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Enhancing Efficiency of Neural Network Model in Prediction of Firms Financial Crisis Using Input Space Dimension Reduction Techniques[1]

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Abstract

The main focus in this study is on data pre-processing, reduction in number of inputs or input space size reduction the purpose of which is the justified generalization of data set in smaller dimensions without losing the most significant data. In case the input space is large, the most important input variables can be identified from which insignificant variables are eliminated, or a variable can be used in combination with several variables. This approach leads to reduction in number of inputs and input variances and improvement in results. This research intends to build the best neural network model using financial variables (the financial ratios profit and loss statement and balance sheet) and such techniques as Mean Equality Test or Independent Samples Test (IST) , Multiple Discriminant Analysis (MDA), and Principal Constituents Analysis (PTA) in order to reduce the input size and space and to enhance financial crisis model's prediction power and eventually to aid better decision making on the part of users of financial statements in prediction of financial crisis.

In this research, four financial crisis prediction models (Artificial Neural Network (ANN), Combination of Principal Constituents Analysis and Artificial Neural Network model, Combination of IST and ANN, and Combination of MDA and ANN) are used for prediction of financial crisis two years prior to its occurrence. Next, given the obtained results, the models are compared with each other and the best model is extracted. Considering the test results, use of the IST in construction of Neural Network model was found more efficient in prediction of firms' financial crisis relative to other techniques investigated in this research

Keywords: financial crisis, Multiple Discriminant Analysis (MDA), Principal Constituents Analysis (PCA), Neural Networks (NN)

Introduction

Using Data Pre-Processing, data with smaller input space and smoother relationships can be extracted for use in construction of the intended models and improve of decision making.

Decision making is considered an integral part of management. In fact, decision making is the choice of a solution from among a variety of solutions. A manager is constantly faced with situations requiring his decision making. Since the purpose of financial accounting information is provision of a base for economic decision making, and since every decision making involves information acquisition, processing and analysis, as well as logical and appropriate inference from the information, models for prediction of firms' financial state in their business environment are indispensable for right decision making. Financial crisis prediction models are the tools for prediction of firms' future state by giving indications to their bankruptcy. Investors and creditors have a keen interest in predictors of firms' financial crisis, because in case of bankruptcy they incur heavy losses [1].

Research purpose

Financial crisis prediction models are among the techniques and tools used for prediction of firms' future state through calculation of financial crisis by combining a group of financial ratios. Financial and commercial prediction power from perspective of both private investor and society is of importance, since it is an evident signal to incorrect resource allocation. The early warning on bankruptcy probability by prediction of financial crisis enables management and investors to take preventive actions and to distinguish desirable investment opportunities from the undesirable ones [11]. The mail purpose of this study is construction of Neural Network Model and enhancement of its efficiency using Data Pre-Processing (use of PCA, Mean Equality Test (IST), and Multiple Discriminate Analysis) in order to timely warn the management about the firm's continuity and to help the investors and creditors in their economic decision making on purchase of firms' shares or granting loan and financial facilities to companies.

PRIOR RESEARCH

To predict financial crisis of the listed companies on the TSE, Mohammad Reza Nikbakht used Artificial Neural Networks Technique and Multiple Discriminant Analysis. The used neural network was trained by Error-Back Propagation (EBP) method and had three layers, i.e. input, through-put (middle) and output layer, comprising 1, 4, and 5 neurons, respectively. Research results indicate significant difference between Multiple Discriminant Analysis and Neural Network as well as smaller value for the error of first type relative to the error of second type in the preferred prediction [12].

Farajzadeh Dehkordi, Master Thesis in Accounting, Teachers Training University: purpose of this study was bankruptcy prediction modeling of the firms listed on the stock exchange using two MDA and

Genetic Planning. To construct the mentioned models, first, a full list of financial ratios was prepared and after study of the ratios, 42 financial ratios were extracted for construction of the model and using Mean Equality Test of the two societies, the two models were built. Finally, Genetic Planning Model and Multiple Discriminant Analysis Model succeeded in correct classification of firms in the training sample with an accuracy of 94% and 77% and firms in the hold-out sample with an accuracy of 90% and 73%, respectively [5].

