The Research of SME Financial Crisis Warning Model Based on Neural Network

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Abstract. SMEs (Small and medium-sized enterprises), as an important part of national economy in our country, play an irreplaceable role. With the development of the economy, SMEs are facing both opportunities and fierce competition. Compared with the mature companies, SMEs have their own features, such as the weakness of the ability of resisting risk, the lacking of capital, deficiency in the ability to raise funds and etc. Therefore, in the complex environment, a more suitable financial risk early warning system is needed. In this paper, such a financial crisis early warning model of SMEs was established, focusing on the characteristics of the SMEs, selecting the data from the SMEs listed in the stock markets in Shanghai and Shenzhen from 2011 to 2015 as samples, choosing 13 financial index input values, finally using the neural network tool in Matlab 2012b. The result displayed that the model is suitable for SMEs, and the accuracy is high.

Introduction

SMEs play an important role in our country national economy, which have made the tremendous contribution for our country's rapid economic development, created a large number of employment opportunities. However, with the continuous development of economic globalization, the SMEs are facing the opportunities and the intense competition at the same time. Compared with the mature large companies, the SMEs have their own characteristics, such as the weakness to resist the management risk, the lacking of capital, the poor ability to raise funds and etc. All these characteristics make the SMEs easier to fall into financial crisis. According to the U.S. ‘fortune’ magazine, the relevant data showed that the expectation of SMEs’ life were less than seven years. Some other data told us that the expectation of SMEs’ lifespan in our country was only 2.9 years. According to what has been discussed above, in order to avoid the SMEs fall into the financial crisis and collapsed, it is very necessary to set up a financial crisis warning for the SMEs.

The financial crisis refers to the enterprise loss of ability to repay their matured debt. Once the financial crisis or bankruptcy happens, it will cause the huge loss, unemployment and the failure of debt recovery, thus directly affecting the country's economic development and social stability. So it is essential to become aware of the financial crisis as early as possible and take the necessary measures to intervene. Financial crisis warning system is the mechanism to discover and resolve the financial crisis. The common methods are mainly qualitative analysis and quantitative analysis of two kinds. Dalkey and Helmar from the Rand Corporation proposed the Delphi method in 1964, known as the expert investigation method, is the most widely used method of qualitative analysis [1]. Beaver is the founder of the modern financial crisis early warning. He is the first one to use the statistical analysis method, with univariate analysis to construct financial crisis early warning model [2]. Beaver pointed out that the security of debt and the asset-liability ratio is important index to judge whether a company is in the financial crisis, the closer to the failures, the lower the error rate would be. Followed by an American scholar Altman, who used the "operating assets/total assets" and the "retained earnings/total assets" and other five indicators to establish a multivariate model named Z-score method [3]. Martin used the logit model to establish the financial crisis early warning model firstly [4].
With the development of data mining technology, some scholars also began to use data mining technology in financial crisis early warning. Odom and Sharda adopted Altman’s five financial indicators, selecting 65 normal companies and 65 failed companies as samples, to establish the early warning model of neural network [5]. Sung, Chang and Lee proved that, in the changing economic environment, using model based on inductive rules method to predict bankruptcy can be more accurately than using multiple discriminant analysis model [6]. Myoung-Jong Kim and Ingoo Han analyzed the advantages of using the genetic algorithm to predict bankruptcy [7]. In addition to the above methods, Frydman used the decision tree theory [8], Elmer and Borrowsk used expert system [9], Dimitras used rough set theory [10], Zopounidis used multicriteria decision theory [11]. They all built the financial risk warning model respectively. Feng Yu Lin and Sally McClean used data mining method to warn the early financial risk basing on four independent methods (Discriminant analysis, Logistic regression, neural network and decision tree method) [12]. They tried different combinations of these methods, established three hybrid model and made the empirical analysis. The results showed that under the same conditions, mixed model was better than single method.

In our country, financial crisis warning research started relatively late, the scholars mainly use statistical methods to modeling: Wu and Lu established related logistic regression, Fisher discriminant and linear probability model [13]. Liang and Guo combined the logistic model with the random effect, and testified that the model was superior to the traditional logistic model [14]. Xu and Shen proposed an analysis framework combining internal control and financial crisis early warning [15]. Wu proposed the analysis framework embedded stakeholders behavior and two kinds of basic power to influence the enterprise's financial situation as the main object of the financial crisis warning and the related sensitivity analysis method [16]. Li set up a financial crisis early warning model based on the appropriate financial indicators and genetic algorithm [17]. Zhao proposed a model using the concept of enterprise financial risk hierarchy tree model and time series dynamic maintenance [18].

