Research Article

Dynamic Early Warning Method of Multiclassification Financial Crisis of Listed Companies Based on Particle Swarm Optimization

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In the Internet plus era, the environment of the world’s economy is changing towards globalization and information. The development of Chinese enterprises is facing hitherto unknown opportunities. Meanwhile, the financial risks facing enterprises are increasing day by day, because the constraints of environmental factors, economic and market factors, laws and regulations, social and cultural factors, policy environmental factors, and other unpredictable environmental factors have brought uncertainty to the financial situation of enterprises. The way a company handles its own financial risk has a big impact on its overall success. Many enterprises fall into economic crisis early because they do not pay enough attention to financial problems in the early stages and do not take effective measures to deal with the crisis situation in a timely manner, resulting in internal management confusion, deterioration of the external environment, capital chain problems, and serious asset losses. It is difficult to recover, and individuals who are experiencing a more significant financial crisis are at risk of becoming bankrupt. As a result, the success or failure of an enterprise’s early development is determined by the success or failure of its subsequent development. As a result, in order to devote more resources to the study of enterprise financial risk, this paper develops a variety of dynamic early warning models of financial crises in publicly traded companies by analyzing relevant theories of financial risk and combining the particle swarm optimization algorithm. This model has great efficiency and scientific early warning capabilities, and it can better forecast business financial crises.

1. Introduction

In the era of “Internet plus,” information technology develops rapidly, and the world economy is becoming more and more globalization and informationalized. The environment of production and operation is changing rapidly, and opportunities and challenges coexist. As the most dynamic economy in the world, the continuous improvement of the level of scientific and technological development and the continuous deepening of economic reform have made China’s market economy maintain a healthy and stable development trend [1–3]. Chinese firms are confronted with extraordinary prospects, but they are also hampered by a variety of environmental variables, including economic and market factors, rules and regulations, and social and cultural issues. Policy and environmental issues, as well as other financial risks, are all unexpected. Environmental issues have added unpredictability to businesses’ financial situations, and the financial risks they confront are growing day by day. The global economic situation is now gloomy, and many businesses have yet to recover from the effects of the financial crisis [4]. The external environment is worsening, internal management is chaotic, asset losses are significant, capital chain issues exist, and the financial position is particularly concerning. The general growth of businesses is inextricably linked to how they handle their own financial crises. Because they do not pay enough attention to early financial issues and adopt timely and effective actions to deal with the crisis, most firms face major financial crises or even bankruptcy in the later stages, which is particularly adverse to the future growth of enterprises [5, 6]. Therefore, many enterprises and relevant research institutions began to study the financial risk of enterprises. Among them, a key research direction of securities market investment
and practice research is the financial risk prediction of listed companies.

After a period of development, the development mechanism of foreign capital market is more standardized and perfect than that of domestic capital market, and the relevant research results are also more fruitful. According to incomplete statistics, foreign scholars began to study the financial crisis of enterprises in the 20th century [7]. Combined with the development of science and technology, foreign scholars have put forward discriminant analysis model, conditional probability model, and survival analysis model for the research of enterprise financial risk. These research results have been widely used in listed enterprises and achieved remarkable results.

Fitzpatrick was the first to explore the univariate early warning model using a single financial indicator. Several bankrupt and nonbankrupt firms are among the study subjects. He looked at the financial indicators of both sorts of businesses. The findings suggest that the property right ratio and net equity interest rate best reflect the company’s financial status among the financial indicators analyzed. However, owing to a lack of applicable theories at the time, the study was only able to reach the statistical description stage [8]. On the basis of predecessors, Beaver increased the data amount of the study sample. To begin, he examined the research company’s financial indicators, selecting five variables with various eigenvalues from 30 financial indicators and predicting the company’s financial risk level. The financial ratio of total liabilities of cash flow to total assets of net profit was discovered to be a better predictor of a company’s financial crisis. Furthermore, different financial indicators predict different aspects, laying the groundwork for the development of multivariable prediction methods. Professor Altman was one of the first to use the discriminant approach to his research. He created two control groups, a bankrupt group and a nonbankrupt group, with the same number of participants as the study samples, and analyzed the company’s financial index data using the scoring model (i.e., Z-score model) in the multivariate discriminant analysis approach [9]. The linear weighting of the chosen financial index data is one of them, and the discriminant value (Z-value) is one of them.

