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Compressed Sensing and Its Applications in Risk Assessment for Internet Supply Chain Finance Under Big Data

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ABSTRACT Plenty of research focuses on supply chain finance and its risk, qualitatively or quantitatively. However, there are only a little literature studies on the Internet supply chain finance (ISCF), especially on its risk by quantitative analysis. After analyzing the information of partners' panorama data and upstream and downstream data in the internet supply chain, this paper constructs a multiple dimensional intelligent risk assessment system for ISCF. By using the analytic hierarchy process gray assessment theory, a risk assessment model of ISCF is built. Based on the collected big data, tracking and monitoring partners' panoramic data, and upstream and downstream data of the supply chain in real time, the risk of ISCF can be calculated through the assessment model, so the investor can decide whether to finance or not before lending and monitor the lender dynamically after loaning. Taking Zhong-ken Supply Chain Co., Ltd., a focal company in the supply chain, as an example, this paper evaluates the risk of lending to one financing enterprise and obtains a specific risk value, by which to describe the risk degree. Therefore, the model has certain practicability.

INDEX TERMS Compressed sensing, internet supply chain finance, risk assessment, analytic hierarchy process gray model, panorama data, big data.

I. INTRODUCTION

In recent year, supply chain finance has become a good way to solve the financial issues of small and medium-sized enterprises (SMEs). Supply chain finance is the financial cooperation between upstream and downstream enterprises in the supply chain, which can not only reduce the average cost but also increase the supply chain income [1]. Supply chain finance needs services and technology, two of which can integrate investor, financing enterprises and service providers together to form a chain, thus make the transport process be more transparent and optimize cash payment [2]. Modern supply chain is a complex operation and management process, and almost every supply chain operation is accompanied by a large number of financial activities [3]. Supply chain finance not only breaks the traditional thinking of bank that financing to individual enterprises, but also regards the upstream and downstream enterprises in the supply chain as a whole, and thus determines the financing plan based on the chain relationship and industry development [4]. Supply chain finance has become a prevailing financing source for thousands of small and medium-size enterprises (SMEs) [5] and thus enhances the competitiveness of the supply chain [6].

Supply chain finance is a credit model, so it is bound to be accompanied with risk. Although supply chain finance is an alternative method of overcoming the problem of information asymmetry, it cannot eliminate the risk completely. There is still some possibilities of failure of the risk aversion mechanism and thus generates financial risk [7]. From the perspective of information, there may be moral hazard and adverse selection in the pledge loan credit contract under asymmetric information [7]. From the perspective of financing, there may be five aspects of risk such as financing process risk, environmental risk and information technology risk and so on [8]. From the perspective of risk, the most important is

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TABLE 1. Risk assessment system of internet supply chain finance.

	Primary	Secondary	Third level
Risk Assessment of ISCF A	Risk of financing enterprises B1	Solvency C11	Asset-liability ratio, current ratio, quick ratio, cash ratio
		Operational capability C12	Accounts receivable turnover rate, inventory turnover rate
		Profitability C13	Sales profit margin, return on total assets
		Development status C14	Executive work experience, executive assets, executive credit status, employee quality
		Credit status C15	Debt repayment status, tax status, product service reputation, financial reputation, business reputation
		Internet Finance status C16	Customer evaluation, order status
	Risk of focal company B2	Solvency C21	Asset-liability ratio, quick ratio, cash ratio
		Profitability C22	Sales profit margin, return on total assets
		Credit status C23	Credit rating, existing guarantee status
	Risk of logistics enterprises B3	Enterprise strength C31	Enterprise size, competitive advantage
		Credit status C32	Credit rating, service reputation
		Operational risk C33	Internal violations, internal fraud risk, external fraud risk
	Risk of pledge B4	Product price change C41	Range of price change
		Product liquidation C42	Product differentiation degree, product demand status
		Product management status C43	Vulnerability level, natural disaster situation
	Risk of internet B5	Network technology risk C51	Network technology level
		Network security risk C52	Hacking situation
	Risk of external environment B6	Environmental risk C61	Economic environmental risk, policy environmental risk
		Industry risk C62	Industry development risk, industry competition risk

credit risk [9], and many other kind of risk such as market risk and liquidity risk are also common in reality [10].

