Research on Financial Benefit Distribution of Supply Chain Finance Based on Risk Factor

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Abstract. Because there are many unfair distribution phenomena in the existing distribution model of supply chain financial benefits, it is necessary to establish a fair and reasonable distribution method of benefits. Firstly, this paper analyzes the risks faced by financing companies, core enterprises, banks and third-party logistics enterprises under the prepayment financing model in supply chain finance, and then quantifies the risks of each member enterprises through BP neural network. Finally, the initial benefit distribution model of prepayment financing model is constructed by combining the maximum entropy method, and the initial benefit distribution model is modified by the risk value faced by each member company, and the rational distribution of the interests of each member enterprise is realized.

1. Introduction

Given that smes have been faced with difficulties in financing, financial institutions have launched supply chain financial services. However, under the current mode of profit distribution, there are many unfair distribution phenomenons, which will affect the stable development of supply chain finance, how to reasonably distribute the profit becomes a key problem.

Scholars have studied the profit distribution of supply chain finance through different methods: Liang xiaofei successfully adopted the Stackelberg game model. It is pointed out that the cooperation mode that can achieve pareto is the best[1]. Hu guohui used the Shapley value method to study the income distribution of all parties in the financial model of agricultural supply chain [2]. Wang qing proposed the theory of risk factor in view of the unfairness caused by the Shapley value method in the income distribution of the inventory pledge financing mode[3].

These studies have their own characteristics and shortcomings. On the basis of summarizing previous research results, this paper takes the prepaid payment financing model in supply chain finance as the research object, and introduces the concept of risk factors to quantify the member companies through BP neural network.

2. Establishment of risk assessment index system for each member enterprise

Due to the different environment faced by different companies, the risks they take are different. When an enterprise participates’s profits cannot make up for its losses caused by taking risks, the initiative of corporate cooperation will decline. Therefore, it is necessary to consider the specific risks assumed by each member company in the formulation of the benefit distribution plan.
2.1. Risk measurement indexes of financing enterprises and core enterprises

In the prepayment financing mode, the sales revenue of pledged goods of financing enterprises is the repayment source of the whole system, and the core companies bear responsibility for goods repurchase. It can be considered that financing enterprises and core enterprises face the same risks.

Table 1. Risk metrics for financing companies and core enterprises.

| The serial number | Indicators                                         | The serial number | Indicators                                         |
|-------------------|---------------------------------------------------|-------------------|---------------------------------------------------|
| 1                 | Financing enterprise sales rate                   | 8                 | Market price stability                            |
| 2                 | Product qualification rate of core enterprises    | 9                 | Clarity in the allocation of powers and responsibilities |
| 3                 | Core enterprises on time delivery rate            | 10                | Years of cooperation with sales customers         |
| 4                 | Profitability of core enterprises                 | 11                | The rationality of organizational structure        |
| 5                 | Market share of core enterprises                  | 12                | Diversity of sales method                         |
| 6                 | Length of cooperation                             | 13                | Technical input ratio                             |
| 7                 | Trading frequency                                 | 14                | Employee education level                          |

2.2. Risk measurement indexes of banks

In the prepayment financing mode, Banks are not only faced with risks brought by other three parties, but also other risks that may lead to their own business losses.

Table 2. Risk metrics for banks.

| The serial number | Indicators                      | The serial number | Indicators                      |
|-------------------|---------------------------------|-------------------|---------------------------------|
| 1                 | Default rate                    | 9                 | Process standardization         |
| 2                 | Credit rating                   | 10                | Timely rate of sharing information |
| 3                 | Current ratio                   | 11                | Accuracy of sharing information  |
| 4                 | Sales margin                    | 12                | Rationality of organizational structure |
| 5                 | Assets and liabilities          | 13                | The clarity of the distribution of powers and responsibilities |
| 6                 | Loan repayment rate             | 14                | Technology investment ratio      |
| 7                 | On-time payment rate            | 15                | Employee qualification level     |
| 8                 | Process design maturity         | 16                | Liquidity                       |

2.3. Risk measurement indexes of third-party logistics enterprises

In the operation of prepayment financing mode, third-party logistics enterprises are mainly responsible for the storage and supervision of pledges, and act as an intermediary between Banks and financing enterprises.

