Study on Transmission Path and Prevention of Supply Chain Financial Risk Based on DEMATEL - AISM Model

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Abstract. Supply chain finance promotes the effective operation of all aspects of the supply chain and greatly promotes the development of the modern social economy. But because of its complexity, supply chain finance faces many risks, so it is vital to study and prevent supply chain finance risks. Aiming supply chain financial risks, this paper uses DEMATEL-AISM (Decision-making Laboratory Analysis-Confrontational Interpretation Structure Model) to analyze various factors affecting the development of supply chain finance and identify its transmission path. It is proposed to strengthen legal control, credit control, proficiency, supply chain management and supply chain operations, and find out and understand the things and links that are highly related to supply chain finance.; create a stable supply chain financial market environment and ensure market efficiency and other preventive measures. In this paper, the DEMATEL-AIM method is innovatively applied to identify and analyze supply chain financial risks, and the complex supply chain financial system is systematically analyzed. The relationship between indicators and the structure of the index system is found, which is helpful to identify the influencing factors of supply chain financial risks at all levels and their internal transmission mechanism. The preventive measures of supply chain financial risks are put forward, which provides ideas for effective prevention and treatment of supply chain financial risks and promotes the sustainable development of supply chain finance.

Keywords: DEMATEL-AISM; supply chain finance; risk transmission path; influencing factors.

1. Introduction

Supply chain financial risk is in the process of commercial banks providing financial services to supply chain enterprises, due to the influence of various uncertain factors that cannot be predicted in advance, so that the actual income of supply chain financial products deviates from the expected income, or the assets cannot be recovered and the possibility of loss. It is of great significance to identify the supply chain financial risks, understand their transmission paths and their prevention, to revitalize supply chain financial funds and improve the supply chain financial services level.

Previous studies on supply chain financial risk in China mainly focused on the analysis of specific important risks in the process of supply chain finance, such as the identification and prevention of credit risk and moral hazard. Some studies comprehensively analyzed some major financial risks in supply chain finance, and found the strong and weak risk factors in the financial risk evaluation system. Some studies also studied the causes and prevention of the overall risk of supply chain finance from the characteristics and structure of supply chain finance.Kuang et al. [1] took 940 equipment manufacturing samples from SME board of Shenzhen Stock Exchange from 2014 to 2018 as the research object, and constructed the credit risk index system of SMEs under supply chain finance. Dai [2] established the corresponding credit risk evaluation index system based on the characteristics of online supply chain finance financing mode. It demonstrated the reliability of the C-SMOTE-RF model in online supply chain finance credit risk evaluation. Jin et al. [3] studied retailer default risk and control based on revenue sharing-bidirectional option contracts. Li Zhi et al. [4] found that the macroeconomic indicators of the external environment are more important in the financial risk evaluation system of the international supply chain. In contrast, the risks of third-party logistics enterprises and commercial banks are less in the international supply chain's financial risk evaluation system. Wang et al. [5] described the development trend and scenario of supply chain finance. They proposed three major risks of supply chain due to its complex development trend, credit problems,

and the disconnection between risk prevention and control system and business development. Finally, the corresponding suggestions were put forward from four aspects.

The research results related to supply chain financial risks, Most of them study the causes and preventive measures of the leading supply chain financial risks. There are few studies on the correlation between supply chain financial risks and the conduction process between risks. Based on the current research results and the complexity and systematicness of supply chain financial risks, this paper innovatively uses the DEMATEL-AISM model to diagnose the relationship between various financial risks. Then, it studies the transmission path of supply chain financial risks, finds out the deep and prominent factors affecting supply chain financial risks, and puts forward preventive measures. This study is conducive to the deep analysis of supply chain financial risks' structure and transmission path, strengthening the prevention of supply chain risks, revitalizing supply chain financial funds, and promoting the rapid development of supply chain finance and the social economy.

2. Construction of supply chain financial risk system

In all aspects of supply chain finance, risk factors can affect the overall supply chain financial risk. These risk factors interact and transmit each other, resulting in the overall supply chain financial risk. By reading the relevant literature on supply chain financial risk and referring to expert opinions, this paper constructs the supply chain financial risk system and establishes the impact indicators, divided into two categories and 13 specific indicators, respectively numbered as Fi (i = 1,2,3...13).