Dai Fang used the traditional wall scoring method to combine the selected financial ratios according to the linear relationship and gave them, respectively, in their respective proportion [10]. At the same time, he compared them with the standard ratio and evaluated the enterprise credit value on the basis of determining the score of each index and the cumulative score of the overall index. Domestic scholars Hong et al. [11] optimized the classical scoring model and applied the improved Z value model to the financial risk prediction of transportation enterprises. The research found that the ratio of net cash flow to current liabilities can better reflect the degree of financial risk of enterprises.

At present, according to a large number of research data, the stable development and healthy growth of enterprises in the future are very important, so we will measure the indicators of enterprise operation according to the overall financial situation of enterprises [12, 13]. In order to ensure the current business decision-making and operation management of an enterprise, the healthy operation of an enterprise should be maintained according to various factors such as good financial situation and operation results. Because the operation and management of each enterprise will exist in financial risk, most enterprises will have financial crisis if the financial risk level exceeds the warning value due to some poor management or wrong decision-making [14–18].

At present, according to a large number of research data, the stable development and healthy growth of enterprises in the future are very important, so we will measure the indicators of enterprise operation according to the overall financial situation of enterprises. In order to ensure the current business decision-making and operation management of an enterprise, the healthy operation of an enterprise should be maintained according to various factors such as good financial situation and operation results [19–21]. Because each enterprise’s operation and management are subject to financial risk, most businesses will experience a financial crisis if the financial risk level surpasses the warning value as a result of bad management or poor decision-making. In general, the operation and financial condition of businesses may accurately represent the current state of business financial crises. As a result, it may be assumed that the financial risk of the company can be studied and anticipated to some degree based on the organization’s overall operations. As a result, researchers and research institutes may use the predictability of company financial risk as a theoretical foundation. The business environment that businesses encounter is getting more complicated and changing as economic globalization deepens. Risk prediction is becoming an increasingly crucial aspect of company management and development planning in order to preserve long-term growth [23, 24]. Scientific and reasonable financial risk prediction can effectively represent the current state of firm development and assist organizations adapt financial risks in time, based on past development experience to ensure that businesses expand in a steady and efficient manner.

2. Particle Swarm Optimization Algorithm

In the 1990s, American scholars James Kennedy and Russell Eberhart analyzed and studied the group behavior of birds and proposed particle swarm optimization algorithm [25, 26]. The so-called particle swarm optimization algorithm introduces the concepts of “population” and “evolution” according to the fitness value and retrograde operation of individuals in the population. The characteristic of particle swarm optimization algorithm is to treat each individual in the population as a “particle” without mass and volume in multidimensional space, which flies at a certain speed in multidimensional space. Flight speed is not blind but dynamically adjusted according to individual flight experience and group flight experience [27, 28].

Set \( X_i = (x_{i1}, x_{i2}, \ldots, x_{im}) \) as the current position of particle \( I \), \( V_i = (v_{i1}, v_{i2}, \ldots, v_{im}) \) as the current flight speed of particle \( I \), and \( P_i = (p_{i1}, p_{i2}, \ldots, p_{im}) \) as the best position experienced by particle \( I \), that is, the position with the best fitness value experienced by particle \( I \), which is called the best position of the individual. For the minimization problem, the smaller the value of the objective function, the better the corresponding fitness value.
Table 1: Financial risk indicators.

