Supply Chain Financial Default Risk Early Warning System Based on Particle Swarm Optimization Algorithm

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1. Introduction

At present, with the rapid development of China’s market economy reform and the increasingly fierce competition among enterprises, it is difficult to obtain bank credit under the influence of factors such as business scale, business philosophy, credit rating, and asset management, which directly affects the financing and development of enterprises. With the in-depth promotion of interest rate marketization, the demand of financial institutions for the allocation of various financial assets has increased significantly, and the linkage and risk infectivity among various financial sub-markets have been increasing. At present, China’s economy is under great downward pressure, and the possibility of financial risk exposure and cross market transmission and diffusion is increasing. With the development of supply chain financial business, the supply chain financial network tends to be complex. Supply chain finance essentially belongs to credit guarantee. Once the risk breaks out at any node in the middle, the risk will spread in logistics, capital flow and credit guarantee relationship, resulting in serious credit crisis and economic losses. Therefore, the research on the contagion mechanism of supply chain financial credit risk is particularly important. This paper first analyzes the causes and mechanism of supply chain financial credit risk infection, studies the control strategy of financial market risk cross infection, and then puts forward the corresponding prevention mechanism.

Supply chain finance has also changed the traditional financing mode of small and medium-sized enterprises. For a single enterprise, it is aimed at the whole supply chain, and the most key point in this supply chain is the “1” core enterprise. This core enterprise leads the supply chain from the most upstream raw material procurement, intermediate product production to the final product production and sales, and connects the upstream and downstream
enterprises; suppliers, manufacturers, and retailers are integrated into an organic whole to provide financing or credit enhancement for these “n” small and medium-sized enterprises in an all-round way so as to realize the optimization and upgrading of the whole supply chain and enhance competitiveness.

In supply chain finance, the pledge as guarantee is mostly movable properties such as commercial paper, raw materials, and semifinished products, and the price of these movable properties will change with the change of market supply and demand level. Once the price of the collateral is lower than the market price at the time of mortgage due to the change of price, financial institutions will suffer losses, and supply chain finance will also face market risks.

Although supply chain finance extends credit to small and medium-sized enterprises and core enterprises as a whole, which enhances the ability of commercial banks and other financial institutions to resist credit risk to a certain extent, small and medium-sized enterprises or core enterprises will still be default, and the supply chain financing model will inevitably be affected by credit risk. Moreover, since there is more than one enterprise in the supply chain. The impact of default risk spreads rapidly, so this credit risk is highly contagious.

The study is organized in the following way:

Section 2 studies on supply chain finance and discusses the business model of supply chain finance in different countries. Section 3 examines a logistic model analysis of financial credit risk in supply chain and chooses the sample data and establishes the analysis of the logistic empirical model. Section 4 defines the model regression analysis of model regression. Section 5 is the conclusion of the study.

2. Related Work

Some representative studies on supply chain finance emerged in recent years are as follows: Zhu et al. [1] classify the business model of supply chain finance in China from different angles, analyzed the shortcomings of this business model, and finally proposed to establish a visual platform to innovate the business operation model and risk control model of domestic supply chain finance. Zhang [2] studied the coal power supply chain financing strategy of coal companies with capital constraints and income uncertainty, proposed the prepayment mechanism, obtained the optimal operation strategy of coal companies and power companies under the prepayment mechanism, and compared it with the bank loan financing case. This paper investigates China’s supply chain finance industry, introduces common financial products, points out the shortcomings of China’s supply chain finance development, and provides suggestions to private enterprises and decision makers on how to promote the development of supply chain finance. Bradea and Delcea [3] analyzed a kind of supply chain financial system, mainly discussed two financing methods: direct financing and supply chain financial financing, analyzed two methods of supply chain profit distribution, then deduced the profit distribution mechanism model, and indicated that selecting supply chain financial financing is more beneficial to the supply chain according to the profit function. Jiao et al. [4] elaborated the basic model of supply chain finance, a financial innovation service product, and discussed the risks of supply chain finance. The fuzzy ordered regression support vector machine is used to analyze the supply chain financial risk under the risk assessment index system. The results are not only effective but also the accuracy can be further improved. Fuertes and Kalotychou [5] analyzed the characteristics of supply chain finance, expounded the research and application of block chain technology in the field of supply chain finance in recent years, and summarized and predicted the application of block chain technology in supply chain finance. Lobianco et al. [6] discussed and determined the requirements for improving supply chain financial solutions based on the data collected from technology and service providers focusing on global supply network problems. Tasgetiren et al. [7] designed a supply chain financial simulation model based on Simon’s finite rationality rather than absolute rationality of multiagent simulation technology in order to solve the actual operation problem of simulating the supply chain financial system. This paper simulates the impact of the behavior of banks, small and medium-sized enterprises, and storage companies on the financial credit risk of supply chain, and gives an empirical analysis. Establishing a game model, this paper analyzes the perfect information game and the accounts receivable financing mode of both sides, and forms Nash equilibrium [8]. Through analysis, it is concluded that strengthening the punishment of various violations will help to reduce credit risk and improve the financing level of enterprises [9].

