A RE-EXAMINATION OF TWO MAJOR BANKRUPTCY PREDICTION MODELS

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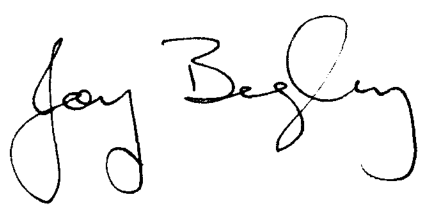
ABSTRACT

This thesis examines two major bankruptcy prediction models existing in the literature: Altman's Z-score model and Ohlson's probabilistic model. The objective is to test whether the model parameters have changed from what they were when Altman and Ohlson originally estimated their models. Two reasons for expecting the parameter change are examined: (i) the change in U.S. bankruptcy law in the 1970s; and (ii) the increased use of financial leverage in the 1980s.

The first portion of this thesis reviews the bankruptcy prediction literature and discusses the change in U.S. bankruptcy law and capital structure. The evidence presented in this study indicates that business failures have increased since 1980 and financial leverage follows an upward trend from the 1970s to the 1980s.

The following four hypotheses associated with the original Altman and Ohlson models are developed: (1) the Type-I Error Hypothesis: the change in U.S. bankruptcy law in the 1970s increases the Type-I (classifying bankrupt firms as nonbankrupt) error rate; (2) the Type-II Error Hypothesis: the increased use of leverage in the 1980s increases the Type-II (classifying nonbankrupt firms as bankrupt) error rate; (3) the Intercept Hypothesis: the change in the bankruptcy law in the 1970s will cause a significant increase in the intercept in Ohlson's model; and (4) the Leverage Hypothesis: the increased use of leverage in the 1980s will result in a significant decrease in the coefficient on TLTA (total liabilities /total assets) in Ohlson's model.

The remaining portion of the thesis discusses sample design and tests the four hypotheses. Two samples from the 1980s are examined: a paired sample of 99 bankrupt and 99 nonbankrupt firms; and a sample of 99 bankrupt firms and 1,980 nonbankrupt firms. Using these samples, the predictive abilities of Altman's and Ohlson's models are examined and the models are reestimated to test the four hypotheses. For Altman's model, the empirical results are consistent with the Type-II Error Hypothesis but inconsistent with the Type-I Error Hypothesis. For Ohlson's model, the results are also consistent with the Type-II Error Hypothesis but inconsistent with the Type-I Error Hypothesis. While the empirical results of reestimating Ohlson's model support the Leverage Hypothesis, they do not support the Intercept Hypothesis.



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CHAPTER 1

INTRODUCTION

Prediction of corporate bankruptcy has long been an issue of practical and academic interest. A number of researchers have attempted to construct statistical models to predict the potential bankruptcy of corporate firms. The data used for the prediction is usually gathered from publicly available financial information. The statistical technique used extensively in the earlier studies is discriminant analysis. The aim is to classify firms into one of two groups, bankrupt or nonbankrupt. Beaver (1966) first used such analysis to predict firm failure by examining individual financial ratios. Later, Altman (1968) employed multiple discriminant analysis to distinguish between bankrupt and nonbankrupt firms based on a set of predesignated variables. Altman's multivariate model overcomes the univariate model's problem of different ratios giving conflicting predictions.

A different statistical approach is the probabilistic prediction model which was initially used in bankruptcy prediction by Ohlson in 1980. Ohlson's model estimates the probability of bankruptcy occurring based on a set of predesignated variables. The model also improves upon previous bankruptcy prediction models in certain aspects such as sample selection and the inclusion of firm size as an independent variable.

A correct and early identification of the bankruptcy event is of particular importance to investors, creditors, auditors and management itself. Foster (1986) indicates that a successful bankruptcy prediction model can be of assistance to investors in debt securities when they assess the likelihood of a firm experiencing problems in making interest and principal repayments. He also states that research on bankruptcy prediction has relevance to lending institutions, both in deciding whether to grant a loan (and its conditions) and in devising policies to monitor existing loans. Altman and McGough (1974) suggest that a bankruptcy prediction model can also be a useful aid to an auditor in making a going-concern judgement. Furthermore, Foster argues that "bankruptcy can mean that a firm incurs both direct and indirect costs. Direct costs include fees to professionals such as accountants and lawyers. Indirect costs include the lost sales or profits due to the constraints imposed by the court-appointed trustee. ... It may well be that if early warning signals of bankruptcy were observed, these costs could be reduced by management arranging a merger with another firm or adopting a corporate reorganization plan at a more propitious time." Therefore, Deakin (1972) points out that a model that correctly predicts potential business failure well in advance can serve to reduce losses associated with bankruptcy by providing an early indication of impending bankruptcy to these interested parties.

Altman's and Ohlson's models appear to be the two most frequently referenced bankruptcy prediction models in the accounting literature. There is considerable evidence that these models continue to be popular today. Altman's model is more popular among financial analysts, while academic researchers appear to prefer to use Ohlson's model to estimate the relative probability of bankruptcy among firms. Academic books frequently suggest Altman's model as a potential tool used by analysts to forecast financial distress.[1] Investment management books, designed for practitioners, also suggest the use of Altman's model for investment decision making.[2] Even some financial analysis software packages incorporate Altman's model in their analysis.[3] Altman's and Ohlson's models are also very popular in academic research. Altman's model is frequently used by academics as an indicator of bankruptcy risk.[4] Ohlson's model is also often used and referenced in academic research.[5]

Although both Altman's and Ohlson's models frequently appear in the literature, they are by no means perfect measures of the likelihood of bankruptcy. One potential limitation of both models is that they are estimated based upon data from the 1940s-1970s.

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[1]For example, the books of Foster (1986), Watts and Zimmerman (1986), Hawkins (1986), Brealey et al. (1986), Finnerty (1986), Yadav (1986), Brigham et al. (1987), Bernstein (1993) and Stickney (1993) all make references to the use of Altman's model. In addition, Foster (1986), Watts and Zimmerman (1986), and Yadav (1986) also reference Ohlson's model.

[2]For example, Platt (1985), Shim and Siegel (1988), and Ramaswami and Moller (1989).

[3]For example, "FisCAL: Financial Analysis and Planning Computer Software Package" distributed by the Halcyon Group.

[4]For example, O'Neal (1988), Becker and Burns (1989), and Shim (1992).

[5]For example, Lo (1986), Barnes (1986), Lau (1987), Burgstahler et al. (1989), Bell and Tabor (1991), and Han et al. (1992).

Their applicability outside of that period is, therefore, questionable. It is expected that the model parameters have changed from what they were when Altman and Ohlson developed their models. There are two major reasons why the model parameters are expected to have changed. The first reason is that the bankruptcy law in the U.S. changed dramatically in the late 1970s. The change in bankruptcy law reduced the costs of filing bankruptcy, therefore, the law change is expected to increase the number of firms filing for bankruptcy. The second reason is the increased use of financial leverage in the 1980s. Due to the proliferation of Leveraged Buyouts (LBOs) and other highly leveraged transactions in the 1980s, capital structure has changed dramatically for more and more firms.[6] Brealey and Myers (1991) state that for the debt ratio of manufacturing corporations in the U.S. "there is a clear upward shift from the 1950s to the 1980s. Recent events have dramatized the shift to debt financing. The rapid growth of the junk bond market means by definition that firms have levered up: Junk is junk because firms have borrowed beyond conventional targets."(p.331). Because financial leverage is a significant factor in both Altman's and Ohlson's models, the increased use of debt in the 1980s is likely to change the parameters of the models.

The purpose of this paper is to test whether the model parameters have changed from what they were when Altman and Ohlson developed their models. In order to do so, the predictive abilities of the two models are tested and the models are reestimated using

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[6]Empirical evidence on this point is presented in Chapter 2.

data from the 1980s. There are other ways in which Altman's and Ohlson's models might be further improved to increase their ability to predict bankruptcy.[7] However, it is not the purpose of this study to address these issues.

The paper is organized as follows. Chapter 2 provides a review of the literature. The change in U.S. bankruptcy law and the change in capital structure are discussed. The evidence on business failures over three decades and evidence of increased use of leverage in the 1980s are presented. Four hypotheses associated with Altman's and Ohlson's models are developed. Chapter 3 discusses the data and sample design. Two samples are collected from Compustat. The sample used to test Altman's model consists of 99 bankrupt and 99 nonbankrupt firms and the sample for testing Ohlson's model consists of 99 bankrupt and 1,980 nonbankrupt firms. Both samples cover the 1981-1990 time period. Chapter 4 tests the four hypotheses given in Chapter 2. First, the predictive abilities of Altman's and Ohlson's original models are examined using the 1980s samples. Then, Altman's and Ohlson's models are reestimated in order to test for a significant change of the model parameters. Chapter 5 concludes the thesis.

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[7]For example, the predictive ability of the models could be improved by adding additional variables that are expected to relate to the occurrence of bankruptcy. Also, different model estimation techniques such as a Cox proportional hazard model or a stepwise procedure might yield superior models.

CHAPTER 2

LITERATURE REVIEW

2.1 FINANCIAL DISTRESS AND BANKRUPTCY

In the bankruptcy prediction literature, the terms "bankruptcy" and "financial distress" are used frequently and alternatively. Many studies do not indicate their relation and difference and sometimes confusion results. Therefore, it is necessary to discuss them here.

Foster (1986) defines financial distress as "severe liquidity problems that cannot be resolved without a sizable rescaling of a firm's operations or structure." Liquidity problems result from non-availability of cash or near-cash resources for meeting the firm's current obligations. As a firm increases its financial leverage, it increases the probability of its financial distress. When a firm is in financial distress, both creditors and shareholders may want it to recover. The firm may resolve its liquidity problems via a dramatic rescaling of its operations (for example, the firm can sell the portion of its asset base) or a merger with another firm. However, in other respects, raising financial leverage increases the probability of potential conflicts between shareholders and creditors. "Shareholders are tempted to forsake the usual objective of maximizing the overall market value of a firm and pursue narrow self-interest instead. They are tempted to play games at the expense of their creditors."[8] In this case, creditors may utilize covenants to restrict shareholders' behaviours that will reduce the firm's value.

Bankruptcy is a legal process and is usually easier to identify than financial distress. Bankruptcy occurs when either creditors or shareholders petition for a bankruptcy order. Once a petition is filed, a third party, the bankruptcy court, will enter, and the firm will inevitably be reorganized or liquidated. Brealey and Myers (1984) state that liquidation is usually voluntary but sometimes involuntary. A licensed trustee will be appointed to take possession of and distribute all the assets of a firm. Altman (1983) notes that a petition for reorganization can be entered voluntarily or involuntarily. When a firm faces temporary financial problems and the business is viable in the long run, reorganization may be a suitable solution.

Although bankruptcy is associated with financial distress, they are not equivalent. Financial distress can lead to bankruptcy. However, as Brealey and Myers (1984) suggest "not every firm which is financially distressed becomes bankrupt. As long as the firm can find enough cash to pay its debt when due, it may be able to avoid bankruptcy for many years. Eventually, the firm may recover, pay off its debt, and escape bankruptcy altogether."

Many models have been developed to predict bankruptcy. Why are people so interested in those models? The major reason is that people want to avoid the costs resulting from doing business with

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[8]Brealey and Myers (1984), p.395.

a firm that may not meet its obligation. That is, people want to be able to predict the financial distress of the firm. However, financial distress cannot be observed with precision. People can observe only something related to the distress - filing bankruptcy. Thus, the studies that would like to develop a model predicting distress, have instead been forced to limit themselves to predicting bankruptcy.

2.2 EXISTING BANKRUPTCY MODELS IN THE LITERATURE

A number of studies have constructed statistical models to predict the potential bankruptcy of firms. Many statistical methodologies, such as, linear discriminant analysis, quadratic discriminant analysis, logit analysis and probit analysis, have been used. Altman's Z-score model and Ohlson's probabilistic model are the two models most commonly mentioned in the literature.

2.2.1 ALTMAN'S Z-SCORE MODEL

Altman (1968) develops a bankruptcy prediction model using Multivariate Discriminant Analysis (MDA). This technique allows a researcher to study the differences between two or more groups of objects with respect to several variables simultaneously. The technique is primarily used for the classification or prediction of qualitative variables, for example, bankrupt or nonbankrupt. An observation is classified into one of several a priori groups, dependent upon the observation's individual characteristics.

Therefore, first of all, two or more mutually exclusive groups should be established, based on objects. "Objects are the basic units of analysis. They may be, for example, people, firms, countries, or the economy at different points in time. In the case of bankruptcy, each firm is an object. The groups must be defined so that each object belongs to one, and only one, group."[9]

"After the groups are established, data is collected for the objects in the groups; MDA in its most simple form attempts to derive a linear combination of these characteristics which 'best' discriminates between the groups. If a particular object, for instance, a firm, has characteristics (financial ratios) which can be quantified for all of the companies in the analysis, the MDA determines a set of discriminant coefficients. When these coefficients are applied to the actual ratios, a basis for classification into one of the mutually exclusive groups exists."[10]

When the analysis is concerned with two groups, linear discriminant analysis for classification into two a priori groups results in one discriminant function of the form:

$$Z = c_0 + c_1X_1 + c_2X_2 + \ldots + c_nX_n$$

where

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[9]Klecka (1980), p.8.

[10]Altman (1971), p.59.

X_i = the i-th classification variable,

c_i = the coefficient value of X_i,

Z = the discriminant score.

The discriminant function thus transforms the value of the individual variables (the X_is) of the object into a single discriminant score (Z). Z is then used to classify the object.

"The MDA technique has the advantage of considering an entire profile of characteristics common to the relevant firms, as well as the interaction of these properties. A univariate prediction model, on the other hand, can only consider the measurements used for group assignments one at a time."[11] "Another advantage of MDA is the reduction in the analyst's space dimensionality, that is, from the number of different independent variables to G-1 dimension(s), where G equals the number of original a priori groups."[12]

In constructing his model, Altman uses a paired sample consisting of thirty-three pairs of manufacturing firms over the period 1946-1965. The range of the total assets (i.e., size of the bankrupt firms) is 0.7-25.9 million dollars one year prior to bankruptcy. For each of the bankrupt firms, a comparable match is chosen from the same industry and asset size and is measured over the same chronological period. Twenty-two accounting and nonaccounting variables are considered in various combinations as

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[11]Ibid. p.59.

[12]Ibid. p.59.

predictors of failure. The following combined ratios performed the best:

X_1 = net working capital/total assets

X_2 = retained earnings/total assets

X_3 = earnings before interest and taxes/total assets

X_4 = market value of equity/book value of total liabilities

X_5 = sales/total assets

With the exception of X_5, each ratio discriminates well individually between the groups. The mean values of the ratios for the bankrupt group are significantly smaller than for the nonbankrupt group.

