A Nationwide Test of Early Warning Research in Banking

Three years ago the United States banking and financial system faced the severest test of its stability and capacity to endure heavy financial strain since the 1930's. The nation's financial institutions came through that test with far less damage than might have been expected during a period of economic and financial trauma. That the rampant inflation of the early 1970's, compounded by a sharp recession and an energy crisis, did not do more damage than it might have probably reflects a far stronger financial base than is commonly recognized. At the same time, the difficulties of the early and mid-1970's disclosed some areas of financial weakness that will occupy the attention of bank managements and bank supervisors for some time to come.

In view of the responsibility of the bank regulatory agencies[1] to maintain a safe and sound banking system that meets the nation's credit needs, the Banking Studies Department of this Bank has for several years pursued a project to discover through statistical techniques banks that appear to be vulnerable to financial deterioration. Statistical early warning procedures are intended to supplement the investigative and analytic tools already used by bank supervisors. The most important tool is the on-site examination, which provides comprehensive and reliable information on the condition of a bank or bank holding company. In aiding bank supervision, statistical early warning can help identify and monitor significant changes that may be taking place in a bank's financial condition between scheduled examinations. Thus, supervisors can be alerted to emerging conditions that indicate more detailed investigation and analysis are needed at particular banks.

In this article, we report on a nationwide test of the early warning concepts and procedures that were developed from information on member banks in the Second Federal Reserve District. This test became possible when nationwide historical data on the bank supervisory ratings of member banks were made available to us by the Board of Governors of the Federal Reserve System.[2] The results strongly suggest that these early warning procedures can provide insight into the degree of bank risk and also can help

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[1] Commercial banks in the United States come under the jurisdiction of three Federal regulatory bodies. The Federal Reserve regulates state-chartered member banks and bank holding companies, the Comptroller of the Currency regulates national banks, the Federal Deposit Insurance Corporation regulates state-chartered commercial banks that carry FDIC deposit insurance and are not members of the Federal Reserve. Further, each of the fifty states has regulatory jurisdiction over the commercial banks they charter.

[2] There are four possible supervisory ratings that can be accorded a member bank. A rating of "1" is the highest indication of soundness and safety. A rating of "2" is considered intermediate, but nonetheless quite satisfactory. Ratings of "3" and "4" indicate financial difficulty and represent the range referred to in this paper as a "low supervisory rating". All these ratings are awarded banks on the basis of information obtained in on-site examinations as well as other relevant information.

improve the efficiency of bank supervision. The statistical screening procedures we have developed facilitate the deployment of resources for the examination of banks that have a measurable potential for weakness, while minimizing supervisory outlays on banking institutions that are strong and likely to remain so. These screening methods have been under discussion within the Federal Reserve System for some time in a joint effort of Federal Reserve personnel to develop improved and more cost-effective methods of detecting actual and potential bank weakness. Those discussions have contributed significantly to the refinement of the early warning techniques reported here. This year a bank surveillance program based on that joint effort and using the methods described in this report was added to Federal Reserve supervisory procedures.

The results of that early warning research were reported in a series of articles published in this Bank's *Monthly Review,* dating back to September 1974. The most recent of these papers was published in July 1976.[3] That report showed that several important measures of bank financial condition—namely, capital in relation to risk assets, operating expenses and revenues, loss provisions, and certain indicators of portfolio risk, all obtained from the data filed regularly in financial reports to the bank regulatory agencies—can be combined to provide an index of bank vulnerability. Research conducted on member banks in the Second Federal Reserve District indicated a strong tendency for member banks that appear most vulnerable on the basis of our bank score index to receive low supervisory ratings subsequent to their receiving weak bank scores on the basis of reported data. A low supervisory rating reflects the judgment of bank supervisors, based on information obtained in an on-site examination, that the bank in question has sustained marked financial deterioration.

The nationwide results reported in this article indicate a remarkable degree of consistency in the extent to which bank vulnerability can be detected through statistical techniques that employ regularly reported financial data. The analysis is effective either for regional groupings of banks or for selected nationwide size classes. This is an important finding, since it suggests that bank supervisors have wide latitude in using regional and national data to conduct early warning analysis. Since banking data usually are available first at the regional offices of the Federal bank regulatory agencies, while national tabulations are ready somewhat later, regional analyses can be conducted without delay. Furthermore, regional groupings may, in some circumstances, provide the most appropriate basis for comparison of the performance of individual banks. National samples, when available, can be useful in the study and surveillance of the practices of institutions engaged in similar types of banking activities.

On bank vulnerability

An empirical investigation of the concept of bank vulnerability must use measures that accurately reflect the ability of a bank to withstand economic and financial strain. This problem might be approached by developing a comprehensive econometric model of bank operations. Such a model would focus on the factors that may stimulate high-risk lending and borrowing as well as those that result in losses leading eventually to closure or supervisory mergers. However, the information required for such an approach would be massive and largely unattainable. Alternatively, the investigation could focus on broader economic and financial factors which have been found to be important leading indicators of financial strength or weakness. From a practical point of view, supervisory judgments necessarily must come into play in the selection of specific measures that could be used as early warning indicators of financial strength or weakness, since it is essential for these measures to have operational significance.

Before turning to the specific variables and procedures this report uses to measure and test vulnerability in banking, a brief word is in order concerning the inherent problems in such an investigation and the nature of certain solutions adopted in this report. To begin with, it is possible to construct a variety of indicators whose ostensible purpose is to measure bank vulnerability on the basis of performance in several financial areas considered important to the investigator. In prior research, we have reported on a specific indicator of bank vulnerability, that is, a bank score or index developed from several financial ratios that are considered important from a supervisory point of view. An objective test of this indicator, and others like it, requires some independent information on the consequences of bank vulnerability—such as the incidence of bank failure, the market discipline imposed by creditors, the behavior of stock prices, the difficulty in attracting capable management, and similar information.

The objective test employed in this and prior reports

[3] See David P. Stuhr and Robert Van Wicklen, "Rating the Financial Condition of Banks: A Statistical Approach to Aid Bank Supervision", *Monthly Review* (Federal Reserve Bank of New York, September 1974), pages 233-38; Leon Korobow and David P. Stuhr, "Toward Early Warning of Changes in Banks' Financial Condition: A Progress Report", *Monthly Review* (July 1975), pages 157-65; Leon Korobow, David P. Stuhr, and Daniel Martin, "A Probabilistic Approach to Early Warning of Changes in Bank Financial Condition", *Monthly Review* (July 1976), pages 187-94. These papers contain a number of references to early warning research conducted by others in the field.

is the incidence of low supervisory ratings among member banks that have been ranked according to an index of vulnerability which is comprised of a group of key financial indicators. In this test, we expect that a high concentration of banks ranking poorly on the index of vulnerability will tend to receive low supervisory ratings in a subsequent period. There are substantive reasons for using this test. A low supervisory rating is objective evidence of a considerable weakness in a bank, since it is developed from information obtained in an on-site examination. While there may well be instances involving malfeasance or criminal activity where the problem cannot be detected in time even by on-site examination, the evidence of the past few years indicates that a large portion of all the member banks that closed or were merged out of existence for supervisory reasons had been identified by examination personnel as institutions having difficulties.[4] Thus, there is good reason to expect that accurate advance information (early warning) of the likelihood of a bank being awarded a low supervisory rating could help to improve the efficiency and effectiveness of bank supervision by providing additional time in which to forestall more severe difficulty.

