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Using A Modified Altman's Z-score Model to Predict Corporate Bankruptcy

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Abstract: Previous research suggests that industry-relative financial ratios are more stable than unadjusted ratios. However, most bankruptcy studies use unadjusted financial ratios to develop bankruptcy prediction models. In this study, we develop an industry-relative bankruptcy model based on Altman's Z-score model. Using a balanced combination of accounting- and market-based ratios from 258 bankrupt and nonbankrupt companies, we develop a modified Altman's Z-score model. The result indicates that a balanced combination of industry-relative accounting- and market-based ratios not only captures different aspects of bankruptcy risk, but also may yield a relatively high classification rate. As such, our findings help managers more accurately estimate bankruptcy risk and thus, have a better opportunity to take corrective actions early, enhancing corporate financial sustainability.

Keywords: bankruptcy; financial failure; financial sustainability; industry-relative ratio; logit models

JEL codes: G01, G32, G33

1. Introduction and Background

Whilst the idea of performance relates to how successfully an organization attains objectives or executes a strategy (Otley, 1999), it is relative performance that stands at the core of the literature on predicting corporate failure and bankruptcy (Foreman, 2003). Not surprisingly, numerous academics and practitioners (e.g., Akbar et al., 2019; Altman, 1968; Altman et al., 1977; Beaver, 1966; Charitou et al., 2013; Gavurova et al., 2017; Ohlson, 1980) conduct extensive studies and apply sophisticated mathematical methodologies to develop bankruptcy classification models through examining and identifying the determinants of corporate bankruptcy.

For example, Pompe and Bilderbeek (2005) employ multivariate discriminant analysis to examine the predictive ability of financial ratios during the successive phases before bankruptcy, as well as the relationship between the age of a firm and the predictability of bankruptcy. They conclude that every ratio investigated has some predictive power. Kim and Nabar (2007) discover that although the likelihood of bankruptcy decreases before bond upgrades, the likelihood increases both before and after bond downgrades.

Agarwal and Taffler (2008) use multivariate discriminant analysis to compare market-based and accounting-based bankruptcy prediction models, and conclude that little difference exists in their predictive ability. Kwak et al. (2012) propose a multiple criteria linear programming (MCLP) method to predict bankruptcy based on preselected 13 financial ratios. They compare their MCLP method to both multiple discriminant analysis and logistic analysis, and conclude that the MCLP method is a viable alternative for bankruptcy forecasting.

Charitou et al. (2013) examine the empirical properties of the theoretical Black–Scholes–Merton (BSM)

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bankruptcy forecasting models, and conclude that a market-based measure of volatility estimated directly from monthly firm value returns possesses relatively high forecasting accuracy. Subsequent work by Gavurova et al. (2017) evaluates four bankruptcy classification models, which are developed from various financial ratios, to determine the most suitable model for predicting bankruptcy in Slovak. They conclude the index IN05 model outperforms others in the Slovak business environment.

More recently, Akbar et al. (2019) employ hierarchical linear mixed model analysis to examine the relationship between bankruptcy risk and the company life cycle with a set of financial ratios and economic variables. Based on a sample of 301 companies from 12 different industries, they conclude that companies suffer a relatively high level of bankruptcy risk during the start-up, growth and decline stages. They hence suggest managers to incorporate the company life-cycle effect into financial planning and decisions to achieve financial stainability.

While numerous academics and practitioners (e.g., Akbar et al., 2019; Gavurova et al., 2017; Kim & Nabar, 2007; Kwak et al.,2012; Li & Miu, 2010) conduct extensive studies to develop bankruptcy-prediction models, these models are, however, primarily based on unadjusted financial ratios. Testing the actual predictive power of these models yields somewhat disappointing results. In fact, bankruptcy models described as highly predictive typically report ex ante classification results considerably lower than the models' ex-post results. This disparity between ex-post and ex-ante results is due principally to differential industry effects and data instability over time (Altman & Izan, 1983; Chen, 2013; Platt & Platt, 1990).