According to the literature review, we can know that although many different method were used to establish the relative model, it is still needed further improvement in the changing environment. In this article, the method based on neural network was used to establish the financial crisis warning model for the SMEs, paying more attention to the characteristics of SMEs growth and risk on the choice of financial index.

**The Theory of Financial Risk**

The financial crisis refers that the enterprise is unable to repay debts, facing difficulties and crisis. It is also known as the financial troubles. The financial crisis is not an accident, but a process of gradual development. It is a certain degree of extreme performance of financial risk. There is two ways to confirm the financial crisis: one is the enterprise bankruptcy. Companies cannot continue to operate in accordance with legal procedures to file for bankruptcy. It is one of the largest financial crisis for the enterprises. Another is that the listed company was special treated or delisted. Continuous losses or low level of shares price will trigger a financial crisis. According to what is mentioned above, we know that the financial crisis has the following characteristics:

**Accumulation:** The financial crisis reflects the financial failure of the internal financing, operation, distribution and a series of business activities in a certain period. Through the accumulation, these mistakes make the latent financial risk into financial crisis.

**Burstiness:** Financial crisis is determined by many subjective and objective factors. Some of the factors can be controlled, but some are explosive.

**Diversity:** Financial crisis is not the result of one single incident, but the comprehensive influence of multiple events.

**Catastrophic:** Whether enterprise bankruptcy or special treatment of a listed company, financial crisis will bring disastrous loss.
**Financial Risk and Financial Crisis**

Financial risk is objective existence. In the process of development, enterprise will encounter all sorts of risks. If the enterprise can notice these risks, timely take corresponding measures to resolve the risk, the business will get better development. If the potential financial risk of the enterprise is unable to be discovered or downplayed after noticed, the financial risks will worsen into a financial crisis. Therefore the final result of a neglected financial risk is financial crisis, but not all financial risk will develop into the financial crisis. If companies can pay attention to the financial risk in the primary stage, it can avoid the financial crisis. In different industries, the enterprises have different financial risk and financial crisis. It requires that enterprise should objectively evaluate the enterprise's financial position, to ensure a healthy enterprise financial operation smoothly. In this paper, the SMEs have their unique risk, when choosing relevant indicators should be especially considered.

**The Neural Network and its Algorithm**

Artificial neural networks (ANNs) is a mathematical model for distributing parallel algorithm of information processing, which imitates animal neural network characteristics. The network depends on adjustment of the internal relations between large amounts of nodes connected in the complex system to achieve the purpose of processing information. And it also has the ability of self-learning and adaptive.

Multilayer feed-forward Network is a common neural network structure. It mainly consists of three parts: input layer, output layer and hidden layer. Multilayer feed-forward Network is a common neural network structure. It mainly consists of three parts: input layer, output layer and hidden layer.

Input layer is the neurons which are used to accept large nonlinear input information called the input vectors.

Output layer is the result from the information transmission, analysis and trade-offs in the neuronal links. It is also called the output vectors.

Hidden layer is composed of huge amount of the neurons between the input and output layer. The amount of hidden layer nodes (neurons) is not fixed, but what we can know is that the more the neurons, the more significant the neural network nonlinear and the robustness of the neural network will be. It is accustomed to use t 1.2 to 1.5 times of the amount of input layer nodes as the amount of nodes in the hidden layer. The Fig.1 is the basic structure of the neural networks:

![Figure 1. The basic structure of the neural networks.](image)

The characteristics and the advantages of the neural network is mainly manifested in three aspects: Self-learning function which has special important meaning for predicting. Associating storage function which can achieved by the feedback network. The ability to search the optimal solution at a high speed which can give a full play to the computer's high speed operational advantage.

Based on the advantages stated above, this article used the neural networks method to finish the data training, in order to establish the financial crisis warning model for the SMEs.
Modeling

Sample Selection
In this article, we chose the sample companies with the ST sign, which means the companies were special treated because of loss in the past two years, defined them as the ones in the financial crisis. The others were defined as the ones without financial crisis. We selected 748 companies from the SMEs listed in the stock markets in Shanghai and Shenzhen from 2011 to 2015 as samples, 70% of them were training set, 15% of them were testing set, 15% of them were examining set.