| Category             | Number | Indicator name                      |
|----------------------|--------|-------------------------------------|
| Short-term liquidity | A1     | Current ratio                       |
|                      | A2     | Quick ratio                         |
|                      | A3     | Cash ratio                          |
|                      | A4     | Asset liability ratio               |
| Long-term solvency   | A5     | Equity to liability ratio           |
|                      | A6     | Inventory turnover                  |
| Operational capacity | A7     | Turnover rate of accounts receivable|
|                      | A8     | Total asset turnover                |
|                      | A9     | Return on assets                    |
| Profitability        | A10    | Operating profit margin             |
|                      | A11    | Cost profit margin                  |
|                      | A12    | Growth rate of total assets         |
| Growth ability       | A13    | Net profit growth rate              |
|                      | A14    | Growth rate of operating profit     |

Figure 1: Process of building enterprise financial risk early warning model with particle swarm optimization algorithm.
described as the basic particle swarm optimization algorithm can be
seen that the global best position. In order to reduce the possibility of particles leaving the search space in the process of evolution, \( v_{ij} \) is usually limited to a certain range; that is, \( v_{ij} \in [-v_{\text{max}}, v_{\text{max}}] \). If the search space of the problem is limited \([-x_{\text{max}}, x_{\text{max}}]\), it can be set as \( v_{\text{max}} = kx_{\text{max}} \).

The specific implementation steps of particle swarm optimization algorithm mainly include the following:

1. Set the population size of particle swarm to \( n \)
2. For \( x_{ij} \) any oral administration, it is uniformly distributed \([-x_{\text{max}}, x_{\text{max}}]\), where \( I \) and \( j \) are arbitrary values
3. For any \( v_{ij} \) oral administration, it is uniformly distributed \([-v_{\text{max}}, v_{\text{max}}]\), where \( I \) and \( j \) are arbitrary values
4. Let \( y_i = x_i \) and \( I \) be any value

The following four stages are used to carry out the particular steps of the particle swarm optimization algorithm:

1. Determine each particle’s fitness value in the population in space
2. The fitness value of each particle in the population’s current position in space is compared to the fitness value of the particle’s global experience position. If the present position’s fitness value is higher than the global experience position’s, the point’s position is considered the global best position
3. Compare the fitness value of each particle’s present location in space in the population with the particle’s

Here, let \( f(x) \) be the objective function of minimization. Then, the current best position of particle \( I \) is determined by the following formula:

\[
P_i(t+1) = \begin{cases} P_i(t), & f(X_i(t+1)) \geq f(P_i(t)), \\ X_i(t+1), & f(X_i(t+1)) < f(P_i(t)). \end{cases}
\]

Let the number of particles in the group be \( s \) and the best position experienced by all particles in the group be \( P_g(t) \), which is called the global best position, then

\[
P_g(t) \in \{ P_0(t), P_1(t), \ldots, P_n(t) \} \mid f(P_g(t)) = \min \{ P_0(t), P_1(t), \ldots, P_n(t) \}. \]

Based on the above definition, the evolution equation of the basic particle swarm optimization algorithm can be described as

\[
v_{ij}(t+1) = v_{ij}(t) + c_1r_1(t)[P_{ij}(t) - x_{ij}(t)] + c_2r_2(t)[P_g(t) - x_{ij}(t)],
\]

\[
x_{ij}(t+1) = x_{ij}(t) + v_{ij}(t+1).
\]

From the above particle evolution equation, it can be seen that \( c_1 \) is the step of adjusting the particle to its own best position and \( c_2 \) is the step of adjusting the particle to the global best position. In order to reduce the possibility

```csharp
public void particle_swarm_optimization (TextBox textbox, panel p, int n)
{
    List<List<double>> w = new List<List<double>>();
    Random r = new Random();
    for (int i = 0; i < n; i++)
    {
        double t = r.NextDouble() - 0.5;
        double z = 0.18;
        List<double> vij = new List<double>(){ -2 * t, -3 * t, r.Next(1000) * t};
        double step = 0.2;
        List<double> f = new List<double>();
        List<double> L = new List<double>();
        List<double> G = new List<double>();
        List<int> I = new List<int>();
        int g = 20;
        for (int i = 0; i < w.Count; i++)
        {
            w[i] = Particle Swarm iterates over a particle(w[i], G, L[i], step);
            f[i] = Seeking fitness(w[i], w[i], w[i]);
        }
        j = test(f, z);
        draw(textbox, p, x, w, j);
        Thread.Sleep(50);
        count++;
    }
}
```