Kiarasi in her master thesis of accounting from Islamic Azad University, Tehran Central Branch, investigates efficiency of the two models of Logit Regression Analysis and Multivariate Discriminant Analysis in prediction of firms success or failure. In this research, 14 financial ratios were used and was concluded that Regression Analysis Model was more efficient relative to Multivariate Discriminate Analysis model [8].

Saadatfar, in his Master Thesis in Economics from Mofid University endeavors to find the best Neural Network structure for firms' bankruptcy prediction using three financial ratios of current ratio, gross profit margin, and net profit to current debt for prediction two years prior to occurrence. Finally, in this research, it is voted in favor of the Neural Network with three layers (Perceptron Model with three neurons in the first layer, nine neurons in the middle layer, and one neuron in the output layer with Error-Back Propagation learning algorithm and Cumulative Learning Methods and Sigmoid Activation Function in the hidden and output layers) compared to the four-layer Neural Networks [9].

Raee, constructed firms' financial distress (insolvency) prediction model using financial ratios and Support Vector Machine the main purpose of which was investigating efficiency of Support Vector Machine in prediction of firms' insolvency. Research results obtained from this model were compared with results of Logistic Regression Model and were voted in favor of Support Vector Machine model relative to Logistic Regression model [16].

Nooreddin in his master thesis in accounting from Islamic Azad University, Tehran Central Branch constructs financial crisis prediction models (models based on MDA traditional methods, Linear Genetic Algorithm, Non-Linear Genetic Algorithm, and Neural Network) to predict financial crisis two years ahead of its actual occurrence. Given the obtained results, the model based on Neural Network was found superior to other models [13].

The first studies on bankruptcy prediction were carried out by Altman (1996) which became known as Altman Model. In this model, he used 5 financial ratios and the model's accuracy was 95% [6].

Adam and Sharda (1990), Caster, Sandock and Borbia (1990), Keden (1991), Kuts and Fent (1993), Lee, Hen and Kuan (1996) compared application of Neural Network Model and Multiple Discriminant Analysis. But Salchenberger, Sinar and Lash (1992), Fletcher and Guss (1993), Ado (1993) compared Neural Network Model with Logit and Ton Models. In all

these studies, Neural Network Model was found more powerful and flexible relative to competing models [2].

Varetto (1998) compared Genetic Algorithm Model with Linear Discriminant Analysis model whereby he found Genetic Algorithm Model superior in the prediction one year prior to the event, but the Linear Discriminant Analysis was found more efficient in the prediction three years ahead of the event. On the other hand it was found that the Linear Discriminant Analysis model was found more stable and generalizable [4].

Kavakami (2004) compard Pre-Selection Algorithm, Genetic Algorithm, Multiple Discriminant Analysis with each other and concluded that the Pre-Selection Algorithm was superior relative to the other two models, and on the other hand, Genetic Algorithm, in turn, was found superior to Multiple Discriminant Analysis [7].

Neural Networks

Neural Networks belong to that group of dynamic systems that by processing on empirical data, transfer the underlying knowledge or law beyond the data to the network structure, and learn the general laws based on calculations on numerical data or samples [15].

Artificial Neural Networks through information analysis are able to derive the existing relationships between data and by applying them against a series of new information they estimate their corresponding values. Therefore, Artificial Neural Networks are mainly applied to estimation of non-linear functions with desirable accuracy [14].

Structure of Artificial Neural Network

Each artificial neural network is consisted of process elements which are the very artificial neurons and these neurons can be organized by a variety of methods to form the network structure. Each artificial neuron receives the inputs, processes them and delivers an output signal. The input can be a raw data or output from other processing elements. The output can be the final product or to be used as an input for another neuron [3].

1. Inputs and outputs: numbers and figures as one or more variables form inputs of a neural network. These inputs, after undergoing special analysis and processes, are turned into one or more output variables. The input plays the role of independent variable and the output the role of dependent variable.

