, leading to a second or extra-market co-variance or risk, and, thirdly, to specific risks unique to the individual bank.

Measuring Capital Adequacy in a Bank

There are four steps to estimating the capital adequacy in an individual bank.

1. The first step is to estimate the risk in each activity. This calls for a basic examination of how risks vary for each activity in which a bank might engage. Ideally, a complete co-variance matrix covering all of the pertinent activities under possible future conditions should be developed. This is not feasible. Our study estimated risks in approximately 10 separate activities. It seems likely that an optimum number of classes of activities for analysis would be between 15 and 20. When an activity encompasses assets with a wide spread in duration, it should be further subdivided by maturity.

2. The next task is to apply the estimated risk matrix to the activities the bank is expected to engage in between now and the next evaluation. Since total risk depends on the proportion of each activity to the total, the estimates of variance by function must be applied to assets aggregated into the desired classes. Each aggregate must be corrected for possible changes in size. Where the bank ends up depends on how it has been changing and where the economy goes. The matrix of expected returns and variances must be applied to the estimates of the average and end-of-period portfolios to obtain an expected income for the period, together with a distribution function for expected income.

3. The risk of insolvency depends on how the initial economic net worth of the bank may be altered by what happens to earnings. The initial capital is available to absorb potential losses. Thus, to measure risks, capital must be properly defined and estimated. Economic, rather than book or reported capital is required. Any exogenous (not dependent on income) capital changes must also be projected. Bank examiners have traditionally requested added capital if they believed it was weak. But they have not had proper measures of weakness.

4. Finally, the actual risk and measure of capital adequacy must be calculated. Several techniques are available for this purpose. Each uses a known relationship between initial net worth, expected income, and capital changes to give expected end-of-period net worth, together with the variance of this expected net worth.

Merton (1974, 1977) has shown that the pricing of deposit insurance as well as most other financial claims on a firm can be thought of as an application of generalized option pricing theory. This theory shows that the value of the fair insurance premium depends only on the risk-free interest rate, the value of the promises to pay, or liabilities at the date of next examination, the time until the examination, the current value of the firm's assets (the difference between the current value of its assets and liabilities being its net worth), and the variance rate per unit time for the logarithmic change in the value of assets. The fair insurance premium will differ depending on the distribution which expected events are thought to follow.

The second approach to measuring risk is through simulations. They enable one to relate the risk in particular portfolios either to a forecast of exogenous variables available from other sources or to a distribution of probable events based on past relationships.

A third approach models risk by use of regression techniques. It determines prediction rules for the systematic and residual risk experienced in the market for the bank's common stock. It aims to measure the predictive significance of a large number of variables as indicators of risk and, hence, as potential targets for management or regulation.

Finding the Risk in a Bank

A variety of risks face lenders at any time. The purpose of risk-management is to insure against unexpected developments which can cause insolvency. Basically, this is a classification problem. While the returns for a given loan depend on its proper underwriting, the risk and returns to a bank depend more on the relationship among activities than on individual loans. To manange risks, one must recognize the basic sources from which dangers spring. It is then necessary to estimate how much risk arises from each activity. Finally, the amount of variance in a bank's portfolio depends on the weight of each type of activity in the total.

A well-diversified portfolio of loans, even with high individual nonmarket risks, should return neither more nor less than a normal (corrected for market risk) profit. Their face interest rates should cover normal returns plus expected

operating costs and losses. Insolvency develops when firms fail to recognize this fact. By reaching for what seem like high promised returns, they either fail to diversify or accept too great a market risk. Typically, they neglect past events which they consider to be abnormal. An emphasis on individual loans misses the true dangers which arise from events affecting whole classes of assets and liabilities. Furthermore, because investors can diversify, nonmarket risks do not carry interest yields commensurate with their face yields. The measurement of risks should emphasize the need to examine broad classes of risks, and not individual loans. An improved classification system can call attention to the most critical areas and allow a better expenditure of effort.

1. Greatest is the risk of interest rate movements. When interest rates rise, banks must pay more for current liabilities. More significant, increases in the long end of the term structure raise discount factors for future promises to pay. The amount this will lower capital values depends on the duration of the portfolio (the present value of the future cash flows). Risk premiums may also increase, lowering capital values still further. The expected cash flow may become less favorable as assets are extended and liabilities lost or shortened.

If the interest rate risk is high, substantial adverse changes may cause insolvency. The degree of danger depends on the scheduled dates of cash flows from assets and liabilities and on the probable magnitude of shifts in the interest rate structure. It is the bank's net exposure, taking into account assets, liabilities, and capital, that determines its total interest rate risk. (Macaulay, 1938; Samuelson, 1943; Hicks, 1946; Grove, 1974).