Internet supply chain finance (ISCF) is the combination of the traditional supply chain finance and the internet finance and appears complex risk for its short time development [11]. Moreover, it is also possible to infect risk among enterprises in the supply chain because of internet [12]. Fortunately, internet finance can reduce risk existed in the supply chain [13], [14]. As far as the types of risk are concerned, there are internet security risks, operational risks, process risks, and legal risks in ISCF [15], and most of the research focuses on credit risk ([16], [14]). As for the research method, [17] predicts the risk changes in Internet supply chain finance through the comprehensive application and simulation of the system dynamics model and the analytic hierarchy process, [18] uses the game theory method to study the bank supply chain finance risk.

In summary, the existed literature about ISCF mainly focuses on its risk identification, especially by qualitative analysis, while only a little research by quantitative method. Therefore, it is necessary to provide an accurate quantitative assessment on the risk of ISCF, by which to provide decision-making reference before lending and risk warning after lending.

II. DESCRIPTION OF THE METHOD

ISCF integrates three elements highly, that is, internet, supply chain and finance. SMEs are no longer absolutely dependent on the focal company, so the traditional ''one-to-many'' relationship model becomes ''many-to-many'' model [19]. Therefore, the critical role of ISCF is related to the panoramic data of partners in ISCF, such as financing company, focal company and logistics enterprise. Another important attribute of ISCF is the upstream and downstream data of supply chain such as pledge status, internet status and external environmental industry status. Moreover, some further indicators should be considered in Table 1.

Most of financing enterprises are SMEs and located in the upstream or downstream of supply chain. According to the literature such as [20], to find out the risk of financing to these SMEs, it is necessary to analyze their solvency, operational capability, profitability, development status, credit status and so on. Furthermore, internet financial status should also be considered.

Focal company risk is one of the most important driving criteria in the risk assessment system of ISCF. Focal company risk refers to the possible loss to investors that may be brought from the change of the focal company. The debt, which cannot be paid by the financing enterprises, may be reimbursed by the focal company, so the factors that can reflect payment ability and willingness, such as solvency, profitability and credit status of the focal company, should be considered. In addition, the existing guarantee status of focal company should also be considered because it is related to the amount of reimbursement.

Logistics enterprises risk refers to the possible loss to the ISCF that may be brought by the enterprises themselves. In supply chain finance, logistics enterprises are the mainstay of out-source business, so many factors such as their strength, credit status and operational risk status should be considered. The strength of the enterprises is used to examine the size and competitive advantage, the credit status reflects its credit rating and service reputation, the operational risk status analyzes the improper operation of the employee and therefore causes problems such as document errors, sending errors as well as fraudulent acts inside or outside the enterprises.

The pledge risk refers to the possible loss that may come from the price changes, liquidity difficulties, and poor management and so on. If the price of the pledge changes greatly, commercial bank and other investors may reduce the credit line of the financing enterprise, which may result in its operation difficulties. Price changes may also bring about the focal company break the supply chain, which may further worsen the payment ability of the financing enterprise and eventually

TABLE 2. Indicator weights of internet supply chain finance.

indicator	λ_{max}	weight	indicator	λ_{max}	weight
Risk of financing enterprises B1	6.1225	0.0434	Solvency C21	3.0092	0.5390
Risk of focal company B2		0.0655	Profitability C22		0.1638
Risk of logistics enterprises B3		0.1604	Credit status C23		0.2973
Risk of Pledge B4		0.1024	Enterprise strength C31	3.0092	0.2973
Risk of internet B5		0.2488	Credit status C32		0.539
Risk of External environment B6		0.3794	Operational risk C33		0.1683
Solvency C11	6.0365	0.1676	Product price change C41	3.0092	0.2972
Operational capability C12		0.2581	Product liquidation C42		0.539
Profitability C13		0.1075	Product management status C43		0.1683
Development status C14		0.0452	Network technology risk C51	2	0.333
Credit status C15		0.3533	Network security risk C52		0.667
Internet Finance status C16		0.0683	Environmental risk C61	2	0.667
			Industry risk C62		0.333

lead to the loss of investors. When there is some change in the pledge goods, such as the form, demand situation, supply market and so on, it may be difficult to liquidate and thus lead to liquidity difficulties. Some pledges have special physical properties, such as perishable quality, which require special management by logistics enterprises. Improper management may result in some loss.