Domestic research on supply chain finance mainly focuses on the field of risk. Representative ones are as follows: Jin and Nadal De Simone [10] summarized the complex risks of supply chain finance into two categories, namely, systematic and nonsystematic risks. Based on the supply chain financial risk assessment, the evaluation index system is constructed and an analytic hierarchy process is applied in the supply chain financial assessment. According to the research results, the systematic risk of supply chain finance is divided into macro and industry systematic risk and supply chain systematic risk, and the nonsystematic risk of supply chain finance is divided into inventory realization risk, operational risk, and credit risk, and the risk evaluation process of supply chain finance is described. Koyuncugil and Ozgulbas [11] studied the credit risk evaluation under the supply chain finance mode and proposed a credit risk evaluation system considering the combination of debt rating and subject rating. Logistic regression and principal component analysis are used to establish a credit risk evaluation model to reduce the limitation that most business evaluation of supply chain finance depends on expert evaluation. By comparing the compliance rate of small and medium-sized enterprises under the traditional bank credit mode and supply chain financial financing mode, it is concluded that supply chain finance has alleviated the financing difficulties of small and medium-sized enterprises to a certain extent, and it is proposed to strengthen the construction of basic customer database, promote the
improvement of existing credit evaluation system, and improve its accuracy. They also [11] analyzed various factors affecting supply chain financial credit risk, selected supply chain financial credit risk evaluation indicators according to 3C theory, and established relevant evaluation systems. Using the fuzzy evaluation method and combining the qualitative evaluation index and quantitative evaluation index, a set of reasonable evaluation index system is established by decomposing the multilevel index of the supply chain financial credit risk system to help banks reduce the credit risk of supply chain finance and promote its healthy development. Mikhail [12] mainly used comparative research and theoretical research methods to deeply analyze the risk elements and model evolution of online supply chain finance. The conclusion is that although online supply chain finance has greatly improved service efficiency and collaborative operation, with the participation of online suppliers and the Internet, the total risk faced by banks has increased. Based on this, suggestions on bank risk control are put forward from five aspects, including strengthening monitoring and early warning, clear definition of rights and responsibilities, strict access conditions, improvement of compensation mechanism, and improvement of operation level. Based on the analysis of risks and manifestations faced by commercial banks’ supply chain finance, Chen and Jin-Shou [13] proposed countermeasures to prevent supply chain financial risks so as to reduce the generation of supply chain financial risks and achieve the goal of sustainable development of commercial banks [14].

3. Logistic Model Analysis of Financial Credit Risk in Supply Chain

Here, we establish a supply chain financial risk assessment index system and usually shows the profitability of a company within a given period of time. We discussed the design of credit risk evaluation index system for supply chain finance. We determine the main methods and comparison of supply chain financial credit risk calculation.

3.1. Design of Credit Risk Evaluation Index System for Supply Chain Finance. This paper draws experience from the previous research results, and combined with the business characteristics of supply chain finance, this paper constructs a supply chain financial risk assessment index system with 17 index variables, including enterprise financial indicators and supply chain operation.

