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An Adaptive Fuzzy Neural Network Model for Bankruptcy Prediction of Listed Companies on the Tehran Stock Exchange

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ABSTRACT

Nowadays, prediction of corporate bankruptcy is one of the most important issues which have received great attentions among academia and practitioners. Although several studies have been accomplished in the field of bankruptcy prediction, less attention has been devoted for proposing a systematic approach based on fuzzy neural networks. The present study proposes fuzzy neural networks to predict bankruptcy of the listed companies in the Tehran stock exchange. Four input variables including growth, profitability, productivity and asset quality were used for prediction purpose. Moreover, the Altman's Z'score is used as the output variable. The results reveal that the proposed fuzzy neural network model has a high performance for the bankruptcy prediction of the companies.

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1. INTRODUCTION

Bankruptcy or financial distress is one of the interesting topics for financial market participants. Occurring bankruptcy is very possible in any corporations because of uncertainty in the current competitive business environment. Usually, bankruptcy happens when a corporation's debt is more than assets or the corporation is not able to pay the debt maturity by schedule. Business failure is one of the main concerns for all organizational levels. Whenever at least half of corporate capital is destroyed under influence of imposed losses, bankruptcy would be happened. One of the constant concerns of stakeholders is that what awaited them at the time of bankruptcy and whether they can predict or prevent it. This is why the corporations are interested in finding ways that can predict bankruptcy with an acceptable accuracy in earlier time in order to reduce the consequences. Prediction models are one of the tools which can help stakeholders to find companies' financial situation. These methods are divided into two groups: (1) Statistical, consists of logit, multivariate discriminate, etc. Firstly, Beaver [1] used univariate data analysis for prediction of bankruptcy and it was continued by Ohlson [2] with multi-variate discriminate analysis and regressions. (2) Artificial intelligence, consists of neural networks [3-6],Genetic algorithms [7], Support vector machine [8] and Case based reasoning [9]. With these helpful prediction models, it would be beneficial for stakeholders to evaluate profit, loss and chance of bankruptcy. Although many of these prediction models are largely accurate, they have some limitations too. For example, discriminate analysis and regression model are usually used for prediction of bankruptcy, but since they are based on mathematical and statistical relations, there exists some restrictions in linearity, normality, etc. In recent studies, they tried to use new suggestions in decision making such as expert system, fuzzy logic and neural networks.

While accuracy and quickness play important roles in these models, new developments in computer sciences and artificial intelligence came to the aid of models [10]. Artificial neural networks (ANN) with the ability of recognizing relations between input data and

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making some guess which will turn out to be outputs is one of the useful prediction models [3, 5, 11-14].

Neural network can be generally applied for predicting bankruptcy of economic units. Studies of Ince & Trafalis [15] indicated that neural models have better performance than linear models. Lee and Choi [16] used back-propagation neural network (BNN) to study bankruptcy of Korean companies, and compared it with multivariate discriminate analysis. They found out that the prediction accuracy of bankruptcy using BNN is greater than that of multivariate discriminate analysis. Du Jardin [17] evaluated neural networks method in predicting financial failure. They found that a neural network based model using a set of variables selected with a criterion that it is adapted to the network leads to better results than a set chosen with criteria used in the financial literature. Based on the accomplished studies in the field of bankruptcy prediction, it could be perceived that the neural network models are capable in this field. However, the parameters which are used for bankruptcy prediction have their own inherent uncertainty and vagueness. In 1965, Zadeh [18] introduced fuzzy logic which is a generalization of set theory that allows a member has a partial membership in a set that helps coping with the inherent uncertainty of the real situations. Hence, the integration of the fuzzy logic with the neural networks models could help to deal with the abovementioned problem.

According to our rigorous literature review far too little attention has been paid to using the integrated model of neural network and fuzzy logic for bankruptcy prediction. In this paper, we used a hybrid model of fuzzy logic and neural networks for predicting corporate bankruptcy of listed companies in Tehran Stock Exchange from 2013 to 2014. The main contribution of the paper is developing a comprehensive model for bankruptcy prediction of the listed companies on the Tehran stock exchange based on a novel fuzzy neural network model.