2. Many discussions concentrate on loan loss or credit risk – the risk that loans will default or perform poorly. Variations in the default rate of typical banks around industry averages have not been large. However, occasionally an individual bank may depart considerably from the average. This potential must be estimated. Poor underwriting of individual loans can lead to above-normal losses, but errors of this kind are typically caught in time. Banks with above-average losses in one period tend to have a reduced probability of a second year of unanticipated losses. They regress back to the mean.

Banks whose loans carry high interest rates seem, as theory says they should, to charge enough to offset any added risk. One cannot assume that a well-diversified portfolio of loans whose individual risks appear high is either more or less profitable or risky than a similarly diversified portfolio of loans whose individual risks appear low. In a fairly competitive market, loans carry interest rates related to their true risks. A class of loans may stay out of line for several years and a bank may underestimate individual risks in attempting to compete, but such errors are not fatal. Studies of bank examinations seem to show that both lenders and examiners are able to recognize past mistakes.

3. Another risk is that operating margins may deteriorate. Margins depend on receipts from assets, on costs of funds, and on operating expenses. Banks may err in their liquidity management. When rates on current liabilities shift, movements may also occur in the amount and source of funds. A rise in market rates may be accompanied by unexpected surges in takedowns of commitments. In considering operating risks, attention must be paid to items not shown on the balance sheet. In addition to commitments, foreign exchange contracts, letters

of credit, and trust operations may be important. One fortunate fact with respect to operating risks is that, on the whole, a sudden deterioration is unlikely. Most situations cast shadows well in advance. Dangers arise primarily from failure to correct past trends.

4. Among banks as a whole, the greatest risks and most common cause of failure are due to fraud, either internal or external, and to insider abuse. Owners and managers alter the portfolio to enhance their personal investments or those of family and friends. There can also be defalcations by members of the staff; or the bank can be defrauded as a result of undue trust or inadequate investigation of borrowers.

5. The final and a very significant risk for most banks is a failure to diversify. This risk may arise from a concentration of long-term maturities and, therefore, excessive interest rate risks or from loans. Banks may concentrate loans in specific industries or in certain localities – small banks in single towns or neighborhoods; large banks assuming too many foreign risks – or they may lend to a related group of investors or companies, or indulge in excessive short-term borrowing.

The idea of diversification to reduce risks is well recognized. Federal statutes and regulations restrict the size of loans to a firm or individual in relation to the bank's capital. While such rules are useful in guaranteeing a minimum, they fail to insure an adequate degree of diversification.

Nondiversification arises when a group of loans or investments are likely to react in the same way to outside forces. While concentration to a single borrower can be important, other factors can also dominate nondiversification. Thus, a portfolio of long-term bonds is not diversified even though it contains hundreds or even thousands of different borrowers. Loans to 100 real estate investment trusts have only slightly increased diversification over a portfolio of 50 REITs. For certain purposes, the entire net balance of loans made abroad may constitute a single risk. The effectiveness of diversification depends on selecting loans or activities where the correlation among the activities is either negative or slight.

Bank regulators have traditionally considered risks of illiquidity to be critical. We do not treat such risks as a separate factor. A liquidity risk is either (a) another name for interest rate risk or (b) included in operating risks. This latter risk arises from the danger of high transactions costs or interest penalties when parts of a portfolio must be shifted to others because of negative cash flows.

These costs exclude losses which may have been incurred because interest rates rose in the past. Liquidation problems relate not to the maturity dates of an asset, but to shiftability. Commercial loans, even when due, may not be shiftable. Foreign loans are another example where liquidity can evaporate. Liquidation costs depend on the state of the economy; they rise rapidly in periods when markets are under pressure. Contrary to usual treatment, liquidity risks may vary greatly even among items with identical maturities.

Several of these risks are related to the size of banks. Dangers of nondiversification and of insolvency due to fraud or insider abuse diminish as the size of a bank grows. Such risks are less likely to be as significant a part of the total, and

therefore to cause insolvency, in larger organizations. The U.S. National Bank of San Diego is the exception that proves the rule; but this case also proves the need for logic in recognizing what is meant by diversification, in contrast to efforts merely to enforce narrowly conceived regulations.

Our regulatory system does not seem to have faced up to the differences which size makes on operations and risks. The largest 250 banks, with over $500 million of assets in each, hold over 60 percent of bank assets. The smallest 10,000 banks hold only about 10 percent of all assets. For the larger banks, a much greater share of assets, liabilities, and decisions will be market-dominated. Dependence on particular situations and localities is far less likely.

Among the smaller banks, moral hazard remains a critical issue. If this could be reduced to a negligible factor, risks in banking could be treated far more like insurance problems elsewhere. No one expects fire losses to be zero; yet the problem is handled efficiently through insurance with minimum regulation. A key question is whether, with a proper recognition of what is involved, auditing or other processes could be depended on to reduce the risks of moral hazard and mal-diversification to acceptable and insurable levels. To date, regulations have done a poor job of clarifying major risks and reducing them to a minimum. They have not been designed to correct the most pressing problems.

