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A multi-industry bankruptcy prediction model using back-propagation neural network and multivariate discriminant analysis

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ABSTRACT

The accurate prediction of corporate bankruptcy for the firms in different industries is of a great concern to investors and creditors, as the reduction of creditors' risk and a considerable amount of saving for an industry economy can be possible. This paper presents a multi-industry investigation of the bankruptcy of Korean companies using back-propagation neural network (BNN). The industries include construction, retail, and manufacturing. The study intends to suggest the industry specific model to predict bankruptcy by selecting appropriate independent variables. The prediction accuracy of BNN is compared to that of multivariate discriminant analysis.

The results indicate that prediction using industry sample outperforms the prediction using the entire sample which is not classified according to industry by 6–12%. The prediction accuracy of bankruptcy using BNN is greater than that of MDA. The study suggests insights for the practical industry model for bankruptcy prediction.

1. Introduction

Prediction of corporate bankruptcy is of a great concern to investors/creditors, borrowing firms, and governments. As a result of the collapse of Enron, many voices have called for a revolution of existing bankruptcy warning systems to detect or prevent bankruptcy problems in real time. Bankruptcy can happen to any organizations because the business environment is increasingly undergoing uncertainty and competition these days. The reduction of creditors' risk and a considerable amount of saving for an economy can be possible from even a slight improvement with respect to assessing credit risk. An improvement in accuracy of even a fraction of a percent in scoring models to estimate the probability of default leads to enormous future savings for the credit industry (West, Dellana, & Qian, 2005). Assessment of bankruptcy offers invaluable information by which governments, investors, shareholders and the management can make their financial decisions in order to prevent possible losses. The study of bankruptcy provides an early warning signal and detects areas of weaknesses. Accurate bankruptcy prediction usually leads to many benefits such as cost reduction in credit analysis, better monitoring, and an increased debt collection rate.

A number of publications have pursued this subject and extending conventional models for prediction during the past 50 years. The number of bankruptcy prediction models has grown enormously due to the growing availability of data and the development of improved econometrical techniques during the 1980s and 1990s. Most of this work has been influentially led by a small number of early papers (e.g., Altman, 1968; Ohlson, 1980; Zavgren, 1985) on US quoted companies. The methods for bankruptcy prediction can be grouped in two categories: statistical and artificial intelligence models. The first group consists of Logit, multivariate discriminant analysis, etc. The tool first applied to bankruptcy prediction was the univariate data analysis proposed by Beaver (1966), which was followed by the multi-variate discriminant analysis and regressions (Ohlson, 1980). The second group includes neural networks (Chauhan, Ravi, & Chandra, 2009; Cho, Kim, & Bae, 2009; Pendharkar, 2005; Tseng & Hu, 2010), genetic algorithms (Etemadi, Rostamy, & Dehkordi, 2009; Lensberg, Eilifsen, & McKee, 2006), and support vector machine (Min & Lee, 2005; Yang, You, & Guoli Ji, 2011), and case based reasoning (Cho Hong & Ha, 2010). While some of these models show high predictive accuracy levels, the absence of bankruptcy theory makes attempts to establish a generally accepted model for bankruptcy prediction unsuccessful.

Although the discriminant analysis and linear regression model have become the most commonly used in bankruptcy prediction, their inherent drawbacks of statistical assumptions such as linearity, normality and independence among variables have constrained both applications. Recent trends in the development of artificial intelligence have brought forth new alternatives in solving nonlinear problems. The expert system, fuzzy logic, and neural networks are a great help to a manager in predicting bankruptcy making

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decisions. Neural networks have many different topologies for problem dissimilarities. Among them, back-propagation is the most well known and commonly used, categorized as one of the supervised learning models. It draws the mapping function between the input and output from the provided data set. The back propagation neural network (BPN) usually contains one input layer, one or two hidden layer(s) and one output layer. Each layer of a neural network structure has several units and output units of a layer are input units of its next layer. The purpose of back-propagation training is to produce the weight of each edge, in order to minimize the squared error sum between the actual value and the predicted value.

Previous studies on neural network applications for bankruptcy prediction have been targeting single industry or not investigated the industry difference in bankruptcy prediction. For example, He and Kamath (2005) evaluated the effectiveness of two successful bankruptcy models by Ohlson (1980) and Shumway (2001) with the help of a mixed industry sample in discriminating between bankrupt and non bankrupt firms from an individual industry the equipment & machinery manufacturing (EMM) industry. Dewaelheyns and Van Hulle (2006) suggested that models involving both bankruptcy variables defined at subsidiary level and at group level provide a substantially better fit and classification performance. These studies did not examine the difference in industries in terms of independent variables, prediction accuracy, and practically usable models. It is still elusive whether generic prediction models are still successful in predicting individual industry. Further, although there exist a number of studies on using neural networks on bankruptcy prediction, the studies on using multi-industry data and developing models for multi-industry are almost rare. This paper intends to fill this void. This paper focuses on the different back propagation neural network (BNN) models for construction, retail, and manufacturing industries. This study intends to show the optimal tested for each industry by using the bankruptcy data of Korean companies. The study includes the comparison of predictive accuracy with multivariate discriminant analysis (MDA) and shows the implications of difference in prediction models and results.