The reader should recognize that there is a wider dimension to the testing of vulnerability discussed in this paper. It is evident that many banks ranking poorly in our index of vulnerability do not subsequently receive low supervisory ratings and by far most of the banks awarded low supervisory ratings recover. Also, occasionally, some banks that encounter severe difficulty may seem to be strong prior to a crisis. We believe the apparent inconsistencies are few in number and the reasons for them can at this point be left for future research.

Specific measures of vulnerability

Since our objective is to measure financial vulnerability, we studied a number of financial factors that are generally believed to be closely related to the fundamental causes of bank weakness in cases where outright criminal activity is not the principal factor. These causes are mainly: (1) poor management, (2) erosion of earnings and capital, (3) poor internal control of expenses, and (4) unanticipated loan or investment losses.

In the earliest stages of the study of early warning indicators, data from examination reports were utilized to construct indicators of bank financial condition and to determine whether or not supervisory judgments in the Second Federal Reserve District could be replicated by means of statistical variables.[5] A measure of success was achieved, and this led to a search for early warning variables that could be obtained solely from the financial reports filed by banks with the bank regulatory agencies, without the benefit of information gained from an on-site examination. We predicated this search on the belief that the potential for marked financial deterioration in banks can be discerned from the condition and income reports regularly reported by member banks.[6]

Management caliber is generally considered one of the most important factors affecting bank soundness, and therefore several measures of management ability were studied. One of the first tests of this nature made use of net income in relation to equity capital—that is, the rate of return on investment—since we hypothesized that good management should be reflected in relatively high income. We found, however, that this variable can provide erroneous early warning signals since reported income cannot be adjusted for the riskiness of the underlying loan portfolio that generates the profit. Thus, a bank in the early stages of pursuing high-risk loans may show an impressive profit record only to report marked difficulty at a later date as many of the risky loans default. This was indeed the case when banks receiving low supervisory ratings over the period studied often reported above-average income in the two or three years prior to the emergence of the difficulty.[7] As an alternative, we have employed an efficiency variable—namely, a measure of operating expenses in relation to revenues—which has proved to be a relatively reliable leading indicator of management ability to operate a sound and efficient organization.[8]

Another variable utilized in earlier work involved dividends in relation either to capital or to income. We found that banks paying relatively high dividends tended to be strong. This evidence might be inter-

[4] An extensive, but not exhaustive, search of public records of failures or supervisory mergers of member banks during 1970-76 disclosed that in forty-three out of fifty-eight cases the bank in question had been awarded a low supervisory rating at least one year prior to the crisis. Of course, the reader should be aware that the number of these situations is only a very small fraction of the total number of member banks awarded low supervisory ratings in these years.

[5] See footnote 3 (Stuhr and Van Wicklen).

[6] See footnote 3 (Korobow and Stuhr).

[7] Unpublished research—conducted by Joel E. Majors, Examiner, at the Federal Reserve Bank of Atlanta early in 1977—unearthed a similar finding.

[8] The operating expenses/operating revenues variable also has been identified by both Majors and Sinkey as an important leading indicator of impending difficulty for banks. Majors (see footnote 7); Joseph F. Sinkey, Jr., "A Multivariate Statistical Analysis of the Characteristics of Problem Banks", *Journal of Finance* (March 1975), pages 21-38.

preted to indicate that most bank managements reward stockholders only if the underlying financial position is strong. However, the higher the dividend the less the contribution is made to capital through retained earnings which, potentially at least, could weaken the bank. Moreover, the role of holding company affiliations presented a complication that could not readily be explored. Thus, dividend payout is not now being used in our early warning research.

It was expected at an early stage of the research that increased size might be positively related to bank soundness, on the grounds that large organizations are able to attract superior management and diversify loans more widely than small ones. Nevertheless, our empirical work, based on the evidence available in the Second Federal Reserve District, could not isolate size as a significant factor influencing bank vulnerability. It may be that, while large banks have operational and managerial advantages, they also tend to be associated with the more venturesome aspects of banking such as liability management, term lending, and the like.[9]

The effects of branching on bank vulnerability were also investigated, without clear results. The concept of branch banking appears to have complex implications for bank vulnerability, since a broad network of branches adds to a bank's expenses but also expands the opportunities for diversification. This category of variable, therefore, has not been actively investigated in the latest research.

Rates on loans and time and savings deposits were also studied in earlier research. It was felt that these variables would capture some of the risk aspects of the loan portfolio and measure the costs associated with reliance on time deposits. While the loan rate frequently appeared to be significant, it was difficult to separate the risk aspects from the market interest rate factors and, therefore, this variable was dropped. We did not find the rate paid on time deposits to be a consistently significant indicator of vulnerability.[10]

While investigation of many financial variables for member banks in the Second Federal Reserve District resulted in the elimination of a large number of variables, these investigations should not be considered exhaustive. Different results might emerge from new data available as a result of the recent expansion of the financial information banks are required to report or from the use of a different model than the one tested in this report.

In the refinement of the early warning research reported in previous articles, several of the variables were redefined to incorporate insofar as possible the banking operations conducted at the foreign offices of the nation's banks that engage in worldwide operations. On the basis of such new data for member banks in the Second Federal Reserve District, and limited tests for other Districts, five financial variables proved to be the most useful early warning indicators.[11]

(1) Loans and leases ÷ total sources of funds
(2) Equity capital ÷ adjusted risk assets
(3) Operating expenses ÷ operating revenues
(4) Gross charge-offs ÷ net income + provision for loan losses
(5) Commercial and industrial loans ÷ total loans.

The exact definition of each of these variables is given in the box on page 41.

Data for the five variables above are readily available both currently and on a historical basis and have consistently produced promising results. They have been the subject of intense discussion within the Federal Reserve System in connection with a System-wide surveillance program. We deemed it useful, therefore, to investigate the early warning value of these particular variables in a nationwide test.

A nationwide framework of analysis

In broadening the investigation to the nationwide universe of member banks, we have taken two directions: (a) several regional groups were established and (b) a number of size classifications were created. Banks were grouped by region to determine whether financial practices, risk factors, and supervisory judgments vary in specific regions across the nation. The particular regional groups selected (see map) were chosen largely on pragmatic grounds. The main constraints were to protect the confidentiality of supervisory data for each Reserve District and to limit the total number of banks under analysis in one sample to a group that could be handled by a computer program. As shown on the map, the nation's member

[9] This view does not preclude the possibility that differences in vulnerability may be found through a nationwide study of banks of varying sizes.

[10] See George J. Benston, "Interest Payments on Demand Deposits and Bank Investment Behavior", *The Journal of Political Economy* (October 1964), pages 431-49, and Albert H. Cox, Jr., *Regulation of Interest Rates on Bank Deposits*, Michigan Business Studies, Volume XVII, Number 4, (Bureau of Business Research, Graduate School of Business Administration, The University of Michigan, Ann Arbor, Michigan, 1966).

[11] One of the six variables (measuring liquidity) employed in the July 1976 report was dropped because its contribution was found to be insufficient to warrant its continued inclusion. Further, it was found that the use of loss provisions in place of gross charge-offs yielded closely similar results, suggesting that many banks provide for future loan losses on the basis of current loss experience.