The estimated discriminant function is[13]

$$Z = .012X_1 + .014X_2 + .033X_3 + .006X_4 + .999X_5$$

By observing those firms which have been misclassified by the discriminant model in the initial sample, Altman finds that all firms having a Z-score greater than 2.99 clearly fall into the nonbankrupt group, while those firms having a Z-score below 1.81 are all bankrupt. The area between 1.81 and 2.99 is defined as the zone of ignorance or gray area because of the susceptibility to error classification. Since errors are observed in this range of values, there is uncertainty about whether a new firm whose Z-score falls in this range is expected to go bankrupt or not. Hence, it is

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[13]With the exception of X_5, all ratios are being measured in percentages.

desirable to establish a guideline for classifying firms in this area. The process used by Altman begins with identification of the sample observations that fall within the overlapping range. Then, the minimum number of misclassifications is found. In the analysis, the best critical value falls between 2.67 and 2.68, and therefore 2.675, the midpoint of the interval, is chosen as the Z-score that discriminates best between the bankrupt and nonbankrupt firms.

The accuracy of Altman's model in the prediction of bankruptcy can be measured by the total error rate in classifying his sample. He reports an overall error rate of 5 per cent one year prior to bankruptcy and 18 per cent two years prior to bankruptcy. Beyond two years the accuracy in prediction falls very rapidly: the error rate is 48 per cent in the third year prior to bankruptcy.

2.2.2 OHLSON'S PROBABILISTIC MODEL

Ohlson (1980) uses a logit model to predict bankruptcy. The logit model is a conditional probability model. Conditional probability models assume that firms are faced with an outcome between two alternatives and that the outcome depends on their characteristics. A probability model is generally used when a dependent variable is qualitative. There are many situations in which a dependent variable is qualitative, for instance, the outcome of whether a firm goes bankrupt or not, or the choice of whether a household purchases a car or not. In these cases, one purpose of a probability model is to determine the probability that an event will occur. The interpretation of the dependent variable is that it is a probability measure for which the realized value is 0 or 1.

A cumulative probability distribution function is used to constrain the predicted values within the acceptable [0,1] limiting values of a probability. The cumulative logistic probability function has the following form:

$$P = F(Z) = [1+\exp(-Z)]^{-1} \qquad (2.1)$$

where "exp" represents the base of nature logarithm. Z is a theoretical continuous index. P is the probability that an event will occur, given Z. It is easy to see that P is increasing in Z. If $Z = +\infty$, P is 1, and when $Z = -\infty$, P takes the value 0. Thus, P can never be outside the range [0,1].

The logit probability model is based on the cumulative logistic probability function. It is assumed that there exists a theoretic continuous index Z which is determined by an explanatory vector X. The form of a logit model is

$$\ln[P/(1-P)] = Z = \beta X \qquad (2.2)$$

In this notation, X is a vector of attributes; β is an unknown parameter vector to be estimated and P is the probability that an event will occur, given X. The rationale for this form can be seen by solving equation (2.1) for Z. We then have equation (2.2).

It is assumed the probability that an event will occur is a linear function of the firm attributes. The logit probability model derives the probability of a dependent variable by assigning coefficients to the independent variables. These coefficients can be interpreted as the effect of a unit change in an independent variable on the index Z.

It should be noted that observations on Z are not available. Instead, we have data that distinguish only whether firm observations are in one category (i.e., bankrupt), or a second category (i.e., nonbankrupt). The dependent variable in equation (2.2) is the logarithm of the odds, P/(1-P), that a particular event will occur. "One important appeal of the logit model is that it transforms the problem of predicting probabilities within (0,1) interval to the problem of predicting the odds of an event occurring within the range of the real line."[14]

If P happens to equal either 0 or 1, the odds will equal 0 or infinity and the logarithm of the odds will be undefined. Thus, the application of ordinary least-squares estimation to equation (2.2) is inappropriate.[15] Therefore, the most suitable procedure used in such a case is the maximum likelihood method.[16] Logit analysis solves the problem of how to obtain the parameters while at the same time obtaining information about the underlying index Z.

The data used in Ohlson's study is from the nineteen-seventies (1970-1976). The final sample consists of 105 bankrupt firms and 2,058 nonbankrupt firms. The data for bankrupt firms is obtained

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[14]Pindyck and Rubinfeid (1991), p.259.

[15]Ibid. p.260.

[16]Detail will be discussed in Section 4.2.2.1.

from 10-K financial statements as reported at the time. As Ohlson states, "This procedure has an important advantage: the reports indicate at what point in time they are released to the public. One can therefore check whether the firm enters bankruptcy prior to or after the date."[17] Nonbankrupt firms are obtained from the Compustat tape. A sample of 2,058 nonbankrupt firms is chosen so as to be more representative of the proportion of bankrupt and nonbankrupt firms occurring naturally in the economy. Every nonbankrupt firm in the sample contributes with only one vector of data points. The year of any given firm's report is chosen randomly.

Ohlson uses the logit model to examine the effect of four basic factors on the probability of bankruptcy. The four basic factors are: (1) the size of the company; (2) a measure(s) of the financial structure; (3) a measure(s) of performance; (4) a measure(s) of current liquidity. Nine ratios are considered as independent variables to represent the above four factors. They are:[18]

1. SIZE = ln(total assets/GNP price-level index). The index assumes a base value of 100 for 1968. Total assets are as reported in dollars.
2. TLTA = Total liabilities divided by total assets.
3. WCTA = Working capital divided by total assets.
4. CLCA = Current liabilities divided by current assets.

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[17]Ohlson (1980), p.110.

[18]Ibid. pp.118-119.

5. OENEG = One if total liabilities exceeds total assets, zero otherwise.

6. NITA = Net income divided by total assets.

7. FUTL = Funds provided by operations divided by total liabilities.

8. INTWO = One if net income was negative for the last two years, zero otherwise.

9. CHIN = $(NI_t - NI_{t-1})/(|NI_t| + |NI_{t-1}|)$, where NI_t is net income for the most recent period. The denominator acts as a level indicator. The variable is thus intended to measure change in net income.

Using these predictors, Ohlson computes three sets of coefficients. Model 1 predicts bankruptcy within one year; Model 2 predicts bankruptcy within two years, given that the company does not fail within the subsequent year; Model 3 predicts bankruptcy within one or two years. Table 2-1 shows the first two sets of the parameters of Ohlson's empirical results.

With the exception of OENEG, all of the predictor signs for Model 1 are consistent with Ohlson's expectations. While Ohlson expects that the sign of OENEG is indeterminate, it is negative in Model 1. While three of the coefficients (WCTA, CLCA and INTWO) have t-statistics less than two, the others are all statistically significant at a respectable level. In addition, SIZE appears as an important predictor of bankruptcy because it has a relatively large t-statistic.

An overall measure of goodness-of-fit is given by the likelihood ratio index. For Model 1, the ratio is 84 percent, and this is significant at an extremely low α-level. For Model 2, the ratio is 79 percent. This decrease is in accordance with the expectation that the accuracy decreases as the lead time increases.

Table 2-1

Ohlson's Estimated Bankruptcy Prediction Models

	Variables									
	SIZE	TLTA	WCTA	CLCA	OENEG	NITA	FUTL	INTWO	CHIN	CONST
Model 1 (Predicting bankruptcy within one year)										
Coefficients	-.407	6.03	-1.43	.0757	-1.72	-2.37	-1.83	.285	-.521	-1.32
t-statistics	-3.78	6.61	-1.89	.761	-2.45	-1.85	-2.36	.812	-2.21	-.970
Model 2 (Predicting bankruptcy beyond one, but within two years)										
Coefficients	-.519	4.76	-1.71	-.297	-1.98	-2.74	-2.18	-.780	.4218	1.84
t-statistics	-5.34	5.46	-1.78	-.733	-2.42	-1.80	-2.73	-1.92	2.10	1.38

In Ohlson's model, the cutoff point which minimizes the sum of the Type-I and Type-II errors is .038. Ohlson defines Type-I and Type-II errors in the opposite manner to Altman. For consistency, Altman's definition is also used for Ohlson's model in this study. That is, a Type-I error occurs when P is less than the cutoff point and the firm is bankrupt. Similarly, a Type-II error occurs when P is larger than the cutoff point and the firm is nonbankrupt. Using the cutoff point of .038, Ohlson finds that 17.4 percent of the 2,058 nonbankrupt firms and 12.4 percent of the 105 bankrupt firms are misclassified.

2.3 THE ROLE OF RATIOS IN PREDICTING BANKRUPTCY

2.3.1 TRADITIONAL USE OF RATIOS

"The development of financial ratios for the purposes of analyzing accounting data is one of the important outcomes of accounting evolution."[19] Ratios can be used to evaluate a firm's performance and assess its ability to pay its debt. Stickney (1990) states that ratios are useful tools because they summarize data in a form that is more easily understood, interpreted and compared in financial statement analysis.

The use of ratios dates back to the 1890s when the current ratio was used in credit decisions made by U.S. banks. Later the use of ratios focusing on profitability measures both for credit purposes and managerial analysis began. "Around 1919 the Du Pont Company began to use its famous ratio triangle system for managerial decision making, providing the foundation for the modern interfirm comparison scheme in accounting."[20]

There are two principal reasons for using financial ratios. One is that ratios can be used to make inferences based on changes in a firm's financial variables over a period of time. The use of ratios controls for the effect of changing firm size on the

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[19]Horrigan (1968), p.284.

[20]Barnes (1987), p.449.

financial variables being examined in the time-series context. The second reason for using ratios is to aid in comparisons between a firm and its industry by, once again, adjusting for differences in firm size. Firm-specific ratios can be compared with the industry standard, and the firm's performance inferred based on the difference between its ratios and the industry standard.[21] In either case, ratios are used, as opposed to the actual values of the financial variables of interest, to facilitate comparison while controlling for size.

2.3.2 MAJOR BANKRUPTCY PREDICTIVE MODELS USING RATIOS

Recently financial ratios have been used for predictive purposes. The ratios are used as inputs by researchers in statistical models which predict a firm's credit rating, risk, its potential for bankruptcy and its potential as a takeover target. The main focus, however, has been on developing statistical models which use ratios to predict bankruptcy.

Beaver (1966) uses financial ratios in predicting business failure. He uses a sample of 79 failed firms and a matched sample of 79 non-failed firms and studies their financial ratios for a period of up to five years before failure. The nonfailed firms are selected using the paired-sample technique; that is, for each failed firm in the sample a nonfailed firm is chosen from the same industry and asset-size group one year prior to the year of failure

[21]This is usually referred to as cross sectional analysis.

for the failed firm. The objective of such a sample design is to control for systematic size and industry differences in financial ratios.

Financial ratios for the failed firms in Beaver's study are available for up to five years before failure. The data for each failed and nonfailed pair corresponds to the same time period. Thirty financial ratios from the various conventional ratio categories are calculated for each firm in the sample. A cutoff point is chosen by ranking the value of each ratio. The cutoff point is the value that minimizes total misclassification. Beaver finds that the mean values of the ratios of both groups lay in the predicted directions: the cash flow and the reservoir of liquid assets are, on average, smaller for the failed firms than for the nonfailed firms. Although the failed firms have less capacity to meet their obligations, they have more debt than the nonfailed firms. Therefore, Beaver concludes that financial ratios have predictive ability. The technique used in the study is referred to as classification analysis and is essentially univariate. The shortcomings inherent in the univariate analysis is that different ratios can imply different predictions for the same firm.

As mentioned previously, Altman (1968) uses multiple discriminant analysis (MDA) to estimate a model that uses ratios to discriminate between failed and nonfailed firms. Altman's multivariate model overcomes the univariate model's problem of different ratios giving conflicting predictions.

Altman et al. (1977) develops a "second-generation" model called "Zeta analysis". The new model is essentially the same as the old Z-score model, but takes great care in adjusting the financial statement data for information contained in the footnotes (e.g., lease data, contingent reserves, intangibles, minority interests, etc).[22] The ZETA model for bankruptcy classification appears to be quite accurate for up to five years prior to failure. Over 90 percent of the sample is successfully classified one year prior to bankruptcy and 70 percent up to five years prior. Furthermore, inclusion of retailing firms in the same model as manufacturers does not seem to weaken the results. This model is based on the data from 1969-1975.

Another approach described in Section 2.2.2 is the probabilistic bankruptcy prediction model. Ohlson (1980) develops a probabilistic model of bankruptcy prediction using LOGIT to estimate the coefficients of the variables in the model. Ohlson does not base his choice of variables on any theoretical framework but chooses them on the basis of their reasonableness and their use in the previous bankruptcy prediction literature. The model overcomes several problems encountered in discriminant analysis including the assumptions that financial ratios are normally distributed and that bankrupt and nonbankrupt firms have the same variance-covariance matrix.

There are many other prediction models in the literature. However, the aforementioned models represent the major empirical

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[22]Only some of these adjustments are made in the ZETA model because the data for the nonbankrupt firms are taken from the Compustat Annual Industrial Tape.

research conducted in the area.

2.3.3 CHOICE OF PREDICTIVE VARIABLES

Karels and Prakash (1987) suggest that "the causes of business failure have been attributed to internal and external factors. Internal factors stem from poor management which is manifested through lack of responsiveness to change, inadequate communication, over expansion, mishandling of major projects and fraud. External factors can include labor problems, governmental regulation and natural causes such as weather disasters. Researchers have used financial ratios to account for these factors." The various ratios are used to indicate aspects of a company's health such as profitability, liquidity and solvency.

As early as 1942, Merwin studied financial ratios and concluded that failing firms exhibit significantly different ratio measures than continuing entities. For example, generally, current ratios of failed firms are less than those of the industry as a whole.

Watts and Zimmerman (1986) point out that accounting data is useful in predicting bankruptcy because lending agreements often use financial ratios to restrict managers' actions. For example, a firm may be required to maintain a minimum current ratio. Breach of the financial ratio covenant places the firm in default and can lead to bankruptcy.

However, Watts and Zimmerman also argue that breach of a covenant involving financial ratios does not necessarily lead to bankruptcy. Hence, although defaults are defined using ratios there is no mechanical association between ratios and bankruptcies. A firm's bondholders will not file for bankruptcy if the costs of filing (lawyer and accounting fees and the opportunity costs of using a trustee) outweigh the benefits of eliminating the shareholder's option.

Watts and Zimmerman finally conclude that while technical default does not automatically lead to bankruptcy, the use of accounting numbers in covenants to signal default provides debtholders with the option to force bankruptcy. It is, therefore, not surprising that studies use these financial ratios (e.g., current ratio and debt-to-assets ratio) to predict bankruptcy.