**Code 1:** Public void particle swarm optimization (TextBox textbox, panel p, int n).
global best position. The location of the point is considered the global best position if the fitness value of the present position is higher than the fitness value of the global best position.

(4) Determine if the particles match the aforementioned requirements. Set the location of each particle’s starting velocity if fulfilled.

3. Selection of Financial Indicators

Looking at the research results of many scholars at home and abroad, we cannot help but see that there is no fixed method and basis for the selection of financial risk prediction model indicators. This paper designs financial risk indicators based on relevant theories, combined with the summary of the previous literature and the characteristics of listed companies in China, and preliminarily selects various indicators, as shown in Table 1:

(1) Solvency index: the initial assets of an enterprise are mainly composed of the invested assets of investors and the borrowed assets of creditors. The enterprise needs to be responsible for the legitimate interests of creditors. Whether it can have sufficient funds or goods within a limited time range is very important to repay the loans of creditors. When evaluating the financial situation and operating results of an enterprise, the solvency of the enterprise is often taken as an important consideration. Good solvency helps to enhance the confidence of creditors and promote the sustainable and healthy development of the enterprise.

(2) Operation ability index: enterprise managers improve the production efficiency of enterprises by using less asset ratio, have a higher market share, realize the rapid turnover of internal funds, and create a higher income level. This enterprise operation mode is called operation ability, which is an important index to evaluate the degree of financial risk of enterprises. Strengthening the improvement of their own operation ability can not only bring more substantive benefits to the enterprise but also improve the overall management level, avoid resource waste, and realize the optimal allocation. The specific evaluation indicators of operating capacity include inventory turnover rate, fixed assets turnover rate, total assets turnover rate, and accounts receivable turnover rate.

(3) Index of profitability: profitability is the most direct expression of an organization's operational outcomes, which is represented in a variety of financial indicators. Internal managers, as well as external investors and creditors, pay close attention to the profitability of the enterprise in order to ensure that the enterprise has good profitability, which is conducive to increasing investor, creditor, and market confidence in the enterprise and is more conducive to the enterprise’s future sustainable, stable, and healthy development. The rate of return on total assets is one of the particular profitability measures. Earnings per share, net assets per share, return on net assets, expense profit margin, and other financial metrics are all important.

(4) When analyzing the financial risk degree of an enterprise, the growth ability index will fully consider the sustainable growth ability of the enterprise. If the enterprise is small in scale but has great development potential in the future, it can also attract many investors to invest capital in this type of enterprise. For example, the gem in the stock market exists for those startups with good development momentum. Investors' confidence in the future development of the enterprise will help the enterprise absorb a large amount of capital and improve the overall business scale and management level.

4. Build Enterprise Financial Risk Early Warning Model Based on Particle Swarm Optimization Algorithm

4.1. Construction Steps. The following are the essential processes in creating an enterprise financial risk early warning model based on the particle swarm optimization algorithm:
4.1.1. Research the Sample Data Standardisation Procedure. The numerical size and dimension of the input data are typically different as the study sample data at the input of the model; thus, the data must be preprocessed before network training. The normalisation technique is the most widely used data standardisation processing method, which converts all data into numbers between [0,1], eliminating the amount value discrepancy of various orders between dimensional data. The maximum and minimum methods are the most often used data normalisation methods. The following is the formula:

\[
x_i = \frac{x_i - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}},
\]

where \(x_{\text{min}}\) is the minimum value of sample data and \(x_{\text{max}}\) is the maximum value of sample data.