Exogenous risk (Y1) refers to a series of risks faced by supply chain finance under the change of the external macro-environment. Market risk (F1) refers to market price fluctuations, financial exchange rate changes, resulting in changes in the price of pledges, liquidity changes, resulting in risk. Policy risk (F2) refers to the risk of supply chain finance caused by changes in national economic policies. When the state policies restrict industry development, the industry's supply chain will be affected from the source to the final retailer, and the related credit and financial business will be affected. Industry risk (F3) refers to the industry downturn or downturn that will directly cause the loss of supply chain operations, thereby affecting financial security. For restrictive or sunset industries, implementing supply chain finance will have greater risks. Regional risk (F4) refers to the specific financial risks the internal supply chain faces in various regions. The causes are the internal control mechanism of the regional financial industry, the integrity of the financial market, the quality of financial industry assets, and the human resources conditions of the financial industry.

Endogenous risk (Y2) refers to the risks each subject faces in the supply chain financial system in various aspects of operation and control activities. Credit risk (F5) refers to the risk of financial institutions suffering economic losses due to the refusal of enterprises to perform their repayment obligations at the expiry of the contract [6]. Operational risk (F6) refers to the risk of direct or indirect loss caused by imperfect or problematic internal operation processes, personnel, system, or external events. The authenticity risk of trade background (F7) refers to the huge risks faced by banks in blindly granting credit to borrowers without real trade backgrounds, such as forgery of trade contracts, problems in the existence or legitimacy of accounts receivable, defects in the quality of pledged materials or malicious withdrawal of bank funds by buyers and sellers in fictitious transactions. Supply chain management and operational risk (F8) refers to the risk in the operation and management of supply chain enterprise, such as the management mechanism problems in the process of enterprise operation or the collapse of supply chain finance business caused by the deterioration of enterprise operation. Supply chain correlation risk (F9) indicates that supply chain enterprise correlation degree is low, the financing gap caused by risk is uncontrollable, or it will cause losses to supply chain finance business participation in enterprise management. In short, legal risk (F10) is the possibility that the borrowers in the supply chain violate the legal contract and bring losses to financial institutions. In the supply chain financing mode, the participants are multi-party, and the relevant legal liability is also complex and relevant. On the one hand, due to the imperfect legal system in China, may lead to legal risks; on the other hand, subjective violations between different subjects may

also bring legal risks to other relevant parties [7]. Moral hazard (F11) refers to the possibility that financial transaction parties subjectively violate financial contracts, change the use of funds and cause loss of financial assets to obtain certain benefits [8]. The risk of real right guarantee (F12) refers to the risks caused by real right guarantees, such as the loss of collateral, the large fluctuation of collateral price, the deterioration of collateral quality, and the difficulty of collateral realization. Financial risk (F13) refers to the financial loss of the enterprise itself caused by the management decision and financial management decision of the supply chain node member enterprises and the uncertainty of the financial situation or property loss of the whole supply chain, including other supply chain member enterprises, caused by such loss.

3. DEMATEL-AISM model research

3.1 Technical route

Based on the introduction, this paper summarizes and sorts out the risk elements affecting supply chain finance through literature survey and expert evaluation and streamlines them into 13 risk elements. Since there are complex logical relationships between many risk factors affecting supply chain finance that support or constrain each other, to study supply chain finance's risk transmission and prevention, it is necessary to determine the importance and hierarchy of risk factors. Therefore, the DEMATEL-AISM model is introduced to provide a theoretical basis and decision basis for supply chain finance's risk transmission path and prevention focus.

According to the above 13 supply chain finance risk elements, the DEMATEL model can be applied to derive the causality and impact intensity of individual elements and represent them through scattering diagrams, but this method does not divide the structural level and classify the elements. The AISM model can explain the system structure through the adversarial directed topological hierarchy diagram. However, it cannot determine the impact intensity of the elements' role and the elements' importance. Therefore, this paper uses DEMATEL and AISM models to identify and evaluate the root causes and important elements within a complex system and elucidate its structural hierarchy.

In summary, the application model framework of this paper is shown in Figure 1.