Definitions of the Five Early Warning Variables

(1) Loans and leases ÷ total sources of funds (LL.TS)

Numerator: Loans, total domestic and foreign + direct lease financing

Denominator: Total domestic and foreign deposits − cash items in process of collection + Federal funds purchased + other liabilities for borrowed money

(2) Equity capital ÷ adjusted risk assets (EQ.ARA)

Numerator: Total equity capital + loan valuation reserves + deferred taxes of Internal Revenue Service bad debt reserve + minority interest in consolidated subsidiaries

Denominator: Total assets + loan valuation reserves − total cash and due from banks (domestic offices only) − United States Treasury securities − United States Government agency securities − trading account securities − Federal funds sold

(3) Operating expenses ÷ operating revenues (EXP.OP)

Numerator: Total operating expenses

Denominator: Total operating revenues

(4) Gross charge-offs ÷ net income + provision for loan losses (GCO.NI)

Numerator: Loan losses charged to reserves

Denominator: Net operating income + provision for loan losses

(5) Commercial and industrial loans ÷ total loans (CI.LN)

Numerator: Commercial and industrial loans booked at domestic offices

Denominator: Total gross loans booked at domestic offices.

banks are grouped into four regions: Northeast, Midwest, South, and West. These groups were formed from the combination of data for several Federal Reserve Districts. The Northeast region is comprised of the First, Second, Third, and Fourth Districts; the Midwest region the Seventh and Eighth Districts; the South, the Fifth, Sixth, and Eleventh Districts; and the West, the Ninth, Tenth, and Twelfth Districts.[12]

As noted, the prior research did not uncover any significant relationship between bank size and potential strength or weakness. In this report, a fuller investigation of size classification was made possible by the availability of nationwide supervisory data. Moreover, it is a common procedure in the analysis of financial institutions of the same size and character of business to determine whether the particular type of institution under study is performing up to par or meeting standards for its industry or peer group. The main purpose of this investigation, therefore, is to shed light on the question of whether peer-group analysis contributes to accurate and cost-effective early warning measures of bank vulnerability.

We created six nationwide size classifications in terms of the total assets of member banks: zero to $10 million, $10 million to $20 million, $20 million to $50 million, $50 million to $100 million, $100 million to $300 million, and $300 million and over. The classes were chosen so as to have a smooth gradation in size while maintaining in each size class a sufficient number of banks that received low supervisory ratings over the period studied to permit statistical analysis. We chose the largest size class—those banks having $300 million and over in total assets—to correspond to the group of member banks that provide quarterly income reports to the Federal Reserve and the Comptroller of the Currency. These expanded quarterly reports can, in time, be expected to provide useful early warning information.

Estimation of early warning functions

There are two phases in the development of an empirical forecast. The first step is to estimate the relationship in the sample data. Once the estimation is completed and a functional relationship is obtained, that relationship must be tested using separate and distinct data from that employed to estimate the function. No matter how accurately a function may fit past data, the acid test of its usefulness is its ability to provide accurate forecasts for a future period.

The July 1976 report defined and tested a relationship between bank scores developed from key financial ratios for member banks in a given base year versus the incidence of low supervisory ratings among those banks in a subsequent period. Financial ratio data were calculated for member banks in the Second Federal Reserve District. The average value of each of the five financial ratios was computed and the difference of each bank's value from the appropriate average obtained. Measuring the value of each bank's ratio in relation to the group average enables us to determine the extent to which a bank is unusually strong or weak with respect to the five key financial characteristics. The differences from the average for each variable were divided by the standard deviation for the entire group.[13] This step, in effect, weights each bank's deviation from the average to reflect the degree to which bank practices vary in each of the key financial characteristics.

[12] An alternative grouping in which all member banks in the nation could be considered together was rejected because it would have been too unwieldy. However, we believe the regional groupings to be a fair indication of how such a nationwide sample would behave.

[13] The standard deviation is a measure of the variability of sample data about the average. The method of computing a standard deviation can be found in most basic statistics textbooks.

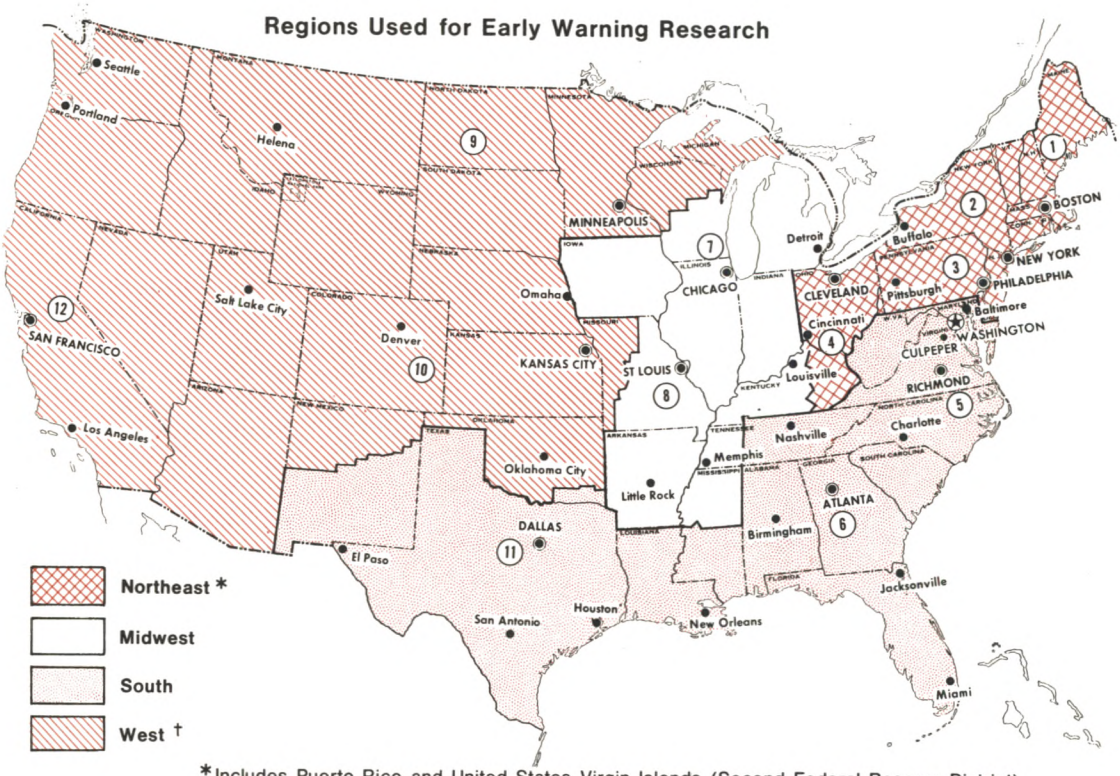
Further, these "standardized" deviations about the average can be added together for each bank to form a bank score or index. This procedure captures the combined influence of all the variables and ensures that moderate weakness in several ratios will not be overlooked. In combining the standardized deviations to form the bank score, each deviation from the mean is given an appropriate algebraic sign to indicate whether high or low values of the variables imply vulnerability or strength. For example, larger than average ratios of total loans, expenses, charge-offs, and commercial and industrial loans are indicative of high-risk exposure and, therefore, suggest vulnerability. Similarly, smaller than average values of these ratios are indicative of low-risk exposure and, hence, strength. In the case of the equity capital ratio, for example, above-average values are desirable, since a high ratio indicates a strong capital cushion, whereas a below-average capital ratio indicates a low level of protection. Each of the key variables thus provides an unambiguous indication of strength or weakness, an indication which of course must be tested.