There is no consensus as to which ratios are most important for predicting bankruptcy. The reason for this is that theoretical models provide little foundation as a guide in the choice. For example, Beaver (1966) computes 30 ratios and selects six as "best". Altman (1968) chooses five variables as predictors which he considers most important. Ohlson (1980) frankly states:

> "No attempt was made to select predictors on the basis of rigorous theory. To put it mildly, the state of the art seems to preclude such an approach. The first six predictors were partially selected simply because they appear to be the ones most frequently mentioned in the literature."(p.118).

Table 2-2 presents the ratios employed by several researchers in their empirical studies of bankruptcy. The diverse selection of financial ratios used in predicting bankruptcy is apparent from the table. Such diversity is not surprising given the limited theoretical basis for choosing the ratios.

Table 2-2

Variables Used in Major Empirical Studies of Bankruptcy

Variables	Beaver (1966)	Altman (1968)	Altman et al. (1977)	Ohlson (1980)
working capital/total assets	X	X		X
current assets/current liabs	X		X	X
cash flow/total assets	X			X
total debt/total assets	X			X
MVCE/total assets[1]		X		
sales/total assets		X		
EBIT/total assets		X	X	
EBIT/(interest+lease payments)[2]			X	
net income/total assets	X			X
retained earnings/total assets		X	X	
MVCE/(MVCE+book value of other equities)			X	
std err of EBIT/total assets			X	
firm size			X	X
no credit interval	X			
net income dummy variable[3]				X
two year % change in NI				X
net worth dummy variable[4]				X

[1]MVCE = market value of common equity.
[2]EBIT = earnings before interest and taxes.
[3]one if net income is negative for two years,zero otherwise.
[4]one if total liabilities exceeds total assets,zero otherwise.

2.4 REASONS TO EXPECT THAT THE MODEL PARAMETERS HAVE CHANGED

This study investigates two potential reasons why the parameters of Altman's and Ohlson's models are expected to have changed from what they were when they were originally estimated. One reason is that the bankruptcy law in the U.S. changed dramatically in the late 1970s. The change is expected to increase the number of firms filing for bankruptcy. The second reason the parameters are expected to change is because of the increased use of debt in the 1980s. Due to the proliferation of LBOs and other highly leveraged transactions in the 1980s, the capital structure of many firms has changed. In the remainder of this section, changes in the bankruptcy law and in capital structure are discussed and evidence of a change is reported.

2.4.1 CHANGE IN THE BANKRUPTCY LAW

The Bankruptcy Act in the United States emerged in 1898. The Act applied only to corporate liquidation and contained no provision for corporate reorganization. The Bankruptcy Act served the U.S. until 1938 when it was repealed and replaced with a new Bankruptcy Act. The new Bankruptcy Act appeared to be in response to the massive social and economic upheaval caused by the Great Depression. The new Bankruptcy Act, which was well known as the Chandler Act, made a remarkable change to the original act. Under the Chandler Act, corporations could choose to either liquidate under Chapter VII or reorganize under Chapter X or XI.

LIQUIDATION

Liquidation could happen either through a court petition or a trustee decision. "When it is deemed that there is no hope for rehabilitation or if prospects are so poor as to make it unreasonable to invest further efforts, costs, and time, the only alternative remaining is liquidation. Economically, liquidation is justified when the value of the assets sold individually exceeds the capitalized value of the assets in the marketplace."[23]

Liquidation was sometimes referred to as "straight bankruptcy" under the former Bankruptcy Act. "Its purpose is to achieve a fair distribution to creditors of whatever nonexempt property the debtor has and to give the individual debtor a fresh start through the discharge in bankruptcy."[24]

CHAPTER X

Chapter X proceedings applied to publicly held corporations and secured creditors. "This bankruptcy procedure could be initiated voluntarily by the debtor or involuntarily by three or more creditors with total claims of $5,000 or more."[25]

"Chapter X automatically provided for the appointment of an independent, disinterested trustee or trustees to assume control of

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[23]Altman (1983), p.12.

[24]Treister et al. (1988), p.17.

[25]Altman (1983), p.10.

the company for the duration of the bankruptcy proceeding. Actually the act provided for the appointment of the independent trustee in every case in which indebtedness amounted to $250,000 or more. Where the indebtedness was less than $250,000, the judge could either continue the debtor in possession or appoint a disinterested trustee."[26] "The trustee appointed by a court had wide investigative powers and had the first opportunity to propose a plan of reorganization. All other interested parties, except the debtor, might also file proposals. The debtor could not file a plan until the trustee's time to file had elapsed."[27] Chapter X gave creditors preferential treatment relative to shareholders.

When a petition for Chapter X was filed, the committees representing each class of creditors and shareholders would be formed. The trustee or a representative committee would confer with the creditors' committees and prepare a reorganization plan. The plan could provide for the exchange of securities, the selection of new management, and an adequate means of executing the plan.

The plan had to be approved by two-thirds of each class of creditors by value. Also, the plan had to be approved by shareholders unless total liabilities exceeded total assets. Finally, if the plan was fair and feasible, the court would also approve and confirm it. "Chapter X followed the principles of absolute priority. The junior creditors had no interest under the

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[26]Ibid. p.10.

[27]Ibid. p.11.

plan until most senior creditors were paid in full."[28] The Chapter X proceeding was the least common, but it was an important type of corporate bankruptcy reorganization.

CHAPTER XI

Chapter XI applied to corporate and non corporate entities and to individuals. It could only be initiated voluntarily by a debtor and affected only unsecured creditors.

A court had the power to appoint an independent trustee to manage the corporate property or, as was frequently the case, to permit the old management team to continue its control during the proceedings. Chapter XI placed the bankrupt's assets strictly in the custody of the court and made them free from any prior pending court proceeding. "The bankrupt's petition for reorganization usually contained a preliminary plan for financial relief. The prospect of continued management control and reduced financial obligations made Chapter XI particularly attractive to present management."[29]

During the proceedings, after a plan was proposed by a debtor, a referee called the creditors together to go over the proposed plan and any new amendments that had been proposed. If a majority in number and amount of each class of unsecured creditors consented to the plan, the court could confirm the plan and make it binding

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[28]See U.S. Congress (1973), Report of the Commission on the Bankruptcy Law of the United States, Part I, p.245.

[29]Altman (1983), p.9.

on all creditors.

"Usually, the reorganization plan provided for a scaling-down of the size and composition of creditor's claims and/or an extension of payments over time."[30] New financial instruments could be issued to creditors in lieu of their old claims. The debtor could borrow new funds that had preference over all unsecured indebtedness. Although the interest rate on such new credit was expected to be high, it still enabled the firm to secure an important new source of financing.

Chapter XI arrangements, if successful, tended to be faster than the more complex Chapter X cases. Also, Chapter XI was usually less costly than the proceedings that involved all security holders. Successful out-of-court settlements, however, were usually even less costly.

THE BANKRUPTCY REFORM ACT OF 1978

In 1978, U.S. Congress enacted the Bankruptcy Reform Act. The Chandler Act was officially repealed on October 1, 1979. Since then, the bankruptcy practices for most companies have been governed by the Bankruptcy Reform Act which is usually referred to as the Bankruptcy Code.

Altman (1983) states that the major reason for revising the Chandler Act is that "it was no longer functioning in its intended manner due to changes in social and economic conditions of the country over three decades. The bankruptcy courts were faced with

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[30]Ibid. p.9.

an increasing number of bankruptcies as more and more consumers and businesses made use of the process. More than one-quarter of the referees in bankruptcy had problems in the administration of their duties and suggested modifications to the Chandler Act."

Altman also points out that "one of the major goals of the Bankruptcy Reform Act of 1978 is to speed up the process because the longer a firm spends in bankruptcy, the higher the costs to debtors, creditors and society in general. ... In an attempt to reduce the time spent in bankruptcy, the Bankruptcy Reform Act lays down several time limits and generally makes it easier to enter the bankruptcy process."

The chapters of the Bankruptcy Code that are of interest in this study are Chapter 7 (liquidation) and Chapter 11 (reorganization). An extremely important change appears in Chapter 11. Chapter 11 is a consolidated chapter for business rehabilitation. It adopts much of the old Chapter XI arrangements and incorporates a good portion of Chapter X.

Under Chapter 11, a petition for reorganization can be filed voluntarily by a debtor or involuntarily by creditors. "If the debtor has more than 12 creditors, three creditors whose claims must total at least $5,000 in aggregate must join in the involuntary petition. If there are fewer than 12 creditors, two creditors or a single creditor holding claims of at least $5,000 may file."[31] In order to file an involuntary petition, the creditors must "show that the debtor is generally not paying his

[31]Altman (1983), p.15.

debts as such debts become due or that within 120 days before the filing of petition, a custodian was appointed and took possession of the debtor's assets."[32]

A debtor may propose his plan of reorganization within 120 days after filing his petition. After this period, if a trustee has been appointed by the court, any interested party may file a plan as well. The court holds hearings on the plan and will approve and confirm it if it is fair and feasible. The confirmation requires that the plan be accepted by two thirds in amount and one half in number of each class of creditors and by two thirds in amount, regardless of number of shareholders. "The court may confirm a plan even if a class of creditors object if the court finds that the interests of that class are not impaired by the plan."[33]

Chapter 11 also provides for the appointment of committees to represent the interests of certain classes of claimholders before the court. The committees normally consist of the seven largest members of a particular class who are willing to serve, and are empowered to hire legal counsel and other professional help. Committees' operating expenses are paid out of the bankrupt firm's assets. Appointment of a committee of unsecured creditors is mandatory in Chapter 11 cases; additional committees can be appointed to represent other classes, including shareholders, at the discretion of the judge.

Chapter 11 permits the debtor to continue running his business.

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[32]Ibid. p.15.

[33]Ibid. p.22.

The bankrupt firm is expected to continue as a going concern after leaving bankruptcy. To protect the firm from creditor harassment while it tries to reorganize, Chapter 11 imposes an automatic stay. The stay prevents creditors from collecting on their debt or foreclosing on their collateral until the firm leaves bankruptcy.

Due to the change in the bankruptcy law, the rate of bankruptcies is expected to increase. One reason for expecting this is that under the new law, it is likely to be easier to enter and later leave the bankruptcy process therefore the reorganization is expected to take less time. As a result, more firms are expected to take advantage of this option. Altman (1983) indicates that "the attempt to reduce reorganization time is important, since there is a positive correlation between the time spent in reorganization and the direct cost of bankruptcy. The latter includes legal and accounting fees, trustee and filing fees, and other tangible costs involved with the bankruptcy process."(p.26). The other reasons, as Ramaswami and Moeller (1990) state, are "the Bankruptcy Code has become an increasingly popular management tool for companies seeking not only protection from creditors but also as a bargaining ploy in their confrontations with the labor unions."(p.4).

Table 2-3 contains information on business failures from Business Statistics 1961-1988. This data is supplied by Dun & Bradstreet Inc. (hereafter D & B) which defines business failures to include businesses that (1) ceased operations following assignments or bankruptcy with losses to creditors, (2) voluntarily withdrew, leaving unpaid obligations, or (3) were involved in a court action such as receivership, reorganization, or arrangement.

As of January 1984, D & B expanded the compilation of business closing statistics in certain industry groupings. As a result, calculations of industrial breakdowns have been changed to reflect the new collection criteria, and data reported for individual industries prior to 1984 are not comparable with succeeding years. However, the annual failure rate can still be used for a relative comparison between years.

Table 2-3 lists the number of industrial and commercial failures and the annual failure rate which is expressed as the annual number of failures per the 10,000 industrial and commercial enterprises followed by the D & B. The rate is the most continuous time series bankruptcy statistic. The last column of Table 2-3 shows that the annual failure rate is relatively low in the 1970s. However, since 1980, the rate has increased dramatically. This tendency is illustrated by Figure 1.

The change in bankruptcy law in 1978 is expected to have contributed to the increased rate of bankruptcies in the 1980s and is likely to have led to a change in the parameters of Altman's and Ohlson's bankruptcy prediction models.