Table 3. Risk metrics for third-party logistics.

| The serial number | Indicators                                         | The serial number | Indicators                                         |
|-------------------|---------------------------------------------------|-------------------|---------------------------------------------------|
| 1                 | Rationality of organizational structure          | 4                 | Employee qualification level                       |
| 2                 | The clarity of the distribution of powers and responsibilities | 5             | Timely rate of sharing information                 |
| 3                 | Technology investment ratio                       | 6                 | Accuracy of sharing information                    |
3. Overview of BP neural network model

In the prepaid account financing mode, the risks faced by each member enterprise vary greatly, and the risk indicators may be highly correlated, and there are both quantitative data and qualitative data in these indicators. BP neural network can solve the above problems.

3.1. Construction and training of BP neural network model

The model set in this paper consists of three parts: input layer, hidden layer and output layer. The number of input nodes refers to the number of risk measures of each participant. Input nodes of financing enterprises, core enterprises, Banks and third-party logistics enterprises are 14, 14, 16 and 6 respectively. The calculation formula of the number of hidden layer neurons:

\[ n_1 = \sqrt{m_1 + m_2 + a} \]  
\[ n_1 \leq \sqrt{m_2(m_1 + 3)} + 1 \]  
\[ n_1 = \sqrt{0.43m_1m_2 + 0.12m_2^2 + 2.54m_2 + 0.77m_1 + 0.35 + 0.51} \]  

- \( n_1 \) represents the number of nodes in the hidden layer;
- \( m_1 \) represents the number of nodes in the input layer;
- \( m_2 \) represents the number of nodes in the output layer.

In addition, due to the large differences between indicators and the different dimensions of different indicators, the system function premnmx is adopted in this paper to conduct standardized processing of samples. The normalization method is as follows:

\[ x'_i = (x_i - x_{\text{min}})(x_{\text{max}} - x_{\text{min}})^{-1} \]  

- \( x_{\text{min}} \) is the minimum value in the data sequence;
- \( x_{\text{max}} \) is the maximum value in the data sequence.

3.2. Calculation of risk impact coefficient

The risk impact coefficient \( R_i \) can be obtained by normalizing the risk value of member enterprise \( i \), and the formula is as follows:

\[ \chi_i = R_i \left( \sum_{i=1}^{d} R_i \right)^{-1} \]  

- \( \chi_i \) represents the risk impact coefficient of member enterprise \( i \);
- \( R_i \) represents the risk value of member enterprise \( i \).

4. Supply chain financial profit distribution model based on maximum entropy method

4.1. An initial profit distribution model based on maximum entropy method

In the prepayment financing mode, the cooperative entity consists of four member enterprises: financing enterprise, core enterprise, bank and third-party logistics enterprise. Among them, \( v(I) \) represents the best interests of the overall cooperation of the system; \( v_i(I) \) represents the benefits of participating enterprise \( i \); \( \phi(i) \) is the profit obtained when the enterprise operates independently; \( v(S) \) represents the income from the cooperative form S. This problem is discretized, and \( p_i = v_i(I) / v(I) \).
represents the probability of the total benefits obtained by the ith member enterprise. Then its maximum entropy value can be defined as:

\[
\max H = - \sum_{i=1}^{4} p_i \ln p_i = - \sum_{i=1}^{4} \frac{v_i(I)}{v(I)} \ln \frac{v_i(I)}{v(I)}
\]  

(6)

\[
\sum_{i=1}^{4} v_i(I) = v(I)
\]

(7)

\[
v_i(I) \geq \varphi(i)
\]

(8)

\[
\sum_{i=5}^{n} v_i(I) \geq v(S)
\]

(9)

\[
v_i(I) > 0 \quad i = 1, 2, 3, 4
\]

(10)

4.2. Revision of profit distribution model

The maximum entropy method can make up for the shortcomings of other methods. However, it assumes that all enterprises bear the same risk, which is obviously inconsistent with the fact. In this section, the initial profit distribution model is improved by introducing risk correction factor. In order to facilitate the research, the following assumptions are made:

\[
\sum_{i=1}^{4} v'_i(I) = v(I)
\]

(11)

\[
v'_i(I) \geq \varphi(i)
\]

(12)

\[
\sum_{k=5}^{n} v'_k(I) \geq v(S)
\]

(13)

• \(v'_i(I)\) represents the interest distribution of member enterprise \(i\) after correction;

• \(v'=(v'_1(I), v'_2(I), v'_3(I), v'_4(I))\) represents the modified profit distribution vector.

