Int. J. Nonlinear Anal. Appl. 15 (2024) 5, 121–142
ISSN: 2008-6822 (electronic)
http://dx.doi.org/10.22075/ijnaa.2023.33026.4385

Bankruptcy prediction using the Black-Scholes asset pricing model (Experimental evidence: Tehran Stock Exchange)

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(Communicated by Seyyed Mohammad Reza Hashemi)

Abstract

The bankruptcy of companies is essential in financial literature, and the development of bankruptcy forecasting techniques and models is the priority of financial research goals. Many studies have been conducted on predicting the bankruptcy of companies. This study first used a combination of theoretical and expert analysis to determine the financial ratios and macroeconomic variables affecting bankruptcy. Thus, bankrupt companies were distinguished from non-bankrupt ones referring to Black and Scholes's asset pricing models based on the intrinsic value of liabilities and assets. Therefore, 144 companies were studied in the 12 years of 2010-2021 in the screening process. The analysis of multilayer artificial neural networks for evaluating the reliability of the results in identifying the factors affecting the prediction of bankruptcy and prioritizing these factors showed that the least important factor was the ratio of capital to the net profit of the company and the most critical factor was the ratio of profit before interest and taxes to the total assets of the company.

Keywords: Bankruptcy, Expert assessment, Black-Scholes Asset pricing model, Factors affecting bankruptcy, Bankruptcy prediction
2020 MSC: 37N40

1 Introduction

Bankruptcy is an essential problem for companies, which is intertwined with the primary goal of every company that survives and has many destructive effects on the stakeholders with many social costs. Today, access to resources is more limited due to the increasing competition of economic enterprises, which has increased the probability of bankruptcy. Therefore, bankruptcy and its related issues are critical problems in the financial economy of companies and the theory of the behavior of companies. Anticipating bankruptcy has many positive effects, such as informing company managers and investors about the possibility of bankruptcy and making better decisions to reduce costs.

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Received: February 2023 *Accepted:* May 2023

Investors can reduce their potential financial losses by anticipating bankruptcy, which requires accurate and timely analysis and prediction of bankruptcy. Failure to predict bankruptcy accurately or to do so on time will cause more significant losses to investors than bankruptcy.

Traditional, modern, and diverse tools and methods, each of which has its strengths and weaknesses, have been introduced so far to predict bankruptcy. Anticipating the occurrence of bankruptcy before the signs of financial distress and bankruptcy is one of the ways to prevent bankruptcy. Predicting bankruptcy and finding and fixing the problem's root can lead to satisfactory results in preventing bankruptcy. The stakeholders of the company, such as investors, banks and lending institutions, and policymakers, are also very interested in bankruptcy prediction in addition to companies themselves. Thus, bankruptcy prediction will be useful when the predicted time for bankruptcy should be longer than the current time. In other words, the time horizon should be longer so that the companies have enough time to take the necessary measures to prevent bankruptcy. Predictions should be made when the signs of financial distress and disruption in performance are not yet clear and tangible, and the occurrence of bankruptcy cannot be predicted with simple evaluations. Lack of scientific selection of essential and effective variables for bankruptcy lead to many problems.

Companies' stakeholders are always worried about what consequences will await them in the event of bankruptcy and how to predict and solve the bankruptcy of companies in advance [42]. From the point of view of macroeconomic theories, the economic progress of society has a consistent and proportional relationship with its investment amount. When this investment is not made in suitable opportunities or used in a way that does not have the necessary efficiency, it will cause damage to the national economy. Providing predictive models about companies' financial status is one way to help investors. The closer the predictions are to reality, the more correct decisions will be based on. Bankruptcy prediction models are one of the tools for estimating the future state of companies. Investors and creditors have a strong tendency to predict the bankruptcy of firms because, in case of bankruptcy, they will be charged many costs. Each of these models has its strengths and weaknesses. Therefore, hybrid models have minimal disadvantages because they overcome the failings of one technique by using other techniques [42]. Confidence for investors (natural and legal persons) is an essential topic in financial management and investment. Many studies have been performed in advanced industrialized countries on the investment decision process. Investors always want to avoid the risk of burning their capital by anticipating the possibility of bankruptcy of a company. Therefore, methods are sought to estimate the financial bankruptcy of companies [39].

In the last 40 years, predicting corporate bankruptcy has become one of the major research topics in financial literature. Much academic research has tried identifying the best bankruptcy prediction models based on available information and statistical techniques [15].

Due to the importance of predicting bankruptcy, many studies in this field have been conducted abroad and some inside the country. Studies have led to the presentation of a model for predicting bankruptcy, and each model can predict the bankruptcy of companies with a certain percentage of confidence. The findings indicated that new bankruptcy prediction methods, such as Altman's model, should be preferred over traditional methods. An accurate prediction of bankruptcy does not necessarily require a large number of financial ratios. In other words, many explanatory variables in bankruptcy prediction models do not mean its better performance [45]. Therefore, this research uses Black and Schulz's asset pricing models to distinguish between bankrupt companies and non-bankrupt ones and aims to provide a local bankruptcy forecasting model so that the stakeholders can make decisions with more confidence by relying on the predictive power of these models. Predictive tools are an early warning of the financial crisis that enables managers, investors, and creditors to take preventive and corrective measures to change underlying decisions or operational policies, redefine strategies, and improve resource allocation by reducing losses.

In this research, the financial factors affecting bankruptcy are explained to prevent the occurrence of financial crises and eventual bankruptcy of listed companies by identifying these factors by fitting logistic regression models.

2 Theoretical foundations

Predicting a company's bankruptcy has become an important research area in accounting and finance in the last 70 years. Researchers worldwide are developing corporate bankruptcy prediction models (28; 29; 31; 32; 17). Several financial bankruptcy prediction models were proposed in the late 1960s. Several studies have investigated the performance of these models in predicting corporate bankruptcy (34; 28; 29; 31; 32).

The issue of corporate bankruptcy was first proposed and predicted by [7]. Since the largest bankruptcy prediction model was introduced by [3], many studies have predicted large companies' financial distress and bankruptcy. In many cases, the authors consider the final failure (bankruptcy) as the dividing line between failed and non-failed (only

financially distressed) companies [41].

There are many financial, economic, and accounting studies on financial bankruptcy. With few exceptions, accounting-based measures have mainly been used to predict the probability of financial bankruptcy. [7, 3, 48], used accounting information to assess bankruptcy risk in a static model. These models based on accounting information test the usefulness of the information in a company's financial statements to provide a correct assessment of financial bankruptcy risk [23].

[35] showed that the Z-score model contains an accurate method for predicting company failures. In addition, the study showed the ability of the Z indicator that the model predicted financial bankruptcy in the first year was 66%. This percentage decreased to 52% in the second year, 39% in the third year, and 20% in the fourth year before bankruptcy. [3] analyzed the structure of the Z-score model by applying it to a sample of 200 Chinese retail companies. This study showed that the model correctly predicts bankruptcy with 94% accuracy.

[40] applied the Z-score model to a sample of US bank holding companies in 1997-2004 and found that the CFO did not cope with excess risk. [27] used Altman's Z-score model to evaluate the financial stability of the ICT industry in South Asia. This study found that, out of five countries, two were economically stable because their Z value was higher than the reference (2.99). In contrast, the remaining states were not financially sound and were classified in the gray area. The World Bank needs special attention to improve the financial situation of developing countries in South Asia.

In research, [13] developed a neural network model to predict the bankruptcy of American banks due to the recent financial crisis and used a combination of a multilayer perceptron model and self-constructing maps as a tool to investigate bankruptcy up to three years before that. Based on the data between 2002 and 2012, the neural network model could predict bankruptcy better than traditional models with 96% accuracy.

The first research in the field of bankruptcy prediction in Iran was carried out by [39]. The application of Altman's model in listed companies was investigated, and the correct prediction of bankrupt companies equivalent to 75% was proved from 1996 to 1999. [15] analyzed the predictive ability of the Altman and Ehlson models in bankruptcy prediction. The results indicated that Ehlson's prediction model and the extracted model, according to the logistic regression method, have higher prediction accuracy. [5] used Springgate and Falmer methods based on the information of 90 companies from 2005 to 2010 to predict the bankruptcy of companies listed on the Tehran Stock Exchange. The results showed that Falmer's model is more conservative than Springit's.

[1] used the multilayer perceptron method with genetic algorithm supervision to predict bankruptcy. The results showed that the multilayer perceptron neural network with genetic algorithm supervision is better than the two classical models and can predict with 97.6% accuracy.

[6] used the Pearson correlation coefficient model to test the assumptions and determine the dependence between intellectual capital components and their relationship with the company's bankruptcy risk, and the Kolmogorov Smirnov test to test the normality of the variables. The results indicated that intellectual capital and its components have an inverse and significant relationship with the bankruptcy risk of companies.

[29] used 24 explanatory variables in their research process. The variables of financial ratios, current ratio, ratio of working capital to total assets, ratio of profit before financial cost and tax to total assets, and the ratio of return on total assets had a greater effect more significant in the model compared to other explanatory variables.

[18] compared four famous forecasting models, including vector machine, artificial neural networks, artificial neural networks optimized with a genetic algorithm, and logit regression. Finally, the artificial neural network optimized with a genetic algorithm showed the best performance compared to other models. The best model for predicting bankruptcy was using financial ratios in an artificial neural network optimized with a genetic algorithm.

[16] modeled and predicted bankruptcy using accrual and actual profit management variables. The accuracy and precision of bankruptcy models before and after adding profit management variables were measured using logistic regression. The results showed that the predictive ability of Altman, Springit, and Zambejski bankruptcy models increased significantly after adding accrual profit management variables compared to the original models. Further, real profit management parameters weaken the predictive power of the Altman, Springit, and Zimjeski models. According to the evidence obtained in this research and other similar research, accrual profit management variables have informational content and can inform about bankruptcy risk.

[28] showed that the decision tree model could predict the bankruptcy of companies with financial constraints. In addition, the prediction accuracy of the decision tree model has a high performance in predicting the bankruptcy of companies with financial constraints.

3 Method

This correlational, applied, and field study is considered descriptive in terms of method.