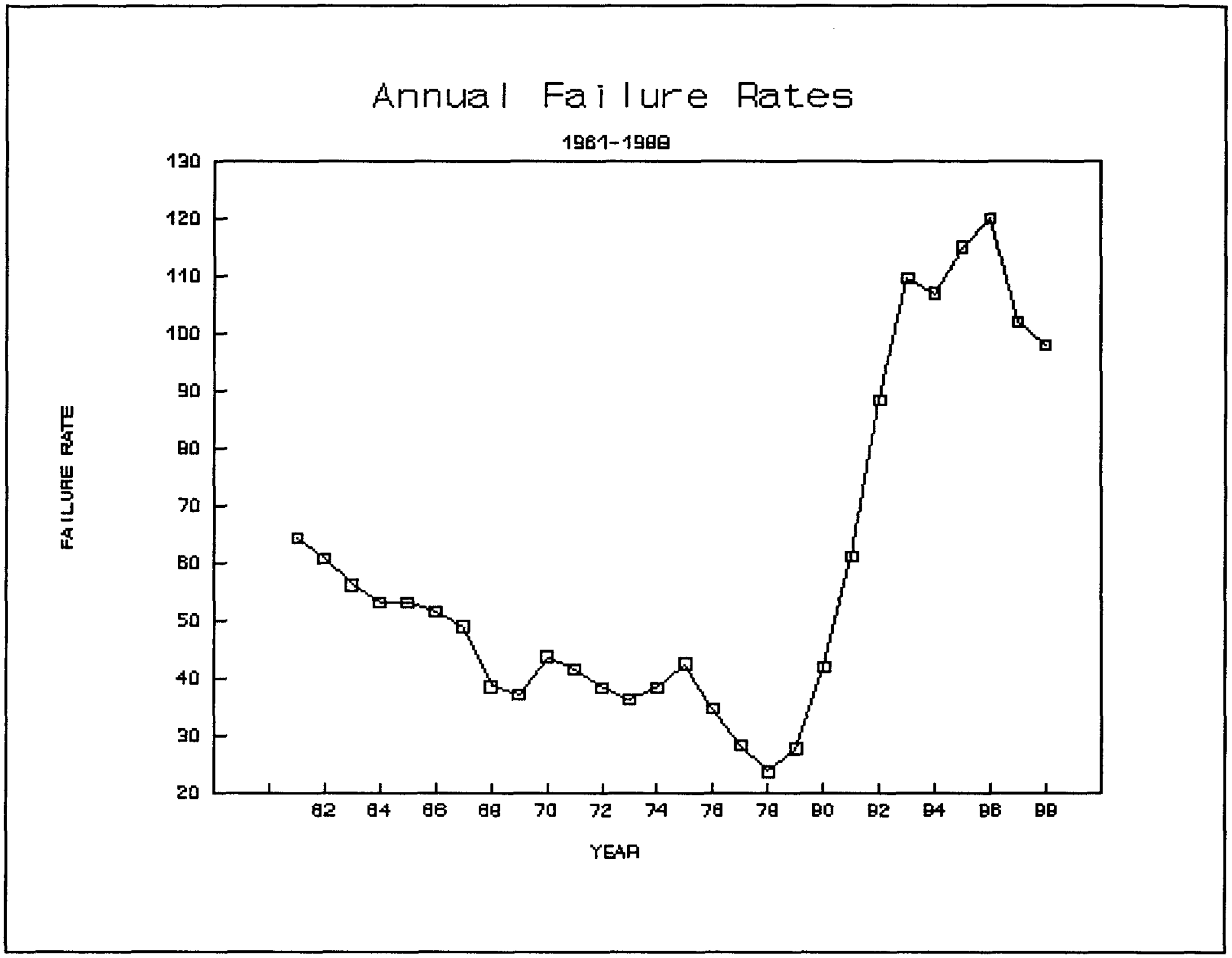
Table 2-3

Industrial and Commercial Failures

Year	Total	Commercial Service	Construction	Manufacturing and mining	Trade: Retail	Trade: Wholesale	annual failure rate (Number of failures per 10,000 firms)
	Number of Failures						
1961	17,075	1,472	2,752	2,825	8,292	1,734	64.4
1962	15,782	1,339	2,703	2,575	7,552	1,613	60.8
1963	14,374	1,373	2,401	2,409	6,681	1,510	56.3
1964	13,501	1,226	2,388	2,254	6,241	1,392	53.2
1965	13,514	1,299	2,513	2,097	6,250	1,355	53.3
1966	13,061	1,368	2,510	1,852	6,076	1,255	51.6
1967	12,364	1,329	2,261	1,832	5,696	1,246	49.0
1968	9,636	1,106	1,670	1,513	4,366	981	38.6
1969	9,154	1,159	1,590	1,493	4,070	842	37.3
1970	10,748	1,392	1,687	2,035	4,650	984	43.8
1971	10,326	1,464	1,545	1,932	4,428	957	41.7
1972	9,566	1,252	1,375	1,576	4,398	965	38.3
1973	9,345	1,182	1,419	1,463	4,341	940	36.4
1974	9,915	1,320	1,840	1,557	4,234	964	38.4
1975	11,432	1,637	2,262	1,645	4,799	1,089	42.6
1976	9,628	1,331	1,770	1,360	4,139	1,028	34.8
1977	7,919	1,041	1,463	1,122	3,406	887	28.4
1978	6,619	773	1,204	1,013	2,889	740	23.9
1979	7,564	930	1,378	1,165	3,183	908	27.8
1980	11,742	1,594	2,355	1,599	4,910	1,284	42.1
1981	16,794	2,366	3,614	2,224	6,882	1,708	61.3
1982	24,908	3,840	4,872	3,683	9,730	2,783	88.4
1983	31,534	6,617	5,267	4,433	11,429	3,598	109.7
1984	52,078	12,787	6,936	5,759	13,787	4,882	107.0
1985	57,252	16,647	7,004	5,662	13,501	4,835	115.0
1986	61,601	20,966	7,110	5,699	13,623	4,865	120.0
1987	61,384	23,928	6,775	4,912	12,272	4,353	102.0
1988	57,093	22,756	6,811	4,703	11,485	4,451	98.0

Source: Business Statistics 1961-1988, Supplement to "Survey of Current Business".

Figure 1



Source: Business Statistics 1961-1988, Supplement to "survey of Current Business".

2.4.2 CHANGE IN CAPITAL STRUCTURE

During the 1980s, highly leveraged transactions became extremely popular among U.S. corporations. This increased use of leverage has emerged as one of the important economic and political issues of the 1980s. Several factors could explain this economic phenomenon.

First, entering the 1980s, as Ramaswami and Moeller (1990) point out, "the U.S. corporate sector could no longer afford the low debt/equity of the 1950s and 1960s - the golden era for U.S. industry. ... The business and financial environment of the 1980s is quite different from that of the 1960s and early 1970s. Rapid technological change, worldwide competition for major products, and the fluctuating global financial market conditions are important characteristics of the business environment in the 1980s. These were not present in 1960s and early 1970s."

Ramaswami and Moeller also state that " the more competitive, globalized market environment of the 1980s and beyond calls for a greater measure of risk-taking by U.S. managers. Increasing the debt-equity ratio is one way of institutionalizing that attitude with some discipline. When one's survival is in question, better husbanding of resources, sharper focus, and quicker response to changing market conditions could be expected."

Second, obtaining tax benefits is one of the most important factors leading corporations to finance through debt. The purpose is to enhance shareholder value. Larger amounts of debt used in

LBOs, leveraged asset acquisitions, and asset recapitalizations such as leveraged share repurchases generate larger interest deductions reducing taxes and increasing shareholder wealth.

Third, entering the 1980s, "commercial banks were under tremendous pressure after the deregulation of deposits. They did not have good places to put their money. ... They needed something new."[34] They began to look at the cash flow coverage of the company rather than the value of total assets to determine the level of senior debt the firm could carry. The appearance of junk bonds further increased the availability of debt.

Fourth, LBOs had a significant effect on the American financial scene in the 1980s. "An LBO is a purchase of a company's stock with borrowed money."[35] That is, it is characterized by a general substitution of debt for equity in the capital structure of the acquired entity.

In essence, an LBO is a transaction in which a buying group acquires ownership of a corporation or a subsidiary of a corporation. The group consists generally of outsider investors, members of management, other employees and some shareholders. "An LBO is financed primarily through borrowings from one or more lenders. The lenders will look to the assets and/or the cash flow of the company as the source of repayment of the debt."[36]

"Before 1981, LBOs were characterized as relatively small

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[34]Amihud (1989), p.106.

[35]Ramaswami and Moeller (1990), p.xx.

[36]Amihud (1989), p.175.

transactions, generally less than $50 million, where the purchase price was approximately equal to the assets, and the financing was a mortgage."[37] Furthermore, their size was restricted due to the convention of financing the transaction by taking back a security over the assets.

"In 1981, this was changed by Kohlberg, Kravis, Roberts & Co. in a transaction called 'Houdaille'. For the first time, a $400 million transaction was done where the financing wasn't tied directly to the amount of assets. The bank financing was the first 'cash flow loan' in which the banks decided that, instead of looking strictly at current assets and plant and equipment to determine the amount of senior debt, they would look at the cash flow coverage of the enterprise."[38] Since then, LBOs with substantial amounts of money involved have become popular. In 1985, the use of junk bonds proliferated, changing from simply financing for companies that were either in trouble or growing to acquisition financing.

Today, many companies have adopted new thinking with respect to their debt loads. Management now pays more attention to the benefits of debt. It is argued that as long as a firm rests its debt-raising ability on both the firm's ability to generate cash and the protection offered by the intrinsic value of its assets, the use of debt makes sense. The use of debt also enables a firm to reduce tax payments through the interest deduction. Finally, LBOs

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[37]Ibid. p.103.

[38]Ibid. p.104.

allow large shareholders to be bought out, and thus act as a useful defense tactic against hostile takeovers. Danzi et al. (1990) suggest that an ideal LBO firm should have a healthy, stable cash flow, marketable tangible assets, scope for improving asset management, and potential for asset redeployment.

As evidence of the increased use of leverage in the 1980s, leverage ratios from the Compustat database for all industrial firms, the S & P 500 and S & P industrial firms are summarized in Table 2-4. Debt-to-total assets ratios from year to year for each group of firms are computed. The results indicate that, on average, leverage in the 1980s follows an upward trend. Figure 2 also shows this tendency. To determine whether the increased use of leverage from the 1970s to 1980s is significant, a t-test of the difference between the mean leverage ratio in the 1970s and in the 1980s is performed for the S & P 400 and the S & P 500 firms. For the S & P 400 firms, the leverage increase is not significant. For the S & P 500 firms, the leverage increase is significant at the 10% level.

The increased use of debt by otherwise healthy firms in the 1980s is expected to lead to a change in the parameters of Altman's and Ohlson's models.

Table 2-4

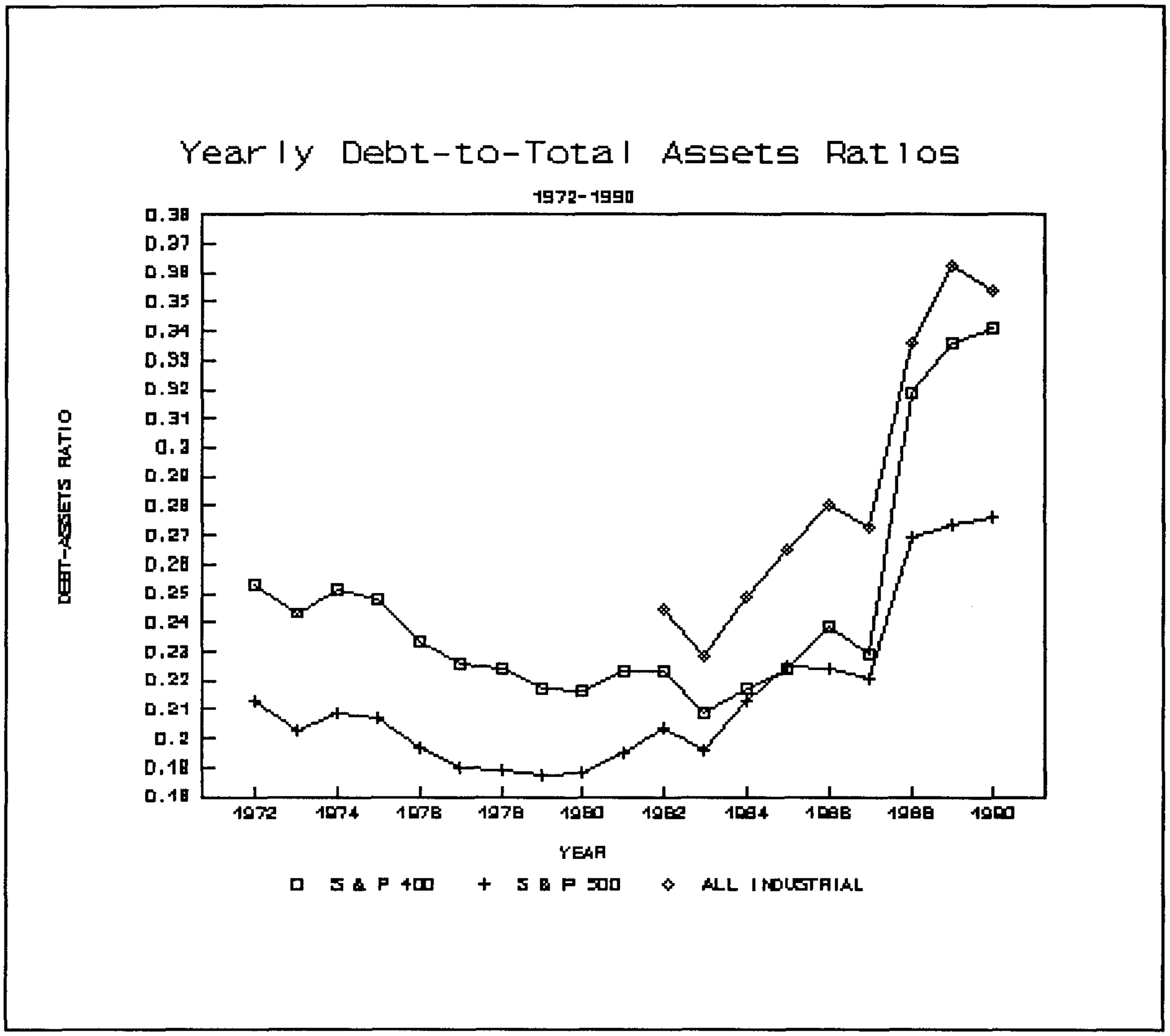
Total Debt-to-Total Assets Ratios[a]

YEAR	S & P 400	S & P 500	ALL INDUSTRIAL[b]
1972	25.31%	21.26%	
1973	24.33%	20.29%	
1974	25.17%	20.83%	
1975	24.76%	20.74%	
1976	23.35%	19.68%	
1977	22.60%	18.96%	
1978	22.37%	18.93%	
1979	21.68%	18.77%	
1980	21.67%	18.84%	
1981	22.36%	19.52%	
1982	22.29%	20.36%	24.47%
1983	20.87%	19.59%	22.81%
1984	21.73%	21.26%	24.88%
1985	22.41%	22.50%	26.48%
1986	23.84%	22.44%	28.01%
1987	22.90%	22.04%	27.30%
1988	31.84%	26.90%	33.57%
1989	33.59%	27.37%	36.25%
1990	34.07%	27.37%	35.34%

[a]Source: S & P Compustat PC PLUS.

[b]The ratios from 1972 to 1981 for all industrial are unavailable.

Figure 2



Source: S & P Compustat PC PLUS

2.5 HYPOTHESES AND PLAN FOR THE FOLLOWING ANALYSIS

With regard to the expectation for the parameter change in Altman's and Ohlson's models, four hypotheses are developed.

(1) The Type-I Error Hypothesis: The change in U.S. bankruptcy law in the 1970s is predicted to increase the Type-I (classifying bankrupt firms as nonbankrupt) error rate for both Altman's and Ohlson's models with respect to the 1980s data. The reason for this argument is that the change in bankruptcy law leads to an increased number of firms filing for bankruptcy.

(2) The Type-II Error Hypothesis: The increased use of leverage by healthy firms in the 1980s is predicted to increase the Type-II (classifying nonbankrupt firms as bankrupt) error rate for both Altman's and Ohlson's models with respect to the 1980s data. Since financial leverage is one factor in both models, the higher level of debt will result in a lower Z-score and a higher predicted probability of bankruptcy for firms. Thus, a firm having a high level of debt is more likely to be predicted to go bankrupt, even when the firm is profitable, healthy and growing.

Ideally, these two hypotheses should be tested by comparing the results from the 1980s sample with those from a true holdout sample applied to Altman's or Ohlson's original model. For Altman's model, Moyer's 1970s sample[39] can be treated as a holdout sample. For Ohlson's model, unfortunately, such a holdout sample is unavailable. Given the lack of a true holdout sample for Ohlson's

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[39]See Moyer (1977).

model, we would expect the Type-I and Type-II error rates to increase when the model is applied to a sample outside of the original estimation sample. This leads to a bias in favour of finding evidence in support of the above two hypotheses.

(3) The Intercept Hypothesis: The change in bankruptcy law in the late 1970s is predicted to lead to a significant increase in the intercept of Ohlson's model. It is possible that the coefficients of some of the other ratios in Ohlson's model may have changed as a result of the change in the bankruptcy law. However, it is not immediately obvious which ratios they would be. Therefore, we look for an effect of the change in the bankruptcy law by looking for an increase in the average likelihood of bankruptcy that is independent of the ratios in the model. That is, we look for an increase in the intercept to the model. To the extent that the effect of the change in the bankruptcy law is related to one or more of the ratios in Ohlson's model, this test will not capture that effect.