In the current report, the five key financial ratios are combined in a manner equivalent to the procedure used in the July 1976 report, except that rather than bank scores a direct estimate is obtained of the probability that a bank will receive a low supervisory rating under given economic conditions in the future.[14] Moreover, the method used in this report yields separate estimates of the contribution of each of the five key variables to the estimated probability that a particular bank will receive a low supervisory rating.

The actual estimation of the probability function is analogous to a regression analysis in which the observed dependent variable is the occurrence or nonoccurrence of a particular event. In this report, the

[14] The data employed are the condition and income reports filed by all member banks from 1975 dating back to 1969, the earliest year for which data are available to us in a consistent and machine-readable form.

Regions Used for Early Warning Research



*Includes Puerto Rico and United States Virgin Islands (Second Federal Reserve District).

†Includes Alaska and Hawaii (Twelfth Federal Reserve District).

This map shows the four regions as they appear on the basis of the current boundaries of the twelve Federal Reserve Districts. The boundary between the Eleventh and Twelfth Federal Reserve Districts was altered in January 1977. Thus, the South and West regions used in this study differ very slightly from those shown on the map.

dependent variable is the occurrence or nonoccurrence of a low supervisory rating. The value of one is assigned to those banks that received a low supervisory rating during the relevant estimation period; the value of zero is assigned to those banks that did not receive a low supervisory rating. The independent variables are the five financial ratios. Various earlier tests of the relationship between the bank scores and the incidence of low supervisory ratings suggested a nonlinear function and we have used an equation of the form shown in the accompanying box.

The function we are using reflects our expectation concerning the relationship between the independent variables and the probability of receiving a low rating. As bank vulnerability increases—indicated by the values of the five variables—the probability of financial weakness increases as well, approaching a limit of one. Conversely, as bank vulnerability decreases, the probability of finding weakness approaches zero. The relationship between changes in the variables and changes in the estimated probability of future weakness is relatively complex. Since the function is nonlinear, the exact incremental effect of a change in any one variable on the probability of future weakness depends on the value of all the variables in combination. For example, a change toward strength or weakness in the operating expense ratio will have a large or small effect on the estimated probability of weakness, depending on the extent of the strength or weakness in the other four variables. In general, if a bank is extremely strong or extremely weak in most of the key variables, a change in one variable alone would not contribute greatly to a change in the estimated probability of future weakness.

The coefficients a_0, a_1, a_2, a_3, a_4, a_5 of the function are estimated using a maximum-likelihood technique that assigns high probabilities of weakness to banks that receive low supervisory ratings during the estimation period and low probabilities to those that do not.[15] The "goodness of fit" of the probability estimates can be evaluated by comparing them with (a) the ideal situation in which there is a perfect fit—that is, where each bank that received a low supervisory rating over the estimation period is given a 100 percent probability of receiving a low rating—and (b) the opposite extreme, a situation where high- and low-rated banks are accorded the same probability, indicating that the

The Probability Function

$$P = .5 + \frac{1}{\pi} \arctan (a_0 + a_1 LL.TS + a_2 EQ.ARA + a_3 EXP.OP + a_4 GCO.NI + a_5 CI.LN)$$

where

P	= Probability that a bank will receive a low supervisory rating;
LL.TS	= Loans and leases ÷ total sources of funds;
EQ.ARA	= Equity capital ÷ adjusted risk assets;
EXP.OP	= Operating expenses ÷ operating revenues;
GCO.NI	= Gross charge-offs ÷ net income + provision for loan losses;
CI.LN	= Commercial and industrial loans ÷ total loans; and
a_0	= a constant term.

five variables have no explanatory power. A statistic known as the likelihood ratio index (LRI) provides a convenient form for this comparison. Similar to the R-square of linear regression analysis, it ranges from zero to one, where values very close to zero show that the probability estimates approach the equal probability assumption and values close to one suggest the case of a perfect prediction.[16] In the results reported here, the estimation procedure was constrained[17] in a manner that parallels the process of generating bank scores, a technique already in use for supervisory

[15] In the estimation procedure, the following expression is maximized:

$$L = \underset{\text{(low-rated banks)}}{\Sigma \log P_i} + \underset{\text{(other banks)}}{\Sigma \log (1 - P_i)}$$

This means that the coefficients a_0, a_1, a_2, a_3, a_4, a_5 of the early warning function are chosen so as to maximize the value of L. P_i is the probability of a low supervisory rating.

[16] If $L_{max.}$ is the value of L for the estimated equation, and L_0 the value under the assumption that the five early warning variables have no explanatory power, the LRI is defined as:

$$LRI = (L_0 - L_{max.}) \div L_0.$$

The significance of the LRI can be tested, using the test statistic $-2\,(L_{max.} - L_0)$, which under the equal probability (null) hypothesis is distributed as a chi-square with the number of degrees of freedom equal to the number of explanatory variables. High values of the test statistic indicate that the estimated equation is unlikely to have been obtained by chance if "true" probabilities were equal for all the banks. See D. McFadden, "Conditional Logit Analysis of Qualitative Choice Behavior" in P. Zarembka, ed., *Frontiers of Econometrics* (New York: Academic Press, 1974); pages 105-42.

[17] The coefficients are subject to the following constraints: (a) The appropriate algebraic sign is applied to each coefficient in accordance with its expected contribution to bank vulnerability. (b) The relative importance of each financial ratio in the function is inversely proportional to its respective standard deviation and directly proportional to a coefficient determined by the maximum likelihood estimation. It is possible to fit a nonlinear function without imposing these constraints. In general, the unconstrained functions provide results not greatly different from those of the constrained estimations.

purposes within the Federal Reserve System. It is hoped that the analysis and evidence presented in this report will aid in the further development and refinement of this supervisory use.

Regional early warning functions

The base year of 1969 and the subsequent three years 1970 through 1972 provide a convenient starting point for the estimation of early warning functions. (Since the data cover only 1969-75, the sample periods available for study are limited.) It may be helpful for the reader to consider the general framework in which these early warning functions are estimated before focusing on the specific details of the results. First of all, the total number of member banks that received low supervisory ratings over the 1970-72 estimation period is small in all four regions, ranging from 41 banks or 3 percent of the total number of member banks in the Midwest to 149 member banks or 10 percent in the South (see Table 1). These percentages can be thought of as the overall average probabilities that banks in each of the regions would deteriorate to the point of receiving a low supervisory rating in an economic environment similar to the one that prevailed over the three years 1970-72.