(1) Enterprise financial index profitability refers to the profitability of an enterprise, also known as the value-added ability of a company’s capital. It usually shows the profitability of a company within a given period of time. In this paper, the indicators are return on net assets, net interest rate of total assets, and gross profit margin of sales and net sale rate. Solvency refers to the ability of an enterprise to use its assets to pay long-term and short-term debts. Whether the company is able to provide cash or repay debts is the key to the survival and healthy development of a company. The selection of indicators in this paper is current ratio, quick ratio, cash ratio, and asset liability ratio. The growth ability involves the ability of a company to continue to develop. The selection of indicators in this paper is divided into year-on-year growth rate of earnings per share, year-on-year growth rate of operating profit, and year-on-year growth rate of operating revenue. Operating capacity refers to the role of an enterprise in the realization of financial objectives by establishing the constraints of the external market environment and combining the distribution and reorganization of internal human resources and means of production. The selection of indicators in this paper includes current asset turnover, total asset turnover, inventory turnover, and account receivable turnover.

(2) In the supply chain operation, we select two indicators: the establishment year of the enterprise and the bad debt rate of accountsreceivable to evaluate the operation of the whole supply chain. The bad debt rate of accounts receivable is selected from the bad debt rate of accounts receivable of agricultural listed companies in the current year.

3.2. Main Methods and Comparison of Supply Chain Financial Credit Risk Measurement. The main methods of calculating the credit risk of supply chain finance and related credit evaluation are neural network method, linear programming method, discriminant analysis method, classification tree method, and logistic regression method. To judge the quality of the evaluation method and its model, the classification error rate and the robust analysis of the model should be regarded as the main standard. The robust model is based on the model’s prediction ability for samples outside the sample. The prediction accuracy will not be considerably affected when the robust model predicts samples outside the sample. Nonlinear methods such as the neural network have relatively unique advantages only in terms of prediction accuracy. Although the prediction accuracy of linear scoring methods such as logistic regression, linear programming, and discriminant analysis is lower than that of nonlinear methods such as the neural network, the stability of the model is stronger, and the credit evaluation of supply chain finance may be more important. The prediction ability of a more robust model will be better because the evaluation of supply chain financial credit risk and information asymmetry has a great impact on the results.

In order to obtain more comprehensive results, some accuracy must be sacrificed in exchange for higher robustness of the model, that is, linear scoring methods such as linear programming, logistic regression, and discriminant analysis have better robustness than other methods, which is also the reason why this paper adopts the logistic regression model. However, because the logistic model is sensitive to the multidimensional correlation of independent variables in the model, principal component analysis and cluster
analysis are often used to select representative variables so as to reduce the correlation in sample variables. Therefore, this paper first uses principal component analysis to process the data and then uses logistic regression to calculate the company’s compliance rate.

3.3. Selection of Sample Data. Most authors use the financial data of domestic listed companies as the source of model prediction data. Due to the small scale of many agricultural related small and medium-sized enterprises in the upstream and downstream of the supply chain and imperfect financial management, it is difficult to obtain their data. Therefore, this paper directly selects the financial data of listed companies of agricultural enterprises as the data source of model analysis.

The data sources of this paper are from Wande and Guotai’an databases. The specific data sources are listed companies such as bowling treasure, Beidahuang, Daoquan, and Denghai seed industries. The financial data of each listed company from 2014 to 2016 are selected for analysis. Because not all the above agricultural listed companies can find the bad debt rate of accounts receivable in the three years from 2014 to 2016, and some agricultural listed companies only have relevant data for one or two years, this paper finally forms an unbalanced panel data containing 91 sample sizes.

3.4. Establishment of Logistic Empirical Model. The logistic model assumes that the enterprise’s compliance probability obeys the logistic distribution and sets a series of indicators (X, Kmn) in the supply chain financial credit risk evaluation index system as independent variables. By establishing the logistic regression model, the company’s compliance probability is predicted. When using the logistic model, it is first necessary to determine whether the value of the virtual variable is 0 or 1, and the virtual variable represents an attribute variable; 1 and 0 represent the existence and absence of attributes or states, respectively. Therefore, the prediction of the target condition is transformed into a probability calculation problem when the virtual variable value is 1. In the logistic model, the dependent variable y has only two values, 0 and 1, respectively, of which 1 is compliance and 0 is default. We set the risk tolerance standard P of the agricultural supply chain finance company according to the risk tolerance and compare P with p to determine whether the compliance probability of the cooperative enterprise has reached the standard of cooperation.