2. Number of layers and neurons: neurons are the most important element of artificial neural system lying in three input, output and hidden layers. Neurons of input layer receive input data, and the throughput (hidden) and output layers are information processing units. In these units, algebraic operations are performed on input information the result of which as a new input is transferred to other units in the next layer.

3. Weights: various input variables to the network have different values to which different weights are assigned. These weights which are assigned ahead of the throughput (middle, hidden) layer and output layer are produced by Random Numbers Method and are corrected in use of the network.

4. Transformation Functions (Activity Functions): Transformation Functions too are put in output layer and hidden layers of neural network, and given the weights of each input, they allow output overall calculation [9].

In this research, Back Propagation Neural Network (BPNN) was used in which Multi-Layer Perceptron (MLP) that belongs to the group of Static Networks (feed forward) was employed. In static models, information processing course direction is from input towards output without any return in the units' communication system [10].

Principal Constituents Analysis (PCA)

This technique is used to reduce data through transformation of principal variables into a smaller set, so as this small set explains the reason for the major part of the variance present in the data.

The break-down into principal constituents is one of the simplest multivariate statistical methods. Purpose of this break-down is finding some combinations from P number variables (X1, X2, …, Xp) in order to create independent (uncorrelated) indices of Z1, Z2, … Zp. Non-correlation between these indices is a useful feature, because non-correlation means that the indices measure various aspects of the data. However, the indices are so arranged that Z1 has the greatest changes, Z2 is ranked next, and so on, and eventually we have:

$$Var(Z1) \geq var(Z2) \geq var(Z3) \geq \ldots \geq var(Zp)$$

Where Var(Zi) denotes variance of Zi in its intended data set. Zis are called principal constituents. At the time of break-down into principal constituent, often it is hoped that variance of many constituents to be so small that can be ignored. In this case, changes in the data set can be sufficiently explained by a few numbers of Z-variables with significantly large variances. Hence, performance of this analysis is enhanced. It should be noted that the break-down into main constituents cannot always reduce a large number of initial variables into fewer number of transformed variables. In fact, if the initial variables do not have correlation, this experiment will be absolutely worthless. The best results are obtained when the initial variables have high correlation. In this case, display of 20 to 30 initial variables by 2 or 3 principal constituents will be desirably possible. If such desirable cases occurs, principal constituents can be interesting as the criteria for representation of the data's different aspects. In addition, cutting down on number of initial variables is possible, since many of them measure similar aspects [17].

Independent Samples Test (IST) of two societies

Variables' mean is examined to see whether the variables' mean in the group of financially distressed firms differs from that of the financially healthy firms or not. Therefore, test of the research's variables is performed to find out about significance of a financial ratio's mean difference in two groups of distressed and health firms.

In other words, this test intends to see whether mean of a financial ratio in group of firms in financial crisis differs from that in group of financially healthy companies or not. To perform this test, Independent Sample T-test has been used.

Multiple Discriminant Analysis (MDA)

MDA is combination of two or several independent variables representing salient difference between the two groups. This is done through maximization of intr-group variance relative to intra-group variance based on a statistical decision making rule which is expressed as the ratio of inter-group variance to intra-group variance.

Thus, when we have a hypothesis suggesting that means of two or several groups is equal, MDA can be employed to test this hypothesis. To do this, in this technique, each independent variable is multiplied by its weight and then the variables are summed up together. The obtained result is in fact a combined difference (discrimination) for each observation included in the analysis. By calculation of mean differences of all individuals in one group, mean of the group is obtained. Group mean is in fact a gravity center. Comparison of the groups' gravity center indicates position of each one relative to the under study dimensions [5].

Research hypotheses

Based on the four selected models, six hypotheses are made as follows:

First hypothesis: the model based on combination of Independent Sample Test with Artificial Neural Network (IST + ANN) relative to ANN alone is more powerful in prediction of financial crisis.

Second hypothesis: the model based on combination of IST and ANN (IST + ANN) relative to the model based on combination of Principal Constituents Analysis (PCA) and ANN (PCA + ANN) is more efficient in prediction of financial crisis.