Table 1

Ability of Regional Early Warning Functions to Identify Low-Rated Banks: 1970-72

Characteristic	Northeast	Midwest	South	West
Total member banks (1969)	1,295	1,406	1,533	1,480
Banks that received low supervisory ratings, 1970-72	56	41	149	120
Percentage of total	4.3	2.9	9.7	8.1
Average probability of low supervisory rating from function (in percent):				
Banks that received low supervisory ratings	15.7*	8.8*	25.4*	17.6*
Banks that did not receive low supervisory ratings	4.5*	3.0*	9.0*	8.1*
Percentage of total low-rated banks placed in weakest percentiles by the function:				
Weakest 10 percent	44.6	46.3	38.3	35.0
Weakest 20 percent	60.7	65.9	56.4	54.2
Weakest 50 percent	85.7	95.1	83.2	81.7
Likelihood ratio index (LRI)	0.097†	0.090†	0.147†	0.106†

* These probabilities are significantly different from those that would be expected if the probability of severe deterioration was uniformly distributed. A chi-square test yielded significant results with confidence of 99.9 percent or better.

† Statistically significant at confidence level of 99.9 percent.

The job of the early warning function is to estimate more precisely than the overall average the chances for a low supervisory rating for each of the banks in the four regions. The effectiveness of the function is suggested by the probability it accords member banks that received low supervisory ratings over the estimation period versus the probability accorded banks that did not receive low ratings. In the Northeast, Midwest, and South, the low-rated banks have an average estimated probability of weakness about three times that of banks that did not receive low supervisory ratings. In the West the probability accorded low-rated banks is just over twice as large. The function thus provides an information gain that is large in the case of banks that received low supervisory ratings in each region. This gain is especially large in the case of banks that received low supervisory ratings and that are placed by the function in the weakest percentiles. It is these information gains that are responsible for the high statistical significance of the LRI's of the regional functions.

When the banks are arrayed from the lowest to the highest probability of financial deterioration, the weakest percentiles of each region contain a high concentration of those banks that actually received low supervisory ratings over the estimation period. The weakest 20 percent of the banks in each of the four regions contains over 50 percent of all the low-rated member banks observed during 1970-72. The weakest 50 percent contains 82 percent to 95 percent of all these low-rated banks.

The reader may wonder why the function awards a less than 100 percent probability to those banks that, in fact, received low supervisory ratings over the estimation period. The answer is that, while the financial variables employed in this research are indicative of vulnerability, they cannot with perfect accuracy predict whether that vulnerability will in each case be translated into marked financial deterioration. The events under investigation in this report are probabilistic in the sense that intangible management and other factors not captured by the variables can often be the deciding factor in the success of a bank. Thus, it is the difference between the probabilities the function awards strong banks and those the function awards weak banks that is important rather than the levels of the probabilities alone.

Improving supervisory efficiency

The efficiency of bank supervision can be improved by concentrating on banks that are classified as vul-

nerable. Member banks considered strong can be subject to on-site examinations at less frequent intervals or may be given a more limited type of examination than banks considered vulnerable. Banks are considered vulnerable or strong in each region on the basis of their position in the bank array. As explained in the July 1976 *Monthly Review,* the computation of the gain in efficiency is based on information concerning the historical distribution of low-rated banks, the size of these banks, and their location in the bank array. Using these data, we can obtain for an estimation period a dividing line between banks that appear strong and those that appear vulnerable.

The procedure employed for this purpose is highly sensitive to classification errors with respect to relatively large banks. The costs of failing to designate as vulnerable relatively large member banks that subsequently receive low supervisory ratings would preclude substantial net savings in the cost of conducting on-site bank examinations. An early warning function yields a large potential gain in efficiency only when a high percentage of banks that receive low supervisory ratings over the estimation period—particularly the largest of those banks—are given relatively high probabilities of weakness by the function.

In each of the bank arrays, there is at some point an optimal cutoff probability separating banks that should have priority in scheduling on-site examinations from banks whose examination can be deferred or reduced in scope. However, this point can be found only after the fact, using a computer program. This program determines the cost of classification errors at every possible cutoff point and selects the highest possible gain in efficiency.[18] The optimal gains are shown in Table 2 and range from 43 percent to 79 percent. Since the optimal cutoff point will never be available at the time a forecast is made, a judgmental rule based on experience is required. One such rule consistent with the findings is to select for a full examination the weakest 50 percent of the array in each region. This might well involve full examinations of more banks than necessary in retrospect. Nonetheless, even using a rough rule of 50 percent, the potential gains in efficiency are substantial in the estimation period for each region, ranging from 26 percent to 36 percent. Moreover, this rule can be modified in light of operational experience.

Table 2

Characteristics of Regional Early Warning Functions: 1970-72

Characteristic	Northeast	Midwest	South	West
Gain in efficiency (in percent):				
At optimal cutoff	58.3	78.8	42.5	46.8
At 50 percent cutoff* ..	32.6	36.4	28.8	26.2
Function elasticities at 50th percentile:†				
LL.TS	+0.86	+0.55	+0.83	+0.72
EQ.ARA	−0.12	−0.18	−0.33	−0.20
EXP.OP	+1.16	+1.03	+1.26	+1.36
GCO.NI	+0.04	+0.06	+0.10	+0.02
CI.LN	+0.27	+0.14	+0.29	+0.17

* Probability level that divides the array of banks in each region at the 50th percentile.

† A positive elasticity coefficient indicates that an increase in a variable increases the probability of weakness; a negative coefficient indicates that an increase reduces the probability. See box on page 41 for definitions of five early warning variables.

Importance of early warning variables

While all five early warning variables have been found to contribute substantially to the ability to identify banks likely to receive a low supervisory rating, the specific contribution of each is of interest, particularly with respect to banks that are close to a threshold of vulnerability. Where this threshold is located cannot, of course, be determined precisely. Several levels of vulnerability have been studied in this report. One is the 50th percentile of the bank array, which is a working rule to set priorities in the scheduling and format of on-site examinations. Another possible cutoff is the weakest 20th percentile, which should include a higher proportion of banks that subsequently receive low supervisory ratings. The early warning functions are tested for the effect of changes in each of the five variables by obtaining elasticities of each of these variables at the selected thresholds. This measures the percentage change in the probability of weakness resulting from a given percentage change

[18] For details of the cost function, see footnote 3 (Korobow and Stuhr, pages 162-63). In the calculation of these cost savings after the fact, we assumed that the expense incurred in an on-site examination of a bank deemed vulnerable is fully offset by the supervisory benefit of early detection in those cases in which the vulnerable bank does in fact become weak. In those cases in which the vulnerable bank does not deteriorate, the examination costs are charged against any savings that would have resulted from deferring on-site examinations of strong banks that remain strong. Thus, the gain in efficiency is the percentage cost saving exclusive of the costs of examining those vulnerable banks that subsequently deteriorate markedly.

in one of the independent variables. The computation uses the average values of the variables that prevail for a small sample of the member banks that are located in the vicinity of the 50th percentile and a small sample of those close to the weakest 20th percentile of the arrays in each region. Using these average values, we computed elasticity coefficients for each of the five early warning variables when they were changed by 10 percent. The resulting elasticity coefficients at the 50th percentile threshold are shown in Table 2.[19] A positive coefficient indicates that an increase in a variable increases the probability of weakness; a negative coefficient indicates that an increase reduces the probability.