Internet risk refers to the possibility of loss caused by network technology or network security in the online business of supply chain finance, mainly including network technology risks and network security risks. The network technology level plays an important role in ISCF, so it is necessary to continuously develop technology to improve and complete the network platform and network system. Moreover, network channels may be also subject to hacker attacks, security risks and other network vulnerabilities.

External risk may be influenced by two aspects. One is environmental risks, which include economic environmental risk and policy environmental risk; the other is industrial risk, which involves industry development risk and industry competition risk. SMEs in the upstream and downstream of the supply chain are small in size and vulnerable to macroeconomic conditions, so they may encounter economic environmental risk. Policy change may lead to the change of rights and obligations in supply chain, national industrial policy change may also has an impact on business activities, so internet supply chain may be confront with policy environmental risk. Industry development risk mainly considers the development status of the industry that the supply chain is located. If the industry is in the growth stage or mature stage, then the operational risk of each enterprise will be small, otherwise the operational risk will be large. The industry competition risk considers the competition situation in the industry in which the supply chain is located. The more homogenous the products are, the fiercer the industry competition becomes.

III. ANALYTIC HIERARCHY PROCESS GRAY ASSESSMENT

To assess risk, analytic hierarchy process assessment method can be used, but the method is subjective and may have problems such as information loss [20]. Gray comprehensive evaluation method can also be used to assess, this method can make up the fault of analytic hierarchy process assessment but cannot measure the consistency of expert judgement [21]. Therefore, the paper combines these two methods and builds an analytic hierarchy process gray assessment method to determine the financial risk of the internet supply chain.

A. ANALYTIC HIERARCHY PROCESS ASSESSMENT

In the internet supply chain financial risk assessment system, these indicators have different degrees of impact on risk and so their weights are different too. It is necessary to determine the weight of each indicator by means of analytic hierarchy process.

From Table 1, the target layer is the risk assessment of ISCF, the criteria layer is the six primary risk indicators, each risk indicator corresponds to its own project hierarchy. According to the corresponding importance of these indicators, experts score and thus form a judgment matrix. Calculate the maximum eigenvalue of the judgment matrix and the corresponding feature vector, and then determine whether the judgment matrix under the maximum eigenvalue satisfies the consistency test. Otherwise, experts will score again until the consistency condition is satisfied. Through the analytic hierarchy process, the following weights are obtained (see Table 2).[1]

B. GRAY ASSESSMENT

1) ASSESSMENT SAMPLE MATRIX

First of all, with the traditional five-level classification idea of loan risk, the risk indicators of internet supply chain finance are divided into five categories according to the risk level, which are very low risk, low risk, medium risk, high risk and very high risk, respectively. Furthermore, these five kind of risk will be assigned 1 point, 2 points, 3 points, 4 points and 5 points, respectively. If the risk level is between two of these indicators, the value will be assigned 1.5 points, 2.5 points, 3.5 points, and 4.5 points, respectively. There are two methods for expert to deal with score, one is accurate scoring and the other is interval scoring. If the expert judges the score of each indicator according to their own experience, it is necessary to consider the consistency of these scores. Suppose that there are N experts to score the indicators and denote the ith expert's score on the indicator Cjk as d_{ijk},

[1] Experts come from universities and the agricultural investment enterprises, which are the core in the supply chain. There are 67 experts to score.