The rest of the paper is organized as follows: Section 2 talks about Fuzzy neural network. In section 3, a detailed explanation of research methodology is given. Section 4 begins with the statistical ratios of listed companies and analyses bankruptcy model we have choose. At the end of this section, the results have been compared to real data with experimental tests. Finally, section 5, explains the conclusion of our work.

2. FUZZY NEURAL NETWORK

Artificialneural network has input and output layers. Information enters to a neural network through input layer and is processed in all layers before reaching output layer. In an ANN, simple artificial nodes, known as "neurons", are connected together to form a network which mimics a biological neural network. Mathematical model of neural networks use predetermined learning algorithm, and a cost function. Although artificial neural networks and fuzzy systems are significantly different from each other in terms of structure, but according to their strengths and weaknesses, it can be mentioned that the two systems are complementary to each other [19-21]. By creating fuzzy neural network, using natural language phrases for components of artificial neural network (input, output, and neuron), concepts that are often ambiguous and uncertain will be realized. This happens with specific changes in the components of artificial neural network. For example, while conventional neural networks are composed of identical neurons, neurons forming fuzzy neural networks usually are heterogeneous and fuzzy neural networks are composed of diverse neurons which have various computational features (such as using OR and AND) [22].

One of the most important systems of fuzzy neural networks is Sugeno fuzzy model introduced by Sugeno [23]. First-order Sugeno fuzzy model uses if-then rules as follows:

If Input x = A and Input y = B, then Output is f = pA + qB + r, where, p, q and r are constants. Figure 1 shows a Sugeno fuzzy model with five layers with the firing strength of the rule, w_i. This fuzzy model was employed in our study.

3. PROPOSED METHODS

In this section, a brief description of the research methodology is given. In order to predict the bankruptcy of the companies, the input and output variables are selected. Those variables are extracted from the literature. Then, some experts of the current area of the research were asked to validate the extracted variables. Hence, "Growth", "Profitability", "Productivity" and "Asset quality" have been chosen as the predictor variables.

We used Altman bankruptcy prediction model [24] (Z-score) to estimate the bankruptcy of the selected companies. Altman calculated Z as the following:

$Z = 0.717\ x_1 + 0.847x_2 + 3.107x_3 + 0.42x_4 + 0.998x_5,$

where, Z indicates the general index, x_1 the ratio of working capital to total assets, x_2 the ratio of retained

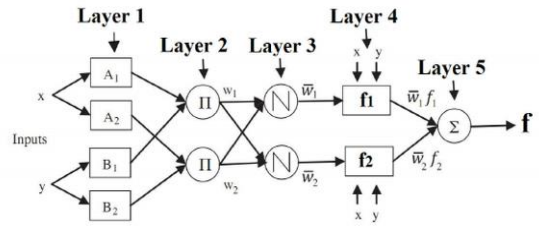

Figure1. A view of a Sugeno fuzzy model with five layers

earnings to total assets, x_3 the ratio of earnings before interest and taxes to total assets, x_4 the ratio of the company's book value to book value of total debt, x_5 the ratio of sales to total assets.

In this model, the lower is Z, the greater the financial crisis such that the companies with Z-score of higher than 2.9 have low probability of bankruptcy while those with Z-score less than 1.23 have high probability of bankruptcy. When Z-score is between 1.23 and 2.9 it is considered as doubtful area. With this model Altman could achieve 94% correct prediction.

Data analysis for prediction was conducted using a Sugeno fuzzy model designed in MATLAB software. Firstly, we normalized the data which were collected from specific companies using Equation (1). Then, fuzzy neural network was modeled for each variable. In this case, a neuron which consists of larger absolute values was preferred during learning.

$$X_n = \frac{\mathrm{X_i} - \mathrm{Xmin}}{\mathrm{Xmax} - \mathrm{Xmin}} \quad (1)$$

The inputs of four models were entered to adaptive network-based fuzzy inference system (ANFIS). Their conversion function which was a generalized bell membership function with the following formulation was determined.

$$bell(X; a, b, c) = \frac{1}{1+\left|\frac{X-c}{a}\right|^{2b}} \quad (2)$$

After modeling all the four variables, final fuzzy neural network was presented. Finally, we tested the results to assess the predictability of our applied hybrid mode.