To remedy the problem, Altman and Izan (1983), Chen (2020), and Platt and Platt (1990, 1991) propose using industry-relative ratios to control for industry and time variations that cause data instability within samples. The rationale for this is straightforward: sample mean financial ratios and sample variability depend on not only the distribution of companies across industries, but also on the cyclical level of each industry. Thus, relating a company's financial ratio to the industry average should cancel out or at least alleviate differential industry effects and data instability over time.

The object of this study is therefore to develop a bankruptcy prediction model based on industry-relative ratios through modifying Altman's Z-score model. The reason we chose Altman's Z-score model is because the generalizability of Altman's Z-score model has been rigorously examined (Grice & Ingram, 2001; Hamid et al., 2016; Hamid et al., 2016).

2. Research Methods

2.1 The Data

Our sample of bankrupt companies includes companies that encountered bankruptcy or liquidation events as defined by the COMPUSTAT database. We exclude companies that do not have complete data sets available on the COMPUSTAT database for six years prior to bankruptcy. (Although our study period of bankrupt companies is five years before bankruptcy, the computation of some financial ratios (e.g., growth rates) requires an additional year prior to bankruptcy. We therefore need to collect data for six years before bankruptcy. In addition, due to data accessibility, our study period is limited between 1986 and 2008, covering 23 years.) Applying the criteria results in 129 companies included in bankruptcy between 1986 and 2008, ranging in size from \$0.6 million to \$25,576.4 million in five-year-average assets.

To isolate key variables that distinguish bankrupt from nonbankrupt companies, we select a sample of nonbankrupt companies from COMPUSTAT to match the bankrupt companies. The nonbankrupt companies have the same NAICS (North American Industry Classification System) code, nearly equal average asset size for five years, and complete data sets available for the same years as the matched bankrupt firm up through six years before bankruptcy.

The 129 nonbankrupt companies range in size from $0.4 million to $25,998.2 million in five-year-average assets. The average sizes of the bankrupt and nonbankrupt firms are $442.4 million and $465.0 million, respectively. The result of a paired-samples t-test further confirms a statistically insignificant difference between the means of the bankrupt and nonbankrupt firms with a p-value of 0.10.

We compute the financial ratios and industry averages using data from COMPUSTAT. To obtain an industry average that is comparable across industries, we use two-digit NAICS codes. Companies with the same first two-digit NAICS code are classified in the same industry.

The 129 firms come from 14 sectors, including mining, construction, manufacturing, retail, transportation and warehousing, information, finance and insurance, real estate and leasing, professional, scientific and technical services, administrative and support, waste management and remediation services, and accommodation and food services. The 14 sectors include 2,613 companies.

The final data sets were split into two subsamples: the ex-post (within sample) data and the ex-ante (out-of-sample) data. We use the ex-post data to build models that test our hypotheses; the data includes information for 158 equally matched bankrupt and nonfailed companies from 1986 to 1994. We use the ex-ante data, composed of 100 equally matched bankrupt and nonfailed companies between 1995 and 2008, to study the predictive ability of the models that test our hypotheses.

2.2 Variables and Analysis

Based on Altman's (1968) Z-sore model, we selected five financial ratios for examining whether a significant difference exists in the mean values of the financial ratios between bankrupt and nonbankrupt companies. These ratios include working capital to total assets, earnings before interest and taxes to total assets, sales to total assets, market value of equity to book value of total debt, and retained earnings to total assets. Of the ratios, market value of equity to book value of total debt is the only market-based ratio. Agarwal and Taffler (2008) and Li and Miu (2010) state that market-based and accounting-based bankruptcy-prediction models show little difference in their predictive ability; however, combing the two approaches, not only captures different aspects of bankruptcy risk, but could enhance the predictability and stability of bankruptcy-prediction models.