then the Baker concentration factor is:

$$\rho_{jk} = [\sum_{i=1}^{N} (d_{ijk} - \sum_{i=1}^{N} \frac{d_{ijk}}{N})^2]^{\frac{1}{2}} \frac{\sum_{i=1}^{N} d_{ijk}}{N}. \tag{1}$$

The smaller the coefficient, the more consistent tendency of the indicators evaluation results, the better effectiveness of the assessment. In general, if the coefficient is less than 0.05, the expert score satisfies the consistency test; otherwise, experts need to re-score and then determines whether the concentration coefficient satisfies the consistency test. When the expert scores the evaluation index according to his own experience, denote the lower limit of the score as $\underline{m_i}$ and the upper limit as $\overline{m_i}$, from the Centralization Statistical Method, the risk evaluation value R can be expressed as

$$R = \frac{\frac{1}{2}\sum_{i=1}^{N} \overline{m_i}^2 \underline{m_i}^2}{\sum_{i=1}^{N} (\overline{m_i} - \underline{m_i})^2}. \tag{2}$$

Confidence values c_i is

$$c_i = \frac{1}{1 + \frac{\sum_{i=1}^{N} (\overline{m_i} - R)^3 - (\underline{m_i} - R)^3}{3\sum_{i=1}^{N} (\overline{m_i} - \underline{m_i})}}. \tag{3}$$

The higher the confidence, the more accurate the expert's assessment of the indicators, the better the consistency; otherwise the expert scores need to be re-examined and the consistency will also be checked again. Thus, the evaluation sample matrix D of the secondary indicators can be determined

$$D = \begin{bmatrix} d_{111} & d_{211} & \ldots & d_{N11} \\ \vdots & \vdots & \vdots & \vdots \\ d_{116} & d_{216} & \ldots & d_{N16} \\ d_{121} & d_{221} & \ldots & d_{N21} \\ \vdots & \vdots & \vdots & \vdots \\ d_{123} & d_{223} & \ldots & d_{N23} \\ \vdots & \vdots & \vdots & \vdots \\ d_{161} & d_{261} & \ldots & d_{N61} \\ d_{162} & d_{262} & \ldots & d_{N62} \end{bmatrix}_{19 \times N}, \tag{4}$$

where 19 is the number of the secondary risk indicators.

2) GRAY CLASS ASSESSMENT

From Hu(1996), to assess the gray class, it needs to know the grade number of gray classifications, the gray number of the gray classifications, and the corresponding whitening weight function. Since the indicator risk is divided into five levels, it is necessary to determine five evaluation gray classes. Assume that the assessment gray class number is r, where $r = (1, 2, 3, 4, 5)$, the higher the number the lower the risk. For any gray class number r, gray number $\oplus_r \in [0, r, 2r]$, whitening weight function f_r can be expressed as

$$f_r(d_{ijk}) = \begin{cases} d_{ijk}/r, & d_{ijk} \in [0, r], \\ 2 - d_{ijk}/2r, & d_{ijk} \in (1, 2r], \\ 0, & d_{ijk} \notin [0, 2r]. \end{cases} \tag{5}$$

Specially, when $d_{ijk} \in [0, 1], f_1(d_{ijk}) = 1$.

3) ASSESSMENT GRAY MATRIX

For any secondary indicator C_{jk}, there will be N scores from experts. Substituting each score into whitening weight function f_r and summing them, gray assessment coefficient of the corresponding class can be obtained. By adding up all the gray assessment coefficients, the total coefficient is obtained. Divide the gray assessment coefficient of each class by the total coefficient can obtain the gray weight μ_{rjk}, that is,

$$\mu_{rjk} = \frac{\sum_{i=1}^{N} f_r(d_{ijk})}{\sum_{r=1}^{5} \lambda_{rjk}} \tag{6}$$

Therefore, assessment vector can be expressed as $V_{jk} = (\mu_{1jk}, \mu_{2jk}, \mu_{3jk}, \mu_{4jk}, \mu_{5jk})$ and the assessment gray matrix has the form $V_j = (\mu_{j1}, \mu_{j2}, \mu_{j3}, \mu_{j4}, \mu_{j5})$, where K is the number of secondary indicators of the primary indicator B_j.