In all four regions the operating expense ratio (EXP.OP) has the highest elasticity, ranging from 1.4 in the West to 1.0 in the Midwest (Table 2). These coefficients mean, for example, that a 10 percent increase in the expense ratio for a bank at the 50th percentile of the array for the West will raise that bank's probability of future weakness by 14 percent; a 5 percent increase will raise the probability by 7 percent, and so forth. The next largest elasticity coefficient is the ratio of loans and leases to total sources of funds (LL.TS), ranging between 0.55 and 0.86 in the four regions. All the other variables have considerably smaller elasticities in every region. Some of these differences in the size of the elasticity may reflect regional variations with respect to business and banking practices, since the elasticities are affected by the variances of the financial ratios.

At the weakest 20th percentile of each of the four regional arrays (not shown in the table), elasticities are generally higher than at the 50th percentile, inasmuch as the function in this range is reflecting the impact of changes that produce marked vulnerability. The expense ratio continues to have the highest elasticity in all regions, ranging in this case from 1.4 to 2.1. The elasticity relating to the ratio of commercial loans to total loans (CI.LN) is raised to 0.70 at the 20th percentile in the South; it is substantially lower in all other regions. In contrast, the elasticity of the equity capital ratio (EQ.ARA) does not change markedly by region at the 20th percentile. Indeed, there is a remarkable degree of consistency among all regions in the relatively high importance of the expense ratio and the three portfolio risk variables in determining the probability of weakness.[20]

[19] These data are provided to illustrate the relative importance of the early warning variables. The reader does not have sufficient information in this report to compute probabilities for specific banks.

[20] Interested readers can obtain this data from the authors.

Forecasting low-rated banks by region

It is not sufficient to estimate a relationship from past data; the estimated relationship must be tested. To evaluate the accuracy of the early warning function obtained for each region, each of the functions is applied to the financial ratios of member banks for a year subsequent to the one used in the estimation period. The computer program we employ to rank the banks in each region in order, from lowest to highest probability of weakness, provides a numerical estimate of each bank's probability of deterioration over the forecast period—given an assumption as to economic conditions in that period. We expect a high concentration of the low-rated banks in each region to appear in the high vulnerability range of the array. Further, using the function probabilities, we can forecast the number of low-rated banks.[21]

The period 1973-75 provides an opportunity to test whether the financial data filed by member banks in earlier years indicates which banks whose supervisory ratings were satisfactory at the time of the forecast would subsequently deteriorate. During those three years, a total of 525 member banks received low supervisory ratings at one time or another. The vast majority of these low-rated banks (three quarters or more in each region) did not have low supervisory ratings in 1972, which is the base year of the three-year forecast.

In the Northeast region, 117 member banks received low supervisory ratings in 1973-75 (Table 3). Looking first at the ability of the early warning function to array the banks in order of vulnerability, the function places 38 percent of all the banks that received low supervisory ratings in the weakest 10 percent of the array, 62 percent in the weakest 20 percent, and 86 percent in the weakest half.[22] The forecast performance of the early warning functions for the other three regions—Midwest, South, and West—is quite similar. In these three regions, too, high percentages of the banks that actually received low supervisory ratings in the forecast period are in the weakest 10, 20, and 50 percent of the bank rankings.

The average probabilities of future weakness accorded by the functions to banks that actually re-

[21] This figure is obtained by adding the probabilities assigned to each bank through the particular percentile range which is of interest. The probability estimates can be recomputed as new data become available, thus providing an ongoing measure of a bank's condition.

[22] These percentages are not shown in Table 3, but can be easily obtained by dividing the *actual* number of low-rated banks the function placed in each percentile in the region by the total number of low-rated banks *actually observed* in that region during the forecast period. See also Table 8.

ceived low supervisory ratings in each of the four regions are relatively high—about 15 percent to 21 percent. This compares with 4 percent to 10 percent for member banks that did not receive low supervisory ratings.

With respect to the use of the array to set priorities for on-site examinations, the dividing line between vulnerable and strong banks is set on the basis of the probability accorded the bank at the 50th percentile for the estimation period. The vulnerable group determined in this manner would receive priority in the scheduling of on-site examinations. Since the median probability of marked weakness is higher in the forecast period than in the estimation period, the size of the vulnerable group is larger (see Table 3) than 50 percent of the total number of banks. Nonetheless, this cutoff point yields gains in efficiency of about 20 percent to 27 percent in the four regions.

Out of the 117 member banks that received low supervisory ratings in the Northeast during 1973-75, 107 banks (not in table) are included in the vulnerable group, while 10 of these member banks are classified as strong. The average size by assets of the low-rated banks that are classified as vulnerable is $1.2 billion; the average size of the low-rated banks classified as strong is $28.8 million. In the Midwest, 58 member banks having average assets of $497 million are classified as vulnerable and received low supervisory ratings; three banks having average assets of $5.2 million are classified strong, but also received low ratings. In the South, 158 member banks averaging $137 million in total assets are correctly classified as vulnerable, whereas 31 banks having average assets of $27 million are incorrectly classified as strong. In the West, 135 member banks having average assets of $336 million are correctly classified as vulnerable, while 23 banks averaging $9 million in assets are incorrectly classified as strong. These results reflect the high importance which the formula that computes efficiency places on the classification of relatively large member banks in accord with supervisory ratings.

The regional functions in general come reasonably close to predicting correctly the number of low-rated banks in various selected percentiles of the bank ranking. In the weakest 20 percent of the arrays in the Northeast, South, and West, the function predicts 83 percent to 98 percent of the total number of member banks that actually received low supervisory ratings. In the Midwest, the comparable figure is 65 percent. The function predicts 76 percent to 82 percent of the total number of low-rated member banks that were observed in the poorest half of the arrays in each region. The functions generally tended to underpredict the total number of low-rated banks that were actually observed during the forecast period, which is not surprising in view of the relatively high incidence of banks that received low supervisory ratings in 1973-75, compared with the incidence in the estimation period of 1970-72.

While a three-year period has proved to be a useful time interval in which to study the relationship between the probability of future weakness and the in-

Table 3

Regional Early Warning Forecast: 1973-75*

Characteristic	Northeast	Midwest	South	West
Total number of low-rated member banks:				
Predicted	96	57	169	144
Actual	117	61	189	158
Actual as percentage of total banks	9.3	4.5	12.4	11.0
Number of low-rated banks placed in weakest percentiles by the function:				
Weakest 10 percent:				
Predicted	51	24	63	50
Actual	45	27	58	50
Weakest 20 percent:				
Predicted	60	30	84	68
Actual	72	46	86	80
Weakest 50 percent:				
Predicted	77	42	126	104
Actual	101	54	153	129
Average probability of a low supervisory rating from function (in percent):				
Banks that received low supervisory ratings	19.7†	14.9†	21.0†	19.2†
Banks that did not receive low supervisory ratings	6.4†	3.7†	9.7†	8.9†
Gain in efficiency (in percent)‡	24.2	26.8	19.7	21.8
Size of vulnerable group (as percentage of total member banks in the region)	60.3	61.9	54.2	57.5

* Sample period: 1970-72.

† Difference from expected probability of a uniform distribution significant at better than 99.9 percent confidence.

‡ Calculated at median probability of the sample period.