To develop a more balanced and stable bankruptcy model that captures different risk aspects, we selected several potential market-based financial ratios for further developing Altman's Z-sore model. Selection of the market-based ratios was based on a comprehensive review of the literature (e.g., Agarwal and Taffler, 2008; Altman, 1968; Altman et al., 1977; Foreman, 2003; Grice and Ingram, 2001; Scott, 1981). Sample market-based ratios include price-earnings ratio (basic), common dividends, market capitalization, market value of equity to book value of total debt, market value of equity to book value of equity, and market capitalization to total debt.

We use a twofold methodology to develop bankruptcy prediction models. First, after defining the computation of an industry-relative ratio. we use univariate logistic-regression analysis to evaluate ex-post and ex-ante classification rates of the financial ratios and industry-relative ratios for all five years before bankruptcy.

Second, we conduct a hierarchical logistic-regression analysis using a maximum Nagelkerke R-squared improvement procedure to develop a bankruptcy model. Validation of the bankruptcy model is by ex-ante Type I (bankrupt firm sample) accuracy, Type II (nonbankrupt firm sample) accuracy, and overall correct classification rates.

3. Research Results

3.1 Initial Analysis

Based on Altman and Izan (1983), Izan (1984), and Platt and Platt (1990, 1991), we define an industry-relative ratio as the ratio of a company's financial ratio relative to the mean value of that ratio for the company's industry at a point in time as shown in equation.

$$\text{Industry - Relative Ratio}_{j,\,i,\,k,\,t} = \frac{\text{Company } i\text{'s Ratio}_{k,\,t}}{k\text{'s Mean Ratio in Industry}_{j,\,t}}, \tag{1}$$

where is financial ratio k of company i at time period t, and company i is a member of industry j.

Using data for the one-to five-year period prior to bankruptcy for the bankrupt and nonbankrupt companies, we apply univariate logistic-regression analysis to evaluate ex-post and ex-ante classification rates of each financial ratio and its corresponding industry-relative ratio. The ex-post data include 158 bankrupt and nonbankrupt companies over the nine-year period from 1986 to 1994; the ex-ante data includes 100 bankrupt and nonbankrupt companies over the 14-year period from 1995 and 2008.

Table 1 lists the taxonomy of financial ratios, Kolmogorov-Smirnov tests, Mann-Whitney tests, and univariate analysis results for all five years prior to bankruptcy for 158 equally matched bankrupt and nonbankrupt companies. We use Mann-Whitney tests for the 10 financial ratios because the data are not normally distributed based on the result of Kolmogorov-Smirnov tests, which indicate that the data are nor normally distributed when the probability value is smaller than the threshold value of 0.05.

Table 1 Taxonomy of Financial Ratios as Bankruptcy-Predictor Attributes, Kolmogorov-Smirnov (K-S) Tests, Mann-Whitney Tests, and Univariate Analysis Results

Financial Ratios	K-S Statistic n = 790	Mann-Whitney Statistic n =790	Overall Ex-Post Classification of One- to Five-Year Period before Bankruptcy (%) (1986-1994)		Overall Ex-Ante Classification of One- to Five-Year Period before Bankruptcy (%) (1995-2008)	
			Unadjusted Ratios	Industry-Relative Ratios	Unadjusted Ratios	Industry-Relative Ratios
Working capital to total assets	0.345^{***}	$130{,}497^{***}$	57.22	50.25	50.20	53.80
Earnings before interest and taxes to total assets	0.390^{***}	$46{,}079^{***}$	57.59	57.34	49.60	51.20
Sales to total assets	0.234^{***}	$73{,}045^{*}$	51.90	49.11	51.60	51.20
Retained earnings to total assets	0.460^{***}	73,680	–	–	–	–
Market						
Price-earnings ratio (basic)	0.361^{***}	$56{,}277^{***}$	62.67	61.27	46.80	51.00
Common dividends	0.392^{***}	$68{,}338^{**}$	64.30	60.13	49.80	49.60
Market capitalization	0.385^{***}	$66{,}199^{***}$	54.56	51.77	50.00	50.00
Market value of equity to book value of total debt	0.424^{***}	$46{,}254^{***}$	66.33	55.95	43.40	46.80
Market value of equity to book value of equity	0.407^{***}	$36{,}744^{***}$	72.53	68.61	43.00	30.60
Market capitalization to total debt	0.426^{***}	$45{,}915^{***}$	62.53	58.23	47.20	48.40

Notes: *P < 0.05, **P < 0.01, and ***P < 0.001.