3.1 Statistical population, sampling method, and sample size

The population included all the companies admitted to the Tehran Stock Exchange in the 12 years of 2010-2021, and the final sample size is determined by the screening method after applying the following restrictions:

- The information needed to calculate the operational variables of the research should be available.
- The companies should have been admitted to the stock exchange since 2010 and be active in the stock market until the end of the research period.
- The end of their financial year should be the end of March.
- It should not be a part of intermediary financial institutions such as banks, insurance, and investment funds.
- The companies should not have a trading break of more than three months.

Table 1: Screening Table

Explanation	Total	Elimination number	Remaining number
All companies admitted to the stock market until the end of 2021	468	-	144
The number of accepted companies that entered the stock market during the research period		59	
The number of companies that have been delisted from the stock market during the research period		71	
The number of companies active in the financial, investment, and banking industry		65	
In order to be homogeneous, companies whose fiscal year does not end at the end of March.		84	
Companies with a trading break of more than three months in the research period		45	
The total number of excluded companies		324	
The number of investigated companies		-	

A total of 144 companies out of all the companies listed in the Tehran Stock Exchange were studied as a sample of the research.

3.2 Research variables

3.2.1 Bankruptcy

In this research, the Black-Scholes model was used to detect the bankruptcy of companies. According to [46] and based on the pricing model of [8], a company enters bankruptcy when the value of its assets is less than its liabilities. In other words, the value of the company's assets does not correspond to the number of its debts. Therefore, in this situation, the equity value will be zero. Therefore, the probability of bankruptcy can be measured based on the intrinsic value of its equity and through the following relationship by referring to the concept of stock option pricing in the Black and Scholes model. The intrinsic value of equity under the Black and Scholes model is defined through the following relationship:

$$E_{i,t} = A_{i,t}\phi(d_1) - L_{i,t}e^{-r(T-t)}\phi(d_2) \tag{1}$$

In which,

$$d_1 = \frac{Ln\left(\frac{A_{i,t}}{L_{i,t}}\right) + (r + \frac{\sigma^2}{2})(T-t)}{\sigma\sqrt{T-t}},\ d_2 = d_1 - \sigma\sqrt{T-t} \tag{2}$$

Finally, the probability of bankruptcy of the company is equal to:

$$P(y_{i,t}=1)=\phi\left(\frac{Ln(L_{i,t})-Ln(A_{i,t})-(\mu+\frac{\sigma^2}{2})(T-t)}{\sigma\sqrt{T-t}}\right) \tag{3}$$

In which, $A_{i,t}$ is the market value of the assets, $L_{i,t}$ is equal to the book value of the total liabilities of the company, $T-t$ is equal to the length of the period in which the intrinsic value of equity is calculated at the beginning (at moment t). Also, $\phi(.)$ represents the standard normal cumulative distribution, μ is the expected value of the logarithmic return on assets $Ln\left(\frac{A_{i,t}}{A_{i,0}}\right)$ during one year and the volatility of the logarithmic return on the company's assets during one year. The mean and standard deviation of the natural logarithm of the monthly market value of the company's assets divided by the market value of the assets at the beginning of the financial period is used to estimate μ and σ, respectively. After calculating the probability value $P[y_{i,t}=1]$, if the value of this probability is more significant than 0.5, the company is identified as bankrupt and, otherwise, non-bankrupt.

3.2.2 Factors affecting bankruptcy

A review of empirical research literature inside and outside the country was conducted, and a list of factors identified in previous research was prepared according to Table (2) to identify potential factors affecting bankruptcy.

The expert evaluation was used for these factors to finalize the identified factors. The experts included financial researchers and a group of legal investors in the Tehran Stock Exchange, who were selected based on at least ten years of experience in capital markets and education related to financial management, financial engineering, accounting, and auditing. Therefore, five experts were selected from researchers and professors, and ten experts were chosen from legal brokers and investors of the Tehran Stock Exchange, which made a total of 15 experts. A questionnaire with closed answers regarding the appropriateness and relevance of each indicator with companies' bankruptcy was prepared, and experts' opinions s were collected (Table 2). At the end of this questionnaire, the factors suggested by the experts were also questioned and used in the expert analysis of the research. For this reason, the expert evaluation process of the study was continued until a consensus regarding the final factors was established among the experts. At each stage, the inappropriate factors identified in the experts' opinions were removed from the studied factors. The factors suggested by the experts were added to the set of studied factors. This process was carried out in 3 stages, and in the third stage, a consensus was reached among the experts regarding the appropriateness of the studied factors. The consensus criterion among experts was the calculation of CVI and CVR indices for each studied factor. Lawche designed the content validity ratio of CVR. Experts' opinions were used in the field of the test content to calculate this ratio. Each of the studied factors was classified based on the 3-point Likert spectrum of "absolutely necessary," "useful but unnecessary," and "unnecessary." Then, based on equation (4), the content validity ratio of Lawshe was calculated for each factor:

$$CVR=\frac{n_e-\frac{N}{2}}{\frac{N}{2}} \tag{4}$$

In which, n_e is the number of experts who have chosen "absolutely necessary" in determining the validity of the content of the factors, and N is the total number of experts. Table 3 shows the minimum value of the CVR index based on the number of evaluator experts for each factor.

According to the number of 15 research experts, the minimum acceptable CVR value to confirm the content validity of the factors is equal to 0.49. CVI content validity index is also provided by Waltz & Bausell. In this method, the experts were asked to determine the degree of relevance of each factor with a spectrum of 4 options: "not relevant," "needs fundamental revision," "relevant but needs revision," and "completely relevant." The number of experts who selected the options "relevant but needs revision" and "completely relevant" was divided by the total number of experts. If the resulting value is smaller than 0.7, the content validity of the factor in detecting bankruptcy or exiting from the bankruptcy of companies is rejected. If it is between 0.7 and 0.79, it should be revised, and if it is more significant than 0.79, it is acceptable. Table 4 presents the results of evaluating experts' opinions regarding potential final factors affecting bankruptcy.

According to experts, 27 financial ratios have effectively created bankruptcy conditions for companies, and their effectiveness is evaluated in the final research model. The initial model for predicting the bankruptcy of companies based on the factors identified in Table 4 can be shown as Equation (5). This model is applied to all the studied

Table 2: Potential factors affecting bankruptcy based on experimental research literature

Factors affecting bankruptcy (identification of variables)	**Researcher**
Debt to equity ratio, accounts receivable turnover, total assets, debt ratio, current ratio, and working capital.	[34]
Working capital, total assets, liquidity, debt, inability to return investment funds	[43]
Accounting and market factors, fundamental factors, macroeconomics.	[36]
Liquidity, asset productivity, debt solvency, ability of assets to sell.	[37]
Ratio of cost of goods sold, current liabilities to total assets, interest expense to sales, current liabilities to total assets.	[20]
Cost of goods sold, gross profit, net profit, total revenue	[33]
Net profit to total assets, financial expenses to total assets, net profit to sales, current assets to total assets, current assets to current liabilities, and current liabilities to sales.	[30]
cash flow to total assets, net profit to total assets, profit before interest and taxes to total assets Ratio of equity to total assets, ratio of total liabilities to equity, cash to current liabilities, cash to total liabilities, cash to total assets	[38]
Average sales every three months, average sales every month, average sales every six months, lowest amount of sales, the highest amount of sales	[22]
Equity to total assets, equity to total liabilities, total liabilities to total assets, net profit to average assets, current assets to total assets	[9]
Current ratio, current ratio, gross profit to sales ratio, operating income to sales	[21]
Company size, profit	[25]
Current ratio, non-current assets to total assets, total assets/profit before interest and taxes, equity/net profit, turnover of total assets	[15]
Audit fee, size of audit firm, tenure of audit firm	[24]
Financial structure, turnover, debt payment, and profitability	[2]
Profitability coefficient, intensity of fixed assets, directors' compensation, independence of the board of directors	[31]
Degree of financial leverage, company size, the ratio of market value to book value	[10]
Cash flow statement ratios	[17]
Ratio of profit before interest expense and tax to total assets, current ratio	[47]
Unconditional conservatism, conditional conservatism, cash conversion cycle, profit management, capital structure	[11]
Financial leverage, liquidity ratio	[19]
Debt ratios, liquidity, activity, profitability, market	[44]
Current ratios, profitability, debt	[14]
Capital-to-profit ratio	[32]
Financial cost to sales, non-current debt to total assets, the natural logarithm of sales, working capital to total assets	[4]
Profit before interest and sales tax, return on equity, return on assets, interest expense coverage, current ratio, current ratio, the ratio of working capital to total assets, risk, stock market return, the relative daily value of shares, and book value to daily value.	[12]
Current assets to current liabilities, profit before interest and tax to total assets, equity to debt, working capital to assets, profit before interest, and tax to sales.	[26]
Total index, the ratio of working capital to total assets, the ratio of accumulated profit to total assets, the ratio of profit before interest and tax to total assets, the ratio of the book value of the company's shares to the book value of total liabilities, the ratio of profit before interest and taxes to total assets	[15]

companies and the entire research period.

$$LN\left(\frac{P[y_{i,t}=1]}{1-P[y_{i,t}=1]}\right)=\beta_0+\sum_{j=1}^{27}\beta_j X_{j,i,t}+\epsilon_{i,t} \tag{5}$$

Table 3: The minimum acceptable amount for the content validity ratio

Number of experts	The minimum proportion of those who agree	Number of experts	The minimum proportion of those who agree
5 people	0.99	13 people	0.54
6 people	0.99	14 people	0.51
7 people	0.99	15 people	0.49
8 people	0.75	20 people	0.42
9 people	0.78	25 people	0.37
10 persons	0.62	30 people	0.33
11 people	0.59	35 people	0.31
12 people	0.56	40 people	0.29