(4) The Leverage Hypothesis: The increased use of leverage in the 1980s is predicted to result in a significant decrease in the coefficient on TLTA (total liabilities/total assets) in Ohlson's model. That is, for the same level of leverage, the estimated probability of bankruptcy is expected to be lower in the 1980s than what it was in Ohlson's sample from the 1970s.

Because statistics such as standard errors and t-values are not available for individual variables in the discriminant model a significant change in the coefficients of Altman's model cannot be tested.

The remaining chapters are organized in the following format. Chapter 3 describes in detail the data and sample design. Two samples are selected from the Compustat database. The data is restricted to the period from 1981 to 1990. A profile analysis is conducted to describe the sample characteristics. Chapter 4 first examines both Altman's model and Ohlson's model based on the data discussed in Chapter 3. The predictive abilities of the two models are examined and the Type-I and Type-II Error Hypotheses are tested. Then, Altman's and Ohlson's models are reestimated using the 1980s samples. The purpose is to determine whether the model parameters have changed since 1980. In particular, for Ohlson's model, the Intercept and Leverage hypotheses are tested. Chapter 5 gives the conclusions of this study.

CHAPTER 3

DATA COLLECTION AND DESCRIPTIVE STATISTICS

3.1 DATA COLLECTION

The majority of the data for this study is obtained from the 1991 Compustat database which contains financial statement data on a large number of companies for the period of 1971-1990. The database includes information on over 7,000 industrial corporations, banks, utilities, and telecommunications companies. The Compustat data is collected from company annual reports, SEC 10-K and 10-Q reports. The majority of companies covered by Compustat are publicly traded rather than smaller private companies. Therefore, there is a sample bias toward larger publicly traded firms in this study.

For a firm to be included in the sample, the following conditions must hold:

1. The firm's financial statement data is available from Compustat for at least two consecutive years during the period 1981-1990.
2. For firms which COMPUSTAT indicates as bankrupt or in liquidation, the firm's bankruptcy filing date is available from the Capital Changes Reporter, from SEC 10-K reports or from the Moody's Manuals.
3. The firm's stock price at fiscal year end is available from the Compustat database or from the Daily Stock Price Record.

4. The firm is not a utility, transportation or financial services firm.

The first condition is required because data from the 1980s is used to examine the predictive power of the existing bankruptcy prediction models. In order to reestimate Altman's and Ohlson's models financial statement data for at least two years is required. The second condition is required to avoid an ex post bias. As was noted in Ohlson (1980), "financial statement data for the bankrupt firms must be selected carefully to ensure that it is available prior to the date of bankruptcy filing. Otherwise, 'back-casting' for many of the bankrupt firms may occur."[40] To avoid this problem, financial statement data for the bankrupt firms is obtained from Compustat in the year prior to the year it filed for bankruptcy. The third condition is imposed because share prices are used to calculate market value, one of the five predictors in Altman's Z-score model. The fourth condition excludes utilities, transportation and financial service firms because "firms in these industries are regulated, are structurally different, and have a different environment,"[41] all of which are expected to affect the link between financial performance and expected bankruptcy. As a consequence, the sample is restricted to mainly commercial and industrial companies.

The bankrupt and nonbankrupt firms are collected separately. In this study, a firm is identified as bankrupt if it is coded by

[40]Ohlson (1980), p.110.

[41]Ibid. p.114.

Compustat as bankrupt. A firm is identified as nonbankrupt if Compustat does not indicate that it was in bankruptcy. Compustat classifies a firm as bankrupt if a petition for bankruptcy or liquidation, either voluntary or involuntary, has been filed.

There are three steps to selecting the sample of bankrupt firms. The bankruptcy footnote on Compustat is used to identify companies, other than utilities, transportation and financial service firms that went bankrupt during the period 1981-1990. One hundred and sixty-two bankrupt firms are identified by this process. The date a firm filed for bankruptcy or liquidation is obtained from the Capital Changes Reporter, SEC 10-K reports or the Moody's Manuals. Forty-nine firms are deleted from the sample because the bankruptcy or liquidation dates are unavailable, reducing the sample to 113 firms. Nine of the 113 firms are deleted from the sample because financial statement data is not available on Compustat, reducing the sample to 104 firms. Thirty-eight of these 104 firms are missing share prices on Compustat. The stock prices of 33 of these 38 firms are obtained from the Daily Stock Price Record (hereafter DSPR) and used to calculate market values. The share prices for the remaining 5 firms are unavailable, and they are dropped from the sample. Thus, in total, 63 bankrupt firms are dropped due to missing data leaving a final sample of 99 firms. A list of the 99 bankrupt firms in the sample is shown in Appendix A.

The distribution of these bankrupt firms across years and across stock exchanges appears in Table 3-1. As Table 3-1 indicates, most of the bankrupt firms are listed on the OTC just prior to their bankruptcy. No bankrupt firms listed on regional exchanges are included in the sample. This is because the market values for these firms are unavailable either from Compustat or from the DSPR.

Table 3-1

Distribution of Bankrupt Firms by Year and by Stock Exchange

	YEAR											
Exchange	81	82	83	84	85	86	87	88	89	90	Total	Percent
NYSE	0	1	1	3	5	2	1	2	1	5	21	21
AMSE	0	1	0	1	1	1	2	3	2	2	13	13
OTC	4	4	3	2	8	6	6	7	11	14	65	66
TOTAL	4	6	4	6	14	9	9	12	14	21	99	100

The sample of bankrupt firms in this study contains a higher percentage of NYSE and OTC firms than is present in Ohlson's sample. Ohlson reports that, in his sample, 8 percent of the firms are listed on the NYSE, 41 percent on the AMSE, and 51 percent of the firms are listed on the OTC or regional exchanges.

Table 3-1 shows that, in general, the number of bankrupt firms in the sample is increasing over time. This is expected given the increasing rate of corporate failures during the 1980's documented by the Dun & Bradstreet Inc. and reproduced in Table 2-3.

The nonbankrupt firms are also selected from Compustat. For Altman's model, a sample of 99 nonbankrupt firms is collected in order to form a paired sample. This paired sample is matched on the basis of industry, asset size and calendar year.

For Ohlson's model, ideally, both bankrupt and nonbankrupt firms should be selected simultaneously as a single random sample from the database. Once the sample is obtained, firms should be identified as bankrupt or nonbankrupt. Given that all bankrupt COMPUSTAT firms with data available are included, all nonbankrupt COMPUSTAT firms should form the nonbankrupt sample. This would result in a sample of approximately 72,830 nonbankrupt firm years.[42] Such a large sample is very difficult to handle in practice due to computer memory limitations.

As a result of these constraints, the following procedures are used in this study to select a smaller sample of nonbankrupt firms. The proportion of bankrupt to nonbankrupt firms is set to 1:20.[43] Thus, 1,980 nonbankrupt firms are required given the sample of 99 bankrupt firms. One hundred and ninety-eight nonbankrupt firms are randomly selected for each year during the 1981-1990 period. It is possible that the same nonbankrupt firm could appear more than once in the sample, due to its inclusion in different years. These procedures result in a sample of 99 bankrupt and 1,980 nonbankrupt firm years.

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[42]The number of firm years is defined as the number of active nonbankrupt firms on Compustat multiplied by the number of years.

[43]This ratio of one bankrupt to 20 nonbankrupt firms is similar to the proportions used in Ohlson (1980) and in Zmijewski (1983).

3.2 DESCRIPTIVE STATISTICS

In order to better describe the sample characteristics, a profile analysis is conducted. Seven financial ratios commonly used in bankruptcy prediction are reported in Table 3-2. The table shows that the ratios deteriorate as one moves from nonbankrupt firms to bankrupt firms two years prior to bankruptcy to bankrupt firms one year prior to bankruptcy. This tendency is in accordance with what one would expect. To determine if there is a significant difference in the ratios between the bankrupt firms one year prior to bankruptcy and nonbankrupt firms, an F-test of the mean difference between the two groups is conducted for each financial ratio. With the exception of SLTA (sales/total assets), all the ratios are significantly different across the two groups at the 1% level. SLTA is significant at the 5% level. This indicates that a significant difference in the ratios of the bankrupt and nonbankrupt firms exists.

Table 3-2

Profile Analysis of the Bankrupt and Nonbankrupt Firms in the Sample

	Nonbankrupt Firms		Bankrupt Firms			
			Two Years Prior to Bankruptcy		One Year Prior to Bankruptcy	
Variable[a]	mean	std dev	mean	std dev	mean	std dev
TLTA	.5026	.2854	.8873	.5274	1.1068	.7179
WCTA	.3504	.2631	.0329	.5017	-.0864	.5668
CLCA	.5512	1.2445	1.4235	3.0260	1.9642	3.7041
NITA	.0876	.1561	-.2783	.5666	-.3930	.8135
FUTL	.4076	.7477	-.2005	.6882	-.2197	.5137
RETA	.3477	0.2045	-.0083	1.0639	-.7268	1.5556
SLTA	1.5685	.8439	1.2827	1.0416	1.1998	.7188
Number of firms	1980		95		99	

[a]TLTA = Total Liabilities/Total Assets
WCTA = Working Capital/Total Assets
CLCA = Current Liabilities/Current Assets
NITA = Net Income/Total Assets
FUTL = Funds from Operations/Total Liabilities
RETA = Retained Earnings/Total Assets
SLTA = Sales/Total Assets

CHAPTER 4

MODEL TEST AND REESTIMATION

In this Chapter, the predictive abilities of Altman's and Ohlson's bankruptcy prediction models are tested using the samples of firms from the 1980s. Altman's and Ohlson's models are then re-estimated to test whether the parameters have changed.

4.1 THE PREDICTIVE ABILITIES OF ALTMAN'S AND OHLSON'S MODELS

In this section, Altman's Z-score model is applied to firms from the 1980s and its ability to correctly classify bankrupt and nonbankrupt firms is reported. Ohlson's model is also tested in a similar manner.

4.1.1 TEST OF ALTMAN'S Z-SCORE MODEL

Altman's Z-score model[44] is estimated using data from the period 1946-1965. In this section, the predictive ability of Altman's model is tested on data from the 1980s.

Altman determines that a cutoff of $Z=2.675$ minimizes the error classification rate for his sample.[45] If $Z < 2.675$, a firm is

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[44]Altman's Z-score model is described in Section 2.2.1 of Chapter 2.

[45]Altman chooses this cutoff point to minimize the total number of Type-I and Type-II errors for his sample. Choosing a cutoff in this manner is equivalent to assuming that the costs of Type-I and Type-II errors are equal. However, in general, Type-I errors are

classified as bankrupt. Otherwise, the firm is classified as nonbankrupt.

Type-I (classifying bankrupt firms as nonbankrupt) and Type-II (classifying nonbankrupt firms as bankrupt) error rates for Altman's original sample are summarised in Panel A of Table 4-1. Altman reports the overall error rate for his sample is 5 percent one year prior to bankruptcy. The Type-I and Type-II error rates are 6 and 3 percent, respectively. Two years prior to bankruptcy the overall error rate is 17 percent.

Altman also uses a non-random "hold-out" sample[46] to evaluate the predictive ability of his model.[47] The sample consists of 25 bankrupt and 66 nonbankrupt firms. When Altman's initial model is applied to this sample, the overall error rate is 16.5 percent. The Type-I and Type-II error rates are 4 and 21 percent, respectively.

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likely to be more costly than Type-II errors.

[46]Watts and Zimmerman (1986) point out that "The use of a holdout sample is important methodologically. Knowledge of a firm's ratios and whether it went bankrupt or not is used to determine the discriminant function and the 'optimal' z score cutoff for the estimation sample. Essentially, hindsight is used. When the discriminant function and 'optimal' cutoff is applied to another sample, the effect of hindsight is not present and the discriminant function will not predict as well. Hence, the use of a holdout sample is necessary to evaluate the discriminant function's predictive ability."

[47]Altman points out the non-random nature of his holdout sample: "a sample of sixty-six firms is selected on the basis of net income (deficit) reports in the years 1958 and 1961, with thirty-three from each year. Over 65 per cent of these firms had suffered two or three years of negative profits in the previous three years reporting."

Table 4-1

Comparison of Type-I & Type-II Error Rates From Applying Altman's Model to His Own Sample Versus the 1980s Sample

Panel A: Altman's Original Sample[a]

Predictive Ability One Year Prior to Bankruptcy

	Number Correct	Percent Correct	Percent Error	N
Type-I[b]	31	94	6	33
Type-II[c]	32	97	3	33
Total	63	95	5	66

Predictive Ability Two Years Prior to Bankruptcy

	Number Correct	Percent Correct	Percent Error	N
Type-I	23	72	28	32
Type-II	31	94	6	33
Total	54	83	17	65

Panel B: 1980s Paired Sample

Predictive Ability One Year Prior to Bankruptcy

	Number Correct	Percent Correct	Percent Error	N
Type-I	88	89	11	99
Type-II	67	68	32	99
Total	155	78	22	198

Predictive Ability Two Years Prior to Bankruptcy

	Number Correct	Percent Correct	Percent Error	N
Type-I	67	71	24	95
Type-II	62	67	33	93
Total	129	69	31	188

[a]Altman's original sample is the sample Altman used to estimate his bankruptcy prediction model.
[b]bankrupt predicted to be nonbankrupt.
[c]nonbankrupt predicted to be bankrupt.

The new paired sample of 99 bankrupt and 99 nonbankrupt firms from the 1980s is used to test Altman's original model. Panel B of Table 4-1 shows the results of applying Altman's model to the new paired sample.[48] The overall error rate is 22 percent one year prior to bankruptcy. The Type-I error rate is 11 percent and the Type-II error rate is 32 percent. The overall error rate two years prior to bankruptcy increases substantially to 31 percent.

Ideally, it is preferable to compare the results for the 1980s sample with those for a 'random' holdout sample from a period before the change in the bankruptcy law and the change in the use of debt. The analysis in Moyer (1977) provides such a holdout sample. Moyer examines the predictive ability of Altman's Z-score model applying Altman's model and cutoff point to 27 bankrupt and 27 nonbankrupt firms from 1965-1975. Moyer's results can therefore be thought of as applying to a random holdout sample of bankrupt and nonbankrupt firms taken from a period before the legal and corporate changes this current study is concerned with. Moyer reports an overall error rate of 25 percent. The Type-I error rate one year prior to bankruptcy is 39 percent and the Type-II error rate is 12 percent. Comparing these with the results for the 1980s sample, the Type-I error rate has declined and the Type-II error rate has increased in the 1980s period. These results are consistent with the Type-II Error Hypothesis, but are inconsistent with the Type-I Error Hypothesis.