As the table shows, a significant difference exists in the mean values of bankrupt and nonbankrupt companies for nine of the ten ratios in all five years before bankruptcy. Significance of difference in means exists when the probability of the Mann-Whitney test is smaller than 0.05.

The results indicate that the ex-post and ex-ante classification rates of the unadjusted ratios range from 72.53% to 51.90% and 51.60% to 43.00%, respectively. The market value of equity to book value of equity ratio and sales to total assets ratio possess the highest ex-post and ex-ante univariate classification accuracy for all five years, respectively. The respective ex-post and ex-ante classification rates of industry-relative ratios range from 68.61% to 49.11% and 53.80% to 30.60%. The market value of equity to book value of equity ratio and the working capital to total assets ratio have the highest ex-post and ex-ante classification accuracy, respectively.

3.2 The Model

Scott (1981) describes Altman's (1968, 1977) Z-score model as the most impressive bankruptcy-prediction model in terms of classification accuracy and adherence to his theoretical model of financial insolvency. Subsequent work (see, for instance, Altman & Izan, 1983; Izan, 1984; Pindado et al., 2008) furthers this support, noting that Altman's Z-score model is the most common assessment of bankruptcy risk. Following this trend, we base our model specification on Altman's Z-sore model.

We selected four industry-relative variables from the original variables in Altman's (1968) Z-sore model, including working capital to total assets (WC/TA), earnings before interest and taxes to total assets (EBIT/TA), sales to total assets (S/TA), and market value of equity to book value of total debt (MVE/BVD). We did not include the ratio of retained earnings to total assets (RE/TA), as it is not a significant predictor based on the Mann-Whitney statistic reported in Table 1.

Of the four variables, WC/TA, EBIT/TA, and S/TA are accounting-based. MVE/BVD is the only market-based ratio. Agarwal and Taffler (2008) and Li and Miu (2010) all note that market-based and accounting-based bankruptcy-prediction models show little difference in their predictive ability; combing the two approaches, however, capture different aspects of bankruptcy risk and could increase the stability of the bankruptcy model. Therefore, to develop a more balanced and stable bankruptcy model that captures different risk aspects, we add two market-based ratios from *Market* in Table 1.

Table 2 reports industry-relative logit model results using a maximum Nagelkerke R-squared improvement procedure for the 158 bankrupt and nonbankrupt firms one- to five- years before bankruptcy. As the table shows, the logit model at step 1 (Model 1, based on Altman's Z-score model excluding RE/TA) includes the WC/TA, EBIT/TA, S/TA, and MVE/BVD variables, where 0.69% of the variation in the ex-post data is explained. At step 2, the optimal logit model (Model 2) from adding an additional market-based ratio consists of WC/TA, EBIT/TA, S/TA, MVE/BVD, and the market value of equity to book value of equity (MVE/BVE) explains 20.43% of the variation in the ex-post data, which is 19.74% more than that of Model 1. Adding MVE/BVE results in a significant improvement.

At step 3, the optimal logit model (Model 3) from including an additional market-based ratio consists of WC/TA, EBIT/TA, S/TA, MVE/BVD, MVE/BVE, and price-earnings (P/E) ratio, capable of explaining 21.36% of the variation in the data that is 0.93% more than Model 2. The reason we selected industry-relative MVE/BVE and P/E ratios is because they have higher overall ex-post classification rates than other market-based ratios (see Table 1). As also seen in the bottom portion of Table 2, the condition numbers of Model 3's eigenvalues are smaller than 2.02, suggesting no evidence of multicollinearity in the model (Belsley et al., 1980). Therefore, Model 3 is the optimum industry-relative bankruptcy model.