Table 4: The minimum acceptable amount for the content validity ratio

No.	Factors affecting bankruptcy	CVI	CVR
1	Debt to equity ratio	1	0.6
2	Accounts receivable circulation period compared to accounts payable circulation period	1	0.73
3	Current ratio	0.87	1
4	Liquidity ratio	0.93	0.87
5	Macroeconomic factors (producer price index)	0.93	0.73
6	Macroeconomic factors (exchange rate)	0.93	0.73
7	Market factors (stock market index growth)	0.87	1
8	Ease of financing (the presence of financial institutions such as banks in the composition of institutional owners)	0.93	0.87
9	Asset productivity (the ratio of operating profit to total assets)	0.93	1
10	The ratio of the cost of goods sold to total sales	0.93	0.87
11	Interest expense to sales ratio	0.8	0.73
12	The ratio of earnings before interest and taxes to total assets	0.93	0.87
13	Ratio of sales to current liabilities	0.93	0.73
14	The ratio of operating cash flow to total assets	1	0.87
15	The ratio of cash to current liabilities	0.93	0.73
16	Annual sales growth	1	0.87
17	Instantaneous ratio	0.87	0.73
18	The ratio of net profit to total sales	1	1
19	Financial leverage (the ratio of total debt to total assets)	0.93	0.87
20	Managers' bonus ratio to net profit	0.93	0.6
21	Cash conversion cycle	1	0.87
22	Capital to net profit ratio	0.87	0.6
23	The ratio of working capital to total sales	0.93	0.87
24	Return on assets	0.93	1
25	Interest expense coverage ratio	0.87	0.87
26	The ratio of retained earnings to total liabilities	1	0.6
27	The ratio of cash balance to total liabilities	0.87	0.87

In which, $P[y_{i,t} = 1]$ is the probability of bankruptcy of company i in year t. According to the Black-Scholes model, this parameter has a value greater than 0.5 in bankrupt companies, and in companies that have exited bankruptcy, it has a value smaller than 0.5.

$X_{1,i,t}$: is the ratio of total liabilities to the market value of equity of company i in year t.

$X_{2,i,t}$: the ratio of the accounts receivable turnover period to the accounts payable turnover period of company i in year t.

$X_{3,i,t}$: the current ratio of company i in year t, calculated from the ratio of current assets to current liabilities.

$X_{4,i,t}$: the liquidity ratio of company i in year t equals the ratio of cash balance to the company's total assets.

$X_{5,i,t}$: the producer price index in year t, obtained from the central bank database.

$X_{6,i,t}$: the exchange rate (US dollar) at the end of year t.

$X_{7,i,t}$: the stock market index growth percentage in year t compared to the previous year.

$X_{8,i,t}$: virtual variable is the ease of financing company i in year t, and if there are financial institutions such as banks in the composition of the company's institutional owners, it is equal to 1, and otherwise, it is equal to zero.

$X_{9i,t}$: The productivity of company i's assets in year t equals the ratio of operating profit to the company's total assets.

$X_{10,i,t}$: the ratio of the cost of goods sold to the total sales of company i in year t.

$X_{11,i,t}$: the ratio of interest expense to sales of company i in year t. The company's facility interest payment is used to measure the interest cost.

$X_{12,i,t}$: the ratio of profit before interest and tax to the total assets of company i in year t.

$X_{13,i,t}$: the ratio of sales to current liabilities of company i in year t.

$X_{14,i,t}$: the ratio of operating cash flow to the total assets of company i in year t.

$X_{15,i,t}$: the ratio of cash to current liabilities of company i in year t.

$X_{16,i,t}$: the annual sales growth of company i in year t compared to the previous year.

$X_{17,i,t}$: the current ratio of company i in year t, calculated from the sum of cash and accounts receivable divided by the company's current liabilities.

$X_{18,i,t}$: the ratio of net profit to total sales of company i in year t.

$X_{19,i,t}$: the ratio of total debt to total assets of company i in year t.

$X_{20,i,t}$: the ratio of managers' bonus to the net profit of company i in year t.

$X_{21,i,t}$: cash conversion cycle of company i in year t, which is calculated from equation (3-6):

$$CCC_{i,t} = DIO_{i,t} + DSO_{i,t} - DPO_{i,t} \tag{6}$$

So, $DIO_{i,t}$ represents the receivables collection period, $DSO_{i,t}$ shows the inventory turnover period, and $DPO_{i,t}$ donates the creditor's deposit period.

$$DIO_{i,t} = \frac{Average\ accounts\ payable\ at\ the\ beginning\ and\ end\ of\ the\ period}{Purchase} \times 365 \tag{7}$$

$$DSO_{i,t} = \frac{Average\ inventory}{Cost\ of\ goods\ sold} \times 365 \tag{8}$$

$$DPO_{i,t} = \frac{Average\ accounts\ receivable\ at\ the\ beginning\ and\ end\ of\ the\ period}{Net\ sales\ revenue} \times 365 \tag{97}$$

$X_{22,i,t}$: The ratio of working capital to the net profit of company i in year t. $X_{23,i,t}$: The ratio of working capital to total sales of company i in year t.

$X_{24,i,t}$: The return on company i's assets in year t equals the net profit ratio to the company's total assets.

$X_{25,i,t}$: The interest cost coverage ratio of company i in year t is calculated from the profit before interest and the tax deduction to the company's interest costs.

$X_{26,i,t}$: The ratio of accumulated profit to the total liabilities of the company i in year t.

$X_{27,i,t}$: The ratio of cash balance to total liabilities of company i in year t.

4 Descriptive statistics of research variables

This section presents the central indicators, such as the average and dispersion indicators of each research variable"s standard deviation, minimum, and maximum. The mean was the main central index and showed the average of the data. If the data are lined up regularly on an axis, the mean value will lie precisely at the equilibrium point or center of gravity of the distribution. Standard deviation is one of the dispersion parameters and shows the amount of data dispersion. The summary of the descriptive statistics related to the model's variables is presented in Table 5.

Table 5: Descriptive statistics of research variables

Variable	Symbol	Mean	Median	Max	Min	Standard Deviation
Debt to market value ratio	X1	1.540344	0.811767	37.43978	0.022896	2.576876
The ratio of accounts receivable turnover to accounts payable	X2	11.10511	3.857413	410.8481	1.167223	30.20176
Current ratio	X3	1.379799	1.202603	13.15063	0.164266	1.013658
Liquidity ratio	X4	0.245783	0.230204	0.730425	0.000155	0.132538
Producer price index	X5	18.18716	15.60000	34.70000	9.000000	8.419047
Exchange rate	X6	11277.72	9667.000	31838.00	3280.000	8972.072
Stock index growth	X7	-0.14941	-0.19794	0.265549	-0.51857	0.254663
Ease of financing	X8	0.334610	0.000000	1.000000	0.000000	0.472005
Asset efficiency	X9	0.129934	0.115594	0.675738	-1.99553	0.152073
Cost of goods sold	X10	0.823690	0.869826	5.219746	0.210373	0.183281
Interest expense to sales ratio	X11	0.083448	0.040965	4.161530	3.47E-06	0.175027
The ratio of earnings before interest and taxes to assets	X12	0.094890	0.085876	0.626784	-2.4437	0.157987
Sales to current debt ratio	X13	1.808345	1.459573	13.40556	0.044176	1.330114
The ratio of operating cash flow to assets	X14	0.120658	0.103550	0.812109	-0.38701	0.130053
The ratio of cash flow to current liabilities	X15	0.531673	0.430129	5.799699	-0.000912	0.456260
Annual sales growth	X16	0.246350	0.147526	56.05918	-0.93105	1.530688
Instantaneous ratio	X17	1.104573	0.991852	12.07834	0.027275	0.824889
The ratio of net profit to total sales	X18	0.119173	0.107759	6.853162	-4.4479	0.371177
Debt-to-asset ratio	X19	0.645281	0.633104	4.002704	0.046905	0.287759
Managers' bonus ratio to net profit	X20	0.158154	0.004340	175.8000	-2.03602	4.463166
Cash conversion cycle	X21	560.5749	228.5218	79291.26	-4197.67	2238.349
The ratio of working capital to net profit	X22	6.601880	1.075034	11437.40	-1909.45	301.9027
The ratio of working capital to sales	X23	0.065071	0.130191	15.52834	-11.3447	0.864238
return on assets	X24	0.094890	0.085876	0.626784	-2.4437	0.157987
Interest cost coverage	X25	163.6710	3.090973	143150.6	-1511.11	3696.571
The ratio of retained earnings to total debt	X26	0.345836	0.191853	10.01875	0.052421	0.755801
The ratio of cash balance to total debt	X27	0.451906	0.372258	3.970060	0.000855	0.358169
Bankruptcy	BANKRUPTCY	0.242018	0.000000	1.000000	0.000000	0.428442

4.1 Description of financial ratios affecting bankruptcy

According to Table 5, the ratio of debt to the market value of the companies' equity was equal to 1.540 on average. The ratio of the turnover period of accounts receivable to the turnover period of accounts payable companies was equal to 11.1051. During the research period, the current ratio of companies has an average value of 1.379, and their liquidity ratio has an average value of 0.2457. The producer price index during the research period had an average value of 18.1871%, and the exchange rate had an average value of 11277 Tomans. The growth of the stock market index during the research period was equal to -0.1494, and the measure of ease of financing companies was equal to 0.3346 on average. The productivity of the companies' assets had an average value of 0.1299, and the cost of goods sold to the companies' total sales had an average value of 0.8236. The ratio of interest expense to income from sales was equal to 0.0834 on average, and the ratio of profit before interest and tax to the company's assets was equal to 0.0948. The ratio of sales to current liabilities of companies was estimated to be equal to 1.808, and the ratio of cash flow to assets was 0.1206. The ratio of cash flow to current liabilities of companies had an average value of 0.5316, and the annual sales growth of companies had an average value of 0.2463. The current ratio of companies had an average of 1.1045, and the ratio of net profit to total sales was estimated as 0.1191. The ratio of debt to companies' assets was 0.6452 on average, and the ratio of managers' bonus to net profit was 0.1581 on average.

The company cash conversion cycle was estimated to be 560.574 days on average, and the ratio of working capital to companies' net profit was 6.601. In contrast, the average ratio of working capital to companies' sales was 0.0650. The companies' return on assets had an average value of 0.0948, and their interest cost coverage during the research period was equal to 163.6710. The ratio of accumulated profit to the company's total debts was equal to 0.3458, and

the ratio of cash balance to total debt was estimated to be equal to 0.4519. According to the estimates, 20.24% of the observations showed the bankruptcy of the companies under the Black-Scholes model, and 71.25% of them managed to get out of bankruptcy during the research period.