Third hypothesis: the model based on combination of IST and ANN (IST + ANN) relative to the model based on combination of Multiple Discriminant Analysis (MDA) and ANN (MDA + ANN) is more efficient in prediction of financial crisis.

Fourth hypothesis: the model based on combination of PCA and ANN (PCA + PCA) relative to the model based on combination of PCA and ANN (PCA + ANN) relative to the model based on combination of MDA and ANN is more powerful in prediction of financial crisis.

Fifth hypothesis: the model based on combination of PCA and ANN (PCA + ANN) relative to the ANN model is more efficient in prediction of financial crisis.

Sixth hypothesis: the model based on combination of MDA and ANN (MDA + ANN) relative to ANN model is more powerful in prediction of financial crisis.

Research variables:

Execution of every research involves specification and definition of its variables. Variables based on their role in research are divided into two following groups:

Dependent variables

Independent

Dependent variables: in this research, dependent variables are both financially healthy and distressed companies.

Independent variables: independent variables in this research include financial ratios as presented in table 1.

Research methodology

1) Research type: this study is of applied type which employs a survey-exploratory methodology based on correlation.
2) Data collection method: the information regarding the under study financial ratios was extracted from the TSE software 'RAHAVARD'.
3) Statistical population and sample: statistical population in this research includes the listed companies on the TSE that from 1996 through to 2008 have reported their financial ratios to the stock exchange.

The statistical sample of the under study firms are divided into two major groups:

First group: includes 73 financially healthy firms or firms without financial crisis. The main criterion in selection of this group of firms was non-subjection of these companies to article 141 of the Commercial Law during the under study period.

Second group: includes 69 firms in financial crisis, and the main criterion in their selection was subjection of this group to article 141 during the period in question.

4) Data analysis method: first using RAHAVARD software, financial statements of all listed firms on the stock exchange during 1996-2008 were extracted. Next, using Excel software, the intended financial ratios were calculated and given article 141 of the Commercial Law, the firms were divided into two groups of financially healthy and distressed companies.

Table 1: Used Financial Ratios (independent variables)

Variable	Financial ratio	Variable	Financial ratio
X1	Working capital to equity	X13	Total debt to accumulated profit or loss
X2	Working capital to sales	X14	Total debt to total asset
X3	Working capital to total debt	X15	Accumulated profit or loss to total asset
X4	Working capital to total asset	X16	Operational margin to sale
X5	EBIT to equity	X17	Financial cost to gross profit
X6	EBIT to sales	X18	Current asset to total asset
X7	EBIT to total debt	X19	Current asset to current debt
X8	EBIT to total asset	X20	Net profit to sale
X9	Equity to total debt	X21	Net profit to total asset
X10	Equity to total asset	X22	Current debt to total asset
X11	Sales to total debt	X23	Current debt to equity
X12	Sales to total asset		

In the group of financially healthy firms, two random selection phases were used; first, from the firms' total population, the sample firms were selected, next, the intended fiscal year was randomly selected from the period 1996-2008.

In the group of financially distressed firms, given limited number of the firms, random selection was not possible, so all the firms that for several successive years or only for one year have been subjected to article 141 of the Commercial Law all financial information of whom was fully available were placed in the sample.

After selection of the sample firms, each group of companies were once again randomly dividied in two training and hold-out groups, as presented in table 2.

It should be noted that in all models, the above sample structure has been used.

Models introduction:

A. Artificial Neural Network (ANN) construction: to construct Back Propagation Neural Network (BPNN) model, all of the 23 financial ratios have been used whose parameters are presented in table 3. The condition of learning suspension for all models was determined based on the ideal performance achievement, minimum performance radiant, and number of repetitions, and the criterion for preservation of the best learning situation was based on the least error.

B. Combined model of Principal Constituents Analysis and Artificial Neural Network (PCA + ANN)

In this model, first, using MATLAB software, input space is reduced from 23 data to 12 data, and by specification of parameters according to table 3 the model was constructed.