Some Estimates of Risk

The first step in estimating risks, as indicated by the previous discussion, is to measure the expected variance in the returns to an individual bank, given its selection of assets and liabilities. Ideally, this estimate should be made by applying a co-variance matrix for classes of assets to a bank's individual portfolio.

In our study of bank risks, a great deal of effort was devoted to attempts to measure the variance of specific activities. The greatest success was found in the study of interest rate risks. Because interest rate risks are closely related to movements in the risk-free interest rate and because such rates are set in a well-functioning market, it is not too difficult to measure the probability of movements in the risk-free rate applicable to assets with varying durations and maturities (cf. McCulloch, 1978b). With estimates of how movements of specific assets and liabilities of a bank relate to those in the government bond market, it is possible to estimate the interest rate risk of a bank as a whole (Maisel and Jacobson, 1978).

The data on credit and operating risks, while not as extensive, seem adequate for many purposes. These data consist of time series of loan losses and operating income changes for banks as a whole, and of similar information for large banks and bank holding companies. In addition, extensive data are available on the levels and year-to-year changes in total loan losses and operating income for each bank since 1970. These were analyzed through studies of the year-to-year movements of the cross-section of all individual banks.

Information on the risks of mal-diversification and of moral hazards is far harder to obtain. There are records of the number of banks which have become insolvent for these and related reasons. The actual numbers are small. Moreover, these events occurred under a regime of regulations and detailed bank examina-

tions. They give little indication of what would happen under a system of freer choices and minimal regulations. However, some measures for these risks can be obtained through simulations and examinations of related problems in other industries.

Another sphere in which information is minimal is on the co-variances among risks. Here, however, data on a number of activities indicate that while an assumption of complete correlation among risks is conservative, it probably does not greatly distort the situation; that is, the co-variance term can be ignored.

As a result, we conclude that currently the exact measurement of risks is not possible. However, the theories and available empirical estimates can show orders of magnitude and can pinpoint critical problems. Many types of risks can be quantified. The procedures point toward methods of reducing the remaining areas of uncertainty. With more detailed data from individual banks, the reliability of such estimates could be rapidly improved.

Interest Rate Risks

When interest rates move, banks are affected in at least four ways.

1. Their cash flows alter as the rate at which commitments are taken down changes, assets are paid off more or less rapidly, and deposit liabilities shift.
2. The interest rates paid and received on liabilities and assets tied to market rates move with those rates.
3. The term structure of interest rates shifts. If the term structure moves up, the value of future promises to pay becomes less.
4. The discounts for risk may widen. These changes will have the same effect as movements in the risk-free rate.

We have tried to measure interest rate risks by two separate methods. The first calculates the probable variance in the risk-free rate of assets and liabilities at maturities from 3 months to 30 years. These estimates are based on the listing of actual month-to-month movements of government securities between 1951 and 1977. (McCulloch, 1975) These variances are combined into a weighted total variance depending on the duration of the activities conducted by typical banks.

The second technique calculates the interest rate elasticity of net worth of specific institutions. Potential changes in capital values are estimated from econometric models of past lending and borrowing. Possible movements in interest rates are based on maximum past shifts in the term structure.

The first column in Table 1 shows the percent changes from the end of one year to the next in the value of a government security with an average duration of three years. (Through three years there are only minor differences in the variance of pure discount instruments and notes of the same maturity. As maturity increases, the effect of semi-annual interest payments and, therefore of differences in duration, alters the relationship between the two instruments.) Three years has been roughly the duration of the assets in a typical bank. The table shows a maximum year-to-year change of 5¾ percent. For assets with a six-year duration, the maximum change is about 8½ percent. The year-to-year variance increases regularly with duration. For the first three years, the rate of

increase is rapid; it then continues to rise, but at a decreasing rate.

The final row in the column shows the variance of the log of the change in the value of the asset with a three-year duration, assuming that the price depends only on movements in the risk-free rate. Because of changes in the discount for risk, the total variance of the actual assets in a bank would be somewhat greater.

The assumption is frequently made, as in the Black-Scholes option pricing model, that changes in value due to interest rate movements follow a log-normal distribution. McCulloch and others have argued that the distribution of the prices of interest-bearing securities is far more fat-tailed or leptokurtic. To reflect this fact, McCulloch has developed an option pricing formula based on a log-symmetric stable distribution (McCulloch, 1978a). The distribution assumes a greater probability of extreme events. The application of the more fat-tailed distribution greatly increases the estimated risk from interest rate changes. Thus, McCulloch shows that for a 20-year par bond, the risk that the price will change by 10 percent or more during a year is estimated to be covered by a fair insurance premium of 0.06 percent if a log-normal distribution is used, compared to a premium of 1.17 percent under the log-symmetric stable distribution which he has fitted to past interest rate changes.