Due to the two consecutive years of loss, a company would be special treated in the third accounting year. For the reliability and accuracy of the result, the data in the first three year (year t-3) should be selected to predict whether the company would be special treated in this year (year t). For example, in order to predict whether a company would be special treated in 2015, its related data in 2012 to 2014 should be tested. All the data in this article were from sina.com and CSMAR database.

Financial Index Selection
Considering the characteristics of SMEs, we paid attention to both traditional financial index and the untraditional index which not only reflect the debt paying ability but also the level of the risk and the growth ability. After screening, 13 index which are listed below in Table 1 are picked out to be the model index. The index of debt paying ability show the situation of liabilities and assets can pay for it. If the liability proportion is too high, the company is in the high risk. The second row show the operation ability and the third row is the ability to profit. If a company has a high ratio in this two parts, it means that the company has more capacity to face the risk. The forth row show the financial risk and the operation risk and the last row show the ability of growth. Compared with the big enterprise, the risk of SMEs and the growth ability are more influential.

<table>
<thead>
<tr>
<th>Ability</th>
<th>Index</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debt paying ability</td>
<td>1. Current ratio</td>
<td>=Current Assets/Current Liabilities</td>
</tr>
<tr>
<td></td>
<td>2. Asset-liability ratio</td>
<td>=Total Liabilities/Total Assets</td>
</tr>
<tr>
<td></td>
<td>3. Cash flow of the debt ratio</td>
<td>=Operating activities net cash flow / Total Liabilities</td>
</tr>
<tr>
<td></td>
<td>4. Time interest earned ratio</td>
<td>=EBIT/Interest cost</td>
</tr>
<tr>
<td>operation capacity</td>
<td>5. Current asset turnover</td>
<td>=Sales Revenue / Current assets ending balance</td>
</tr>
<tr>
<td></td>
<td>6. Inventory turnover</td>
<td>=COGS/ Average inventory balance</td>
</tr>
<tr>
<td></td>
<td>7. Accounts receivable turnover</td>
<td>=Credit sales revenue /Average Accounts Receivable balance</td>
</tr>
<tr>
<td>profitability</td>
<td>8. Return on Sales</td>
<td>=Selling profit/ Sales Revenue</td>
</tr>
<tr>
<td></td>
<td>9. Return on assets(ROA)</td>
<td>=Net profit/Total Assets</td>
</tr>
<tr>
<td>The level of risk</td>
<td>10. Degree of operating leverage (DOL)</td>
<td>=(Net profit + income tax expense +Finance expense+ Depreciation and amortization) /(Net profit + income tax expense +Finance expense)</td>
</tr>
<tr>
<td></td>
<td>11. Degree of financing leverage (DFL)</td>
<td>=(Net profit + income tax expense +Finance expense) /(Net profit + income tax expense)</td>
</tr>
<tr>
<td>Growth ability</td>
<td>12. Growth of ROE</td>
<td>=(The final return on equity - The initial return on equity)/The initial return on equity</td>
</tr>
<tr>
<td></td>
<td>13. Growth of Sales</td>
<td>=(The final sales revenue - The initial sales revenue)/The initial sales revenue</td>
</tr>
</tbody>
</table>

Part of the data were shown in Table 2:
Table 2. Part of the data of Samples.

<table>
<thead>
<tr>
<th>Stock Code</th>
<th>Date Due</th>
<th>Current ratio X1</th>
<th>Asset-liability ratio X2</th>
<th>Cash flow of the debt ratio X3</th>
<th>Time interest earned ratio X4</th>
<th>Current asset turnover X5</th>
<th>Inventory turnover X6</th>
<th>Accounts receivable turnover X7</th>
<th>Return on Sales X8</th>
<th>ROA X9</th>
<th>DOL X10</th>
<th>DFL X11</th>
<th>Growth of ROE X12</th>
<th>Growth of Sales X13</th>
</tr>
</thead>
<tbody>
<tr>
<td>002001</td>
<td>2014-12-31</td>
<td>2.7052</td>
<td>0.2311</td>
<td>0.5537</td>
<td>14.4366</td>
<td>0.7894</td>
<td>2.0123</td>
<td>4.9926</td>
<td>0.1940</td>
<td>0.0951</td>
<td>1.3216</td>
<td>1.0591</td>
<td>-0.4268</td>
<td>-0.2628</td>
</tr>
<tr>
<td>002002</td>
<td>2014-12-31</td>
<td>0.5241</td>
<td>0.7093</td>
<td>-0.0210</td>
<td>3.4149</td>
<td>1.3465</td>
<td>9.1750</td>
<td>7.2047</td>
<td>0.1044</td>
<td>0.0503</td>
<td>1.2959</td>
<td>1.3349</td>
<td>-0.3368</td>
<td>-0.1756</td>
</tr>
<tr>
<td>002003</td>
<td>2014-12-31</td>
<td>2.8935</td>
<td>0.1513</td>
<td>1.0329</td>
<td>116.7786</td>
<td>1.9890</td>
<td>5.5871</td>
<td>10.2188</td>
<td>0.0503</td>
<td>0.1086</td>
<td>1.3752</td>
<td>1.0065</td>
<td>-0.5305</td>
<td>-0.5444</td>
</tr>
</tbody>
</table>