4.2 Durability of research variables

The Levene and Chu test was used to check the significance of the research variables in the section on factors affecting bankruptcy.

Table 6: Results of the Durability test of research variables

Variable	LLC statistics	Significance
Debt to market value ratio	-41.8177	0.0000
Accounts receivable to payable turnover period	-28.3390	0.0000
Current ratio	-13.4584	0.0000
Liquidity ratio	-10.9834	0.0000
Producer price index	-15.7500	0.0000
Exchange rate	-15.4491	0.0000
Stock index growth	-40.8350	0.0000
Ease of financing	-11.3459	0.0000
Asset efficiency	-15.0886	0.0000
Cost of goods sold	-88.3751	0.0000
Interest expense to sales ratio	-25.5553	0.0000
The ratio of earnings before interest and taxes to assets	-14.8723	0.0000
Sales to current debt ratio	-26.4421	0.0000
The ratio of operating cash flow to assets	-460.413	0.0000
The ratio of cash flow to current liabilities	-20.2908	0.0000
Annual sales growth	-27.9237	0.0000
Instantaneous ratio	-11.6999	0.0000
The ratio of net profit to total sales	-27.2087	0.0000
Debt-to-asset ratio	-8.55227	0.0000
Managers' bonus ratio to net profit	-88.8504	0.0000
Cash conversion cycle	-17.2294	0.0000
The ratio of working capital to net profit	-61.5596	0.0000
The ratio of working capital to sales	-14.2594	0.0000
Return on assets	-14.8723	0.0000
Interest cost coverage	-19.1237	0.0000
The ratio of retained earnings to total debt	-9.95309	0.0000
The ratio of cash balance to total debt	-13.7362	0.0000

When the null hypothesis based on a single root in the series values is rejected, it can be accepted that the studied series are valid. Otherwise, differentiation, regression over time, or Box and Cox transformations should be used. Table 6 shows that the significance levels of all the mentioned tests are smaller than the first type error of 0.05. As a result, the statistical null hypothesis of the test based on the existence of a unit root was rejected. The studied series are at this error level; therefore, the variable values' behavior will not undergo trend changes over time.

5 Correlation analysis of variables and formation of principal components

In this section, the linear correlation analysis between pre-bankruptcy financial ratios was analyzed, the results of which are explained in the following discussion:

5.1 Factors affecting bankruptcy

First, the linear correlation between the studied variables should be checked.

A) Correlation analysis

Table 7 shows the results of estimating Spearman's linear correlation coefficients between each of the variables in predicting the bankruptcy of companies. The relationships of many pairs of variables used in predicting bankruptcy were significant at the error level of 0.05, and these relationships led to high collinearity between the variables in the logistic regression model.

Table 7: Correlation test results of bankruptcy predicting factors*

Variable	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27
X1	1.000																										
X2	-0.060	1.000																									
X3	-0.227	0.022	1.000																								
X4	-0.091	-0.156	0.178	1.000																							
X5	-0.005	0.057	0.031	0.089	1.000																						
X6	-0.016	0.042	0.006	0.071	0.876	1.000																					
X7	0.007	0.002	-0.004	0.006	-0.147	-0.566	1.000																				
X8	-0.057	0.011	-0.030	0.132	0.003	0.002	0.001	1.000																			
X9	-0.257	0.308	0.285	-0.011	0.183	0.180	-0.049	0.046	1.000																		
X10	0.131	-0.066	0.007	0.106	-0.035	-0.041	0.027	0.011	-0.298	1.000																	
X11	0.209	-0.008	0.028	-0.108	-0.046	-0.051	0.034	-0.100	-0.257	0.197	1.000																
X12	-0.307	0.124	0.345	-0.005	0.154	0.147	-0.037	0.038	0.916	-0.293	-0.305	1.000															
X13	-0.249	0.044	0.660	0.189	0.048	0.046	-0.005	0.020	0.341	-0.052	-0.204	0.365	1.000														
X14	-0.209	0.090	0.103	-0.046	0.102	0.111	-0.042	0.087	0.545	-0.252	-0.146	0.462	0.298	1.000													
X15	-0.219	-0.004	0.713	0.627	0.061	0.050	0.001	0.075	0.197	-0.041	-0.020	0.258	0.593	0.320	1.000												
X16	-0.020	0.069	0.039	-0.069	0.016	0.019	-0.006	-0.027	0.087	-0.018	-0.017	0.083	0.026	-0.015	-0.020	1.000											
X17	-0.104	-0.166	0.896	0.255	-0.044	-0.045	0.016	-0.014	0.212	-0.001	0.019	0.263	0.563	0.031	0.718	0.011	1.000										
X18	-0.231	0.174	0.246	-0.090	0.090	0.079	-0.019	0.014	0.566	-0.282	-0.120	0.642	0.177	0.224	0.116	0.116	0.177	1.000									
X19	0.420	-0.132	-0.498	-0.023	-0.027	-0.008	-0.021	-0.029	-0.497	0.213	0.277	-0.633	-0.440	-0.283	-0.406	-0.051	-0.428	-0.533	1.000								
X20	-0.004	-0.008	-0.007	-0.008	-0.020	-0.024	-0.004	-0.018	-0.010	0.009	-0.008	-0.019	-0.021	-0.013	-0.004	-0.008	-0.002	-0.010	-0.012	1.000							
X21	-0.054	0.033	0.032	0.005	0.045	0.048	-0.026	0.023	-0.028	0.026	-0.074	-0.007	0.045	-0.016	0.030	-0.010	0.028	0.030	-0.076	-0.003	1.000						
X22	-0.019	-0.008	0.014	0.011	-0.016	-0.020	-0.008	-0.005	-0.026	0.016	-0.012	-0.011	-0.007	-0.026	0.016	-0.008	0.016	-0.006	-0.027	0.943	-0.003	1.000					
X23	-0.244	-0.040	0.400	0.185	0.062	0.045	0.005	-0.031	0.245	-0.164	-0.001	0.309	0.228	0.058	0.298	0.027	0.357	0.605	-0.531	0.004	0.014	0.016	1.000				
X24	-0.307	0.124	0.345	-0.005	0.154	0.147	-0.037	0.038	0.916	-0.293	-0.305	0.863	0.365	0.462	0.258	0.083	0.263	0.642	-0.633	-0.019	-0.007	-0.011	0.309	1.000			
X25	-0.020	0.035	0.012	-0.030	-0.010	-0.021	0.016	0.041	0.011	-0.056	-0.021	0.045	-0.006	0.031	-0.013	-0.005	-0.007	0.052	-0.042	-0.002	-0.002	-0.001	0.007	0.045	1.000		
X26	-0.243	0.201	0.806	-0.053	0.049	0.054	-0.025	-0.029	0.468	-0.103	-0.066	0.542	0.593	0.283	0.476	0.072	0.657	0.431	-0.582	-0.023	0.124	-0.014	0.323	0.542	0.026	1.000	
X27	-0.240	-0.036	0.687	0.684	0.058	0.047	0.001	0.087	0.219	-0.013	-0.057	0.287	0.572	0.321	0.965	-0.023	0.681	0.132	-0.445	-0.003	0.060	0.019	0.111	0.287	-0.012	0.502	1.000

* Gray cells: significance at 0.05 level

B) principal components analysis

According to Table 7, the relationships of many predictor variables of bankruptcy were significant at the error level of 0.05, creating collinearity in the logistic research model. Therefore, the variables with high collinearity can be removed from the model the dimension of the problem can be reduced using principal components analysis to solve the problem of collinearity among the variables. Principal component analysis with the most significant number of components was used to avoid removing helpful information from the problem because the variables identified in this section resulted from the expert evaluation process. In this analysis, the number of principal components was considered equal to 26 components so that 100% of the information in the data is studied in the form of main components.

This analysis is based on the formation of independent linear combinations of variables. The main component is formed with t least 1 component and at most the number of variables, and each component are independent of other

components. Therefore, the main components obtained from them can be used instead of the central values of the variables in the logistic research model. Table 8 presents the results obtained for the coefficient of each of the research variables in the formation of each of the main components of the model.