Table 2 Industry-Relative Logit Model Results Using a Maximum Nagelkerke R-Squared Improvement Procedure

Variables and Sources	Model 1			Model 2			Model 3		
	Coeff.	SE of Coef.	P Value	Coef.	SE of Coef.	P Value	Coeff.	SE of Coef.	P Value
Intercept	0.0574	0.0834	0.4916	0.6824	0.1119	0.0001	0.7926	0.1216	0.0001
WC/TA	0.0002	0.0008	0.8044	-0.0004	0.0009	0.6724	-0.0004	0.0009	0.6454
EBIT/TA	-0.0008	0.0024	0.7354	0.0007	0.0039	0.8582	0.0007	0.0038	0.8608
S/TA	-0.0347	0.0195	0.0753	0.0165	0.0237	0.4872	0.0176	0.0236	0.4557
MVE/BVD	0.0001	0.0001	0.5375	0.0004	0.0001	0.0005	0.0004	0.0001	0.0007
MVE/BVE				-0.5351	0.0675	0.0001	-0.5324	0.0676	0.0001
P/E							-0.1241	0.0545	0.0228
NK R^2 (%)	0.69			20.43			21.36		
INK R^2 (%)				19.74			0.93		
CNE	<1.3605			<2.0177			<2.0183		

Notes: SE = Standard Error; NK R^2 = Nagelkerke R^2; INK R^2 = Improved Nagelkerke R^2; and CNE = Condition Numbers of Eigenvalues.

3.3 Classification accuracy

Type I, Type II, and overall correct classification accuracy evaluate the ex-post and ex-ante accuracy. Table 3 reports the ex-post and ex-ante classification accuracy of Model 3's industry-relative and unadjusted analysis for the one- to five-year period before bankruptcy, where the coefficients of Model 3's unadjusted analysis are obtained with unadjusted ratios.

Table 3 Ex-Post and Ex-ante Classification Accuracy of Model 3 – Industry-Relative and Unadjusted Analysis (One- to Five-Year Period Before Bankruptcy)

Year	Industry-Relative Ratios			Unadjusted Ratios		
	Bankrupt Percentage Correctly Classified	Nonbankrupt Percentage Correctly Classified	Overall Percentage Correctly Classified	Bankrupt Percentage Correctly Classified	Nonbankrupt Percentage Correctly Classified	Overall Percentage Correctly Classified
Panel A. 1986-1994 Ex-Post Data: 158 Firms						
1	98.73	98.73	98.73	98.73	98.73	98.73
2	84.81	54.43	69.62	77.22	64.56	70.89
3	84.81	51.90	68.34	82.28	63.29	72.79
4	82.27	55.70	68.99	79.75	68.35	74.05
5	83.54	58.23	70.70	77.22	68.35	72.79
Average	86.83	63.80	75.28	83.04	72.66	77.85
Panel B. 1995-2008 Ex-Ante Data: 100 Firms						
1	92.00	92.00	92.00	88.00	94.00	91.00
2	76.00	78.00	77.00	54.00	84.00	69.00
3	74.00	64.00	69.00	60.00	68.00	64.00
4	80.00	52.00	66.00	50.00	62.00	51.00
5	76.00	52.00	64.00	66.00	60.00	63.00
Average	79.60	67.60	73.60	63.60	73.60	67.60

Panel A reports the ex-post classification results, which consist of 158 bankrupt and not-bankrupt firms during the nine-year period, 1986–1994. The respective average Type I, Type II, and overall correct classifications of industry-relative analysis are 86.83%, 63.80%, and 75.28%; those for the unadjusted analysis are 83.04%, 72.66%, and 77.85%. Overall classification accuracy with industry-relative ratios is 2.57% lower than with unadjusted ratios. However, Type I accuracy with industry-relative ratios is 3.79% higher than with unadjusted ratios.