Note: the data are from CSMAR database

The Normalized Processing of Index

As we all know, the index mentioned above described the SMEs from different angles with different dimensions. This will cause the problem to compare them with each other. So before the neural network training, all the original data should be normalized to eliminate the influence caused by different dimensions. There are many methods to normalize. According to the peculiarity of the selected index, the linear dimensionless method was selected which was shown as follows:

To the index which is the less the better: Let the minimum to be 1 and the maximum to be 0. The other index score = (current value - maximum) / (minimum - maximum).

To the index which is the larger the better: Let the maximum to be 1 and the minimum to be 0. The other index score = (current value - minimum) / (maximum - minimum).

The Structure of Network and Parameter Setting

The theory of Kolmogrov has been proved that a neural network, having three layers of the neuron, can approximate any continuous function as long as there are enough hidden nodes. So our model uses the neural network with three layers of the neuron.

The index in Table 1 will be used in the SME financial crisis warning model, so the amount of the input layer neurons is 13. The output is our evaluation of financial crisis situation of SMEs, therefore, the output value is 1 or 0. The amount of the output layer neurons is 2, which represent the possibility of ‘in the financial crisis’ and ‘out of the financial crisis’. When the output is close to 1 means the possibility is high. When the output is 0 means possibility is low. The amount of the neurons in the hidden layer is very important. It not only has a great influence on the performance of the neural network, but also the reason of over-fitness. But until now, there is not a scientific method to determine it, so in this article we use ‘the trial and error method’ to determine that the amount of the hidden layer neurons for 7.

In conclusion, the structure of the neural network for SME financial crisis warning is 13*7*2, the initial value of the weights and threshold of each layer is a random number between 0 and 1.

The Training Process of the Model

In this article, the input value and output value of the hidden layer and output layer were calculated by using S-shaped function. The input of the hidden layer is showed as Eq(1). The output of the hidden layer is showed as Eq(2).

\[ S_j = \sum_{i=1}^{n} \omega_{ij} x_j - \theta_j \]  \hspace{1cm} (1)
\( O_j = \frac{1}{1+e^{-5k}} \) \hspace{1cm} (2)

\( o_{ij} \) is the connection weight between the input layer neuron i and the hidden layer neuron j. All the \( o_{ij} \) make up a weight matrix W. \( \theta_j \) is the threshold of the value of neuron j in the hidden layers, \( S_j \) is the input value of the hidden layer, and \( O_j \) is the output value of the hidden layer.

The input value to the output layer is showed as Eq(3), the output value is showed as Eq(4).

\[
S_k = \sum_{i=1}^{n} u_{jk} O_j - \theta_k
\]

\[ Y_j = \frac{1}{1+e^{-5k}} \] \hspace{1cm} (3)

\( \theta_j \) is the threshold of the value of neuron j in the hidden layers, \( S_j \) is the input value of the hidden layer, and \( Y_j \) is the output value of the hidden layer.

We defined the difference between the output value from the neural network and the actual result from the samples as the corresponding measure error \( E_r \). All the \( E_r \) make up an error matrix E.

\[
E_r = \frac{1}{2} \sum_{k=1}^{r} (T_k - Y_k)^2
\]

\[
E = \frac{1}{r} \sum E_r
\] \hspace{1cm} (5)

Then the model recalculated and amend the connection weight \( o_{ij} \) and \( u_{jk} \) from the output layer to the input layer. The formula are mentioned as follows.

\[
o_{ij} (P+1) = o_{ij} (P) + \eta \delta_j O_j + \alpha(o_{ij} (P) - o_{ij} (P-1))
\]

\[
u_{jk} (P+1) = u_{jk} (P) + \eta \delta_k O_k + \alpha(u_{jk} (P) - u_{jk} (P-1))
\] \hspace{1cm} (8)

\[
0 < \alpha < 1, 0 < \eta < 1
\]