Table 8: Coefficients of variables in the main components before bankruptcy

Variables	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12	PC13	PC14	PC15	PC16	PC17	PC18	PC19	PC20	PC21	PC22	PC23	PC24	PC25	PC26
X1	-0.166	0.041	0.059	-0.020	0.166	0.075	-0.303	0.172	0.034	0.024	0.255	0.253	0.580	-0.235	-0.329	0.373	-0.187	-0.079	0.024	0.009	-0.027	0.006	-0.009	-0.004	-0.003	0.012
X2	0.040	-0.140	-0.035	-0.009	0.184	0.280	0.342	0.415	0.260	0.326	-0.486	-0.117	0.082	-0.223	-0.091	0.023	0.031	0.103	0.199	0.151	-0.072	0.036	0.045	0.048	-0.041	0.031
X3	0.294	0.261	-0.030	-0.020	0.263	0.108	-0.010	-0.019	-0.060	-0.054	0.051	-0.046	0.014	0.087	-0.110	-0.058	0.030	0.221	0.177	0.052	0.039	0.071	-0.474	-0.638	-0.073	0.023
X4	0.093	0.305	0.213	0.026	-0.447	-0.213	-0.017	0.095	0.173	0.059	-0.080	0.140	0.067	-0.251	0.161	0.031	0.115	0.155	0.096	-0.303	-0.524	0.080	-0.052	-0.103	0.094	-0.055
X5	0.056	-0.131	0.549	0.093	0.088	-0.050	0.009	0.145	0.042	0.068	-0.028	0.318	-0.164	0.329	-0.175	-0.031	-0.041	0.009	-0.033	0.023	-0.019	0.017	0.002	0.016	-0.312	-0.512
X6	0.055	-0.144	0.630	0.110	0.135	-0.026	0.018	0.018	-0.030	-0.036	-0.010	-0.008	-0.062	0.083	-0.054	-0.015	-0.024	-0.006	-0.010	0.008	-0.006	-0.002	0.004	-0.018	0.364	0.631
X7	-0.016	0.076	-0.387	-0.090	-0.142	-0.023	-0.030	0.221	0.140	0.192	-0.027	0.595	-0.176	0.426	-0.172	-0.032	0.006	0.035	-0.014	-0.003	0.014	-0.002	-0.003	-0.009	0.166	0.285
X8	0.021	0.002	0.039	-0.009	-0.374	0.087	0.247	0.325	0.066	0.177	0.553	-0.447	0.106	0.283	-0.203	-0.064	0.005	-0.042	0.064	-0.016	0.015	0.011	0.006	-0.007	-0.001	0.000
X9	0.277	-0.294	-0.006	-0.004	-0.102	0.089	-0.220	0.007	0.027	0.037	0.125	0.111	0.040	-0.111	0.088	-0.153	0.141	0.022	0.300	0.084	-0.030	-0.756	-0.059	0.024	0.017	-0.026
X10	-0.095	0.209	0.062	-0.001	0.119	0.191	0.002	0.041	0.155	0.175	0.412	0.097	-0.634	-0.454	0.006	0.139	-0.071	0.082	-0.044	0.083	0.082	-0.031	0.026	0.026	0.020	-0.012
X11	-0.097	0.145	-0.006	-0.033	0.409	-0.103	-0.268	0.352	-0.066	0.292	0.122	-0.076	0.042	0.137	0.527	-0.227	0.026	-0.322	0.035	-0.073	-0.146	0.040	0.001	-0.004	-0.005	0.000
X12	0.306	-0.277	-0.042	0.004	-0.082	0.031	-0.142	-0.005	0.030	0.026	0.109	0.107	0.009	-0.182	-0.005	-0.218	0.001	-0.090	0.094	-0.020	0.093	0.408	0.045	0.007	-0.010	0.009
X13	0.263	0.156	0.015	-0.023	0.014	0.300	-0.015	-0.090	-0.011	-0.076	-0.057	-0.016	-0.106	0.096	-0.121	0.367	0.525	-0.570	0.026	-0.025	-0.137	0.040	0.039	0.049	-0.023	0.013
X14	0.163	-0.210	0.013	-0.019	-0.188	0.326	-0.190	0.028	-0.125	0.106	-0.015	-0.042	-0.022	0.230	0.469	0.540	-0.195	0.296	-0.073	0.096	-0.032	0.116	-0.003	-0.028	-0.023	0.011
X15	0.264	0.344	0.107	0.003	-0.127	0.008	-0.029	0.107	0.064	0.021	-0.134	0.014	0.141	-0.026	0.089	-0.050	-0.086	-0.094	-0.171	0.272	0.404	-0.046	0.037	0.025	0.566	-0.334
X16	0.028	-0.066	-0.031	-0.009	0.168	0.000	0.080	-0.011	0.789	-0.474	0.143	-0.002	0.066	0.148	0.240	0.055	-0.050	-0.013	0.024	-0.009	0.000	0.015	0.007	0.005	-0.002	-0.001
X17	0.261	0.310	-0.035	-0.019	0.173	0.014	-0.102	-0.076	-0.090	-0.128	0.107	-0.051	0.036	0.122	-0.120	-0.146	-0.038	0.293	0.128	0.457	-0.393	0.087	0.296	0.358	-0.063	0.057
X18	0.232	-0.243	-0.107	0.006	0.139	-0.368	0.084	0.113	0.047	0.122	0.125	-0.026	0.056	-0.114	-0.031	0.116	0.315	0.123	-0.662	0.209	-0.157	-0.057	-0.076	-0.087	-0.012	0.015
X19	-0.300	0.068	0.124	-0.016	-0.023	0.124	-0.173	0.056	0.027	-0.019	0.055	0.054	0.143	0.020	0.100	-0.087	0.689	0.418	0.060	0.010	0.336	0.131	0.062	0.082	-0.041	0.014
X20	-0.008	0.027	-0.118	0.694	0.007	0.038	-0.022	0.016	0.003	0.006	0.009	0.015	0.019	0.015	0.006	0.002	0.017	0.000	-0.007	-0.014	0.009	-0.061	0.562	-0.423	-0.022	0.003
X21	0.027	0.026	0.046	0.007	0.085	0.109	0.661	-0.257	-0.176	0.115	0.268	0.402	0.283	-0.035	0.318	-0.026	0.040	-0.047	0.070	0.062	-0.007	0.011	0.015	0.020	0.002	-0.001
X22	-0.001	0.035	-0.113	0.695	0.000	0.037	-0.016	0.021	0.006	0.009	0.014	0.006	0.007	0.014	0.009	0.006	0.008	0.006	0.008	0.001	-0.013	0.058	-0.560	0.426	0.028	0.002
X23	0.206	0.017	-0.056	0.021	0.140	-0.615	0.096	0.038	-0.037	0.100	0.035	-0.066	-0.078	0.027	0.008	0.424	0.058	0.073	0.469	-0.089	0.284	0.031	0.097	0.119	0.001	-0.002
X24	0.306	-0.277	-0.042	0.004	-0.082	0.031	-0.142	-0.005	0.030	0.026	0.109	0.107	0.009	-0.182	-0.005	-0.218	0.001	-0.090	0.094	-0.020	0.093	0.408	0.045	0.007	-0.010	0.009
X25	0.013	-0.043	-0.057	-0.009	-0.034	0.013	0.162	0.607	-0.381	-0.629	0.024	0.129	-0.114	-0.137	0.084	0.026	0.015	-0.004	0.016	-0.002	0.000	-0.008	0.002	0.003	0.000	-0.003
X26	0.305	0.046	-0.069	-0.032	0.305	0.222	0.046	0.012	-0.058	0.012	0.048	-0.040	0.037	0.058	-0.111	-0.045	-0.032	0.268	-0.190	-0.714	0.025	-0.094	0.145	0.210	0.159	-0.095
X27	0.269	0.335	0.108	0.007	-0.167	-0.014	-0.009	0.090	0.073	0.028	-0.099	0.040	0.110	-0.083	0.102	-0.057	-0.128	-0.066	-0.218	-0.053	0.338	-0.131	0.036	0.109	-0.610	0.359
Percentage of explained variance	0.249	0.116	0.078	0.072	0.055	0.046	0.042	0.038	0.037	0.036	0.034	0.033	0.031	0.028	0.028	0.022	0.014	0.013	0.009	0.007	0.004	0.003	0.002	0.002	0.001	0.001
Percentage of cumulative explained variance	0.249	0.364	0.443	0.515	0.569	0.615	0.657	0.695	0.732	0.768	0.802	0.835	0.866	0.894	0.922	0.944	0.958	0.971	0.980	0.987	0.992	0.994	0.997	0.999	0.999	1.000

According to Table 8, 26 main independent components explained all the changes and information in the predictor variables of bankruptcy. Therefore, the linear combinations of the research variables can be determined to form each of their corresponding main components in the form of the following relations:

$$\begin{aligned}
PC_1 = &-0.166X_1 + 0.040X_2 + 0.294X_3 + 0.093X_4 + 0.056X_5 + 0.055X_6 - 0.016X_7 + 0.021X_8 + 0.277X_9 \\
&- 0.095X_{10} - 0.097X_{11} + 0.306X_{12} + 0.263X_{13} + 0.163X_{14} + 0.264X_{15} + 0.028X_{16} \\
&+ 0.261X_{17} + 0.232X_{18} - 0.300X_{19} - 0.008X_{20} + 0.027X_{21} - 0.001X_{22} + 0.206X_{23} \\
&+ 0.306X_{24} + 0.013X_{25} + 0.305X_{26} + 0.269X_{27} \\
PC_2 = &\ 0.041X_1 - 0.140X_2 + 0.261X_3 + 0.305X_4 - 0.131X_5 - 0.144X_6 + 0.076X_7 + 0.002X_8 - 0.294X_9 \\
&+ 0.209X_{10} + 0.145X_{11} - 0.277X_{12} + 0.156X_{13} - 0.210X_{14} + 0.344X_{15} - 0.066X_{16} \\
&+ 0.310X_{17} - 0.243X_{18} + 0.068X_{19} + 0.027X_{20} + 0.026X_{21} + 0.035X_{22} + 0.017X_{23} \\
&- 0.277X_24 - 0.043X_{25} + 0.046X_{26} + 0.335X_{27} \\
PC_3 = &\ 0.059X_1 - 0.035X_2 - 0.030X_3 + 0.213X_4 + 0.549X_5 + 0.630X_6 - 0.387X_7 + 0.039X_8 - 0.006X_9 \\
&+ 0.062X_{10} - 0.006X_{11} - 0.042X_{12} + 0.015X_{13} + 0.013X_{14} + 0.107X_{15} - 0.031X_{16} \\
&- 0.035X_{17} - 0.107X_{18} + 0.124X_{19} - 0.118X_{20} + 0.046X_{21} - 0.113X_{22} - 0.056X_{23} \\
&- 0.042X_{24} - 0.057X_{25} - 0.069X_{26} + 0.108X_{27}
\end{aligned}$$