The logistic model can be expressed as follows:

\[ \ln \frac{p}{1-p} = g(X_1, X_2, \ldots, X_K) \]  \hspace{1cm} (1)

These K factors X_1, X_2, \ldots, X_K are independent variables of the logistic model, so the logistic regression model can be expressed as

\[ \ln \frac{p}{1-p} = B_0 + B_1X_1 + \ldots + B_KX_K \]  \hspace{1cm} (2)

where B_0, B_1, \ldots, B_K is the unknown parameter to be estimated, which can be obtained by sorting out the above formula:

\[ P = \frac{1}{1 + e^{-(B_0 + B_1X_1 + \ldots + B_KX_K)}} \]  \hspace{1cm} (3)

After sorting out the above formulas, we can get the calculation formula of the enterprise’s compliance probability p as

\[ P = \frac{1}{1 + e^{-(B_0 + B_1X_1 + \ldots + B_KX_K)}} \]  \hspace{1cm} (4)

The logistic equation is an increasing function with a value range of (0, 1). The closer the p value is to 1, the better the company’s credit is, otherwise, the worse the credit is.

3.5. Principal Component Analysis. Logistic regression analysis is sensitive to the multidimensional correlation of independent variables in the model. The financial data of listed companies in this paper are from Wande information, and the selected indicators have high correlation. When logistic regression analysis is used, there will be a problem of multicollinearity in the evaluation equation. Therefore, it is necessary to use principal component analysis to select representative independent variables and then use the logistic regression model to calculate the company’s compliance rate. Descriptive statistics is shown in Table 1.

Table 2 shows the descriptive statistics of the original data with SPSS software, including mean, standard deviation, minimum, and maximum.

The value of spherical test x^2 = 1108.639 (136 degrees of freedom), reaching a significant level, so the original hypothesis is rejected. Sig value is less than 0.05, indicating that there are common factors in the total correlation matrix, which is suitable for factor analysis.

From the test results in Table 2, it can be concluded that km · 0.585 > 0.5, which is suitable for factor analysis. Bartlett’s spherical test sig value is 0.00 less than 0.05, indicating that the financial indicators have strong correlation and are suitable for factor scoring. In fact, the previous variable correlation coefficient indicates that there is multicollinearity. This test is to further investigate the partial correlation between variables, and the value is between 0 and 1. If it reaches 0.5 or above, the principal component analysis method can be used, and the value here is 0.585; it shows that the sample is suitable for principal component analysis.

4. Model Regression Analysis

In this section, the experiment is carried out using the component analysis method, and the selected and unselected data are selected for analysis and comparison.

Summary of case handling is shown in Table 3. Table 3 chooses the selected and unselected cases and then determines the data percentage.

Table 4 is the basic information data table. The digital sample cases with data entering the model are screened for
logistic regression, and 0 is the missing case and unselected case.

Through iterative regression, the data in Step 10 is selected. Table 4 shows that $X_1$ and $X_{15}$ variables are retained in the regression equation, and the significance levels of $X_{15}$ and constant terms are below the significance level of 5%. Therefore, the relevant variables pass the test, and the estimated regression model is as follows:

$$
\ln \frac{p}{1-p} = 11.925 + 0.113X_1 - 0.218X_{15},
$$

$$
\frac{p}{1 - p} = e^{11.925 + 0.113X_1 - 0.218X_{15}}
$$

(5)

Here, the $p$ value represents the enterprise’s compliance probability. When the $p$ value is closer to 1, the value of $P$ indicates that the credit risks of the financing enterprise are small; the closer the $p$ value is to 0, the smaller the compliance probability of the financing enterprise. Therefore, the $p$ value predicted by enterprises can be used as an important reference for banks to provide financial services to financing companies. Classification table is shown in Figure 1.

According to Figure 1, in the sample of 19 defaulting enterprises observed in this paper, through the empirical analysis of the model, 16 defaulting enterprises are predicted, with an accuracy of 84.2%, while in the sample of 72 nondefaulting enterprises observed, 69 enterprises are predicted, with an accuracy of 95.8%. Therefore, the overall prediction accuracy of the model is 93.4. It can be seen that the logistic regression model has high accuracy in predicting the financial risk of agricultural supply chain. Company forecasts with different algorithms are shown in Figure 2.