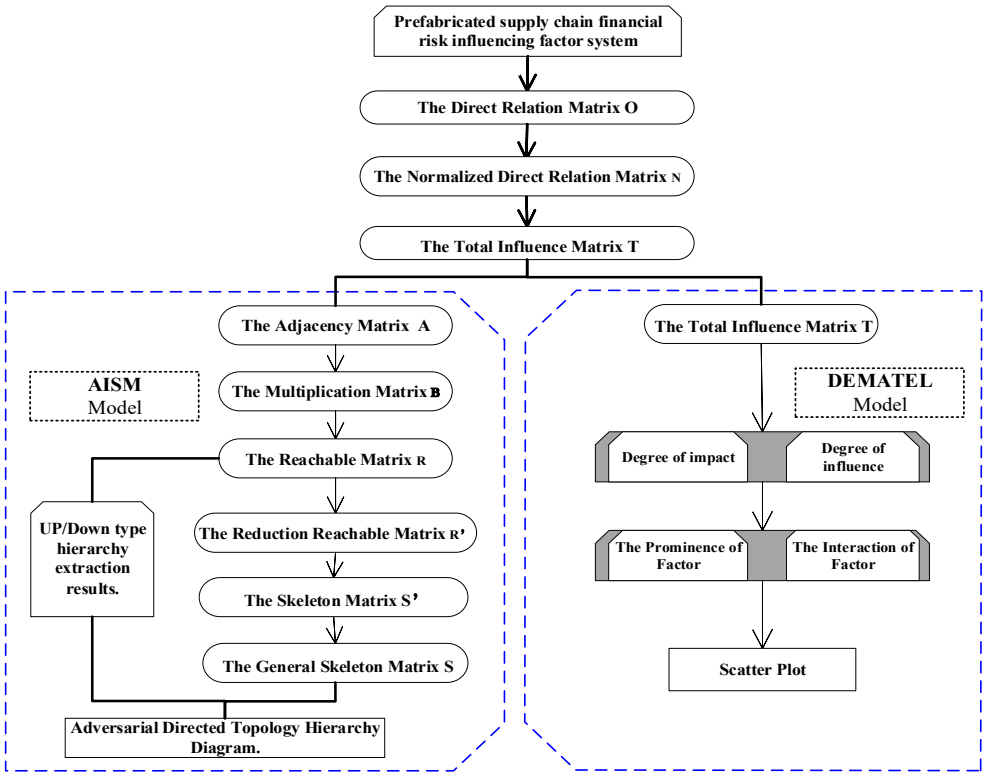


Figure 1 Application model framework diagram

3.2 DEMATEL method

The DEMATEL method (Decision-making Trial and Evaluation Laboratory) is a graphical and matrix-based system analysis method proposed by American scholars A. Gabus and E. Fontela for understanding complex problems in the real world. It can calculate the degree of influence, degree of influence, degree of cause, and degree of the center of each element, to determine the causal relationship between the elements and the position of each component in the system.

STEP1:Determine the direct impact matrix O.In this paper, through the Delphi method [9], we set a 5-level scale of the element influence relationship (Table 2), invite experts and scholars in the field of supply chain finance to assess the strength of the binary relationship of each risk element, and use the averaging method to process the data and determine the direct influence matrix O.Where, the matrix a_{ij} indicates the level of influence of the element F_i on the element F_j, if $i = j$, then a_{ij}=0.

STEP2:Get the norm direct influence matrix N.The direct impact matrix O is normalized to obtain the canonical direct impact matrix N, calculated as follows.

$$N = \left(\frac{\boldsymbol{O}}{Maxvar}\right)_{n\times n} \tag{1}$$

$$Maxvar = \max_{1\le i\le n}\left(\sum_{j=1}^{n} a_{ij}\right) \tag{2}$$

STEP3:Calculate the integrated impact matrix T.Considering the indirect effects of each element and the direct binary impact, the direct and indirect effects are cumulated by using the following calculation formula.

$$T = N + N^2 + \cdots + N^k = \sum_{k=1}^{\infty} N^k \rightarrow T = N(I-N)^{-1} \tag{3}$$

Where I am the unit matrix,and $(I-N)^{-1}$ is the inverse matrix of $(I-N)$.