4. RESULTS AND DISCUSSION

In this section, a detailed explanation of the case study is illuminated. An adjustment mechanism was conducted. To perform adjustment, the influencing factors of each variable were identified and extracted from the literature. Then, the experts were asked to select the most appropriate influencing factors. The results of the mechanism are shown in Table 1.

4. 1. Descriptive Statistics of Listed Companies' Financial Ratios The descriptive data of the companies between 2005 -2014 are tabulated in Table 2.

TABLE 1. Input and output variables

Growth	Growth rate of net sales, total assets, and visible assets
Profitability	Net profit/average assets, net profit/average equity, income before taxes/average assets, and operating income / sales
Productivity	Fixed assets / fixed liabilities, quick assets / total assets, and net balance sheet / total equity
Asset quality	Current assets / total assets, total debt / total assets, total loans / total assets, and equity / total assets, and equity / total loans

TABLE 2. Statistics of financial ratios of listed companies

Financial ratios	Mean	SD	Min	Max
Growth rate of net sales	.2006667	.11840118	.01000	.65000
Sales/ current assets	.0657524	.12184688	-.21000	.31000
Growth rate of visible assets	.0302190	.26758149	-.90000	.70000
Net profit / average assets	.3697199	.51710265	-1.45470	2.72274
Net profit / average equity	1.0839240	1.99011207	-2.92841	8.40730
Income before tax / average assets	.3785121	.19229078	-.20672	1.21345
Operating income / sales	.9369950	3.51648826	-10.75774	20.28378
Fixed assets / fixed liabilities	5.2499575	31.71467306	-141.74185	150.49865
Quick assets / total assets	.0259004	.03112441	-.06113	.11928
Net balance sheet / total equity	1.1135267	8.36559729	-28.61564	47.76863
Current assets / total assets	.6214879	.19229078	-.21345	1.20672
Total Debt / Total Assets	.3785121	.19229078	-.20672	1.21345
Total loans / total assets	.7854977	12.83238497	-41.32761	74.16151
Equity / total assets	.3144797	.19223787	-.15736	.66489
Equity / Total loans	1.0806995	18.69659748	-53.95855	94.35555

To conduct the research, 183 companies of Tehran stock exchange are selected. 93 companies selected as the learning sample and the rest were selected as the test sample. As mentioned before, four variables growth, profitability, productivity and asset quality have been proposed to evaluate the possibility of bankruptcy for the selected companies. Afterwards, as shown in the Table 3, the ANFIS model properties were defined. To the ANFIS model for bankruptcy prediction, matlab software was used. Firstly, for running the model, the

learning and training samples were defined. The method for all of them is hybrid. For each model, error tolerance, epoch and low mean squared error (MSE), have been calculated (Table3). Finally, the model was run.

According to their low mean squared error (MSE), we can say that the variables have successful performance in predicting the financial distress of listed companies.

Figure 2 shows the final fuzzy neural network of our study. The gbell membership function of the final model in fuzzy inference system (FIS) is depicted in Figure 3. Results reported that MSE value for the final model with 100 epochs was 0.0098 which shows its good performance.

To show the proficiency of the proposed ANFIS model, the results of test data achieved through prediction model were compared with the real data. Comparing the results of the proposed model with the values of real data of the companies revealed that the proposed ANFIS model had high accuracy (99%) prediction of the companies. In the following, comparing results of 20 companies are shown in Table 4.