Based on the above assumptions, the initial profit distribution model based on the maximum entropy value method is improved:

\[
v'_i(I) = v_i(I) + v(I) \Delta r_i
\]

(14)

\[
\Delta r_i = \lambda_1(\theta_i - \frac{1}{n}) + \lambda_2(\chi_i - \frac{1}{n}) + \lambda_3(\delta_i - \frac{1}{n}), (i = 1, 2, 3, 4; n = 4)
\]

(15)

Now prove the necessary and sufficient conditions for successful \(v'_i(I)\) allocation:

\[
\sum v'_i(I) = \sum v_i(I) + \sum v(I) \left\{ \lambda_1(\theta_i - \frac{1}{n}) + \lambda_2(\chi_i - \frac{1}{n}) + \lambda_3(\delta_i - \frac{1}{n}) \right\}
\]

\[
\sum v'_i(I) = \sum v_i(I) + v(I) \left\{ \sum \lambda_1(\theta_i - \frac{1}{n}) + \sum \lambda_2(\chi_i - \frac{1}{n}) + \sum \lambda_3(\delta_i - \frac{1}{n}) \right\}
\]

\[
\sum v'_i(I) = \sum v_i(I) + v(I) \left\{ \lambda_1 \sum (\theta_i - \frac{1}{n}) + \lambda_2 \sum (\chi_i - \frac{1}{n}) + \lambda_3 \sum (\delta_i - \frac{1}{n}) \right\}
\]

\[
\sum v'_i(I) = v(I)
\]

5. Calculation example analysis

G company is a large pharmaceutical manufacturer, and S company is one of G company's retailers. With the expansion of the market, it needs a capital of 10 million yuan at present. However, due to its weak comprehensive strength, it is difficult to obtain credit from Banks. In view of the situation of G
company and S company, bank B cooperated with the two companies by using prepayment financing mode, and entrusted L logistics company to conduct supervision.

5.1. *Initial profit distribution results based on maximum entropy method*

First, regardless of the impact of risk factors on the distribution of benefits, the maximum entropy method is used to obtain the initial benefit distribution plan, as shown in the table:

| Company | S   | G   | B   | L   |
|---------|-----|-----|-----|-----|
| Benefits (ten thousand yuan) | 206.71 | 264.29 | 79.29 | 9.61 |

5.2. *Revised profit distribution results*

In this paper, we find that the model error is the smallest when the number of hidden nodes is 13 between the number of nodes 4~13 by using the Matlab toolbox. In this paper, the two training error curves with the smallest error value are shown in Figure 1.

![Figure 1. Training Error Curve for Different Hidden Layer Nodes](image)

In this paper, neural network simulation program is written by Matlab software to train the BP neural network, the training results and test results are shown in Figure 2 and Figure 3, respectively.

![Figure 2. BP Neural Network Training Results](image)

As can be seen from Figure 2, the maximum absolute error between the expected output and the actual output is 6.1%, that is, the output result of this model is basically consistent with the expected output.
Figure 3. The Test Results of BP Neural Network.

It can be seen from Figure 3 that the financing enterprise risk assessment model based on the BP neural network model has very high precision and accuracy. By using the model, the risk assessment value of third-party logistics enterprise L can be obtained. Similarly, the risk assessment values of other member companies and the final benefit distribution scheme are shown in Table 5.

Table 5. Income Distribution Plan.

| The serial number | S   | G   | B   | L   | Summary |
|-------------------|-----|-----|-----|-----|---------|
| risk assessment value | 0.434 | 0.434 | 0.687 | 0.596 | 0       |
| Correction factor  | -0.001 | -0.001 | -0.002 | 0.004 | 0       |
| Benefits (ten thousand yuan) | 205.93 | 263.51 | 78.51 | 11.95 | 559.9   |

It can be seen from Table 5 that the interests of financing enterprises and banks have been reduced, and the transfer to logistics enterprises has taken place, thus making up for the losses caused by logistics enterprises due to risk taking, making the distribution of benefits more reasonable.

This paper analyzes the impact of risk factors on the profit distribution of prepayments financing model in supply chain finance, and quantifies the risk of each member enterprise through BP neural network, and constructs a more fair and reasonable interest distribution method by combining the maximum entropy method. And further promote the stable development of supply chain finance.

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