$$
\begin{aligned}
PC_4 = &-0.020X_1 - 0.009X_2 - 0.020X_3 + 0.026X_4 + 0.093X_5 + 0.110X_6 - 0.090X_7 - 0.009X_8 - 0.004X_9 \\
&- 0.001X_{10} - 0.033X_{11} + 0.004X_{12} - 0.023X_{13} - 0.019X_{14} + 0.003X_{15} - 0.009X_{16} \\
&- 0.019X_{17} + 0.006X_{18} - 0.016X_{19} + 0.694X_{20} + 0.007X_{21} + 0.695X_{22} + 0.021X_{23} \\
&+ 0.004X_{24} - 0.009X_{25} - 0.032X_{26} + 0.007X_{27} \\
PC_5 = &\ 0.166X_1 + 0.184X_2 + 0.263X_3 - 0.447X_4 + 0.088X_5 + 0.135X_6 - 0.142X_7 - 0.374X_8 - 0.102X_9 \\
&+ 0.119X_{10} + 0.409X_{11} - 0.082X_{12} + 0.014X_{13} - 0.188X_{14} - 0.127X_{15} + 0.168X_{16} \\
&+ 0.173X_{17} + 0.139X_{18} - 0.023X_{19} + 0.007X_{20} + 0.085X_{21} + 0.001X_{22} + 0.140X_{23} \\
&- 0.082X_{24} - 0.034X_{25} + 0.305X_{26} - 0.167X_{27} \\
PC_6 = &\ 0.075X_1 + 0.280X_2 + 0.108X_3 - 0.213X_4 - 0.050X_5 - 0.026X_6 - 0.023X_7 + 0.087X_8 + 0.089X_9 \\
&+ 0.191X_{10} - 0.103X_{11} + 0.031X_{12} + 0.300X_{13} + 0.326X_{14} + 0.008X_{15} + 0.001X_{16} \\
&+ 0.014X_{17} - 0.368X_{18} + 0.124X_{19} + 0.038X_{20} + 0.109X_{21} + 0.037X_{22} - 0.615X_{23} \\
&+ 0.031X_{24} + 0.013X_{25} + 0.222X_{26} - 0.014X_{27} \\
PC_7 = &-0.303X_1 + 0.342X_2 - 0.010X_3 - 0.017X_4 + 0.009X_5 + 0.018X_6 - 0.030X_7 + 0.247X_8 - 0.220X_9 \\
&+ 0.002X_{10} - 0.268X_{11} - 0.142X_{12} - 0.015X_{13} - 0.190X_{14} - 0.029X_{15} + 0.080X_{16} \\
&- 0.102X_{17} + 0.084X_{18} - 0.173X_{19} - 0.022X_{20} + 0.661X_{21} - 0.016X_{22} + 0.096X_{23} \\
&- 0.142X_{24} + 0.162X_{25} + 0.046X_{26} - 0.009X_{27} \\
PC_8 = &\ 0.172X_1 + 0.415X_2 - 0.019X_3 + 0.095X_4 + 0.145X_5 + 0.018X_6 + 0.221X_7 + 0.325X_8 + 0.007X_9 \\
&+ 0.041X_{10} + 0.352X_{11} - 0.005X_{12} - 0.090X_{13} + 0.028X_{14} + 0.107X_{15} - 0.011X_{16} \\
&- 0.076X_{17} + 0.113X_{18} + 0.056X_{19} + 0.016X_{20} - 0.257X_{21} + 0.021X_{22} + 0.038X_{23} \\
&- 0.005X_{24} + 0.607X_{25} + 0.012X_{26} + 0.090X_{27} \\
PC_9 = &\ 0.034X_1 + 0.260X_2 - 0.060X_3 + 0.173X_4 + 0.042X_5 - 0.030X_6 + 0.140X_7 + 0.066X_8 + 0.027X_9 \\
&+ 0.155X_{10} - 0.066X_{11} + 0.030X_{12} - 0.011X_{13} - 0.125X_{14} + 0.064X_{15} + 0.789X_{16} \\
&- 0.090X_{17} + 0.047X_{18} + 0.027X_{19} + 0.03X_{20} - 0.176X_{21} + 0.006X_{22} - 0.037X_{23} \\
&+ 0.030X_{24} - 0.381X_{25} - 0.058X_{26} + 0.073X_{27} \\
PC_{10} = &\ 0.024X_1 + 0.326X_2 - 0.054X_3 + 0.059X_4 + 0.068X_5 - 0.036X_6 + 0.192X_7 + 0.177X_8 + 0.037X_9 \\
&+ 0.175X_{10} + 0.292X_{11} + 0.026X_{12} - 0.076X_{13} + 0.106X_{14} + 0.021X_{15} - 0.474X_{16} \\
&- 0.128X_{17} + 0.122X_{18} - 0.019X_{19} + 0.006X_{20} + 0.115X_{[}21] + 0.009X_{[}22] + 0.100X_{23} \\
&+ 0.026X_{24} - 0.629X_{25} + 0.012X_{26} + 0.028X_{27} \\
PC_{11} = &\ 0.255X_1 - 0.486X_2 + 0.051X_3 - 0.080X_4 - 0.028X_5 - 0.010X_6 - 0.027X_7 + 0.553X_8 + 0.125X_9 \\
&+ 0.412X_{10} + 0.122X_{11} + 0.109X_{12} - 0.057X_{13} - 0.015X_{14} - 0.134X_{15} + 0.143X_{16} \\
&+ 0.107X_{17} + 0.125X_{18} + 0.055X_{19} + 0.009X_{20} + 0.268X_{21} + 0.014X_{22} + 0.035X_{23} \\
&+ 0.109X_{24} + 0.024X_{25} + 0.048X_{26} - 0.099X_{27} \\
PC_{12} = &\ 0.253X_1 - 0.117X_2 - 0.046X_3 + 0.140X_4 + 0.318X_5 - 0.08X_6 + 0.595X_7 - 0.447X_8 + 0.111X_9 \\
&+ 0.097X_{10} - 0.076X_{11} + 0.107X_{12} - 0.016X_{13} - 0.042X_{14} + 0.014X_{15} - 0.002X_{16} \\
&- 0.051X_{17} - 0.026X_{18} + 0.054X_{19} + 0.015X_{20} + 0.402X_{21} + 0.006X_{22} - 0.066X_{23} \\
&+ 0.107X_{24} + 0.129X_{25} - 0.040X_{26} + 0.040X_{27} \\
PC_{13} = &\ 0.580X_1 + 0.082X_2 + 0.014X_3 + 0.067X_4 - 0.164X_5 - 0.062X_6 - 0.176X_7 + 0.106X_8 + 0.040X_9 \\
&- 0.634X_{10} + 0.042X_{11} + 0.009X_{12} - 0.106X_{13} - 0.022X_{14} + 0.141X_{15} + 0.066X_{16} \\
&+ 0.036X_{17} + 0.056X_{18} + 0.143X_{19} + 0.019X_{20} + 0.283X_{21} + 0.007X_{22} - 0.078X_{23} \\
&+ 0.009X_{24} - 0.114X_{25} + 0.037X_{26} + 0.110X_{27} \\
PC_{14} = &-0.235X_1 - 0.223X_2 + 0.087X_3 - 0.251X_4 + 0.329X_5 + 0.083X_6 + 0.426X_7 + 0.283X_8 - 0.111X_9 \\
&- 0.454X_{10} + 0.137X_{11} - 0.182X_{12} + 0.096X_{13} + 0.230X_{14} - 0.026X_{15} + 0.148X_{16} \\
&+ 0.122X_{17} - 0.114X_{18} + 0.020X_{19} + 0.015X_{20} - 0.035X_{21} + 0.014X_{22} + 0.027X_{23} \\
&- 0.182X_{24} - 0.137X_{25} + 0.058X_{26} - 0.083X_{27} \\
PC_{15} = &-0.329X_1 - 0.091X_2 - 0.110X_3 + 0.161X_4 - 0.175X_5 - 0.054X_6 - 0.172X_7 - 0.203X_8 + 0.088X_9 \\
&+ 0.006X_{10} + 0.527X_{11} - 0.005X_{12} - 0.121X_{13} + 0.469X_{14} + 0.089X_{15} + 0.240X_{16} \\
&- 0.120X_{17} - 0.031X_{18} + 0.100X_{19} + 0.006X_{20} + 0.318X_{21} + 0.009X_{22} + 0.008X_{23} \\
&- 0.005X_{24} + 0.084X_{25} - 0.111X_{26} + 0.102X_{27}
\end{aligned}
$$