STEP4: Calculate the influence degree and influence degree of each influence element. The influence degree of the influenced element D_i is calculated based on the row sum corresponding to each element, and the influenced degree C_i is calculated based on the column sum with the following formula.

$$D_i = \sum_{j=1}^{n} a_{ij} \tag{4}$$

$$C_i = \sum_{i=1}^{n} a_{ij} \tag{5}$$

STEP5:Calculate the centrality and cause a degree of each influence element. The centrality M_i is the sum of the influence degree D_i and the influenced degree C_i . The cause degree is the difference between the influence degree and the influenced degree, calculated by the following formula.

$$M_i = D_i + C_i \tag{6}$$

$$R_i = D_i - C_i \tag{7}$$

3.3 AISM method

The AISM method (Adversarial Interpretive Structure Modeling Method) is derived from the ISM method. It adds the cause-first hierarchical extraction rules to the ISM result-first hierarchical extraction rules to build a set of adversarial hierarchical topology diagrams to explain the system structure and element causal order. This method is called the adversarial explanatory structure model.

STEP1:Calculate the relationship matrix A, the multiplication matrix B, and the reachable matrix R.To simplify the system structure, the threshold λ is chosen to be introduced, and the relationship matrix A based on the integrated impact matrix T is calculated according to the following formula.

Where $\lambda=\overline{x}+\sigma$ [9], $\overline{x}$ is the mean of the elements in T and σ is the sample standard deviation. Further, considering the factors' effect, the phase multiplication matrix B is calculated according to the following equation.

$$\begin{cases} a_{ij}=1, & a_{ij} \geq \lambda \\ a_{ij}=0, & a_{ij} < \lambda \end{cases}$$

$$A+I=B \tag{9}$$

According to the following equation, the concatenated multiplication of the phase multiplication matrix B yields the reachable matrix.

$$R=B^{k+1}=B^{k} \neq B^{k-1} \tag{10}$$

STEP2: Conduct element hierarchy. According to the following equation and the reachable matrix R, the reachable set $R(F_i)$, the antecedent set $A(F_i)$ and the common set $L(F_i)$ of each factor F_i are established, and the hierarchical division of result and cause priority is carried out with UP and DOWN type hierarchical diagrams, respectively, and the extraction rules are $L(F_i)=R(F_i)$, $L(F_i)=A(F_i)$ to extract the relevant elements layer by layer for the hierarchical division of elements respectively.

STEP3:Calculate the skeleton matrix. The point reduction process is performed on the reachable matrix R. The strongly connected elements in each level of the reachable matrix are checked, and they are point reduced to one element to obtain the point reduced reachable matrix R'. Furthermore, the edge reduction is performed, and the essence of the edge reduction operation is to remove the duplicate paths [10]. The skeleton matrix is obtained according to the following equation, and the general skeleton matrix is obtained by bringing back the strongly connected elements.

$$S'=R'-(R'-I)^2-I \tag{11}$$

STEP4:Draw the adversarial directed topological hierarchy. The adversarial directed topological hierarchy map is drawn based on the element hierarchy results and the skeleton matrix S'.

4. Empirical analysis

4.1 Calculate the impact matrix O.

Table 1 Direct impact matrix O

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13
F1	0	0	2	1	1	1	2	4	2	0	1	1	2
F2	3	0	3	2	0	0	1	2	1	2	1	1	4
F3	4	1	0	2	2	3	2	3	1	1	1	2	2
F4	3	1	2	0	2	2	2	2	3	1	2	1	3
F5	4	2	4	3	0	2	3	3	4	3	4	3	1
F6	1	0	0	0	0	0	0	1	3	2	0	1	3
F7	3	0	2	1	2	0	0	2	1	2	2	3	4
F8	1	0	1	0	1	1	1	0	1	1	1	1	2
F9	1	0	1	1	1	2	2	2	0	0	0	0	0
F10	4	2	4	3	3	4	3	2	0	0	2	4	4
F11	2	2	3	2	0	2	3	2	1	3	0	2	3
F12	1	2	2	2	1	1	0	1	2	2	1	0	3
F13	1	1	2	3	3	2	2	2	3	3	3	4	0

4.2 Calculate the integrated impact matrix T.

The direct impact matrix is normalized according to formulas (1) and (2), and then the combined impact matrix T is obtained according to formula (3), as shown in Table 4.