2. Theoretical background

The credit risk analysis was pioneered by Beaver (1966). The author suggested cutoff threshold values for financial ratio variables in terms of profitability, liquidity, and solvency in order to classify them into two groups. The earliest studies about bankruptcy prediction were adopting the statistical approaches upon empirical data. Altman (1968) developed a statistical linear model and computed an individual firm's discriminant score to estimate the likelihood of bankruptcy. Altman used a combination of five financial ratios out of original list of 22 ratios. Ohlson (1980) utilized the logistic regression with a sigmoid function into the bankruptcy prediction problem. The logistic score, an outcome of logistic regression, is immediately interpretable into a statistical probability. Platt, Platt, and Pedersen (1994) examined the effect of deflation as a means of removing the temporal bias in data used to build a bankruptcy prediction model from the oil and gas producing industry. Clancy and Zhao (1999) suggested a bank failure prediction model based on banks' operations profile as financial intermediaries. Nam and Jinn (2000) investigated the predictive model of business failure using the sample of listed companies of a variety of industries that went bankrupt during the period from 1997 to 1998 when deep recession driven by the IMF crisis started in Korea. Neophytou and Molinero (2004) applied ordinal multidimensional scaling (MDS) to the corporate failure prediction problem, which relies on relations of order and does not suffer from extreme observations problems. Al-Attar, Hussain, and Zuo (2008) posited that abnormal accruals haven a small but significant degree of explanatory power while the explanatory power of abnormal accruals for future cash flows decreases at higher levels of bankruptcy risk. Leng, Feroz, Cao, and Davalos (2011) investigated the long-term performance and failure risk of firms cited in the Securities and Exchange Commission's (SEC) Accounting and Auditing Enforcement Releases (AAERs).

Researchers have applied artificial intelligence (AI) and data mining techniques to bankruptcy prediction. AI techniques are useful in finding out a non-linear relationship between variables. Data mining techniques are very actively utilized for searching an unknown meaning or non-linear pattern in a massive data set. Among these techniques, artificial neural networks have been applied in the context of bankruptcy prediction.

After neural networks are firstly used in bankruptcy literature in 1990, many researcher have applied neural networks in bankruptcy prediction. The use of neural networks has become popular due to the ability to learn and adapt from the data set, the ability to capture nonlinear relationships between variables, and the lack of need-to know functional forms a priori (e.g., Altman, Marco, & Varetto, 1994; Chen, Huang, & Lin, 2009; Sharda & Wilson, 1996; Tam & Kiang, 1992). Neural networks are good at capturing the mapping relationship among variables, especially nonlinear ones; however, they cannot explain the causal relationship among variables, which constrains its application to managerial problems.

3. Variables selection

In bankruptcy prediction, the main concern of interest is to construct the prediction model representing the relationship between the bankruptcy and financial ratios and then deploy the model to identify the high risk of failure in the future. A large number of features are usually included so that the training data is not enough to cover the decision space, which is represented as the curse of dimensionality. Feature selection represents the problem by excluding unimportant, redundant and correlated features in order to increase the accuracy and simplicity of classification model, reducing the computational effort, and enhancing the use of models.

The representative features for bankruptcy prediction can be presented as follows:

- Growth: Net sales growth rate, total asset growth rate, visible asset growth rate
- Profitability: Net profit/average assets, net profit/average shareholder's equity, income before taxes/average assets, interest income/total operating income, non-interest expenses/total operating income
- Productivity: Trading securities/total assets, fixed assets/fixed liabilities, net interest income/average assets, net on balance sheet position/total shareholder's equity
- Liquidity: Liquid assets/total assets, total loans/total deposits
- Asset quality: Permanent assets/total assets, total loans/total assets, loans under follow-up/total loans, specific provision/total loans, specific provision/loans under follow-up, shareholder's equity/total assets, shareholder's equity/total loans

4. Methods

In order to extract the variables that are importantly related to bankruptcy in each industry, *t*-test and correlation analysis are used in establishing the industry prediction model for BNN and MDA. The hit ratio is compared between BNN and MDA using *t*-test. KIS database is used for extracting the sample of the study.