$$
\begin{aligned}
PC_{16} = {} & 0.373X_1 + 0.023X_2 - 0.058X_3 + 0.031X_4 - 0.031X_5 - 0.015X_6 - 0.032X_7 - 0.064X_8 - 0.153X_9 \\
& + 0.139X_10 - 0.227X_{11} - 0.218X_{12} + 0.367X_{13} + 0.540X_{14} - 0.050X_{15} + 0.055X_{16} \\
& - 0.146X_{17} + 0.116X_{18} - 0.087X_{19} + 0.002X_{20} - 0.026X_{21} + 0.006X_{22} + 0.424X_{23} \\
& - 0.218X_{24} + 0.026X_{25} - 0.045X_{26} - 0.057X_{27} \\
PC_{17} = {} & -0.187X_1 + 0.031X_2 + 0.030X_3 + 0.115X_4 - 0.041X_5 - 0.024X_6 + 0.006X_7 + 0.005X_8 + 0.141X_9 \\
& - 0.071X_10 + 0.026X_{11} + 0.001X_{12} + 0.525X_{13} - 0.195X_{14} - 0.086X_{15} - 0.050X_{16} \\
& - 0.038X_{17} + 0.315X_{18} + 0.689X_{19} + 0.017X_{20} + 0.040X_{21} + 0.008X_{22} + 0.058X_{23} \\
& + 0.001X_{24} + 0.015X_{25} - 0.032X_{26} - 0.128X_{27} \\
PC_{18} = {} & -0.079X_1 + 0.103X_2 + 0.221X_3 + 0.155X_4 + 0.009X_5 - 0.006X_6 + 0.035X_7 - 0.042X_8 + 0.022X_9 \\
& + 0.082X_10 - 0.322X_{11} - 0.090X_{12} - 0.570X_{13} + 0.296X_{14} - 0.094X_{15} - 0.013X_{16} \\
& + 0.293X_{17} + 0.123X_{18} + 0.418X_{19} + 0.001X_{20} - 0.047X_{21} + 0.006X_{22} + 0.073X_{23} \\
& - 0.090X_{24} - 0.004X_{25} + 0.268X_{26} - 0.066X_{27} \\
PC_{19} = {} & 0.024X_1 + 0.199X_2 + 0.177X_3 + 0.096X_4 - 0.033X_5 - 0.010X_6 - 0.014X_7 + 0.064X_8 + 0.300X_9 \\
& - 0.044X_10 + 0.035X_{11} + 0.094X_{12} + 0.026X_{13} - 0.073X_{14} - 0.171X_{15} + 0.024X_{16} \\
& + 0.128X_{17} - 0.662X_{18} + 0.060X_{19} - 0.007X_{20} + 0.070X_{21} + 0.008X_{22} + 0.469X_{23} \\
& + 0.094X_{24} + 0.016X_{25} - 0.190X_{26} - 0.218X_{27} \\
PC_{20} = {} & 0.009X_1 + 0.151X_2 + 0.052X_3 - 0.303X_4 + 0.023X_5 + 0.008X_6 - 0.003X_7 - 0.016X_8 + 0.084X_9 \\
& + 0.083X_10 - 0.073X_{11} - 0.020X_{12} - 0.025X_{13} + 0.096X_{14} + 0.272X_{15} - 0.009X_{16} \\
& + 0.457X_{17} + 0.209X_{18} + 0.010X_{19} - 0.014X_{20} + 0.062X_{21} + 0.001X_{22} - 0.089X_{23} \\
& - 0.020X_{24} - 0.002X_{25} - 0.714X_{26} - 0.053X_{27} \\
PC_{21} = {} & -0.027X_1 - 0.072X_2 + 0.039X_3 - 0.524X_4 - 0.019X_5 - 0.006X_6 + 0.014X_7 + 0.015X_8 - 0.030X_9 \\
& + 0.082X_10 - 0.146X_{11} + 0.093X_{12} - 0.137X_{13} - 0.032X_{14} + 0.404X_{15} + 0.001X_{16} \\
& - 0.393X_{17} - 0.157X_{18} + 0.336X_{19} + 0.009X_{20} - 0.007X_{21} - 0.013X_{22} + 0.284X_{23} \\
& + 0.093X_{24} + 0.001X_{25} + 0.025X_{26} + 0.338X_{27} \\
PC_{22} = {} & 0.006X_1 + 0.036X_2 + 0.071X_3 + 0.080X_4 + 0.017X_5 - 0.002X_6 - 0.002X_7 + 0.011X_8 - 0.756X_9 \\
& - 0.031X_10 + 0.040X_{11} + 0.408X_{12} + 0.040X_{13} + 0.116X_{14} - 0.046X_{15} + 0.015X_{16} \\
& + 0.087X_{17} - 0.057X_{18} + 0.131X_{19} - 0.061X_{20} + 0.011X_{21} + 0.058X_{22} + 0.031X_{23} \\
& + 0.408X_{24} - 0.008X_{25} - 0.094X_{26} - 0.131X_{27} \\
PC_{23} = {} & -0.009X_1 + 0.045X_2 - 0.474X_3 - 0.052X_4 + 0.002X_5 + 0.004X_6 - 0.003X_7 + 0.006X_8 - 0.059X_9 \\
& + 0.026X_10 + 0.001X_{11} + 0.045X_{12} + 0.039X_{13} - 0.003X_{14} + 0.037X_{15} + 0.007X_{16} \\
& + 0.296X_{17} - 0.076X_{18} + 0.062X_{19} + 0.562X_{20} + 0.015X_{21} - 0.560X_{22} + 0.097X_{23} \\
& + 0.045X_{24} + 0.002X_{25} + 0.145X_{26} + 0.036X_{27} \\
PC_{24} = {} & -0.004X_1 + 0.048X_2 - 0.638X_3 - 0.103X_4 + 0.016X_5 - 0.018X_6 - 0.009X_7 - 0.007X_8 + 0.024X_9 \\
& + 0.026X_10 - 0.004X_{11} + 0.007X_{12} + 0.049X_{13} - 0.028X_{14} + 0.025X_{15} + 0.005X_{16} \\
& + 0.358X_{17} - 0.087X_{18} + 0.082X_{19} - 0.423X_{20} + 0.020X_{21} + 0.426X_{22} + 0.119X_{23} \\
& + 0.007X_{24} + 0.003X_{25} + 0.210X_{26} + 0.109X_{27} \\
PC_{25} = {} & -0.003X_1 - 0.041X_2 - 0.073X_3 + 0.094X_4 - 0.312X_5 + 0.364X_6 + 0.166X_7 - 0.001X_8 + 0.017X_9 \\
& + 0.020X_{10} - 0.005X_{11} - 0.010X_{12} - 0.023X_{13} - 0.023X_{14} + 0.566X_{15} - 0.002X_{16} \\
& - 0.063X_{17} - 0.012X_{18} - 0.041X_{19} - 0.022X_{20} + 0.002X_{21} + 0.028X_{22} + 0.001X_{23} \\
& - 0.010X_{24} + 0.001X_{25} + 0.159X_{26} - 0.610X_{27} \\
PC_{26} = {} & 0.012X_1 + 0.031X_2 + 0.023X_3 - 0.055X_4 - 0.512X_5 + 0.631X_6 + 0.285X_7 + 0.001X_8 - 0.026X_9 \\
& - 0.012X_{10} + 0.001X_{11} + 0.009X_{12} + 0.013X_{13} + 0.011X_{14} - 0.334X_{15} - 0.001X_{16} \\
& + 0.057X_{17} + 0.015X_{18} + 0.014X_{19} + 0.003X_{20} - 0.001X_{21} + 0.002X_{22} - 0.002X_{23} \\
& + 0.009X_{24} - 0.003X_{25} - 0.095X_{26+}0.359X_{27}
\end{aligned}
$$

Therefore, those mentioned above 26 main components were used as predictors of bankruptcy of companies in the

research model.

5.2 Bankruptcy prediction model

The company bankruptcy forecasting model results were presented using the principal components identified from 27 research variables.

- Logistic regression analysis

This section presents the company's bankruptcy prediction model results using the principal components identified from 27 research variables. The logistic model was fitted using all the main components to achieve the optimal model. Then, the main components that do not affect the probability of bankruptcy were removed from the model. The final bankruptcy prediction model is fitted based on significant principal components. Table 9 indicates the fitting results of these models.

Table 9: Estimation of the logistic regression model for predicting bankruptcy

Explanatory variable	Initial model			Significant components model		
	Coefficient	Z-value	Significance	Coefficient	Z-value	Significance
PC1	-1.977266	-12.94361	0.0000	-1.928313	-13.43064	0.0000
PC2	1.005186	8.033291	0.0000	0.825736	7.211564	0.0000
PC3	1.145397	5.087541	0.0000	1.020195	10.94515	0.0000
PC4	-0.279355	-0.246882	0.8050	-	-	-
PC5	-0.452633	-2.413036	0.0158	-0.331973	-1.948240	0.0514
PC6	0.971220	2.919021	0.0035	0.847549	4.318303	0.0000
PC7	-1.009470	-5.407752	0.0000	-0.900613	-7.889435	0.0000
PC8	-0.260383	-0.458200	0.6468	-	-	-
PC9	0.157597	0.361867	0.7175	-	-	-
PC10	-0.223245	-0.370788	0.7108	-	-	-
PC11	0.565406	2.676204	0.0074	0.439055	3.314531	0.0009
PC12	0.782372	4.524280	0.0000	0.738952	5.720223	0.0000
PC13	1.064616	5.285001	0.0000	1.010462	5.750460	0.0000
PC14	0.092551	0.511468	0.6090	-	-	-
PC15	0.381263	1.586852	0.1125	-	-	-
PC16	-0.311328	-1.447583	0.1477	-	-	-
PC17	3.946246	10.97686	0.0000	3.845400	11.81513	0.0000
PC18	1.619679	5.648241	0.0000	1.613800	6.013547	0.0000
PC19	0.874113	2.084250	0.0371	1.164015	2.849508	0.0044
PC20	1.557956	2.822948	0.0048	1.437979	3.017842	0.0025
PC21	3.463834	6.048705	0.0000	3.016268	6.026977	0.0000
PC22	0.921707	1.963297	0.0496	0.959132	2.100734	0.0357
PC23	-0.509128	-0.584293	0.5590	-	-	-
PC24	-2.581891	-3.641833	0.0003	-2.911749	-3.697013	0.0002
PC25	-3.603996	-2.918249	0.0035	-2.816568	-2.584042	0.0098
PC26	0.428112	0.482732	0.6293	-	-	-
Constant	-3.104561	-13.48427	0.0000	-3.065337	-13.75144	0.0000
Goodness of Fit						
Likelihood ratio statistic	1140.237			1132.617		
Significance of the model	0.0000			0.0000		
McFadden coefficient of determination	0.657868			0.653471		
The significance of Hosmer Lemeshow	0.3427			0.7331		

- Goodness of fit analysis

Based on the Goodness of Fit index, which is calculated by McFadden coefficient of determination index $R^2_{MF} = 1 - \frac{Ln(\hat{\beta}_m)}{Ln(\hat{\beta}_0)}$ as a ratio of the logarithm of the likelihood function for the model without predictor variables ($Ln(\hat{\beta}_0)$

and the model with predictor variables ($Ln(\hat{\beta}_m)$), predictive variables in the final bankruptcy prediction model could improve the likelihood function by 65.37%. The model parameters are estimated based on the maximization of the likelihood function. Therefore, the main predictive components in the final model have been able to be effective up to 65.37% in the accuracy of predicting the bankruptcy of companies. The general relationship between predictor variables and corporate bankruptcy was significant. The significance of the Hosmer-Lemeshow statistic (p-value = 0.7331) for testing the appropriateness of the research regression model was more significant than the first type error of 0.05, which indicates the appropriateness of the logistic regression model. The likelihood ratio test results are referred to determine the correctness of the model. The significance level of the likelihood ratio test (p-value = 0.000) is less than 0.05, which shows the good fit of the research's logistic regression model for predicting companies' bankruptcy.

5.3 Factors affecting bankruptcy

According to the results of bankruptcy prediction models, the 17 principal components out of the total 26 main components had significantly impacted companies' bankruptcy risk in each principal component is a linear combination of all 27 variables of the research, it can be accepted that the 27 variables identified from the expert analysis of the study had a significant impact on the bankruptcy risk of companies. Therefore, the influential factors in the bankruptcy of companies are the number 27 variables and financial ratios discussed.

- Evaluation of the predictive power of the model

The percentage of correct predictions of the model is presented in Table (10) to predict the model's ability to determine the bankruptcy of companies.