If Type-I errors are more costly than Type-II errors then the

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[48]Here, Altman's cutoff point of 2.675 is used.

fact that Altman's model leads to less Type-I errors and more Type-II errors in the 1980s sample may be preferable for many decisions.

4.1.2 TEST OF OHLSON'S MODEL

In this section, Ohlson's bankruptcy prediction model[49] is applied to the sample of firms from the 1980s to assess its predictive ability. This sample consists of 99 bankrupt and 1,980 nonbankrupt firms. Fitting the 1980s sample firms to Ohlson's model, P (the estimated probability of bankruptcy during the following year) is obtained.

Table 4-2 reports for both Ohlson's sample and the current sample the percentage of Type-I and Type-II errors[50] that occur when various values of P are used to classify firms as predicted bankrupt or nonbankrupt. As the cutoff for P increases, the number of Type-I errors increases while the number of Type-II errors decreases.

The results in Table 4-2 are similar to those reported in the previous section when Altman's model is applied to Moyer's sample and then to the 1980s sample. For almost all cutoffs for P, applying Ohlson's model to firms from the 1980s results in a higher rate of Type-II error and a lower rate of Type-I error than

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[49]Ohlson's model is described in Section 2.2.2 of Chapter 2.

[50]For consistency, Altman's definition for Type-I and Type-II errors is also used for Ohlson's model in this analysis. In his study Ohlson uses the opposite definition of Type-I and Type-II errors.

occurred in Ohlson's sample. Ohlson reports that a cutoff point of P=0.038 minimizes the sum of Type-I and Type-II errors for his sample. Like the cutoff used by Altman, this cutoff point is determined based on the assumption that the cost of a Type-I error is equal to the cost of a Type-II error. This cutoff point results in a Type-I error rate of 12.4 percent and a Type-II error rate of 17.4 percent for Ohlson's sample. Applying the same cutoff point to the 1980's sample, the Type-II error rate increases to 26.8 percent while the Type-I error rate falls to 9.1 percent.[51] For the 1980s sample, the cutoff point which minimizes the sum of Type-I and Type-II error rates is 0.1. At this point, 15.15 percent of the bankrupt firms and 11.57 percent of the nonbankrupt firms are misclassified.

Ohlson reports that, in his sample, the mean probabilities of bankruptcy are 0.03 for the nonbankrupt firms, 0.39 for the bankrupt firms one year prior to bankruptcy and 0.20 for the bankrupt firms two years prior to bankruptcy. For the 1980s sample, Ohlson's model predicts mean probabilities of 0.043 for the nonbankrupt firms and 0.555 and 0.395 for the bankrupt firms one and two years prior to bankruptcy, respectively. Given the increased rate of bankruptcy in the 1980s, it is to be expected that Ohlson's model will predict a higher probability of bankruptcy when applied to 1980s data for all three types of firms in the

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[51]In evaluating Ohlson's model, it would be preferable to compare the results from the 1980s sample with those from a 'hold-out' sample from an earlier period. Unfortunately, Ohlson does not report results for a 'hold-out' sample and there are no other published studies testing the predictive power of Ohlson's model.

sample.

The decreased predictive power of Ohlson's model and the increased mean probabilities using the data from the 1980s implies that the model parameters are likely to have changed from what they were during the early 1970's. To test this hypothesis these parameters will be re-estimated, using the 1980s sample, in Section 4.2.

Table 4-2

Comparison of Type-I & Type-II Error Rates From Applying Ohlson's Model 1 to His Own Sample Versus the 1980s Sample

Estimated Probability of Bankruptcy used as Cutoff Points	Ohlson's Sample		1980's Sample	
	Type-I	Type-II	Type-I	Type-II
0.00	0%	100%	0%	100%
0.02	7.6	28.7	5.05	36.57
0.04	14.3	16.7	9.09	26.77
0.06	20.6	11.6	13.13	18.74
0.08	25.7	9.3	13.13	13.89
0.10	26.7	7.2	15.15	11.57
0.20	44.8	3.3	26.26	4.90
0.30	48.6	1.75	35.35	3.28
0.40	57.1	1.07	39.39	2.37
0.50	67.6	0.63	45.46	1.82
0.60	71.4	0.29	52.52	1.11
0.70	76.2	0.19	57.58	0.76
0.80	81.9	0.15	63.64	0.56
0.90	88.6	0.049	69.70	0.45
1.00	100	0	100	0

4.1.3 SUMMARY OF THE RESULTS ON PREDICTIVE ABILITY

Chapter 2 suggests two potential reasons why the model parameters are expected to have changed from what they were when Altman and Ohlson estimated their models. The first reason is the change in U.S. bankruptcy law in the late 1970s. This change is expected to increase the number of firms filing for bankruptcy. The change in bankruptcy law is, therefore, expected to increase the Type-I error rate with respect to the 1980s sample.

The second reason for expecting a change in the model parameters is the increased use of financial leverage in the 1980s. Financial leverage is a significant factor in both Altman's and Ohlson's models. The higher level of debt observed in the 1980s is expected to result in a lower z-score and a higher predicted probability of bankruptcy for firms in the 1980s. That is, a firm having a high level of debt is more likely to be classified as predicted to go bankrupt, even when the firm is profitable, healthy and growing. This increase in the use of leverage by healthy firms is, therefore, expected to result in an increase in the Type-II error rate for the 1980s sample.

Applying Altman's model to his original estimation sample, both Type-I and Type-II error rates have increased for the 1980s sample. These results are consistent with both the Type-I Error Hypothesis that the change in U.S. bankruptcy law in the 1970s increases the Type-I error rate and Type-II Error Hypothesis that the increased use of leverage in the 1980s increases the Type-II error rate. However, treating Moyer's 1970s sample as a holdout sample for Altman's original model, the conclusion for the Type-I Error Hypothesis is different. Because the Type-I error rate is lower and the Type-II error rate is higher for the 1980s sample than for Moyer's sample, the Type-I Error Hypothesis is rejected and the

Type-II Error Hypothesis is still supported.

For Ohlson's model, the Type-I error rate is less and the Type-II error rate is larger for the 1980s sample. The increased Type-II error rate is consistent with the Type-II Error Hypothesis, but the decreased Type-I error rate does not support the Type-I Error Hypothesis.

Ideally, the 1980's error rates using Ohlson's model should be compared with the error rates using a true holdout sample from an earlier period. Unfortunately, such a holdout sample is unavailable. Given that Ohlson's error rates are for the sample of firms used to estimate his model, we would expect the Type-I and Type-II error rates to increase when the model is applied to a sample outside of the original estimation sample. This holdout sample effect is an alternative reason for expecting to find support for the Type-I and Type-II Error hypotheses.

As mentioned above, the Type-I error rate (classifying bankrupt firms as nonbankrupt firms) is lower in the 1980s than in the 1970s for both Altman's and Ohlson's models. This is the reverse of what is predicted if the change in the bankruptcy law in the late 1970s made it less costly for otherwise healthy firms to enter bankruptcy to gain concessions from their creditors. One possible explanation for the lower rate of the Type-I errors in the 1980s is that the increased rate of bankruptcy filings during the 1980s is not due to the change in the bankruptcy law at all, but rather is due to changes in operating and financing strategies that threaten firm viability. Altman (1983) mentions that "since 1980 there has been a continuous economic malaise of the economy combined with other factors such as the deterioration in firm liquidity, increased leverage, and dramatically reduced coverage of financial payments of interest and principal." These factors may lead to an increase in the risk of bankruptcy, that is related to variables already present in Altman's and Ohlson's models.

4.2 MODEL REESTIMATION

4.2.1 REESTIMATION OF ALTMAN'S MODEL

In light of the results in Section 4.1, reestimation of the parameters of Altman's model using the 1980s data appears warranted. The paired sample mentioned in Section 4.1.1 is used to reestimate Altman's model. The model is estimated using the same five variables as in Altman's original model. These variables are X_1, X_2, X_3, X_4 and X_5.[52]

To test the discriminating ability of the individual variables, a univariate F-test of a difference in the means is conducted for each variable. Table 4-3 shows the statistical characteristics of the five variables one year prior to bankruptcy for the 1980s paired sample. Variables X_1, X_2, X_3 and X_4 are all significant at the

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[52]As defined in Section 2.2.1, X_1 = working capital/total assets, X_2 = retained earnings/total assets, X_3 = earnings before interest and taxes/total assets, X_4 = market value of equity/book value of total liabilities and X_5 = sales/total assets. As in Altman's original model, variables X_1, X_2, X_3 and X_4 are measured in percentage terms while X_5 is a simple ratio.

1% level and X_5 is significant at the 5% level. This indicates significant differences exist in these variables between the bankrupt and nonbankrupt groups.

Table 4-4 reports the results of reestimating Altman's model using the 1980s paired sample. In the same manner as Altman, the discriminant analysis technique suggested by Fisher (1936) is used to estimate the coefficients of a linear combination of the variables. Fisher's approach is based on the assumption of equal prior probabilities and equal costs of misclassification. The discriminating power of the model is determined by maximizing λ

Table 4-3

Profile Analysis of the Variables Used to Reestimate Altman's Model

	bankrupt group[a]		nonbankrupt group		
Variable[b]	mean	std dev	mean	std dev	univariate[c] F
X_1	-.0864	.5668	.2893	.2728	35.32**
X_2	-.7268	1.5556	.1184	.5072	26.42**
X_3	-.1206	.3204	.0657	.1238	29.13**
X_4	.3701	.7038	1.5532	1.3288	61.28**
X_5	1.1998	.7188	1.4466	.9054	4.51*

**Significant at the 1% level.
*Significant at the 5% level.
[a]Means and standard deviations for the variables one year prior to bankruptcy.
[b]X_1 = working capital/total assets
X_2 = retained earnings/total assets
X_3 = earnings before interest and taxes/total assets
X_4 = market value of equity/book value of total liabilities
X_5 = sales/total assets
[c]Univariate F-test of the mean difference between the two groups.

which is the ratio of between-groups sums-of-squares to within-groups sums-of-squares.[53] Then, a related F-value is computed to test the null hypothesis that the observations come from the same population. Table 4-4 shows that F-value is 21.8 which rejects the null hypothesis at less than the 1% level. Therefore, a significant difference exists between the bankrupt and nonbankrupt groups and the model has discriminating power.

The model parameters are scaled by a constant so that the cutoff point that minimizes the total number of errors remains at 2.675 as in Altman's original model.

In comparing the reestimated model with Altman's original study, the magnitudes have changed. In particular, the coefficient on X_4 for the new paired sample is larger than in Altman's study. This implies that, for the same level of leverage, the Z-score is larger in the 1980s than in Altman's original study predicting a lower likelihood of bankruptcy. An increase in the coefficient on X_4 is expected given the increased use of financial leverage in the 1980s. This result is consistent with the Leverage Hypothesis. However, since statistics such as standard errors for individual variables are not available for the discriminant function, the significance of the change in this parameter cannot be measured.

Table 4-4 also lists the scaled vectors of Altman's and the reestimated models. The scaled vectors are used to measure the relative contribution of each variable to the total discriminant

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[53]See Tatsuoka (1971), p.159.

Table 4-4

Comparison Between Altman's Model and the Reestimated Model

Panel A: Altman's Original Model

$Z = 0.012X_1 + 0.014X_2 + 0.033X_3 + 0.006X_4 + 0.999X_5$

F-value = 20.7

Relative Contribution of the Variables

Variable[a]	Scaled Vector	Ranking
X_1	3.29	5
X_2	6.04	4
X_3	9.89	1
X_4	7.42	3
X_5	8.41	2

Panel B: Reestimated Model[b]

$Z = 0.013X_1 + 0.006X_2 + 0.032X_3 + 0.017X_4 + 0.826X_5$

F-value = 21.8

Relative Contribution of the Variables

Variable[a]	Scaled Vector	Ranking
X_1	0.245	5
X_2	0.272	3
X_3	0.321	2
X_4	0.831	1
X_5	0.267	4

[a] X_1 = (Working Capital/Total assets)*100
X_2 = (Retained Earnings/Total assets)*100
X_3 = (Earnings before interest and taxes/Total assets)*100
X_4 = (Market value of equity/Book value of total liabilities)*100
X_5 = Sales/Total assets

[b] (1) For comparison, the reestimated model is scaled by a factor of 2.548=(2.675/1.05) to keep the same cutoff as in Altman's original model.
(2) Using the aforementioned sample of 99 bankrupt and 1,980 nonbankrupt firms from 1981-1990, the reestimated model is $Z=0.315X_1+0.048X_2+0.003X_3+0.001X_4+1.063X_5$. However, this model is not suitable for comparison due to the small number of bankrupt firms relative to nonbankrupt firms in the sample.

power of the model.[54]

The rankings of the five variables in the reestimated model are different than in Altman's original model. Panel A shows that X_3 (earnings before interest and taxes/total assets) had the greatest contribution to Altman's original model. However, in Panel B, X_4 (market value of equity/book value of total liabilities) makes the greatest contribution to the reestimated model. Since X_4 is a measure of leverage, this result indicates that financial leverage is a very important factor in predicting bankruptcy in the 1980s.

Table 4-5 reports the Type-I and Type-II error rates for the reestimated model using the new paired sample. As mentioned previously, a cutoff point of Z=2.675 minimizes the total number of errors when the reestimated model is applied to the sample. With this cutoff, the Type-I error rate one year prior to bankruptcy is 12 percent and the Type-II error rate is 22 percent. The overall error rate is 17 percent. Two years prior to bankruptcy the Type-I error rate is 20 percent and the Type-II error rate is 23 percent. The overall error rate is 21 percent.

Table 4-1 summarises the error rates of Altman's original model. Comparing Table 4-5 to Table 4-1, the Type-I and Type-II error rates and the overall error rates one and two years before bankruptcy are, in general, higher for the reestimated model than for Altman's original model.

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[54]The scaled vectors are computed by multiplying a variable's coefficient by the square root of the corresponding diagonal element of the sample variance-covariance matrix.

Table 4-5

Predictive Ability of the Reestimated Altman Model One and Two Years Prior to Bankruptcy

	Number Correct	Percent Correct	Percent Error	N
One Year Prior to Bankruptcy				
Type-I	87	88	12	99
Type-II	77	78	22	99
Total	164	83	17	198
Two Years Prior to Bankruptcy				
Type-I	76	80	20	95
Type-II	72	77	23	93
Total	148	79	21	188

It appears, therefore, that even when Altman's model is reestimated using 1980's data, its ability to identify bankrupt and nonbankrupt firms is less than what it was when it was originally estimated.