Studies by Morrison (1977) and Nadauld (1977) show how much the interest rate elasticity of a financial institution depends on the structure of activities in which it engages. Thus Morrison models a wholesale bank which has only business loans, demand deposits, certificates of deposit, and equity capital. For banks with this structure, a 100 basis point increase in interest rates will lower net worth by only about 0.4 percent. In contrast, Nadauld (1979) shows that for a typical savings and loan association with assets concentrated in long-term mortgages, a change in interest rates of about 100 basis points (with an average change of 250 basis points for the first three years and 80 basis points thereafter) will cause its net worth to drop by 40 percent, or 100 times as much as that of an institution with fairly well-balanced short-term assets and liabilities.

Credit Risks

Tables 1 and 2 contain information on net loan losses and changes in net loan losses as a percentage of net earning assets. Examination of individual banks shows that the assumption that both loan losses and operating income will continue at the rate of the previous year is a good one. Banks determine their expected income on the basis of choices of assets and operations. Because of a slight tendency of banks to regress back toward the mean, that is a conservative assumption.

The risk of insolvency then depends, as illustrated in Figure 1, on the probability distribution of the outcomes of operations around this expected level. The distribution function can be estimated from both time series and cross-sectional information.

The middle column of Table 1 shows the year-to-year changes in net loan losses as a percent of net earning assets for all banks. The signs have been reversed, so that negative signs throughout the table indicate a loss in asset values.

TABLE 1

Time Series of Percent Changes in Capital Value of Bank Net Earning Assets from:

Year	Changes in Interest Rates for Treasury Notes with 3-Year Duration	Changes in Net Loan Losses (signs reversed)	Changes in Operating Income before Losses and Taxes
1966	−3.12%	−0.024%	0.109%
1967	−0.24	0.004	−0.079
1968	−0.03	0.018	0.074
1969	−5.76	−0.015	0.212
1970	5.19	−0.097	−0.022
1971	1.02	0.003	−0.231
1972	−1.77	0.062	−0.091
1973	−2.54	−0.022	0.086
1974	−1.94	−0.095	0.100
1975	−0.22	−0.157	0.079
1976	3.99	−0.017	0.030
Var (log of asset value)	.0008626	.0000039	.0000090

Source: U.S. Treasury, FDIC

The bottom row shows the variance of the logs of the asset value of the average bank due to unanticipated changes in loan losses.

Table 2 contains more detailed information on loan losses as a percent of net earning assets (NEA) for the year 1975. This is the post-war year with the greatest unanticipated loan losses and is close to the maximum in absolute levels. The top two sections of the table show the distribution of banks by losses as a percent of NEA in this year of high losses. The average U.S. bank had net losses of only 0.09 percent. Of over 14,000 banks, 572 had losses exceeding 1 percent of their NEA. Thirty-three banks had losses over 4 percent, including six with losses over 6.0 percent. Excluded from these data are the additional 13 banks which were declared insolvent during the year.

The bottom part of the table shows half of a distribution of banks by the increase in their loan losses as a percentage of net earning assets between 1974 and 1975. Only about 5 percent of banks sustained unexpected losses as high as 0.6 percent of their earning assets. Slightly over 1 percent of banks saw their losses increase by 1 percent or more of NEA.

On the other hand, a high level of losses with low capital can lead to disaster. In 1975 loan losses equaled 50 percent or more of book equity for 28 banks. Since losses are first met from reserves and then from operating income, the number of banks requiring capital to offset loan losses would be somewhat less.

The log-normal variance of the change in net asset values due to the year-to-year movements in losses is shown in the final column. In this year of maximum change, this cross-sectional estimate results in a risk estimate about four times

TABLE 2

Net Loan Losses as a Percent of Net Earning Assets

I. For Banks at Percentile of All Banks:

	1	5	50	95	99
In 1975	0	0	0.09%	0.82%	2.21%

II. Number and Percent of Banks Whose Loan Losses as a Percent of Net Earnings Were:

Class of Banks by Net Earning Assets ($ millions)	1.0 to 1.99%		2.0 to 3.99%		4.0 to 5.99%		6.0 + %	
	No.	%	No.	%	No.	%	No.	%
> 500	14	6.9%	3	1.5%	0	0	0	0
50-500	75	4.2	13	0.7	3	0.2%	1	0.1%
10-49	215	3.1	67	1.0	12	0.2	2	*
< 10	110	2.1	42	0.8	12	0.2	3	0.1%
All banks	414	2.9	125	0.9	27	0.2	6	*

III. For Banks at Percentile of All Banks:

	Median	75	90	95	99	Var log (1+Δ)
Change from 1974 to 1975	0.04	0.17	0.38	0.62	1.17	.000016

*less than 0.05%

Source: FDIC call reports.

as large as does the time-series estimate of variance from credit risks. However, two adjustments might be made in these estimates. The first would be to add a factor to account for the fact that the variance is calculated around the actual rather than the expected loss level. The second would account for the fact that here, too, a more leptokurtic distribution appears to fit the data better than a normal one. The effect of applying such corrections would raise estimated risks somewhat, but they would probably remain well below those estimated for interest rate movements.