Panel B reports the ex-ante classification results of 100 bankrupt and not-bankrupt firms during the 14-year period 1995–2008. The respective average Type I, Type II, and overall correct classifications of industry-relative analysis are 79.60%, 67.60%, and 73.60%; those of unadjusted analysis are 63.6%, 73.60%, and 67.60%. Type I and overall classification results with industry-relative ratios are 16.00% and 6.00% higher than those with unadjusted ratios, respectively, although Type II accuracy with industry-relative ratios is somewhat lower than with unadjusted ratios.

In particular, the difference between ex-post and ex-ante classification results with industry-relative ratios is 1.68%, which is significantly less than with unadjusted ratios (10.25%). This echoes Altman's and Izan's (1983), Chen's (2020), and Platt's and Platt's (1990, 1991) proposition. That is, the difference between ex-post and ex-ante classification results with industry-relative ratios is significantly smaller than with financial ratios.

To evaluate predictive performance of Model 3, we apply Altman's (1968) Z-score model to the ex-post and ex-ante data sets. Table 4 reports the ex-post and ex-ante classification accuracy of Altman's model for the one- to five-year period prior to bankruptcy using industry-relative and unadjusted ratios. As the table shows, the ex-post and ex-ante classification accuracy of Altman's model with industry-relative and unadjusted ratios is lower than that of Model 3 with industry-relative and unadjusted ratios. In particular, a considerable difference in accuracy exists in the year prior to bankruptcy.

Table 4 Ex-post and Ex-ante Classification Accuracy of Altman's Z-Score Model — Industry-Relative and Unadjusted Analysis (One- to Five-Year Period Before Bankruptcy)

Year	Industry-Relative Ratios		Unadjusted Ratios	
	1986-1994 Ex-Post Classification Percent Correct, N = 158 Firms	1995-2008 Ex-Ante Classification Percent Correct, N = 100 Firms	1986-1994 Ex-Post Classification Percent Correct, N = 158 Firms	1995-2008 Ex-Ante Classification Percent Correct, N = 100 Firms
1	71.52	68.00	70.25	70.00
2	67.72	65.00	70.89	64.00
3	65.19	64.00	71.52	62.00
4	72.15	60.00	74.68	67.00
5	68.35	62.00	70.25	62.00
Average	68.99	63.80	71.52	65.00

Further, the respective average ex-post and ex-ante classification results of Altman's model with industry-relative analysis are 68.99% and 63.80%, which are lower than those with unadjusted ratios (71.52% and 65.00%). This implies that industry-relative analysis does not necessarily result in higher forecasting accuracy. Nonetheless, the difference between ex-post and ex-ante classification results with industry-relative ratios is 5.19%, lower than with unadjusted ratios (6.52%). This reconfirms that industry-relative ratios are relatively stable.

In order to further assess predictive performance of Model 3, this study compares its results with the forecasting results from a similar study by Barboza et al. (2017). They combine Altman's (1968) Z-score model with six financial indicators to develop bankruptcy-prediction model based on Machine learning models, producing an 87% classification accuracy one year before bankruptcy. In contrast, the average out-of-sample classification accuracy of Model 3 is 92.00% one year before bankruptcy. This result indicates that Model 3 outperforms the bankruptcy forecasting model of Barboza et al. (2017).

4. Summary and Conclusions

In this study, we develop an industry-relative bankruptcy model based on Altman's Z-score model. The model, which outperforms Altman's Z-score model and Barboza et al.'s (2017) forecasting model, has high classification accuracy one year before bankruptcy, moderate accuracy two years before bankruptcy, and less accuracy in more remote years. This result suggests that a balanced combination of accounting- and market-based ratios not only captures different aspects of bankruptcy risk, but also may yield a relatively high classification rate. As such, management has a better opportunity to take corrective actions early and thereby enhance corporate financial sustainability.

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