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Network Security

Research on Security Risk Management of Supply Chain Finance Based on Blockchain Technology

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Abstract

This paper focuses on the research of supply chain finance security risk management based on blockchain technology. Supply chain finance, as a key model for the deep integration of industry and finance, plays an important role in economic development, but faces multiple risks such as credit, information security, operation and market, which constrains its healthy development. Blockchain technology, with its characteristics of decentralization, non-tampering and traceability, can effectively deal with these risks. It reduces credit risk, safeguards information security, reduces operational risk and copes with market risk by constructing a credible transaction environment, enhancing information transparency, safeguarding data security and utilizing smart contracts to reduce human errors. Based on this, a blockchain-based risk early warning system is constructed and blockchain-enabled risk control measures are proposed. Finally, this paper provides new ideas and methods for the sound development of the supply chain finance industry by introducing blockchain technology.

Keywords: Blockchain Technology, Supply Chain Finance, Security Risk, Risk Warning Management

1. Introduction

1.1 Background to the study

With the acceleration of global economic integration, supply chain finance has become a key model for the deep integration of industry and finance nowadays, and its status has been gradually elevated in the process of economic development [1]. Supply chain finance is a technology based on core enterprises, and the main bodies involved include core enterprises, upstream and downstream small and medium-sized enterprises, financial institutions, and third-party logistics enterprises, which integrates the information, logistics and capital flows in the supply chain, and can effectively alleviate the problem of financing difficulties of small and medium-sized enterprises, and promote the synergistic development of the supply chain [2].

However, with the development of supply chain finance, many security risks have come along with it. First of all, in terms of credit risk, due to the low information transparency of the credit system of small and medium-sized enterprises (SMEs), the overall credit system is imperfect, so it is difficult for financial institutions to accurately assess their credit status, which leads to a high risk of default [3]. In terms of information security risk, with the deepening of digitization, the supply chain financial platform accepts a great deal of information in real time on a daily basis, and once it suffers a cyberattack, it will lead to the risk of data leakage, which seriously threatens the confidentiality of the enterprise's business and the privacy of its customers. Operational risks are also common security risks, such as mistakes in manual operations or internal employee fraud. There are also macroeconomic fluctuations, increased competition in the industry and other influences that can exacerbate operational risks in the supply chain. These risks not only hinder the healthy development of supply chain finance, but also pose a potential threat to the stability of the entire supply chain as well as the security of the financial market, and how to effectively deal with these risks has become a key issue that needs to be resolved [4].

In order to solve the above problems this study introduces blockchain technology, in which the characteristics of untamperability, decentralization, traceability and so on can effectively build a credible transaction environment, enhance the transparency of information to optimize the business process, blockchain characteristics mean that efficient supply chain financing transactions can be verified and tracked to reduce fraud and errors, while reducing the cost of due diligence. Blockchain can improve information asymmetry [5]. Addressing information asymmetry benefits the supply chain by providing greater transparency and traceability to

support improved product delivery. Example. Walmart uses blockchain to track the movement of leafy greens to ensure food safety. This allowed Walmart to quickly identify sources of supply chain contamination during an outbreak. The system requires suppliers to upload data to the blockchain, thereby increasing the transparency and efficiency of the food supply chain. This study theoretically analyzes the research related to blockchain-enabled security risk management in supply chain finance and provides practical risk management strategies for financial institutions, enterprises and supervisory authorities [6].

1.2 Research Status

As early as 2005, Wang et al. mentioned the concept of supply chain finance for the first time in the domestic research, and analyzed the connotation of supply chain finance business and the control of risk in the process of supply chain trade finance, and analyzed how banks can explore and extract the value of supply chain on the basis of effectively grasping the flow of logistics, capital flow and information flow to achieve the development of small and medium-sized enterprises (SMEs) in the supply chain market [7]. By 2007 Liu pointed out the risks in supply chain finance business in his report and categorized the risks into credit risk, market risk, operational risk and legal risk [8]. In 2016, Zhou et al. mentioned the concept of blockchain technology empowering supply chain finance in their study and pointed out in their article that the introduction of blockchain technology breaks the bottleneck of supply chain finance, and it is urgent to introduce blockchain technology to realize open and consistent sharing of transaction data due to the risk management and operational costs of small and medium-sized enterprises (SMEs) [9]. Coming to 2025 Zhang and his team pointed out in their research that the traditional supply chain has certain development dilemmas, including unequal information, core enterprise credit cannot be transmitted, higher financing cost and higher credit risk. Once blockchain technology is introduced, it will break the barrier of information asymmetry, get rid of the core enterprise credit dependence, enhance the efficiency and cost of financing, and prevent financial risks by using smart contracts [10]. Based on the above, this paper further studies the research on security risk management of supply chain finance based on blockchain technology.