Measuring the Risks of Operating Losses

Tables 1 and 3 contain information on the amount and unanticipated changes in operating income before loan losses and taxes as a percent of net earning assets. The third column of Table 1 shows the year-to-year changes for banks as a whole. The largest negative change was that from 1970 to 1971, with a magnitude of 0.23 percent. This was larger than any drop in values due to a

change in credit losses. The movements in expected asset values resulting from changes over time in the operating results of an average bank are more than twice as large as those accounted for by loan losses, but they are still small.

The cross-sectional data in Table 3 show that losses from operations are somewhat less likely to occur than sizable loan losses. In 1975 only 169 banks sustained operating losses of over 1 percent, compared to the 572 banks with loan losses of this magnitude. Furthermore, operating losses were almost entirely concentrated among the smallest banks.

The tables show that there is some, although far from complete, correlation between losses from these two sources. While, on the average, for banks as a whole loan losses and operating losses frequently moved in opposite directions, this was less true for individual banks. Thus, the poorest 1 percent of banks had a negative income of 1.5 percent from operations, while the bottom percentile had total losses of 2.7 percent from operations and loan losses combined. The combined losses exceeded 18 percent of equity for banks in the bottom 1 per-

TABLE 3

Operating Income as a Percent of Net Earning Assets

I. For Banks at Percentile of All Banks:

% NEA	1	5	50	95	99
Income before Loan Losses	−1.5%	0.4%	1.5%	2.8%	3.7%
Income after Loan Losses	−2.7	−0.3	1.3	2.7	3.6
% Book Equity					
Income after Loan Losses	−18.9	−2.0	13.4	24.2	30.1

II. Number and Percent of Banks Whose Operating Losses as a Percent of Net Earning Assets Were:

Class of Banks by Net Earning Assets ($ millions)	1.0 to 1.99%		2.0 to 2.99%		3.0 to 3.99%		4.0 + %	
	No.	%	No.	%	No.	%	No.	%
> 500	0	0	0	0	0	0	0	0
50-500	2	0.1%	0	0	0	0	0	0
10-49	20	0.3	7	0.1%	5	0.1%	4	0.1%
< 10	56	1.1	35	0.7	22	0.4	18	0.3
All Banks	78	0.6	42	0.3	27	0.2	22	0.2

III. For Banks at Percentile of All Banks:

Change from 1970 to 1971	1	5	10	25	Median	Var log (1+Δ)
	−2.31	−0.75	−0.39	−0.11	+0.002	.000039

Source: FDIC Call Reports

cent. There were 36 banks whose losses from both sources exceeded 50 percent of their book net worth.

The final part of Table 3 shows cross-sectional data on the decrease in operating income as a percent of NEA from 1970 to 1971, the year of the largest negative change in this category. One percent of banks saw their operating income drop by 2.3 percent or more. This was a much greater change than was experienced by the banks with the most negative movement in loan losses. On the other hand, changes in operating income can be larger without doing as much harm because many banks move from a sizable amount of earnings to small negative ones, whereas losses almost always move from an initial negative number to a larger one. The variances in the value of assets from changes in operations are somewhat larger than for loan losses but, again, if unanticipated losses from operations followed a log-normal distribution, they would not cause much concern.

Tables 1 to 3 seem to indicate that interest rate risk needs to be watched most diligently. Normal year-to-year movements in loan losses and operations do not add much to total risk. The dangers in this sphere seem to be concentrated in problems of mal-diversification and moral hazard.

Measuring Net Worth

In the measurement of risk and capital adequacy, most attention has been paid to measurement of possible losses in income. Yet the measurement of current and projected net worth should play a role as or even more significant than that of possible losses. Furthermore, the difficulties of measuring net worth are as great, or even greater.

A key factor in total risk is the real or economic value of a bank's capital and those nonincome forces which will cause it to differ at the next evaluation. Because many gains or losses in the value of assets and liabilities are taken into the books only over time rather than when they occur, and because many intangibles are never recorded, the economic value of capital often varies greatly from that shown on a bank's books.

How great the difference is between book and economic value can be seen if we are willing to assume that the value of a bank's stock in the market reflects its true economic value. In the years 1950 through 1975, the market value of the net worth of the approximately 25 banks and bank holding companies carried in the Standard & Poor's Bank Stock Index averaged about 135 percent of their book value. In individual years, the ratio of net worth in the market to book for all of these banks ranged from 1.87 in the highest year to 0.94. Year-to-year changes in this ratio exceeded 40 percent at times. When market-to-book ratios for individual banks are examined by years, an even wider range is found. We have examined the market-to-book ratios for the years 1971-73 for each of 135 banks; they ranged from 2.8 for the bank with the highest ratio to 0.6 for that of the lowest, around a median of 1.2.