C. COMPREHENSIVE ASSESSMENT

For any primary indicator B_j, denote the weight vector of the secondary indicators obtained by analytic hierarchy process as W_j, gray assessment weight matrix as V_j, then the comprehensive assessment vector of can be expressed as B_j. The comprehensive assessment matrix Y is consisted by these vectors. Assume that the risk assessment weight vector of the primary indicator is W, the comprehensive assessment vector of ISCF risk Q has the form $Q = W \times Y$. From the above valuation of five-level risk classification, the comprehensive risk assessment of ISCF is derived as

$$q = q_1 + 2q_2 + 3q_3 + 4q_4 + 5q_5. \tag{7}$$

According to Table 3, I can judge the comprehensive risk is big or small.

TABLE 3. Risk level of internet supply chain finance.

Risk value range	[0,1]	(1,2]	(2,3]	(3,4]	(4,5]
Risk classification	1th	2th	3th	4th	5th
Risk attribute	Very low risk	low risk	Medium risk	High risk	Very high risk

Therefore, when investor provides financing service to SMEs in supply chain, risk can be assessed from the above analysis. Tracking and monitoring the partners' panoramic data and the upstream and downstream data in the supply chain, substituting them into assessment model to determine the risk of the financing enterprise real-time, it will be easy to make a decision on whether to lend before the loan and to provide the risk warn after the loan.

IV. EMPIRICAL ANALYSIS

Take Zhong-ken Supply Chain Co., Ltd., a focal company in supply chain, as an example. One small and medium-size enterprise in downstream of the supply chain needs financing. 10 experts, who work in the supply chain financial industry for more than five years, are invited to score the financial risk of internet supply chain according to some information such as relevant financial statement data. Firstly, they score

$$D = \begin{bmatrix} 2.5 & 1.0 & 2.5 & 3 & 1.5 & 4.0 & 4.0 & 1.0 & 2.5 & 3.0 & 2.0 & 1.0 & 2.5 & 1.5 & 0.5 & 1.0 & 2.5 & 4.5 & 3.0 \\ 2.5 & 1.5 & 3.0 & 2.0 & 4.5 & 3.5 & 1.5 & 2.0 & 3.5 & 1.5 & 1.5 & 2.0 & 2.0 & 2.0 & 0.5 & 1.0 & 3.0 & 4.0 & 3.5 \\ 3.0 & 1.0 & 3.0 & 3.0 & 1.0 & 3.5 & 3.0 & 1.0 & 2.5 & 3.0 & 2.0 & 1.0 & 3.0 & 1.5 & 1.0 & 1.5 & 3.0 & 3.5 & 3.5 \\ 3.5 & 2.0 & 2.0 & 2.5 & 1.5 & 4.0 & 4.5 & 0.5 & 3.5 & 3.5 & 2.5 & 1.5 & 3.0 & 2.0 & 1.0 & 1.5 & 2.5 & 3.5 & 3.0 \\ 3.0 & 1.0 & 2.0 & 2.5 & 2 & 3.5 & 4.0 & 0.5 & 3.0 & 3.5 & 2.0 & 2.0 & 3.0 & 1.5 & 0.5 & 1.0 & 3.0 & 4.0 & 3.0 \end{bmatrix}$$

the secondary indicators and determine the sample matrix as the matrix D, shown at the top of this page.

Secondly, dealing with all columns of the matrix D^T according to equation (6), I can obtain some gray assessment weight vectors for all indicators. Multiplying the gray assessment weight vector of each indicator by the weight vector listed in Table 2, the gray evaluation weight matrix of each index can be obtained as follows.