C. Combined model of Independent Samples Test and Neural Network (IST + ANN)

In this model, first, using SPSS software the data were controlled in terms of normality and after identification of abnormal data, they were removed from the set. Next, due to few numbers of abnormal data, for final decision making regarding selection of financial ratios for construction of the model using IST, mean equality of the ratios between the two groups was tested, and at 5% difference significance, from among 23 financial ratios (independent variables), the variables 2, 3, 4, 13, 18, 19, 22 and 23 (in total, 8 variables) were rejected, and the variables 1, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 20 and 21 (in total, 15 variables) which had different means in the two statistical populations were included.

Table 2: Sample division

Firm	Samples	Training samples	Hold-out samples
Financially healthy	73	58	15
Financially distressed	69	54	15
Total number	142	112	30

Table 3: Models information

models	Used financial ratios	Functions			Max epoch	Transfer Functions			Size of layer		
		Training	Performance	Learning		TF1	TF2	TF3	S1	S2	S3
ANN	23	trainlm	mse	learngdm	1000	tansig	tansig	logsig	3	3	1
PCA+ANN	12	trainlm	mse	learngdm	1500	purelin	logsig	logsig	4	9	1
IST+ANN	15	trainlm	mse	learngdm	1500	tansig	tansig	tansig	9	5	1
MDA+ANN	4	trainlm	mse	learngdm	1500	logsig	logsig	logsig	7	9	1

This test intends to specify the financial ratios that are able to make a distinction between two groups of firms in financial crisis and financially healthy firms. Next, using the above 15 financial ratios and parameters provided in table 3, the model was constructed.

D. Combined model Multiple Discriminant Analysis (MDA) and Artificial Neural Network (MDA + ANN)

After extraction of the final financial ratios (the 15 ratios identified by IST), variables X1m X5, X11, and X12 were extracted using MDA and Stepwise method. These variables include the ratios working capital to equity, EBIT to equity, sales to total debt, and sales to total asset.

Using the above 4 financial ratios and the parameters provided in table 3, the model was constructed.

Hypotheses test results

A. Results obtained from ANN

Table 4 represents the obtained results from the empirical test of ANN model for prediction of financial crisis. This model succeeded in correct classification of the firms present in the training, hold-out, and total sample into financially healthy and distressed firms with a general accuracy of 99.11%, 90% and 97.18%, respectively, so as 112, 30 and 142 firms present in the training, hold-out and total sets have been correctly classified.

Study of the results obtained from this model in the training data indicates that ANN model had an accuracy of 98.15% in correct classification of financially distressed firms in this set (i.e. from 54 financially distressed firms present in this set, 53 firms have been correctly classified). In addition, this model had an accuracy of 100% in correct classification of financially healthy firms in this set (i.e. from among 58 financially healthy firms in this set, 58 firms have been correctly classified).

Study of total results from this model (in training and hold-out sets) indicates that ANN model has an accuracy of 94.20% in correct classification of financially distressed firms in this set (from among 69 financially distressed firms in this set, 65 firms have been correctly classified). In addition, this model has an accuracy of 100% in correct classification of financially healthy firms in this set (from 73 financially healthy firms in this set, 73 firms have been correctly classified).

Table 4: The ANN experimental results

result	Training samples			Hold-out samples			Total samples		
	0	1	Total	0	1	Total	0	1	Total
Number 1	1	53	54	3	12	15	4	65	69
Number 0	58	0	58	15	0	15	73	0	73
Percentage 1	2%	98%	98%	20%	80%	98%	5.79%	94.20%	98%
Percentage 0	100%	0%	100%	100%	0%	98%	100%	0%	98%
General percentage	100%	98%	99.11%	100%	80%	90%	100%	94%	97.18%

Table 5: Results of PCA + ANN experimental test

result	Training samples			Hold-out samples			Total samples		
	0	1	Total	0	1	Total	0	1	Total
Number 1	0	54	54	4	11	15	4	65	69
Number 0	58	0	58	15	0	15	73	0	73
Percentage 1	0%	100%	100%	26.67%	73.33%	100%	5.80%	94.20%	100%
Percentage 0	100%	0%	100%	100%	0%	100%	100%	0%	100%
General percentage	100%	100%	100%	100%	73.33%	86.67%	100%	94.20%	97.18%