Capital accounts in banks consist of equity capital, surplus, undivided profits, reserves for contingencies, and other capital reserves. True economic

capital may differ from this total because: (1) gains or losses on assets from interest rate movements are not recorded; (2) liabilities may be overstated when Regulation Q forbids payment of market interest rates; (3) the value of information, customer relations, and good will may be considerable; (4) reserves for loan losses may not be accurate; (5) the value in use or in liquidation of fixed assets varies; (6) commitments for future loans or foreign exchange purchases and sales may have a positive or negative value; (7) other reserves, such as those for contingencies and deferred taxes, may increase real net worth.

How can real net worth be measured? To some, the answer is simple: Use the market's estimate of value, as in the ratios discussed above. They argue that since the market is efficient, no one can arrive at a better estimate.

But this is far from a satisfactory solution. Usable market estimates would not number even 250 out of a total of over 14,000 banks (although those with fair or better markets hold a majority of all assets). Furthermore, while the market may be efficient in projecting its own future estimate of net worth, this may differ from actual values. The market swings widely in its estimates. It must consider earnings far into the future, not the resources available for payments on a given day.

While efficient in the narrow sense, the market's record of projections, both on an individual and an aggregate basis, is not good. If the market's estimates were accepted, the amount of capital would fluctuate widely. This could affect lending decisions and output. Even if public policy increased the risks assumed by the FDIC to some degree, it might be good policy to smooth the swings in order to discourage pro-cyclical lending. Finally, because it is so heavily influenced by government regulations and actions, there is no reason to expect the market to be estimating the true market values desirable for public policy as against the value of regulations to the individual owners.

Lacking a single simple source of estimates of net worth, must we fall back on book value? Not necessarily. It may be possible to arrive at better estimates than book through valuations of the components of the balance sheet, using market-related data. (Cf. Nadauld, 1979.) Thus, few problems are encountered in a direct estimate of the values of securities. Similarly, it is possible to estimate gains or losses from interest movements in loans and similar accounts from movements in the market rates. Estimates are also available of the expected average net returns from different types of deposits. These expected returns from deposits as well as earnings or losses from other intangibles may be capitalized by the use of rates based either on current market rates or some average of past market rates.

Would such *ad hoc* procedures improve on use of either stock prices or book? The answer seems to be yes. Since capital enters into the risk calculations in a nonlinear form, even minor improvements in estimates may be important in certain critical ranges.

In the same way, some adjustment for expected growth in a portfolio relative to net worth may also be worthwhile. Although the record of sophisticated attempts to project individual balance sheets is not good, in a dynamic situation rough approximations of the future are likely to be better than an assumption of no change.

The Optimum Level of Capital

Capital is risk-offsetting because it can cover losses. It can bridge negative cash flows and pay off creditors. It also earns returns, but does not require cash payments or engender interest-rate risk. Yet banking history reflects a steady decline in the ratio of capital to assets. Why has this occurred? Why has leverage – the ratio of borrowed money to capital – steadily increased?

Financial theory offers two conflicting answers. One emphasizes the advantages to stockholders of increasing leverage, advantages to be gained because of the tax and regulatory system. While, in theory, arbitrage among investors and lenders should wipe out any profits from leverage, this probably does not happen under existing condtions.

In contrast, traditional theory posits a falling cost curve until leverage reaches some optimum point. It pays to reduce the capital ratio until that point is reached. If leverage continues to expand among banks, this indicates that the market judgment is that leverage has not reached an optimum.

In this latter view, failure to pick the optimum point of capital reduces welfare through a waste of scarce resources. On the other hand, if leverage has expanded primarily because it is subsidized by the government, then regulations which prevent it from expanding as far as the market wants do not create a social loss. While neither view can be proved, many believe that bank capital may be far lower now than it would be in a completely free, competitive market. In banking, unlike other industries where excess capital and fixed assets are wasted, most capital is lent out. There are no obvious advantages to substituting one form of liquid capital for another, in contrast to whatever ratio a free market would select.

Estimating Risk in Prototype Banks

While the data on individual classes of risks are not complete, they can be used to estimate how the need for capital or, alternatively, the cost of insurance compares for banks which take greater or fewer risks in their portfolios. Table 4 is constructed to indicate how risks vary among prototype banks. In the table, Bank A selects the safest portfolio – that with the lowest duration or interest rate risk, whose loan losses vary the least, and whose operating income is most stable. Bank B represents an average bank in all dimensions. Bank C is assumed to be willing to take the greatest risks among banks.

In Section I of the table, the estimates of risk are based on time series information. The interest rate risk for Bank A is equal to the variance in the log of the price of a 2-year government note between 1965 and 1976. For Bank B and Bank C, the variances are those for 3-year and 5-year governments respectively. These maturities have been selected to represent typical average maturities found in banks whose assets have low, average, and high durations. It is assumed that movements in governments will reflect movements in the returns for all assets even though, as pointed out previously, interest rate movements cause some additional losses.