1.3 Research content

This study focuses on the security risk management of supply chain finance based on blockchain technology. In the article, firstly, the various types of security risks faced by supply chain finance and how to identify security risks are analyzed in depth. Secondly, the relevant principles and advantages of blockchain technology are explored, and blockchain technology is introduced into the response to supply chain financial risks to clarify the principle of its role in risk reduction. Finally, based on the above research results, a blockchain-based risk early warning system is constructed, and the regulatory and compliance management strategy is improved. It provides new ideas for risk management in supply chain finance industry.

2. Supply Chain Finance and Blockchain Technology Basic Theory

2.1 Overview of supply chain finance

Supply chain finance provides an innovative model of systematic financial services and is a key link that connects upstream and downstream enterprises in the supply chain [11]. It integrates information flow, logistics, and capital flow around the core enterprise, connects manufacturers, suppliers, channel providers, sellers, and the most weekly users into an overall network structure, and provides comprehensive financial solutions such as financing, settlement, and risk management for enterprises in each link of the supply chain. Compared with traditional financial services, supply chain finance can connect the entire upstream and downstream enterprises, linking the financing difficulties of small and medium-sized enterprises [12].

In 2001, Shenzhen Development Bank gradually launched inventory financing credit business in China, i.e., movable property pledge financing business, which marked the formal launch of supply chain finance business in China. With the development of the Internet and financial technology, supply chain finance has flourished [13]. The combination of big data, artificial intelligence, Internet of Things and other technologies with supply chain finance can be more accurately used to assess the credit of enterprises and monitor risks. In addition the application scene of supply chain is also expanding, in addition to the traditional manufacturing and retailing industry also extends to agriculture, medical and other fields [14].

2.2 Principles and Characteristics of Blockchain Technology

Blockchain is a breakthrough technology that enables secure and transparent digital transactions without intermediaries. It operates on a decentralized network where multiple users work together to maintain a shared ledger of transactions. Each transaction is cryptographically linked to previous transactions to form a blockchain, hence the name "blockchain" [15]. This technology ensures that the data stored on the blockchain is tamper-proof and highly resistant to change once it is recorded. In addition blockchain technology transparency, invariance and decentralized consensus are the key aspects of blockchain that can improve efficiency, security and trust across industries. By eliminating intermediaries, streamlining processes and enabling advanced applications such as smart contracts and digital asset management, blockchain has the potential to revolutionize industries such as finance, supply chain management and healthcare. Figure 1 below illustrates the basic architecture of a blockchain system, visualizing the key components and processes involved in a blockchain implementation [16].

2.3 Application Potential of Blockchain Technology in Supply Chain Finance

In supply chain finance, there are two major problems of information asymmetry and credit risk, in addition to the authenticity of supply chain transaction data information, low efficiency of banks' post-lending management and low scientific and technological integration ability of core enterprises, while blockchain technology provides new ideas for these problems [17].

First of all, information asymmetry is a problem faced by supply chain finance. Under the traditional financial model, it is often difficult for financial institutions to obtain the real information of all enterprises in the supply chain, which buries potential financial risks. However, the introduction of blockchain technology brings distributed ledger and information sharing mechanism, which makes all kinds of transaction information and logistics information in the supply chain can be shared in real time to all the participants, and improves the transparency of information [18].