In many cases, it is more serious to make one type of error than the other. That is, the cost of the Type-I error is different from the cost of the Type-II error. Thus, in constructing a classification procedure the objective is to minimize the total cost of misclassification. In this case, Fisher's approach is not appropriate. We must use a general approach called Bayes solution. Fisher's approach is only a special case of Bayes solution.

Anderson (1984) shows that using Bayes general solution the prior probabilities and costs of misclassification can be incorporated into the modelling effort. "The general Bayes solution to the classification problem compares the ratio of the group probability density functions to a classification criterion. The specification of this criterion varies depending upon whether the prior probabilities and/or costs of misclassification are recognized. In either case, the specification of the classification criterion reduces to the selection of the cutoff point used to separate groups."

As Lachenbruch (1975) states, "the main problem with minimizing the cost of misclassification is the difficulty in specifying these costs. The specification of costs is usually done by the user. Most users are not able to do so. In reality, all that is needed is the ratio of costs, but even this is hard to get."

4.2.2 REESTIMATION OF OHLSON'S MODEL

4.2.2.1 MAXIMUM-LIKELIHOOD ESTIMATION OF LOGIT MODEL

As mentioned in Section 2.2.2, OLS estimation of the logit model is inappropriate. This is because in the case of a dichotomous dependent variable, the residuals are heteroscedastic, and OLS yields inefficient estimates. Therefore, the parameters in the logit model are typically estimated by Maximum Likelihood Estimation (MLE).

Recall the logit model:

$$\ln[P/(1-P)] = \beta X$$

where X is a vector of attributes and β is a vector of unknown parameters. Take the bankruptcy event as an example, then P is the probability of bankruptcy, given X. P is not observed, instead, we have information for each observation on whether a firm is bankrupt or nonbankrupt.

Assume there are n bankrupt firms and m nonbankrupt firms. Then, a likelihood function is given by[55]

$$\ln L(\beta) = \sum_{i=1}^{n} \ln P_i + \sum_{j=1}^{m} \ln(1-P_j)$$

MLE is used to find parameter estimates for all variables by maximizing the likelihood of distinguishing the bankrupt firms from the nonbankrupt firms.

"Maximum likelihood estimators possess some very attractive asymptotic properties. All parameter estimates are asymptotically consistent and efficient. In addition, the asymptotical distribution of all maximum likelihood estimators is normal, regardless of the distribution from which the sample is drawn."[56] This means that provided the sample is sufficiently large, inference can be based on the normal distribution. Therefore, the analog of the regression chi-square can be calculated.

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[55]Pindyck and Rubinfeid (1990), p.280.

[56]Doran (1989), p.310.

The logit equivalent of the OLS t-statistic is the likelihood ratio test. This statistic is distributed chi-squared with K degrees of freedom.

4.2.2.2 EMPIRICAL RESULTS

In light of the results in Section 4.1, reestimation of the parameters of Ohlson's model using data from the 1980s appears warranted. The aforementioned sample of 99 bankrupt and 1,980 nonbankrupt firms from 1981-1990 is used to reestimate the model. The model is estimated using the same nine variables as in Ohlson's original model. These variables are SIZE, TLTA, WCTA, CLCA, OENEG, NITA, FUTL, INTWO and CHIN.[57] A profile analysis of these variables for the 1980s sample is reported in Table 4-6.

Table 4-6 shows the means and the standard deviations of the nine variables for three different types of firms: bankrupt firms one year prior to bankruptcy, bankrupt firms two years prior to bankruptcy and nonbankrupt firms. The ratios appear to deteriorate as one moves from nonbankrupt firms to bankrupt firms two years prior to bankruptcy to bankrupt firms one year prior to bankruptcy. The bankrupt firms have larger means than the nonbankrupt firms for

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[57]As defined in Section 2.2.2, SIZE = ln(total assets/GNP price-level), TLTA = total liabilities/total assets, WCTA = working capital/total assets, CLCA = current liabilities/current assets, OENEG = one if total liabilities exceeds total assets, zero otherwise, NITA = net income/total assets, FUTL = funds provided by operations/total liabilities, INTWO = one if net income was negative for the last two years, zero otherwise, and CHIN = $(NI_t-NI_{t-1})/(|NI_t|+|NI_{t-1}|)$, where NI_t is net income for the most recent period.

TLTA, CLCA, OENEG and INTWO, and smaller means for SIZE, WCTA, NITA, FUTL and CHIN. This is in accordance with what one would expect. The bankrupt firms are on average smaller than the nonbankrupt firms. The standard deviations of the variables are all larger among the bankrupt firms, except in the case of FUTL. Ohlson's profile analysis of his 1970s sample reached similar conclusions.

Table 4-6

Profile Analysis of the Variables Used to Reestimate Ohlson's Model

	Nonbankrupt Firms		Bankrupt Firms			
			Two Years Prior to Bankruptcy		One Year Prior to Bankruptcy	
Variable[a]	mean	std dev	mean	std dev	mean	std dev
SIZE	13.4630	2.0315	12.0560	2.0433	11.8990	2.0766
TLTA	.5026	.2854	.8873	.5274	1.1068	.7179
WCTA	.3504	.2631	.0329	.5017	-.0864	.5668
CLCA	.5512	1.2445	1.4235	3.0260	1.9642	3.7041
OENEG	.0252	.1569	.2316	.4241	.3838	.4888
NITA	.0876	.1561	-.2783	.5666	-.3930	.8135
FUTL	.4076	.7477	-.2005	.6882	-.2197	.5137
INTWO	.1015	.3021	.5263	.4773	.6566	.5020
CHIN	.0846	.5334	-.2642	.6242	-.2734	.6351
Number of firms	1980		95		99	

[a]SIZE = ln(total assets/GNP price-level)
TLTA = total liabilities/total assets
WCTA = working capital/total assets
CLCA = current liabilities/current assets
OENEG = one if total liabilities exceeds total assets, zero otherwise
NITA = net income /total assets
FUTL = funds provided by operations/total liabilities
INTWO = one if net income was negative for the last two years, zero otherwise
CHIN = $(NI_t - NI_{t-1})/(|NI_t| + |NI_{t-1}|)$, where NI_t is net income

Comparing the 1980s sample to Ohlson's 1970s sample, the mean and standard deviation of the leverage variable (TLTA) are both larger in the 1980s sample for all three types of firms. This is consistent with the assumption that the use of financial leverage has increased in the 1980s. An F-test is conducted on the difference in means on TLTA. The result supports the conclusion that the significant difference exists between the bankrupt and nonbankrupt firms at the 1% level.

The correlations between the nine variables are shown in Table 4-7. Substantial correlation exists between TLTA, OENEG, CLCA and WCTA. This indicates possible collinearity among these variables.

Table 4-8 reports the results of reestimating Ohlson's model using the new data. Panel A of Table 4-8 reports the model predicting bankruptcy one year prior. Panel B is the model predicting bankruptcy two years prior.[58] In Panel A, while the signs of the parameters are the same as in Ohlson's original study, the magnitudes have changed. In particular, the coefficient on TLTA for the new sample is much smaller than in Ohlson's study. This implies that, for the same level of leverage, the estimated probability of bankruptcy is less in the 1980s than in the 1970s. A decrease in the coefficient on TLTA is expected given the increased use of financial leverage in the 1980s. The chi-square statistics for SIZE, TLTA, NITA, FUTL, INTWO and CHIN are all significant at the 5% level. WCTA is statistically significant at

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[58]Ohlson's original parameter estimates are reported in Table 2-1 of Section 2.2.2.

Table 4-7

Correlation Matrix of the Independent Variables Used to Reestimate Ohlson's Model

variable[a]	SIZE	TLTA	WCTA	CLCA	OENEG	NITA	FUTL	INTWO	CHIN
SIZE:									
R[b]	1.00	-.021	-.015	-.072	-.056	.114	-.051	-.198	.038
SL[c]	.00%	34.4%	49.3%	.09%	1.00%	.01%	2.05%	.01%	8.53%
TLTA:									
R		1.00	-.639	.286	.628	-.362	-.331	.228	-.102
SL		.00%	.01%	.01%	.01%	.01%	.01%	.01%	.01%
WCTA:									
R			1.00	-.512	-.444	.197	.211	-.206	.115
SL			.00%	.01%	.01%	.01%	.01%	.01%	.01%
CLCA:									
R				1.00	.227	-.077	-.081	.127	-.030
SL				.00%	.01%	.05%	.02%	.01%	16.7%
OENEG:									
R					1.00	-.231	-.079	.277	-.072
SL					.00%	.01%	.03%	.01%	.10%
NITA:									
R						1.00	.365	-.436	.203
SL						.00%	.01%	.01%	.01%
FUTL:									
R							1.00	-.223	.082
SL							.00%	.01%	.02%
INTWO:									
R								1.00	-.047
SL								.00%	3.07%
CHIN:									
R									1.00
SL									.00%

[a]SIZE = ln(total assets/GNP price-level)
TLTA = total liabilities/total assets
WCTA = working capital/total assets
CLCA = current liabilities/current assets
OENEG = one if total liabilities exceeds total assets, zero otherwise
NITA = net income /total assets
FUTL = funds provided by operations/total liabilities
INTWO = one if net income is negative for the last two years, zero otherwise
CHIN = $(NI_t - NI_{t-1})/(|NI_t| + |NI_{t-1}|)$, where NI_t is net income
[b]R = Correlation coefficient.
[c]SL = Significant level.

Table 4-8

Results of Reestimating Ohlson's Model

Panel A: Model 1: One Year Prior to Bankruptcy

Variable[a]	Estimates	Chi-square	P-value
INTERCEPT	-2.2473	4.93	0.0263
SIZE	-0.1659	5.52	0.0188
TLTA	1.7518	11.14	0.0008
WCTA	-0.8496	2.69	0.1012
CLCA	0.0350	0.20	0.6537
OENEG	-0.2911	0.32	0.5744
NITA	-2.5018	7.11	0.0076
FUTL	-2.3620	12.33	0.0004
INTWO	0.9512	6.70	0.0096
CHIN	-0.5192	3.85	0.0498
Likelihood Ratio		364.61	
Overall Correct Rate		96.8%	
R-Square		0.660	

Panel B: Model 2: Two Years Prior to Bankruptcy

Variable[a]	Estimates	Chi-square	P-value
INTERCEPT	-0.7325	0.54	0.4629
SIZE	-0.1639	5.89	0.0152
TLTA	0.8749	2.77	0.0961
WCTA	-2.0623	10.88	0.0010
CLCA	-0.2224	3.08	0.0792
OENEG	-0.0916	0.03	0.8680
NITA	-6.1045	22.45	0.0000
FUTL	-1.6608	7.12	0.0076
INTWO	-0.1286	0.11	0.7414
CHIN	-0.3576	2.16	0.1418
Likelihood Ratio		282.99	
Overall Correct Rate		96.4%	
R-Square		0.586	

[a]SIZE = ln(total assets/GNP price-level)
TLTA = total liabilities/total assets
WCTA = working capital/total assets
CLCA = current liabilities/current assets
OENEG = one if total liabilities exceeds total assets, zero otherwise
NITA = net income /total assets
FUTL = funds provided by operations/total liabilities
INTWO = one if net income was negative for the last two years, zero otherwise
CHIN = $(NI_t - NI_{t-1})/(|NI_t| + |NI_{t-1}|)$, where NI_t is net income

the 10% level. The chi-square statistics for CLCA and OENEG are insignificant. These significance levels are similar to Ohlson's results except in the cases of OENEG and INTWO. In Panel B, the estimates of the intercept and the coefficient on CHIN have changed signs from what they were in Ohlson's original study. The coefficient on TLTA in Model 2 is lower than in Ohlson's original study and its significance level is reduced to the 10% level. The chi-square statistics for SIZE, WCTA, NITA and FUTL are significant at the 5% level, while CLCA is significant at the 10% level. OENEG, INTWO and CHIN are not significant at the 10% level.

The likelihood ratio statistic for Model 1 is 364.61 with 9 degrees of freedom, which is significant at the 1% level of significance. This indicates that Model 1 does have power to distinguish bankrupt from nonbankrupt firms. Similar results apply for Model 2.

Table 4-9 tests for a significant difference between the parameter estimates in Ohlson's model and those in the reestimated model. The Z-values in the table are computed by the following formula[59]

$$Z = \frac{\hat{\beta}_{i1} - \hat{\beta}_{i2}}{[\ SE(\hat{\beta}_{i1})^2 + SE(\hat{\beta}_{i2})^2\ ]^{1/2}}$$

where $\hat{\beta}_{i1}$ is the ith estimate from Ohlson's model. $\hat{\beta}_{i2}$ is the ith estimate from the reestimated model. $SE(\hat{\beta}_{i1})$ and $SE(\hat{\beta}_{i2})$ are

[59]This formula is based on the assumption that the two samples are independent.

the standard errors of $\hat{\beta}_{i1}$ and $\hat{\beta}_{i2}$, respectively.

The Z-values indicate whether there is a significant change in the parameters. In Panel A, the coefficient on TLTA for the reestimated model 1 is significantly less than in Ohlson's model at the 1% level. The coefficient on SIZE is significantly less negative than in Ohlson's model at the 10% level. For other coefficients, there is no significant change. Similar to the results for model 1, the coefficient on TLTA for the reestimated model 2 is significantly less than in Ohlson's model 2 at the 1% level. The coefficient on SIZE is again less negative, this time at the 1% level of significance. The reestimated coefficient on CHIN is significantly less than in Ohlson's model 2 at the 5% level. The coefficient on OENEG is significantly less negative and the coefficient on NITA is significantly more negative than in Ohlson's model 2, at the 10% level. There is no significant change for the coefficients on CONST, WCTA, CLCA, FUTL and INTWO. These results support the Leverage Hypothesis, that the coefficient on TLTA has decreased in the 1980s, but they reject the Intercept Hypothesis, that the intercept has increased. It appears , therefore, that the increased rate of bankruptcies in the 1980s is related to the variables that are included in Ohlson's model and not to an overall increase in the probability of bankruptcy for all firms. Based on the analysis presented here, it is not possible to determine whether the increased rate of bankruptcies in the 1980s is due to the change in the bankruptcy law changing the coefficients in Ohlson's model, or not.