Table 2 Integrated impact matrix

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13
F1	0.060	0.023	0.108	0.071	0.069	0.075	0.102	0.167	0.106	0.047	0.070	0.081	0.120
F2	0.161	0.033	0.156	0.117	0.060	0.067	0.094	0.137	0.095	0.112	0.085	0.102	0.195
F3	0.193	0.061	0.083	0.117	0.111	0.147	0.123	0.170	0.108	0.093	0.089	0.131	0.155
F4	0.170	0.063	0.138	0.069	0.113	0.125	0.128	0.147	0.159	0.095	0.117	0.108	0.178
F5	0.243	0.108	0.232	0.179	0.087	0.160	0.189	0.216	0.215	0.176	0.194	0.195	0.182
F6	0.065	0.017	0.040	0.034	0.032	0.037	0.035	0.068	0.116	0.084	0.029	0.066	0.123
F7	0.170	0.042	0.143	0.101	0.117	0.075	0.075	0.146	0.106	0.123	0.121	0.165	0.205
F8	0.072	0.020	0.070	0.036	0.058	0.064	0.064	0.045	0.066	0.062	0.060	0.070	0.103
F9	0.063	0.011	0.057	0.049	0.050	0.079	0.080	0.089	0.032	0.026	0.025	0.031	0.042
F10	0.244	0.111	0.234	0.184	0.169	0.210	0.185	0.191	0.124	0.106	0.151	0.229	0.262
F11	0.155	0.094	0.172	0.129	0.070	0.131	0.157	0.151	0.108	0.153	0.068	0.145	0.196
F12	0.103	0.085	0.124	0.112	0.077	0.088	0.061	0.100	0.116	0.108	0.079	0.066	0.161
F13	0.146	0.079	0.165	0.168	0.154	0.146	0.146	0.165	0.177	0.166	0.159	0.207	0.131

4.3 Calculating influence degree, influenced degree, centrality degree, and cause degree.

Based on the influence matrix T, the influence degree, influenced degree, centrality degree, and cause degree of each influence factor are obtained according to equations (4-7). With the centrality degree as the horizontal coordinate and the cause degree as the vertical coordinate, a scatter plot is drawn in Figure 2.

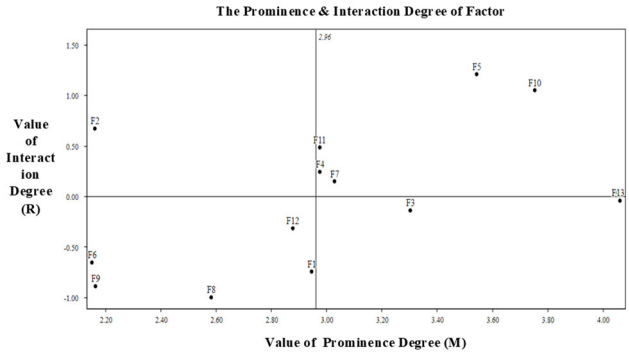


Figure 2 Scatter diagram of the elements of the cause & centricity system

4.4 Calculate the threshold λ and the relationship matrix A.

Introducing thresholds $\lambda=\overline{x}+\overline{\sigma x}$, for the mean of the elements in T and σ the sample standard deviation, we obtain $\lambda = 0.169351$. The relationship matrix A can be obtained from equation (8) above.

4.5 Performing hierarchical partitioning and calculating the skeleton matrix S'.

According to equations (8) and (9) in turn, the reachable matrix is obtained in turn. Based on the reachable matrix K, the elements are divided into adversarial hierarchies, and the division results are shown in Table 5. The reachable matrix K is shrunk to reduce the strongly connected elements, the Tarjan algorithm is applied to rearrange the shrinkage matrix by element hierarchy. The lower triangular skeleton matrix S' is obtained according to equation (11), as shown in Table 6.