Table 4

Regional Early Warning Forecasts: 1974-75

Sample period: 1970-71	Northeast	Midwest	South	West
Total number of low-rated member banks:				
Predicted	93	52	147	108
Actual	110	59	180	140
Number of low-rated banks placed in weakest percentiles by the function:				
Weakest 10 percent:				
Predicted	57	23	63	38
Actual	53	34	56	54
Weakest 20 percent:				
Predicted	65	27	81	51
Actual	75	43	91	77
Weakest 50 percent:				
Predicted	78	39	114	78
Actual	101	55	148	115

Sample period: 1972-73	Northeast	Midwest	South	West
Total number of low-rated member banks:				
Predicted	64	33	103	99
Actual	110	59	180	140
Number of low-rated banks placed in weakest percentiles by the function:				
Weakest 10 percent:				
Predicted	29	14	37	37
Actual	55	34	55	53
Weakest 20 percent:				
Predicted	35	17	50	48
Actual	77	43	91	77
Weakest 50 percent:				
Predicted	49	24	75	72
Actual	102	55	150	115

cidence of low supervisory ratings among member banks, we felt that a two-year period might be a more practical planning horizon from an operational point of view. We therefore selected as a forecast period the two years 1974-75—years in which economic conditions were especially strained.

Forecasts for these years are made using the experience of two alternative historical periods: 1970-71 and 1972-73. (The base year for computation of the five financial ratios is 1969 for the former period and 1971 for the latter.) These two estimation periods differ in an important respect. The 1970-71 period appears to represent a fairly typical one with respect to the incidence of low supervisory ratings among member banks. In contrast, the years 1972-73 were heavily influenced by inflationary factors that may have sustained some weak borrowers and thus delayed the emergence of many problem loans that subsequently resulted in low supervisory ratings for a number of member banks. Thus, the incidence of low supervisory ratings among member banks in 1972-73 was less than might have been expected from the study of financial and supervisory data of other periods.

Comparison of the forecasts yielded by the two estimation periods indicates important similarities as well as differences. In each of the four regions, the two early warning functions ranked the member banks quite similarly (Table 4). In each of the two forecasts, the banks that received low supervisory ratings in 1974-75 are concentrated in the weakest percentiles. About 31 percent to 58 percent of all member banks that actually received low supervisory ratings are in the weakest 10 percent of the bank rankings in each region, 51 percent to 73 percent are in the weakest 20 percent, and 82 percent to 93 percent are in the weakest half of the arrays.[23]

The early warning functions developed from the experience of 1972-73 tended to underpredict the *number* of member banks that would receive low supervisory ratings more substantially than the functions based on the experience of 1970-71. The two forecasts for the West, however, are similar, suggesting that the incidence of problem banks in this region did not change during these alternative estimation periods.

It seems clear from the results that, whatever the eventual number of problem banks may be in a region, a large percentage of these banks is likely to fall in the weakest 10-20 percent of the bank ranking. However, forecasting the exact number of problem banks requires an accurate appraisal of the possible economic

[23] These percentages can be obtained from Table 4 by the same procedure explained in footnote 22. See also Table 8.

environment during the forecast period and the selection of a comparable historical period over which to develop appropriate probability relationships.

Early warning in selected size classes

In general, the early warning functions estimated for size classes of member banks based on data for 1970-72 yielded probability figures not greatly different from those obtained from the regional functions estimated over the same period. As before, banks that received low supervisory ratings during those years were given substantially higher probabilities of weakness than banks that did not receive low ratings (see Table 5). Moreover, the banks that received low supervisory ratings tend to be concentrated in the weakest percentiles of the ranking in each size class. It is notable, however, that the function estimated for member banks having assets of $300 million or more in total assets did a relatively poor job in placing low-rated banks in the weakest 10 percent and 20 percent of the respective bank rankings.

The overall performance of these early warning functions is suggested by the LRIs shown in Table 5. They all indicate a statistically significant information gain over the average probability of marked deterioration in each size class, and they generally exceed the LRIs for each regional functions estimated for the same period. There is a very sharp increase in the LRI of the function estimated for the size class of $50-100 million and then a tapering-down of the index for functions estimated for banks in the $100-300 million and larger size classes. These changes, however, may not be significant because of the relatively small number of low-rated banks in the larger size classes.

As shown in Table 6, all of the functions estimated show high gains in efficiency in retrospect and the gains remained substantial even if a pragmatic decision rule is used—that is, when the vulnerable group is defined as the weakest 50 percent of the banks. The gains in efficiency generally are above those indicated by the early warning functions estimated by region for the same period. It thus seems that, at least in the estimation process, the early warning functions obtained when member banks are grouped by size class have a somewhat improved ability to distinguish high-risk banks in most size classes up to $300 million.

As noted earlier, each of the function coefficients

Table 5

Ability of Nationwide Early Warning Functions Based on Size Classes to Identify Low-Rated Banks: 1970-72

Characteristic	Asset size class of member banks (in millions of dollars) 0-10	10-20	20-50	50-100	100-300	300 or more
Total member banks (1969)	2,409	1,385	1,096	358	290	176
Banks that received low supervisory ratings, 1970-72	173	90	60	16	18	10
Percentage of total	7.2	6.5	5.5	4.5	6.2	5.7
Average probability of receiving a low supervisory rating from function (in percent):						
Banks that received low supervisory ratings	19.0*	18.0*	19.6*	35.1*	27.4*	18.6*
Banks that did not receive low supervisory ratings	7.2*	6.5*	5.6*	4.1*	5.7*	4.8*
Percentage of total low-rated banks placed in weakest percentiles by the function:						
Weakest 10 percent	40.5	46.7	51.7	68.8	50.0	20.0
Weakest 20 percent	61.3	66.7	60.0	81.3	66.7	30.0
Weakest 50 percent	88.4	86.7	88.3	100.0	94.4	90.0
Likelihood ratio index (LRI)	0.120†	0.123†	0.127†	0.278†	0.196†	0.132†

* Difference from expected probability of a uniform distribution significant at 99 percent confidence.
† Statistically significant at confidence level of 99.9 percent.

Table 6

Characteristics of Nationwide Early Warning Functions Based on Size Classes: 1970-72

Characteristic	Asset size class of member banks (in millions of dollars) 0-10	10-20	20-50	50-100	100-300	300 or more
Gain in efficiency (in percent):						
At optimal cutoff	55.6	60.7	66.0	81.5	65.8	45.9
At 50 percent cutoff*	43.0	43.3	45.9	52.3	49.5	38.1
Function elasticities at 50th percentile:†						
LL.TS	+0.60	+0.77	+0.86	+1.12	+1.45	+1.92
EQ.ARA	−0.18	−0.20	−0.43	−0.52	−0.48	−0.63
EXP.OP	+0.90	+1.38	+1.68	+1.92	+2.23	+2.36
GCO.NI	+0.04	+0.06	+0.11	+0.13	+0.08	+0.18
CI.LN	+0.24	+0.22	+0.20	+0.15	+0.39	+0.58

* Probability level that divides the array of banks in each size class at the 50th percentile.