Table 4-9

Test for a Significant Change in the Parameters of Ohlson's Model When Reestimated Using the 1980s Data

Panel A: Model 1

variable[a]	Ohlson's Model estimate	Ohlson's Model std err	Reestimated Model estimate	Reestimated Model std err	Z-value
INTERCEPT	-1.320	1.361	-2.247	1.012	0.547
SIZE	-0.407	0.108	-0.166	0.071	-1.869*
TLTA	6.030	0.912	1.752	0.525	4.064***
WCTA	-1.430	0.757	-0.850	0.518	-0.633
CLCA	0.076	0.099	0.035	0.078	0.322
OENEG	-1.720	0.702	-0.291	0.518	-1.638
NITA	-2.370	1.281	-2.502	0.938	0.083
FUTL	-1.830	0.775	-2.362	0.673	0.518
INTWO	0.285	0.351	0.951	0.368	-1.310
CHIN	-0.521	0.236	-0.519	0.265	-0.006

Panel B: Model 2

variable[a]	Ohlson's Model estimate	Ohlson's Model std err	Reestimated Model estimate	Reestimated Model std err	Z-value
INTERCEPT	1.840	1.333	-0.732	0.998	1.544
SIZE	-0.519	0.097	-0.164	0.068	-2.993***
TLTA	4.760	0.872	0.875	0.526	3.816***
WCTA	-1.710	0.961	-2.062	0.625	0.307
CLCA	-0.297	0.405	-0.222	0.127	-0.177
OENEG	-1.980	0.818	-0.092	0.551	-1.914*
NITA	-2.740	1.522	-6.104	1.288	1.687*
FUTL	-2.180	0.799	-1.661	0.623	-0.512
INTWO	-0.780	0.406	-0.129	0.390	-1.156
CHIN	0.422	0.201	-0.358	0.243	2.473**

***Significant at the 1% level based on a two-tailed test of significance.
**Significant at the 5% level based on a two-tailed test of significance.
*Significant at the 10% level based on a two-tailed test of significance.
[a]SIZE = ln(total assets/GNP price-level)
TLTA = total liabilities/total assets
WCTA = working capital/total assets
CLCA = current liabilities/current assets
OENEG = one if total liabilities exceeds total assets, zero otherwise
NITA = net income /total assets
FUTL = funds provided by operations/total liabilities
INTWO = one if net income was negative for the last two years, zero otherwise
CHIN = $(NI_t - NI_{t-1})/(|NI_t| + |NI_{t-1}|)$, where NI_t is net income

Using a cutoff point of 0.5, the percentage of firms correctly classified is 96.8 percent for Model 1, and 96.4 percent for Model 2. This is higher than for Ohlson's model which correctly classified 96.12 percent of firms using Model 1 and 95.55 percent of firms using Model 2.

A naive model which classifies all firms as nonbankrupt correctly classifies 95.24 percent (1980/(99+1980)) of firms one year prior to bankruptcy and 95.47 percent (1980/(95+1980)) two years prior. Compared to the naive model, the reestimated models perform better.

The Type-I and Type-II errors are computed for selected cutoff points with respect to the reestimated models. The results are listed in Table 4-10. The cutoff point which minimizes the sum of errors is 0.06 for both Models.

Comparing Table 4-10 to Table 4-2, the Type-II error rates are lower and Type-I error rates are higher for the reestimated model 1 than for Ohlson's original model 1 applied to the 1981-1990 data. In comparing the reestimated model 1 with Ohlson's original results, the Type-I and Type-II errors are all lower for any selected cutoff point. In contrast to the poor performance of Altman's model, when Ohlson's model is reestimated with 1980's data it appears to outperform his original model one year prior to bankruptcy. It is not possible to test the predictive ability of the reestimated model 2 to Ohlson's original model 2 for firms two years prior to bankruptcy as Ohlson does not report this analysis for his sample.

Table 4-10

Type-I and Type-II Errors for Selected Cutoff Points

Cutoff Points	Reestimated Model 1		Reestimated Model 2	
	Type-I	Type-II	Type-I	Type-II
0.00	0%	100%	0%	100%
0.02	7.08	25.91	2.02	34.65
0.04	10.10	15.35	10.10	18.03
0.06	13.13	10.51	14.14	12.53
0.08	21.21	7.53	20.20	9.29
0.10	22.22	6.01	25.25	7.07
0.20	38.38	2.93	40.40	2.47
0.30	47.47	1.36	48.48	1.36
0.40	52.52	0.76	55.55	0.61
0.50	59.59	0.40	58.58	0.30
0.60	67.67	0.25	66.66	0.25
0.70	69.69	0.15	69.69	0.25
0.80	74.74	0.15	74.74	0.20
0.90	78.78	0.15	77.77	0
1.00	100	0	100	0

CHAPTER 5

CONCLUSIONS

This study has examined two bankruptcy prediction models existing in the literature. The first one is Altman's Z-score model. Altman's model uses multiple discriminant analysis to distinguish between bankrupt and nonbankrupt firms. The second model is Ohlson's probabilistic model. Ohlson's model uses a logit function to estimate the probability that bankruptcy will occur for a firm. Although a number of studies have constructed statistical models to predict the potential bankruptcy of corporate firms, Altman's and Ohlson's models are the two models most commonly mentioned in the literature.

Altman's and Ohlson's models with their originally estimated parameters have been widely used in the literature since they were developed. There is considerable evidence that these models are still used today. However, there is reason to expect that the model parameters have changed from what they were when Altman and Ohlson originally estimated their models. Therefore, the reexamination of Altman's and Ohlson's models appears justified.

There are two major reasons to expect that the model parameters have changed since the 1970s. The first reason is that the bankruptcy law in the U.S. changed dramatically in the late 1970s. The change in bankruptcy law is expected to increase the number of firms filing for bankruptcy. The evidence provided in this paper supports this expectation. The second reason for expecting a change in the model parameters is the increased use of financial leverage in the 1980s. The statistical data given in this study indicates that the financial leverage follows an upward trend from the 1970s to the 1980s.

In this study, the predictive abilities of Altman's and Ohlson's original models are tested on a paired sample of 99 bankrupt and 99 nonbankrupt firms and on a sample of 99 bankrupt and 1,980 nonbankrupt firms, respectively. The samples are obtained from the firms during the time period of 1981-1990. When Altman's and Ohlson's models are applied to the samples, an increase in the Type-I (classifying bankrupt firms as nonbankrupt) error rate is expected due to the change in U.S. bankruptcy law in the late 1970s and an increase in the Type-II (classifying nonbankrupt firms as bankrupt) error rate is expected due to the increased use of financial leverage in the 1980s.

For Altman's model, Moyer's 1970s sample is used as a holdout sample. Comparing Moyer's results with those for the 1980s sample, the Type-I error rate has declined and the Type-II error rate has increased in the 1980s period. These results are consistent with the Type-II Error Hypothesis, that the increased use of leverage in the 1980s increases the Type-II error rate, but are inconsistent with the Type-I Error Hypothesis, that the change in U.S. bankruptcy law in the 1970s increases the Type-I error rate.

For Ohlson's model, the Type-I error rate is also lower and the Type-II error rate is again higher for the 1980s sample than for Ohlson's original sample. The increased Type-II error rate is consistent with the Type-II Error Hypothesis that the increased use of leverage in the 1980s increases the Type-II error rate. The decreased Type-I error rate is inconsistent with the Type-I Error Hypothesis.

Ideally, these two hypotheses should be tested by comparing the results from the 1980s sample with those from a true holdout sample applied to Ohlson's original model. Unfortunately, such a holdout sample is unavailable. Given the lack of a true holdout sample, we would expect the Type-I and Type-II error rates to increase when the model is applied to a sample outside of the original estimation sample. This is an alternative explanation for the observed increased rate of Type-II errors when Ohlson's model is applied to the 1980s data.

The Altman and Ohlson model parameters are then reestimated using the 1980s samples. Altman's model is reestimated on a paired sample of 99 bankrupt and 99 nonbankrupt firms from the 1981-1990. In comparing the reestimated model with Altman's original study, the magnitudes have changed. However, since statistics such as standard errors are unavailable for individual variables in the discriminant function, the significance of the parameter change cannot be measured. Therefore, considerably more attention is given to the reestimation of Ohlson's model in this study.

Ohlson's model is reestimated on the sample of 99 bankrupt and 1,980 nonbankrupt firms. Comparing the 1980s sample to Ohlson's 1970s sample, the mean and standard deviation of the leverage variable (TLTA) are both larger in the 1980s sample for both bankrupt and nonbankrupt firms. This result is consistent with the assumption that the use of financial leverage has increased in the 1980s.

In comparing the reestimated model with Ohlson's original study, the magnitudes have changed. The results of the reestimation support the Leverage Hypothesis that the increased use of leverage in the 1980s leads to a significant decrease in the coefficient on TLTA in Ohlson's model. However, the results do not support the Intercept Hypothesis that the change in the bankruptcy law in the 1970s leads to a significant increase in the intercept in the model.

The reestimated model performs better than a naive model that classifies all firms as nonbankrupt. Comparing the reestimated model to Ohlson's original model and sample, the Type-I and Type-II error rates for the reestimated model one year prior to bankruptcy are lower for any selected cutoff point. Therefore, for firms very close to bankruptcy, the reestimated model appears to outperform Ohlson's original model.

Because both Altman's and Ohlson's original models make less Type-I errors and more Type-II errors in the 1980s, users of these models may prefer the original model to the reestimated model if their cost of a Type-I error is higher than their cost of a Type-II error. If the cost savings due to the reduced cost of Type-I errors more than offsets the increased cost of Type-II errors, users will prefer the original model. Determining whether this is true or not requires knowledge of the relative cost of the two types of errors, which we do not have information on. Of course, if we had information on the relative costs we could incorporate the costs into developing even better model for users.

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APPENDIX A

Listing of Bankrupt and Liquidated Firms

Company Name	Type[a]	Date
ALLIS-CHALMERS CORP	B	06-29-87
AMDORA CORP	B	04-20-90
AMER HEALTHCARE MGMT	B	08-10-87
AMER MEDICAL ELECTRONICS INC	B	07-16-87
AMERICAN MEDICAL BLDGS INC	B	08-15-90
AMERICAN MONITOR CORP	B	12-18-85
AMES DEPT STORES INC	B	04-26-90
BANYAN CORP	B	05-31-91
BASIX CORP	B	02-29-88
BEST BUY DRUGS INC	B	11-13-87
BLUE DOLPHIN ENERGY	B	06-01-88
BOBBIE BROOKS INC	B	01-15-82
CANTON INDUSTRIAL CORP	B	02-22-88
CARDIS CORP	B	05-25-88
CARE ENTERPRISES	B	03-28-88
CARIBBEAN SELECT INC	B	12-28-90
CF & I STEEL CORP	B	11-07-90
CHARTER CO	B	04-20-84
CIRCLE K CORP	B	05-15-90
CISTRON BIOTECHNOLOGY INC	B	05-26-88
COMPUTER DEVICES INC -CL B	B	10-31-83
CONESCO INDUSTRIES LTD	B	08-20-85
CONSOLIDATED PACKAGING CORP	B	06-20-84
DART DRUG STORES INC	B	08-09-89
DIGICON INC	B	01-31-90
ENDOTRONICS INC	B	03-27-87
EXCALIBUR TECHNOLOGIES	B	03-12-85
FINEVEST FOODS	B	02-04-91
FLAME INDUSTRIES INC	B	05-31-83
FLANIGAN'S ENTERPRISES INC	B	11-04-85
FORUM GROUP INC	B	02-19-91
GLOBAL MARINE INC	B	01-28-86
HALLWOOD HOLDINGS	B	02-05-87
HILLS DEPARTMENT STORES INC	B	02-04-91
IMPERIAL INDUSTRIES INC	B	10-02-86
INTERCO INC	B	01-24-91
INVITRON CORP	L	05-29-91
ITEL CORP	B	01-19-81
JAMCO LTD	B	10-05-87
JG INDUSTRIES INC	B	06-16-81
KENILWORTH SYSTEMS CORP	B	09-01-82
KEY CO -CL B	B	06-20-88
KURZWEIL MUSIC SYSTEMS INC	B	05-07-90
LA POINTE INDUSTRIES	B	02-09-89

APPENDIX A - Continued

Company Name	Type	Date
LIONEL CORP	B	02-19-82
LONE STAR INDUSTRIES	B	12-10-90
LOUISIANA-PACIFIC RESOURCES	B	05-04-84
MAGIC CIRCLE ENERGY CORP	B	04-17-85
MANAGEMENT ASSISTANCE LIQ TR	B	09-09-86
MAXON INDUSTRIES INC	B	08-17-81
MHI GROUP INC	B	11-xx-84
MICHIGAN GENERAL CORP	B	04-22-87
MUELLER INDUSTRIES	B	08-26-82
NATIONAL LUMBER & SUPPLY INC	B	04-03-90
ND RESOURCES INC	B	12-03-84
NUMEX CORP	B	02-xx-81
OLSON INDUSTRIES INC	B	04-04-91
OVERMYER CORP	B	04-17-90
PARTNERS OIL CO	B	04-12-83
PENGO INDUSTRIES INC	B	05-24-88
PETTIBONE CORP	B	01-31-86
PHOENIX RESOURCE COS	B	04-26-88
PUBCO CORP	B	07-02-82
RAMTEK CORP	B	09-29-88
RESURGENS COMMUNICATIONS GP	B	11-30-88
RETAILING CORP OF AMERICA	B	01-04-91
ROBERTSON COS INC	B	07-20-90
SALANT CORP	B	02-22-85
SHIRT SHED INC	B	04-04-85
SILK GREENHOUSE INC	B	07-31-91
SIMETCO INC	B	10-30-86
SMITH INTERNATIONAL INC	B	03-07-86
SOUTHERN HOSPITALITY	B	07-01-88
STANDARD METALS CORP	B	03-07-84
STANWICK CORP	L	02-04-86
STORAGE TECHNOLOGY CP -CL A	B	10-31-84
STUARTS DEPARTMENT STORES	B	12-11-90
SUNF INC	L	12-14-89
SYNTECH INTERNATIONAL INC	B	07-16-90
TACOMA BOATBUILDING	B	09-23-85
TEREX CORP	B	11-04-83
TERRANO CORP	B	09-xx-85
TEXSCAN CORP	B	11-25-85
TGX CORP	B	02-22-90
TODD SHIPYARDS CORP	B	08-17-87
TONS OF TOYS INC	B	12-08-89
TS INDUSTRIES INC	B	08-21-89
ULTIMAP CORP	B	12-18-90
ULTRAK INC	B	03-22-85
UMC ELECTRONICS CO	B	10-23-85

APPENDIX A - Continued

Company Name	Type	Date
UNR INDUSTRIES INC	B	07-29-82
WALL TO WALL SOUND & VIDEO	B	07-20-90
WESTAR CORP	B	11-09-88
WESTERN CO OF NO AMER	B	02-02-88
WHEELING PITTSBURGH CP	B	04-16-85
WICKES COS INC	B	04-24-82
WINJAK INC -CL A	B	12-19-88
WTD INDUSTRIES INC	B	01-31-91
ZENITH LABORATORIES	B	05-04-88

[a]B and L indicate bankruptcy and liquidation, respectively.