4.1.2. Initialize the Position and Velocity of Each Particle. Initialize each particle in the particle swarm as a random number between [0,1].

4.1.3. Calculate the Fitness Value of Each Particle. The purpose of calculating particle fitness value is to find the individual extreme value and global optimal extreme value of each particle in the population. In the actual operation process, combined with the real experimental environment and requirements, the population size is set, and the particle position and velocity are initialized. After the above operations, the fitness value of each particle in the population is calculated.

4.1.4. Update the Speed and Position of Each Particle. In each iteration, the particle updates its speed and position through individual extremum and global extremum.

4.1.5. Update Individual Extremum and Group Extremum. First, determine if the present value is superior before following the new individual and group extreme value. The comparison of the individual fitness value of particles in the group to the individual fitness value before iteration serves as the judgement foundation. If the current value is higher, the individual’s present position becomes the extreme value. Aside from that, the existing situation stays unaltered. At the same time, for the global extreme value, if the particle’s current fitness value is the target group’s global optimal fitness value, and the particle’s current position is considered the group’s global extreme value, we can conclude that the particle’s current fitness value is better than the group’s global optimal fitness value.

4.1.6. End Iteration. The process of building enterprise financial risk early warning model with particle swarm optimization algorithm is shown in Figure 1.

4.2. Code Implementation. The core code is as follows:

4.3. Sample Test Results. Using the above particle swarm optimization code and training the sample set, the optimal solution of parameter weight is 10.30, 1.37, 5.66, and -302.82, and the particle swarm classifier is obtained, as follows:

\[
Y = 10.30 \times \text{return on net assets} + 1.37 \times \text{return on total assets} + 5.66 \times \text{cost profit margin} - 302.5.
\]

The objective function is

\[
z_{\text{min}} = \frac{N_{01} + N_{10}}{N} = 0.372.
\]

4.4. Analysis of Model Results. To offer an intuitive impression of the particle swarm optimization process, set the fitness of the objective function to \(z = 0.18\) and the step size to 0.2 as the standard, and utilise 100 particles to discover the best solution at the same time. Step 1: because the parameters are random, the lines seem jumbled and uninformed, as illustrated in Figure 2. Step 2: as illustrated in Figure 3, all lines will be near to the best direction. Step 3: the closed line makes a nearly straight line. Step 4: as illustrated in Figure 4, the line grows thinner and narrower, eventually approaching a line. Step 5: choose the best option.
The display results of the optimal approach are shown in Figure 3. The display results are shown in Figure 4.

5. Conclusion

In the operation of modern enterprises, a good and stable financial situation is very important for the healthy development of an enterprise. Timely and accurate financial risk prediction can not only serve as a warning to enterprise managers and promote enterprises to improve their operation mode but also help to safeguard the legitimate rights and interests of investors and ensure the orderly operation of the economic market. Following the work of numerous experts both at home and abroad, this study applies artificial neural networks to the subject of financial risk prediction for publicly traded enterprises. This research utilises the particle swarm optimization method to enhance the current enterprise financial risk prediction model and improves the particle swarm optimization technique from two aspects of model input and beginning parameters, in order to make the network structure more streamlined. The prediction model’s accuracy has substantially increased.

Despite the fact that the model provided in this research enhances the accuracy of financial risk prediction, it has a number of flaws: (1) the sample size is too small and unrepresentative. The sample of this paper is the manufacturing companies in China’s listed companies. Due to the possibility of the sample, the financial risk status of small- and medium-sized enterprises is not considered, and the research on different industries is also lacking, so the application of the prediction model has certain limitations. (2) The selection of impact indicators is not comprehensive enough. There are many factors affecting an enterprise’s financial risk level, including financial factors and nonfinancial factors. This paper only studies the financial indicators that can be analyzed quantitatively and ignores the impact of many nonfinancial factors on the enterprise’s financial risk status.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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