† A positive elasticity coefficient indicates that an increase in a variable increases the probability of weakness; a negative coefficient indicates that an increase reduces the probability. See box on page 41 for definitions of five early warning variables.

affect the estimated probability of weakness in a complex way. Nonetheless, there are noticeable differences with respect to the impact of the five variables on the probability of future weakness, as illustrated in Table 6. The table shows the elasticities of the five early warning variables at the 50th percentile for each of the six functions estimated on the basis of size classes. The reader will observe that all the elasticities increase markedly with bank size.[24] At the same time, the average probability of weakness estimated by the functions at the 50th percentile (not in table) tends to diminish with bank size. For example, the average probability of weakness at the 50th percentile for the 1970-72 estimation period is 5.7 percent for banks in the $0-10 million size class, 3.1 percent for banks in the $50-100 million size class, and 3.8 percent for banks in the $300 million and over size class. At the 20th percentile, the probabilities decline for banks of up to $100 million in size and then increase somewhat for larger banks. A possible explanation for this result is that the functions are capturing some of the protective effects inherent in an expanded scale of bank operations. This is the first evidence we have turned up in this project that suggests increased bank size alone has a positive effect on bank soundness. However, for the years 1970-72, the protective effect of bank size appears to reach a plateau quickly and does not show any additional effect for banks above $100 million of total assets.

Looking at the elasticities of each of the five early warning variables at the 50th percentile, the expense ratio (EXP.OP), as in the regional functions, has the largest impact on the probability of weakness in all size classes, followed closely by the ratio of LL.TS. The variables EQ.ARA, CI.LN, and GCO.NI have a substantially lower impact. Further, the relative order of the importance (as measured by elasticity) of the variables in the functions estimated for the selected size classes is similar to that found for the regional functions.

The computation of elasticities at the weakest 20th percentile produced substantially higher elasticities in each class.[25] At the 20th percentile, the order of importance (by size of elasticity) of the equity capital ratio diminishes in the two largest size classes and in almost all other size classes as compared with the elasticities at the 50th percentile. Thus, for this sample, at least, expense and risk factors rather than the

[24] These changes in part reflect the tendency for the variances of each financial ratio to decline with larger size classifications of member banks. The decline in variances suggest that large banks have more in common with respect to their risk exposure and financial management than the substantial number of small banks that serve local markets all across the nation. To determine whether this effect was influenced by the constraints imposed on the variables, the same functions were estimated using an unconstrained regression equation. Much the same effects were observed.

[25] Data not shown but can be obtained from the authors.

Table 7

Nationwide Early Warning Forecast Based on Size Classes: 1973-75

Characteristic	Asset size class of member banks (in millions of dollars) 0-10	10-20	20-50	50-100	100-300	300 or more
Total member banks (1972)	1,656	1,514	1,308	512	335	240
Total number of low-rated member banks:						
Predicted	153	120	107	37	30	28
Actual	142	116	124	38	40	65
Actual as percentage of total banks	8.6	7.7	9.5	7.4	11.9	27.1
Number of low-rated banks placed in weakest percentiles by the function:						
Weakest 10 percent:						
Predicted	62	44	51	21	16	17
Actual	52	32	53	15	10	13
Weakest 20 percent:						
Predicted	79	57	62	24	20	20
Actual	80	65	73	23	14	26
Weakest 50 percent:						
Predicted	114	86	83	30	25	25
Actual	124	96	106	32	27	54
Average probability of a low rating from function (in percent):						
Banks that received low supervisory ratings	21.8*	16.9*	21.6*	24.2*	21.9*	18.1*
Banks that did not receive low supervisory ratings	8.1*	7.2*	6.8*	5.8*	7.2*	9.5*
Gain in efficiency (in percent)†	12.5	36.2	33.5	40.2	15.4	33.5
Size of vulnerable group (as percentage of total member banks in the size class)	84.5	54.0	57.1	58.2	60.9	71.3

* Difference from expected probability of a uniform distribution significant at 99.9 percent confidence level.

† Calculated at the median probability of the sample period 1970-72.

Table 8

Ability of Early Warning Forecasts to Identify Low-Rated Banks Regional versus Nationwide Functions

Characteristic	North-east	Mid-west	South	West	Asset size class (in millions of dollars) 0-10	10-20	20-50	50-100	100-300	300 or more
Percentage of all low-rated banks placed in weakest percentiles by the function, 1973-75:*										
Weakest 10 percent	38.5	44.3	30.7	31.6	36.6	27.6	42.7	39.5	25.0	20.0
Weakest 20 percent	61.5	75.4	45.5	50.6	56.3	56.0	58.9	60.5	35.0	40.0
Weakest 50 percent	86.3	88.5	81.0	81.6	87.3	82.8	85.5	84.2	67.5	83.1
Percentage of all low-rated banks placed in weakest percentiles by the function, 1974-75:†										
Weakest 10 percent	48.2	57.6	31.1	38.6	41.9	41.7	40.3	35.7	31.4	23.9
Weakest 20 percent	68.2	72.9	50.6	55.0	64.5	61.7	59.7	51.8	40.0	42.3
Weakest 50 percent	91.8	93.2	82.2	82.1	84.9	90.4	83.2	83.9	71.4	85.9

* Sample period 1970-72.

† Sample period 1970-71.

protective effects of equity capital became increasingly important as vulnerability increased.

The functions for each of the six size classes *forecast* the actual number of low-rated member banks with a degree of accuracy that is comparable to the regional forecasts, except the forecast for the largest of the size classes (see Table 7). The function's forecast of the number of low-rated member banks for the largest size class tends to overpredict the number of these banks in the weakest 10 percent of the array but sharply underpredicts in the weakest 20 percent. And in the weakest 50 percent, it predicts less than half the actual number of low-rated banks that were observed over the forecast period. This is the least accurate forecast obtained from all the functions.

The probabilities that the functions for each of the size classes accord low-rated banks in the forecast period are relatively high. They range from nearly 17 percent to 24 percent, compared with about 6 percent to 10 percent for banks that remained strong. Again, these differences are highly significant.

The size group functions all yield respectable gains in efficiency. For all size classes except the two largest, the functions arrayed the banks so that banks receiving low supervisory ratings during 1973-75 are highly concentrated in the weakest percentiles.

Concluding remarks

The relative performance of regional and size group early warning functions in arraying banks can be readily seen in Table 8. The table shows the ranking of low-rated member banks in three- and two-year forecast periods separately by region and by size class. The results are similar regardless of forecast period and grouping, although the two largest size groups are somewhat of an exception. The forecasts obtained for banks having total assets of $100 million or more tend to yield rankings that are substantially less efficient in isolating low-rated banks in the weakest 10 percent and in the weakest 20 percent of the array than all the other estimated functions.[26]

The foregoing results suggest that the incidence of marked weakness among relatively large banks was unique in 1974-75. The earlier historical experience therefore was not fully adequate to establish a relationship between early warning variables and the probability of weakness during a period of unusually severe economic strain for this group of banks.

The promising results achieved thus far point toward wide possibilties for further investigation. The number of key financial characteristics of strength or vulnerability undoubtedly can be expanded as more comprehensive banking data become available, and this should lead to improved accuracy of early warning functions. We expect, too, that the methodology described here can be applied to screen banks for vulnerability in certain important aspects of banking. These include United States banking abroad, the activities of bank holding companies, and bank internal audit and control capacity. Progress toward early warning capabilities through statistical methods in these fields would be a valuable aid to bank supervision.

[26] Space limitations prevented the inclusion of estimation and forecast results employing other regions, size classes, and estimation and forecast periods than those presented here. The authors will attempt to provide additional tabulations to interested readers on request.

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