TABLE 4

Example of Risks and Fair Insurance Premia

	Bank A	Bank B	Bank C
		Section I	
Interest Rate Risk	.0006539	.0008627	.0021111
Credit Risk	.0000003	.0000039	.0000251
Operating Risk	.0000011	.0000090	.0000523
Sum of Variances	.0006553	.0008756	.0021885
		Fair Insurance Premia per $ of Liabilities	
5% Capital/NEA	.000221	.000512	.003293
10% Capital/NEA	.0000001	.000001	.000204
		Section II	
Interest Rate Risk	.0006539	.0008627	.0021111
Credit Risk	.0000090	.0000165	.0000185
Operating Risk	.0000298	.0000320	.0000683
Sum of Variances	.0006927	.0009112	.0021979
		Fair Insurance Premia per $ of Liabilities	
5% Capital/NEA	.000263	.000567	.003339
10% Capital/NEA	.0000002	.000002	.000211
		Section II	
		Fair Insurance Premia Interest Risk Based on McCulloch	
5% Capital/NEA	.0047*	.0065*	.0090*
10% Capital/NEA	.0028	.0039*	.0054

*Interpolated

Source: See text. Fair insurance premia for Sections I and II based on Table 1, Merton, *Journal of Banking and Finance, 1* (1977), pp. 3-11.

The variances of asset values arising from credit risks (loan losses) and operating risks are based on the experience of large banks and bank holding companies between 1965 and 1976. The data are taken from the variances of the year-to-year movements in 68 of this country's largest banks. The estimate for Bank A is based on the average of the two banks with the lowest variance. Bank B uses the average of all banks in the country, and Bank C that for the two with the largest variances in this period. The variances from the three risks are added together, excluding any correction for co-variances.

The prototype banks in Section II use the same estimate of interest rate risk as in Section I. However, the estimates for credit and operating risks are based on cross-sectional data. The variances are based on the logs of changes in asset values arising from loan losses of individual banks between 1974 and 1975,

and changes in operating income before loan losses and taxes between 1970 and 1971. These are the years of maximum changes in the postwar period. Bank A uses banks with over $500 million in assets; Bank B uses the data for all banks, and Bank C uses data for banks under $10 million in assets, which have the greatest variance.

We are interested in seeing how risks – fair insurance premia – vary with these types of banks. Merton has shown that the risk of a bank varies with the variance in its asset values and its capital asset ratio (Merton, 1977). Under a set of simplifying assumptions, he has calculated the fair premia for banks with different degrees of variance and capital.

The second part of Sections I and II shows estimates of risk (fair insurance premia) based on Merton's table, and the variances estimated in the upper part of each section. Several points stand out. As shown also in Table 1, the interest rate risk far exceeds credit and operating risks. In fact, among these prototypes, interest rate risk accounts for 95 percent or more of the total.

The amount of capital compared to assets or liabilities is extremely important in determining total risk. Given the type of variances shown for the prototype banks, insolvency is very unlikely if a bank starts the year with a true economic net worth of 10 percent of net earning assets. On the other hand, with capital of 5 percent or less, the chances of insolvency are not negligible. Furthermore, the smaller the capital, the more does the type of risks assumed take on significance. Some banks may have risks 5 to 10 times as great as the average bank. Moreover, these differences are sufficiently large so that banks may appreciably increase their profitability by taking excess risks.

In the techniques used here, how the credit and operating risks are calculated makes little difference. However, an examination of the underlying data indicates that, just as with interest rate movements, the actual changes may not follow a normal distribution. Especially among smaller banks, outlyers in the negative direction exceed normal expectations. If possibilities of fraud and insider abuse were added, the risks from these and other factors would also be somewhat greater than shown in the table.

Some idea of the rapidity with which risks can rise if account is taken of these other factors is shown in Section III. This presents an estimate of the fair insurance premia required if one believes that a log-symmetric stable distribution rather than a log-normal distribution ought to be fitted to project possible future movements in yields. According to McCulloch's tables, the estimated risk of failure with a capital-to-net earning asset ratio of 5 percent is 10 to 30 times as great as under an assumption of a normal distribution.

The amount of risk will also exceed that shown for the banks in Sections I and II if other distributions are used for credit and operating risks, and if adjustments are made for mal-diversification and for moral hazard. Unfortunately, we do not have estimates of how much these will raise the possible variances. It does not seem likely, however, that they will increase so much as to make these other hazards equal interest rate risk.

While we cannot check the accuracy of the data from information about past insolvencies, they appear to be consistent with past events. Actual failures

occur primarily among small banks and among banks with high moral hazards not caught by auditors or the examination system. The critical question is whether the present complex system of regulation is necessary to perform this task, or whether alternative systems of measuring the risks and insuring properly could arrive at a more efficient technique for insuring against large numbers of insolvencies and a threatened breakdown in the banking system.