$$V_1 = \begin{bmatrix} 0.00 & 0.17 & 0.41 & 0.23 & 0.18 \\ 0.30 & 0.27 & 0.18 & 0.14 & 0.11 \\ 0.00 & 0.28 & 0.31 & 0.23 & 0.18 \\ 0.00 & 0.20 & 0.33 & 0.26 & 0.21 \\ 0.16 & 0.33 & 0.22 & 0.16 & 0.13 \\ 0.00 & 0.04 & 0.28 & 0.37 & 0.31 \end{bmatrix},$$

$$V_2 = \begin{bmatrix} 0.00 & 0.06 & 0.29 & 0.35 & 0.30 \\ 0.44 & 0.22 & 0.15 & 0.11 & 0.09 \\ 0.00 & 0.24 & 0.31 & 0.25 & 0.20 \end{bmatrix},$$

$$V_3 = \begin{bmatrix} 0.00 & 0.13 & 0.33 & 0.30 & 0.24 \\ 0.04 & 0.35 & 0.26 & 0.19 & 0.16 \\ 0.25 & 0.29 & 0.19 & 0.15 & 0.12 \end{bmatrix},$$

$$V_4 = \begin{bmatrix} 0.00 & 0.24 & 0.33 & 0.24 & 0.20 \\ 0.12 & 0.34 & 0.23 & 0.17 & 0.14 \\ 0.53 & 0.18 & 0.12 & 0.09 & 0.07 \end{bmatrix},$$

$$V_5 = \begin{bmatrix} 0.34 & 0.26 & 0.17 & 0.13 & 0.10 \\ 0.00 & 0.21 & 0.33 & 0.25 & 0.20 \end{bmatrix},$$

$$V_6 = \begin{bmatrix} 0.00 & 0.04 & 0.28 & 0.37 & 0.31 \\ 0.00 & 0.14 & 0.34 & 0.29 & 0.23 \end{bmatrix}.$$

According to the weight result listed in Table 2, bringing each weight vector into the corresponding gray assessment weight matrix and multiplying these results, I can obtain the total gray assessment matrix.

$$Y = \begin{bmatrix} 0.01 & 0.01 & 0.01 & 0.01 & 0.01 \\ 0.00 & 0.01 & 0.02 & 0.02 & 0.02 \\ 0.01 & 0.04 & 0.04 & 0.04 & 0.03 \\ 0.02 & 0.03 & 0.02 & 0.02 & 001 \\ 0.03 & 0.06 & 0.07 & 0.05 & 0.04 \end{bmatrix}.$$

Multiplying the weight vector of primary indicator in Table 2 with the total gray assessment matrix, a comprehensive assessment vector can be obtained.

$$Q = (0.06\ \ 0.18\ \ 0.28\ \ 0.26\ \ 0.21).$$

Substituting the above assessment vector Q into equation (7) can get the risk assessment value $q = 3.39$. According to Table 3, the risk of financing is much high, so the choice that do not finance will be better for the investor.

V. CONCLUSION

Risk assessment of ISCF is usually based on partners' panorama data and the upstream and downstream data in the supply chain. The former mainly includes financing enterprise information, focal company information, logistics enterprise information and so on, the latter mainly includes pledge information, internet information, external industry and environmental information. Based on the collected big data, a multiple dimensional intelligent risk assessment system is constructed. Through tracking and monitoring of the partners' real-time panoramic data and the upstream and downstream data of the supply chain, the risk of the financing enterprise can be judged timely. Therefore, the decision on whether to finance money or not before lending will be made by investor and risk warning can be made by risk system after lending. As a result, intelligent risk assessment can give more financing opportunities to SMEs, especially those who do not have any credit data in the credit information system of central bank. At the same time, it can also be useful to improve the risk control level of internet supply chain finance.

Because of the widely use of internet, it becomes easier to grasp the solvency, operational capability, profitability, development status, credit status of each partner in the supply chain, it is also easier to obtain information flow such as the price changes, liquidation status of the pledge and management status in the supply chain, which can effectively alleviate the information asymmetry between supply side and demand side. For the data source, it can cover transaction data of e-commerce platform, transaction information of ERP cloud platform, logistics data of warehousing, fiscal and taxation data, transaction cross data of online-to-offline trade, offline terminal data of deep distribution platform and so on. Those data can be obtained easily and used efficiently, therefore reduce risk in the ISCF.

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