TABLE 3. Summary Information of bankruptcy model

Model	Method	Error tolerance	Epoch	MSE
bankruptcy	Hybrid	0.01	100	0.0098

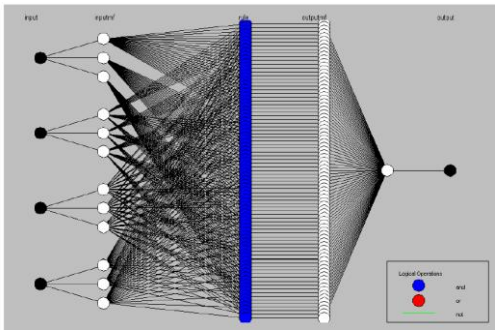

Figure 2. FinalSugeno fuzzy model of the study

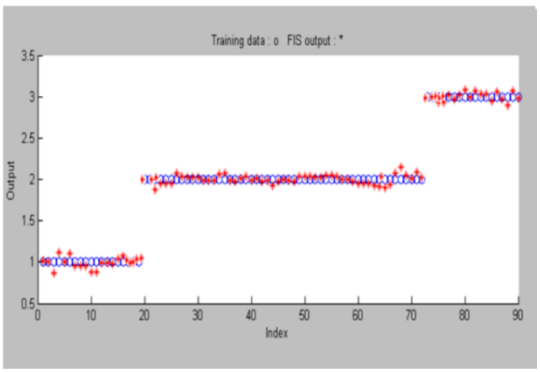

Figure 3. gbell membership function

TABLE 4. Comparing bankruptcy prediction results of fuzzy neural network with real stock price related to the studied companies

Company	Altman score predicted by fuzzy neural network	Real data
1	2.95	2.95
2	3.083	3.085
3	2.142	2.141
4	2.13	2.13
5	2.74	2.74
6	2.90	2.90
7	2.10	2.10
8	2.12	2.12
9	1.43	1.43
10	1.29	1.29
11	2.82	2.82
12	3.01	3.01
13	3.28	3.28
14	3.62	3.62
15	1.46	1.46
16	1.07	1.07
17	2.60	2.60
18	2.61	2.61
19	4.578	4.576
20	5.16	5.16

As shown in the results, the proposed ANFIS model could be a road map for the companies' managers who are interested investment on the stock exchange. It also would help the mangers to aware about their companies' status. For example, the moderate Altman's score show that the company is going to bankrupt. Hence, the manager could make a good decision to prevent this situation.

5. CONCLUSION

The precise prediction of the stock exchange listed companies listed is of a great attention to investors and practitioners. While several studies have been conducted to predict the bankruptcy of the companies, less attention has been paid for developing a neuro-fuzzy model for the prediction purposes. In this study, an ANFIS model is proposed to develop an accurate bankruptcy prediction model that could be considered as the main contribution of the paper. Hence, a group of independent variables is identified to predict the bankruptcy of the listed companies in the stock

exchange of Iran. Based on the experts' opinions, growth, profitability, productivity and asset quality were considered as predictors of bankruptcy. In order to show the bankruptcy level of the companies, the Altman's Z-score model was used. Then, Sugeno fuzzy model was employed as the prediction tool. The results show that the proposed model has a high precision for the prediction purposes. In order to evaluate the results, the results were compared with real data of the companies. The results indicated the output of fuzzy neural networks is similar to the real data of the companies which shows 99% accuracy. The proposed approach of the research could help investors and the companies' managers to have a better insight about their investment. For future studies, it could be a good opportunity to consider the effect of the managerial issues for the bankruptcy prediction of the companies. In addition, model development for a specific industry could be another avenue for the future research.

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چکیده

امروزه، پیش بینی ورشکستگی شرکت های بزرگ یکی از مهم ترین مسائلی است که توجه زیادی را درمیان دانشگاهیان و شاغلین از آن خودکرده است. اگرچه مطالعات متعددی در زمینه پیشبینی ورشکستگی انجام شده است، توجه کمتری به ارائه یک رویکرد سیستماتیک براساس شبکه های عصبی فازی اختصاص یافته است. مطالعه حاضر برای پیشبینی ورشکستگی شرکت های فهرست شده در بورس اوراق بهادار تهران، استفاده از شبکه‌های عصبی را پیشنهاد می‌دهد. چهار متغیر ورودی از جمله رشد، سودآوری، بهره وری وکیفیت دارایی برای هدف پیش بینی مورداستفاده قرارگرفت. علاوه براین، نمره Z آلتمن به عنوان متغیرخروجی استفاده می شود. نتایج نشان می دهدکه مدل شبکه عصبی فازی پیشنهادی عملکرد بالایی برای پیش بینی ورشکستگی شرکت ها دارد.

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