Fair Insurance Premia

A flaw in the present system lies in the fact that banks may find it profitable to increase their risks, since there is only slight relationship between risks and their costs of insurance. This can lead to a constant losing battle by regulators to force specific banks to reduce their risks. Many observers have argued that charging deposit insurance premiums which vary with actual risk is a necessary starting point in solving many regulatory problems. (Barnett, 1976; Scott-Mayer, 1971).

Our studies indicate that some system of variable rates should be feasible. Banks could be divided into 5 or 10 risk classes dependent on their ratio of economic net worth to their assets and the activities in which they are engaged. By using their recent history of earnings and losses, together with the duration of their current activities and their diversification, the detailed examination of individual loans and procedures could be minimized or abolished. Adjustments in rating and charges could be made retrospectively to guard against major shifts in operations.

The number of failures might rise somewhat, but most observers would be willing to trade some losses to poor managers for a greater freedom for the majority. If those taking greater risks were charged for their choices, or if they were required to maintain higher capital as a cushion, the public would be better off.

The actual dangers to our system do not lie in an increased rate of failures of small- or medium-sized banks. Dangers arise primarily from a failure to consider the overall risks in the portfolios of large banks and from inadequate capital. If, to fight inflation or for other reasons, the fluctuations in interest rates continue to grow in intensity, a failure to recognize how these and similar movements impact on portfolios and how they can be guarded against could be expensive for the nation.

References

Barnett, R.E. "Deposit Insurance," an address before the 82nd Annual Convention, Kentucky Bankers Association. Galt House, Louisville, Kentucky, Sept. 13, 1976. Reprinted in *FDIC Annual Report,* 1976, pp. 159-167 (1976).

Boquist, J.A., Racetta, G.A., and Schlarbaum, G.G. "Duration and Risk Assessment for Bonds and Common Stocks." *Journal of Finance,* 30(5), Dec. 1975.

Grove, M.A. "On 'Duration' and the Optimal Maturity Structure of the Balance Sheet." *Bell Journal of Economics and Management Science,* 5(2), 1974, pp. 517-557.

Hicks, J.R. *Value and Capital.* Oxford: Oxford University Press, 1946.

Lanstein, R., and Sharpe, W.F. "Duration and Security Risk." Research Paper No. 451, Graduate School of Business, Stanford University, 1978.

Lintner, J. "The Valuation of Risk Assets and the Selection of Risky Investments in Stock Portfolios and Capital Budgets." *Review of Economics and Statistics,* 47, 1965, pp. 13-37.

Macaulay, F.R. *Some Theoretical Problems Suggested by the Movements of Interest Rates, Bond Yields, and Stock Prices in the United States since 1856.* National Bureau of Economic Research General Series No. 33, Columbia University Press, 1938.

Maisel, S.J. and Jacobson, R. "Interest Rate Changes and Commercial Bank Revenues and Costs." *Journal of Financial and Quantitative Analysis,* Nov. 1978, pp. 687-700.

Markowitz, H.M. *Portfolio Selection: Efficient Diversification of Investments.* New York: Wiley, 1959, 1971.

McCulloch, J.H. "The Tax-Adjusted Yield Curve." *Journal of Finance,* 30(3), 1975, pp. 811-830.

_____. "Interest Rate Risk and Capital Adequacy for Traditional Banks and Financial Intermediaries." National Bureau of Economic Research, Working Papers No. 236, revised July 1978a.

_____. "The Pricing of Short-Lived Options when Price Uncertainty is Log-Symmetric Stable." National Bureau of Economic Research, Working Paper No. 264, July 1978b.

Merton, R.C. "On the Pricing of Corporate Debt: the Risk Structure of Interest Rates." *Journal of Finance,* 29(2), 1974, pp. 449-470.

_____. "An Analytic Derivation of the Cost of Deposit Insurance and Loan Guarantees: An Application of Modern Option Pricing Theory." *Journal of Banking and Finance,* 1(1), 1977a.

Morrison, J. "Interest Rate Risk in Commercial Banking: Some Implications for Capital Adequacy." Dissertation submitted to Graduate Division, University of California, Berkeley, June 1977.

Mossin, J. "Equilibrium in a Capital Asset Market." *Econometrica,* 34, 1966, pp. 768-783.

Nadauld, S.D. *The Interest Rate Elasticity of Net Worth in Savings Institutions.* Unpublished dissertation, University of California, Berkeley, May 1977.

_____. "An Elasticity Net Worth Approach to Capital Adequacy in Savings Institutions." Invited Research Working Paper No. 26, Federal Home Loan Bank Board, July 1979.

Samuelson, P.A. "The Effect of Interest Rate Increase on the Banking System." *American Economic Review,* 35(1), 1943.

Scott, K.E., and Mayer, T. "Risk and Regulation in Banking: Some Proposals for FDIC Reform." *Stanford Law Review,* 23, 1971, pp. 857-902.

Sharpe, W.F. "Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk." *Journal of Finance,* 19(3), 1964, pp. 325-342.