Table 3 Hierarchy of antagonistic elements

Levels	Result first - UP type hierarchy	Reason first - Down type hierarchy
0 Level	F1,F6,F8,F9,F12	F1,F8,F9,F12
1 Level	F3,F13	F3,F13
2 Level	F2,F4,F7,F11	F11,F4,F6,F7
3 Level	F5,F10	F2,F5,F10

Table 4 Skeleton matrix S'

	F1	F6	F8	F9	F12	F3	F13	F2	F4	F7	F11	F5+F10
F1	0	0	0	0	0	0	0	0	0	0	0	0
F6	0	0	0	0	0	0	0	0	0	0	0	0
F8	0	0	0	0	0	0	0	0	0	0	0	0
F9	0	0	0	0	0	0	0	0	0	0	0	0
F12	0	0	0	0	0	0	0	0	0	0	0	0
F3	1	0	1	0	0	0	0	0	0	0	0	0
F13	0	0	0	1	1	0	0	0	0	0	0	0
F2	0	0	0	0	0	0	1	0	0	0	0	0
F4	1	0	0	0	0	0	1	0	0	0	0	0
F7	1	0	0	0	0	0	1	0	0	0	0	0
F11	0	0	0	0	0	1	1	0	0	0	0	0
F5+F10	0	1	0	0	0	0	0	0	1	1	1	0

4.6 Drawing an adversarial directed topological hierarchy.

Finally, according to the results of hierarchical analysis and the skeleton matrix S', a directed topological hierarchy diagram can be drawn. Directed line segments represent the reachable relationships of supply chain finance risk elements, and bidirectional arrows indicate loops, i.e., mutual reachable relationships. At the same time, the lower the level, the more basic the influencing factors are, while the higher the level, the more direct the risk factors. The adversarial directed topological hierarchy is shown in Figure 3, with the UP-type directed topological hierarchy on the left and the DOWN-type directed topological hierarchy on the right.

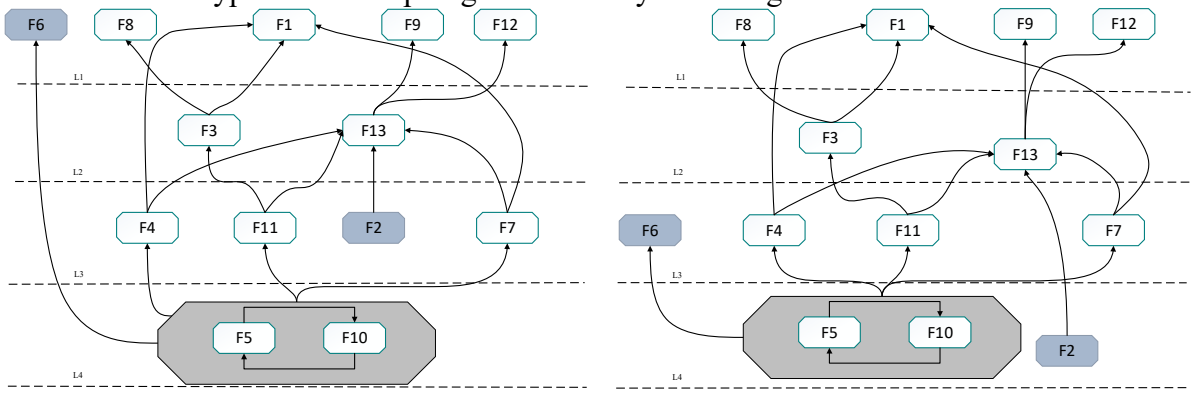


Figure 3 Hierarchical diagram of the antagonistic directed topology

5. Analysis of results

5.1 Circuit analysis

The presence of directed arrows between factors in a multilevel recursive structure diagram indicates a causal relationship between the factors. If there is a bidirectional arrow line between factors, the connection is called a loop, i.e., a strong connection, indicating that the group of factors is causally related to each other. From Figure 3, it can be seen that there is a set of loops in supply chain finance risk: credit risk and legal risk, which indicates that the group of factors is strongly connected and causal within itself. Therefore, when controlling the risk of supply chain finance, the above-mentioned "credit risk and legal risk" group of factors should be controlled in an integrated management way to improve management effectiveness.

5.2 Hierarchical analysis

Figure 3 also shows that the influencing factors of supply chain finance risk form a top-down hierarchical structure with four levels and three orders of directional progression. The system is divided into three levels: the bottom level (F5 and F10) constitutes the essential causal order, the middle level (F2 F3 F4 F7 F11 F13) constitutes the transitional causal order, and the top-level (F1 F6 F8 F9 F12) constitutes the proximate causal order. The lower levels indicate stronger causal attributes (influenced attributes), and the upper levels indicate stronger outcome attributes (influenced attributes).