In this formula \( \delta_j \), \( \delta_k \) is showed as below:

\[
\delta_j = O_j (1-O_j) \sum_{k=0}^{m} \delta_k o_{kj}
\]

\[
\delta_k = Y_k (1-Y_k) (T_k - Y_k)
\] \hspace{1cm} (10)

\( T_i \) is the expectation of whether the sample company is in the financial crisis. \( o_{jk} (P) \) represents the connection weight between the output neuron k and the hidden layer neuron j at the Pth time. The momentum factor \( \alpha \) can control the learning speed and performance of the model. After multiple iterations, the neural network self-training would be ended, when the error matrix E is lower than the given error \( \varepsilon \), otherwise the network would be continue to self-training.
Experimental Results and Analysis

From the above part of the paper, we know that the amount of the output layer neurons is 2, which represent the possibility of ‘in the financial crisis’ and ‘out of the financial crisis’. When the output is close to 1 means the possibility is high. When the output is 0 means possibility is low. For example, when the output is (0.9,0.1), it means the possibility of ‘in the financial crisis’ is 90% and the possibility of ‘out of the financial crisis’ is 10%. So the model will affirm this company has the problem of financial crisis. We selected 748 companies from the SMEs listed in the stock markets in Shanghai and Shenzhen from 2011 to 2015 as samples, chose the index in Table 1 and had the normalized processing, then, utilized the tool box in the MATLAB R2012b to train the model and finally get the results showed in Table 3. (The training process are showed in Fig.2)

![Figure 2. The neural network training process.](image)

<table>
<thead>
<tr>
<th>Schedule</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual in financial crisis, classified as having crisis by the model</td>
<td>50.9%</td>
<td>57.4%</td>
<td>58.1%</td>
<td>64.6%</td>
<td>64.9%</td>
</tr>
<tr>
<td>Actual out of financial crisis, classified as not having crisis by the model</td>
<td>32.3%</td>
<td>29.7%</td>
<td>30.3%</td>
<td>29.8%</td>
<td>30.3%</td>
</tr>
<tr>
<td>Total</td>
<td>83.2%</td>
<td>87.1%</td>
<td>88.4%</td>
<td>94.4%</td>
<td>95.2%</td>
</tr>
</tbody>
</table>

The second line in Table 3 showed us that the proportion of the companies which was classified as having financial crisis and actually were in the financial crisis. The third line in Table 3 showed us that the proportion of the companies which was classified as not having financial crisis and actually were not in the financial crisis. The total proportion of these was the accuracy of the model. From forth line of Table 3, we can see that after being trained by the neural network, the prediction accuracy was higher than 80%, and the closer to the forecast year, the higher the accuracy was. Furthermore, from the result of Matlab training, the MSE of the training set, the testing set and the examining sets are 2.16e-2, 1.119e-2 and 1.906e-2. As we all known, the smaller MSE means the higher prediction accuracy. Therefore, it is considered that the training got a good result.

At last, using the ‘ST Yuanda’ (Stock Code: 002417) as an example, which was specially treated in 2014, to show how it works. The relative data in 2011 was showed as follow:

X1=1.9230, X2=0.4466, X3=-0.1705, X4=29.6043, X5=0.5392, X6=0.9818, X7=1.6787, X8=0.0401, X9=0.0838, X10=1.2581, X11=1.0309, X12=0.3399, X13=-0.2091, put them as the input value into the model, the output is(0.9963,0.0027), which means the possibility of ‘in the risk’ is 0.9963, and the possibility of ‘out of risk’ is 0.0027. Comparing the output in the both situation, the model predicted the company would have a financial crisis in 2014. The result is right. Fig.3 showed the process in which the neural network works.
Conclusion
In this article, a SME financial crisis warning model has been established. In the model, 13 financial index were selected as the input value which show the SMEs’ financial abilities such as debt paying ability, operation capacity, profitability, the level of risk and their growth ability. The Matlab2012b was used to establish and train the neural network, the results indicated that the closer to the forecast year, the higher the accuracy is. We used the company ‘ST Yuanda’ as an example to show the predicting process. We can know that due to the self-learning and the nonlinear processing capacity of neural network, our financial crisis early warning model has a higher accuracy.

However, with the continuous development of economic globalization, the environment is constantly changing. The model still need more practice to fit the changing business environment, in order to make more accurate judgment.

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