As shown in Figure 2, we can evaluate and investigate the mechanism and source of risk by assessing the causes of supply chain financial credit risk infection and then discover the appropriate preventive and control techniques to maintain the supply chain financial industry’s stable development. Before a sequence of transactions can be completed, it is necessary to establish the legitimacy of the transaction backdrop. This study mainly analyzes the causes of supply chain financial credit risk infection from internal and external aspects. In the development of supply chain finance business, it usually includes account receivable guarantee, prepayment guarantee financing, and inventory

### Table 1: Descriptive statistics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>$N$</th>
<th>Minimum</th>
<th>Maximum value</th>
<th>Mean value</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_1$</td>
<td>91</td>
<td>-65.58</td>
<td>23.01</td>
<td>0.778</td>
<td>15.7243</td>
</tr>
<tr>
<td>$X_2$</td>
<td>91</td>
<td>-32.57</td>
<td>14.39</td>
<td>1.217</td>
<td>7.7986</td>
</tr>
<tr>
<td>$X_3$</td>
<td>91</td>
<td>-6.55</td>
<td>79.23</td>
<td>21.981</td>
<td>16.5512</td>
</tr>
<tr>
<td>$X_4$</td>
<td>91</td>
<td>-1436.02</td>
<td>450.42</td>
<td>-7.107</td>
<td>159.919</td>
</tr>
<tr>
<td>$X_5$</td>
<td>91</td>
<td>-4517.54</td>
<td>900</td>
<td>-133.073</td>
<td>738.321</td>
</tr>
<tr>
<td>$X_6$</td>
<td>91</td>
<td>-91.06</td>
<td>248.44</td>
<td>1.795</td>
<td>37.7909</td>
</tr>
<tr>
<td>$X_7$</td>
<td>91</td>
<td>-2610.59</td>
<td>1750.64</td>
<td>-12.327</td>
<td>423.602</td>
</tr>
<tr>
<td>$X_8$</td>
<td>91</td>
<td>2.52</td>
<td>3931.91</td>
<td>70.854</td>
<td>414.919</td>
</tr>
<tr>
<td>$X_9$</td>
<td>91</td>
<td>0.63</td>
<td>10.92</td>
<td>3.325</td>
<td>2.6615</td>
</tr>
<tr>
<td>$X_{10}$</td>
<td>91</td>
<td>0.01</td>
<td>1.46</td>
<td>0.487</td>
<td>0.2776</td>
</tr>
</tbody>
</table>

### Table 2: KMO and Bartlett’s inspection.

| Kaiser–Meyer–Olkin measure of sampling adequacy | 0.585 |
| Bartlett’s sphericity test | Approximate chi square | 1108.639 |
| | df | 136 |
| | Sig | 0.00 |

### Table 3: Summary of case handling.

<table>
<thead>
<tr>
<th>Unweighted cases</th>
<th>N</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Included in analysis</td>
<td>91</td>
<td>100</td>
</tr>
<tr>
<td>Missing cases</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>91</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selected cases</th>
<th>N</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Included in analysis</td>
<td>91</td>
<td>100</td>
</tr>
<tr>
<td>Missing cases</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>91</td>
<td>100</td>
</tr>
</tbody>
</table>

### Table 4: Variables in equation.

<table>
<thead>
<tr>
<th>Variable</th>
<th>$B$</th>
<th>S.E</th>
<th>Wals</th>
<th>df</th>
<th>Sig</th>
<th>$\exp (B)$</th>
<th>95% C of $\exp (B)$</th>
<th>Lower limit</th>
<th>Upper limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_1$</td>
<td>0.113</td>
<td>0.06</td>
<td>3.523</td>
<td>1</td>
<td>0.061</td>
<td>1.12</td>
<td>0.995</td>
<td>1.26</td>
<td></td>
</tr>
<tr>
<td>$X_{15}$</td>
<td>-0.218</td>
<td>0.059</td>
<td>13.818</td>
<td>1</td>
<td>0</td>
<td>0.804</td>
<td>0.717</td>
<td>0.902</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>11.925</td>
<td>3.148</td>
<td>14.37</td>
<td>1</td>
<td>0</td>
<td>152475</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>
qualification financing. A very important premise is to ensure the authenticity of the transaction background before it is possible to complete a series of transactions. The financial data for listed companies used in this article come from Wande, and the metrics chosen have a high connection. By decomposing the multilevel index of the supply chain financial credit risk system using the fuzzy evaluation method and combining the qualitative and quantitative evaluation indexes, a set of reasonable evaluation index system is established to assist banks in reducing the credit risk of supply chain finance and promoting its healthy development.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

References