Table 6: Results of IST + ANN model experimental test

result	Training samples			Hold-out samples			Total samples		
	0	1	Total	0	1	Total	0	1	Total
Number 1	0	54	54	2	13	15	2	67	69
Number 0	58	0	58	15	0	15	73	0	73
Percentage 1	0%	100%	100%	13,33%	86.67%	100%	2.89%	97.10%	100%
Percentage 0	100%	0%	100%	100%	0%	100%	100%	0%	100%
General percentage	100%	100%	100%	100%	86.67%	93.33%	100%	97.10%	98.95%

Table 7: Results of MDA + ANN model experimental test

result	Training samples			Hold-out samples			Total samples		
	0	1	Total	0	1	Total	0	1	Total
Number 1	0	54	54	2	13	15	2	67	69
Number 0	58	0	58	13	2	15	71	2	73
Percentage 1	0%	100%	100%	13.33%	86.67%	100%	2.90%	97.10%	100%
Percentage 0	100%	0%	100%	86.67%	13.33%	100%	97.26%	2.74%	100%
General percentage	100%	100%	100%	86.67%	86.67%	86.67%	97.26%	97.10%	97.18%

Table 8: Models accuracy test results

Data/ models		Total samples	ANN	PCA+ANN	IST+ANN	MDA+ANN
Training samples	Number	112	111	112	112	112
	Percentage	100%	99, 11%	100%	100%	100%
Hold-out samples	Number	30	27	26	28	26
	Percentage	100%	90,00%	86.67%	93.33%	86.67%
Total samples	Number	142	138	138	140	138
	Percentage	100%	97, 18%	97.18%	98.59%	97.18%

B. Results obtained from combined model of PCA and ANN (PCA + ANN)

Table 5 presents the results obtained from PCA + ANN experimental model for prediction of financial crisis. This model succeeded in correct classification of firms present in training, hold-out and total samples into two groups of financially distressed and healthy firms with a general accuracy of 100%, 86.67%, and 97.18%, respectively, so as from 112, 30 and 142 firms present in the training, hold-out and total sample, 112, 26, and 138 firms have been correctly classified.

Results of this model in training hold-out and total data can be analyzed according to the results obtained from ANN model.

C. Results obtained from the combined model of IST + ANN

Table 6 presents the results obtained from test of IST + ANN model for financial crisis prediction. This model succeeded in correct classification of firms present in training, hold-out and total sample into two groups of financially healthy and distressed firms with a general accuracy of 100%, 93.33% and 98.95%, so as from 112, 30, and 142 firms present in training, hold-out and total set, 112, 28 and 140 have been correctly classified.

Results of this model in training, hold-our and total sample can be analyzed according to the results from ANN model.

D. Results obtained from the combined model of MDA + ANN

Table 7 presents results obtained from MDA + ANN model experimental test. This model succeeded in correct classification of firms present in training, hold-out and total sample into two groups of financially healthy and distressed firms with a general accuracy of 100%, 86.67% and 97.18%, respectively, so as from 112, 30 and 142 firms present in training, hold-out and total set, 112, 26 and 138 firms have been correctly classified.

Results of this model in training hold-out and total data can be analyzed according to results obtained from ANN model.

Conclusion

The obtained results according to tables 8 regarding prediction power indicate superiority of the combined model IST + ANN to all the other models as well as extraction of identical results from all the other models. Therefore, hypotheses 1, 2 and 3 are confirmed and hypotheses 4, 5 and 6 are rejected.

In this research, using the statistical techniques PCA, IST and MDA, and ANN model and their combination, four models are obtained.

The obtained results from this research indicate that use of data pre-processing can improve efficiency of the financial crisis prediction model, and financial ratios can be good predictors of firms' financial crisis. In addition, given the high prediction power of the examined models, managers are enabled to take necessary actions before bankruptcy occurrence. Investors, financiers and auditors can profit from this model in their economic decision making when granting financial facilities, or judging on firm's business continuation.

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Nots

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