5.3 Centrality analysis

Centrality is one of the most widely used and important conceptual tools used to analyze networks, and centrality is a measure of centrality, which is a positive indicator, i.e., the larger the value, the more important it is. From Figure 2, it can be seen that the top five factors influencing supply chain finance risk in descending order of centrality are: F13 financial risk, F10 legal risk, F5 credit risk, F3 industry risk, and F7 trade background authenticity risk. Therefore, the factors mentioned above should be focused on when analyzing and controlling supply chain finance risks.

5.4 Cause degree analysis

The cause degree reflects the cause and effect attributes of the factor and is divided into positive cause degree and negative cause degree. A positive value is a causal factor, and the larger the value, the easier it is to influence other factors; Negative value is the effect factor, and the larger the absolute value, the easier it is to be influenced by other factors.

From Fig. 2, we can see that the factors influencing the risk of supply chain finance are, in descending order, F5 credit risk, F10 legal risk, F2 policy risk, F11 moral risk, and F4 regional risk. The factors with a high positive cause degree can easily influence other factors, so the management of the factors mentioned above with a high positive cause degree should be paid attention to when controlling the risk of supply chain finance.

The results of AISM model analysis show that the deep bottom factors are F5 credit risk and F10 legal risk, indicating that credit risk and legal risk are the root factors affecting supply chain finance risk; The direct influencing factors are operational risk, supply chain management, operation risk, supply chain relatedness risk, market risk, and physical security risk.

6. Conclusion

In this paper, we analyze the supply chain financial risk, find out the factors affecting supply chain financial risk, judge the importance of factors by using the DEMATEL model, analyze the cause degree and centrality of each factor, and use the AISM model to classify them in a hierarchy, and find out the root factors affecting supply chain financial risk are credit risk and legal risk, and the direct factors are operational risk, supply chain management, and operational risk, supply chain relatedness

risk, market risk, and physical security risk are the direct influencing factors. The policy recommendations are as follows.

(1) Enhance legal control and improve relevant laws and regulations. In the supply chain context, Internet finance has been developing rapidly in recent years. However, there are various types of disputes in its development because the laws and regulations on Internet finance have not been built perfectly. Therefore, in order to meet the development needs of Internet finance, it is necessary to strengthen the relevant legal construction and standardize the development of dispute resolution, so as to ensure that Internet supply chain finance can be developed more scientifically and legally. It is also necessary to pay attention to and develop the credit platform on the Internet, to build the legal level of Internet information security, and to severely punish the behavior of untrustworthy units or untrustworthy persons.

(2) Construct a credit collection system and strengthen credit control. A reliable credit collection system is an indispensable set of weapons for enterprises to reduce credit risks in developing financing business, and the supply chain finance business is no exception. At the same time, information sharing, business collaboration, and risk-sharing should be carried out among the upstream and downstream enterprises of the whole supply chain to improve the cooperation among all subjects to reduce corporate defaults and credit risks.

(3) Strengthen internal controls and reduce operational risk. Operational risk mainly stems from the failure of internal control and corporate governance mechanisms. Because post-loan management is an important step in the credit business of supply chain finance, the probability of operational risk is higher than that of traditional business, which requires banks to set up special departments responsible for post-loan tracking and management of pledges.

Pledges are managed mainly by logistics companies or warehousing companies. Banks should strengthen their ties with these companies, pay attention to their qualifications, and conduct random checks.

Specifically, we should urge the logistics enterprises to continuously improve warehouse management and warehouse management information technology, develop a perfect risk control program for the handling of quality goods, delivery, and strengthen the ability to supervise the quality of goods. Formulate strict operation specifications and supervision procedures to eliminate the risks arising from internal management loopholes and irregularities.

(4) Establish strategic partnerships to reduce supply chain management and operation risks. Establish strategic partnerships to reduce supply chain management and operational risks. To establish a long-term strategic partnership, we first need to strengthen the trust among supply chain members; Secondly, strengthen information exchange and sharing among members; Finally, a formal cooperation mechanism is established to realize benefit sharing and risk-sharing among supply chain members.

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