Table 10: The percentage of correct predictions of the bankruptcy prediction model

Prediction group	Correct prediction (percentage)	Incorrect prediction (percentage)
Bankrupt	76.33	23.67
Non-bankrupt	92.44	7.56
All companies	88.54	11.46

According to Table 10, the bankruptcy prediction model using the principal components consisting of 27 financial ratios can correctly predict 88.54% of companies' bankruptcy and non-bankruptcy situations. The power of this model in accurately detecting non-bankrupt companies (92.44%) was more than its power in correctly detecting bankrupt companies (76.33%). The results showed the high power of identified financial ratios and their main components in predicting the bankruptcy of companies.

6 Artificial neural network analysis

The main components affecting the bankruptcy of companies were also used in the analysis of multilayer artificial neural networks, and the prediction of bankruptcy of companies was also made using this analysis to evaluate the reliability of the results. This analysis identified the number of one hidden layer with three neurons based on the lowest prediction error. For this purpose, the entire research observations were divided into two groups learning observations (70%) and tests (30%), and the artificial neural network learning process was performed on the learning group. The results of the method's accuracy in predicting the bankruptcy of companies were done using test data that did not play a role in the learning process of the algorithm. Figure 1 illustrates how to form a neural network with input, hidden, and output layers in predicting corporate bankruptcy.

Based on Figure 1, principal components and one bias parameter were entered into the neural network's input layer as predictive factors. A hidden layer consisting of a skew parameter and the number of three neurons was formed using the hyperbolic tangent transfer function, which led to the prediction of dependent variable values (bankruptcy/non-bankruptcy) in the output layer. The artificial neural network composed of the main components could correctly predict 90.9% of companies' bankruptcy or non-bankruptcy situations, indicating its high power in detecting bankruptcy or non-bankruptcy companies using the main components of financial ratios. Figure 2 shows the ROC curve of this analysis, which reflects the accuracy and precision of the method's prediction.

Based on Figure 2 and Table 10, the area under the curve for comparing the accuracy and prediction accuracy in both groups of bankrupt (green curve) and non-bankrupt (blue curve) companies was more significant than 0.8 and

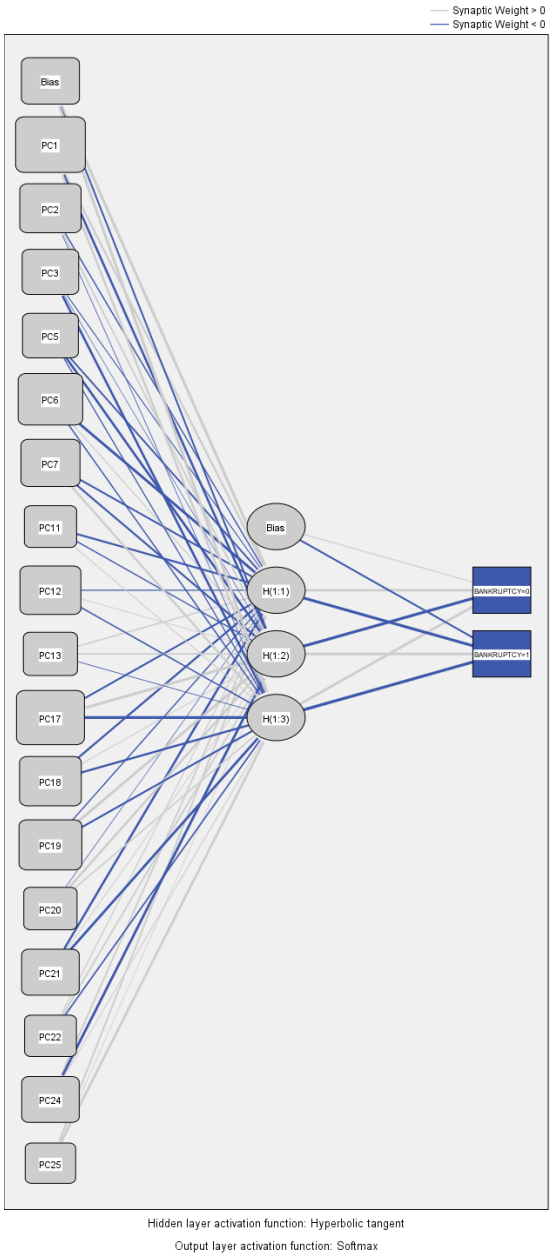

Figure 1: One-layer artificial neural network in predicting corporate bankruptcy

equal to 0.964. These results showed this analysis's high power in predicting companies' bankruptcy and, as a result, its validity.

Table 11: Accuracy and accuracy of bankruptcy prediction in artificial neural network

Criteria	Result
The area under the ROC curve	0.964
Correct prediction accuracy	90.9

The normalized coefficients of their importance were used in the artificial neural network analysis to measure the importance of each of the main components in predicting the bankruptcy of companies (Table 12).

The results of this table are presented in Figure 3.

The first principal component was the most critical factor in the bankruptcy of companies. Based on the magnitude

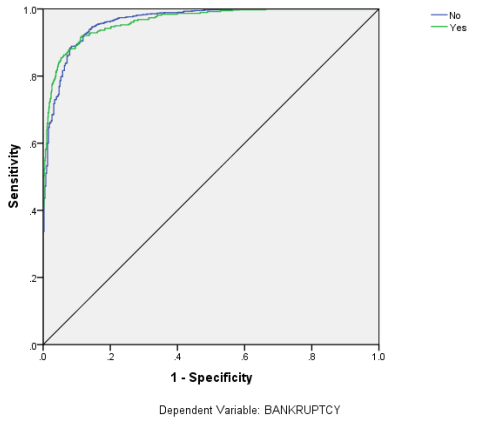

Figure 2: ROC curve of artificial neural network in bankruptcy prediction

Table 12: Importance coefficients and normalized importance of components in predicting bankruptcy

Main component	Importance coefficient	Normalized significance coefficient	Order of importance
PC1	0.112	1.000	1
PC2	0.072	0.641	6
PC3	0.048	0.432	11
PC5	0.045	0.402	12
PC6	0.088	0.783	3
PC7	0.061	0.541	8
PC11	0.028	0.251	15
PC12	0.069	0.617	7
PC13	0.037	0.332	13
PC17	0.103	0.924	2
PC18	0.074	0.659	5
PC19	0.079	0.702	4
PC20	0.033	0.294	14
PC21	0.054	0.481	9
PC22	0.026	0.230	16
PC24	0.053	0.474	10
PC25	0.019	0.170	17

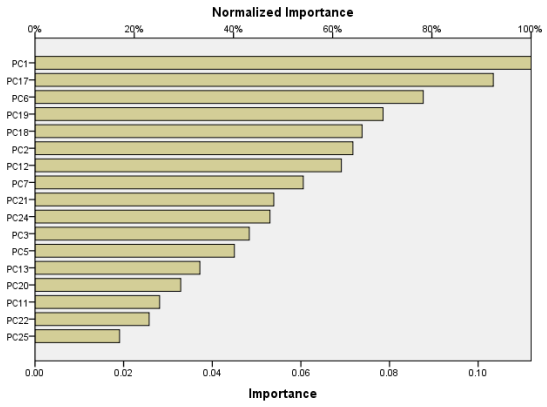

Figure 3: Order of importance of components in predicting bankruptcy

(absolute value) of the coefficients of each variable in the formation of this component, the order of importance of financial variables in corporate bankruptcy can be summarized as follows:

1. The ratio of profit before interest and tax to total assets
2. Return on assets
3. The ratio of accumulated profits to total debts

4. Financial leverage (the ratio of total debt to total assets)
5. Current ratio
6. Asset productivity (the ratio of operating profit to total assets)
7. Ratio of cash balance to total debts
8. Ratio of cash to current liabilities
9. Ratio of sales to current liabilities
10. Instantaneous ratio
11. Ratio of net profit to total sales
12. Ratio of working capital to total sales
13. Debt-to-equity ratio
14. Ratio of operating cash flow to total assets
15. Ratio of interest expense to sales
16. The ratio of the cost price of the sold goods to the total sales
17. Liquidity ratio
18. Macroeconomic factors (producer price index)
19. Macroeconomic factors (exchange rate)
20. Accounts receivable circulation period compared to accounts payable circulation period
21. Annual sales growth
22. Cash conversion cycle
23. Ease of financing (the presence of financial institutions such as banks in the composition of institutional owners)
24. Market factors (stock index growth)
25. Interest cost coverage ratio
26. Ratio of managers' bonus to net profit
27. Ratio of capital to net profit.

7 Conclusion

Lack of knowing the variables affecting bankruptcy is one of the problems of bankruptcy prediction. Many variables lead managers, creditors, researchers, and other people to examine other researchers' experiences or select some variables among the set of influential variables to investigate the causes of company bankruptcy. The need for a more scientific selection of practical and essential variables for bankruptcy makes them face many problems. Therefore, it is possible to predict the financial crisis in companies and apply the necessary measures regarding revising the company's control by knowing the essential and influential factors of bankruptcy. This research determined financial ratios and macroeconomic variables affecting bankruptcy, helplessness, and financial recovery for the first time in Iran using theoretical and expert analysis. According to Black-Scholes asset pricing models, which emphasize the intrinsic value of liabilities and assets, bankrupt and non-bankrupt companies were distinguished. In addition, the financial factors affecting bankruptcy were explained by fitting logistic regression models to prevent financial crises and eventual bankruptcy of listed companies by identifying these factors. For this purpose, financial ratios were first made independent of each other through principal component analysis. Then, the main components affecting bankruptcy were identified under logistic regression models, and finally, the final logistic model was presented to predict bankruptcy. Moreover, the analysis of multilayer artificial neural networks was used to evaluate the reliability of the results in detecting the factors affecting bankruptcy and to prioritize the importance of these factors through this analysis, and the following findings were obtained:

The normalized coefficients of their importance were used in the artificial neural network analysis to measure the importance of each of the main components in predicting the bankruptcy of companies. Based on the results, the least important factor in determining the bankruptcy of companies was the ratio of capital to the company's net profit. The profit ratio before interest and taxes to the company's total assets was the most important. The company's bankruptcy risk can be reduced with the right policy in line with the management of each of these ratios.

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