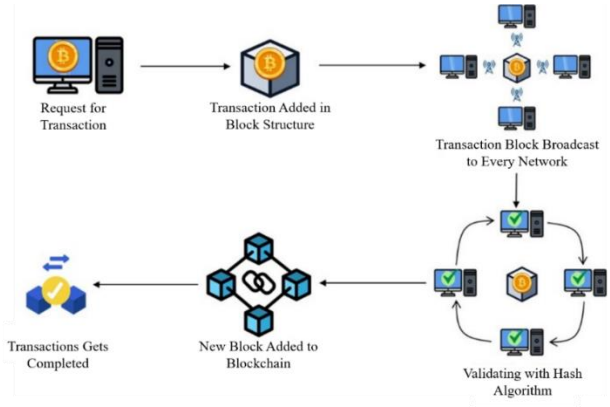

Figure 1 The basic architecture of a blockchain system

In addition credit risk is also the core risk of supply chain finance, as the credit system of SMEs is in need of improvement, so the credit assessment conducted by formal financial institutions faces difficulties. The consistency and non-tamperability of the blockchain ensures that the data on the blockchain is time-stamped, and even tampering with the data of a certain node will leave an imprint, so this solves the bank's concern about tampering with the information, and in Figure 2 below we can see the coupling diagram of the electronic payment vouchers and the financing signals. In commerce, banks can also easily see where each transaction is going, reducing the cost of monitoring [19].

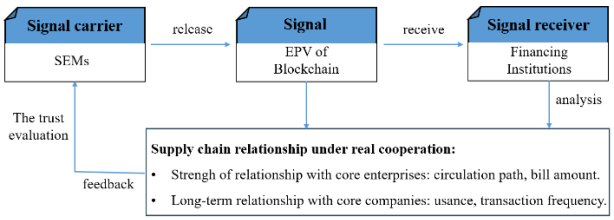

Figure 2 Coupling of electronic payment voucher and financing signal.

Finally blockchain technology can also improve the scientific and technological integration ability of core enterprises, with the help of emerging technologies such as artificial intelligence and machine learning, the transaction data recorded on the blockchain will be integrated, which not only solves the problem of unequal information, but also promotes the transparency between enterprises [20].

3. Supply Chain Finance Security Risk Analysis

3.1 Identification of risk types

The types of risks existing in supply chain finance were roughly mentioned in the previous section, and this paragraph will unfold in detail around the possible existence of supply chain finance, including credit risk, information security risk, operational risk and market risk [21].

The most prominent risk in supply chain finance is credit risk, which manifests itself in various forms and is mainly due to the following reasons: firstly, SMEs are small in scale, which usually means that the financial system is not perfect, and financial institutions find it difficult to estimate their real financial status. Secondly, SMEs have a weak sense of credit, which may lead to false financial statements. Finally, the complexity of transactions between enterprises in the supply chain leads to the fact that the credit endorsement of the core enterprise may not be maximized [22].

The threat of information security risk in the supply chain finance environment has also gradually come to the fore. Due to the gradual development of the digital era, the transaction link of supply chain finance is also vulnerable to hacking, which may cause leakage of customers' personal information and transaction data. The emergence of information security risk involves two levels, firstly, on the technical level, software design defects, weak network protection links, etc. can cause security loopholes, leading to hackers to take advantage of the opportunity. In addition, at the management level, the risk of information leakage is increased by the weak security awareness of employees, human error or imperfect information security management system [23].

In the daily operation of supply chain finance, human errors and insider fraud may occur, which are collectively referred to as operational risks. The causes of this type of risk mainly include irregular business processes, unclear operating standards, and improper staff training, etc. For example, in the loan business, staff members are negligent in verifying the information submitted by enterprises, which results in enterprises that do not meet the lending criteria obtaining financing. In addition, there are cases in which internal employees collude with external enterprises to fabricate false information in order to obtain loans fraudulently [24].

Finally, supply chain finance may have market risk on the macro level, which includes the influence of macroeconomy, vicious competition in the industry and so on. The main reason for the market risk is the above two points, the macroeconomic recession will trigger the enterprise profit margin compression, business difficulties and other circumstances lead to the decline of repayment ability. The harm of market risk is not to be underestimated, not only in the financial institutions of the loan risk, but also affect the stability of the entire supply chain. When macroeconomic

risk occurs, the related enterprises in the supply chain will suffer from the impact of business conditions, resulting in the interruption of transactions between upstream and downstream enterprises in the supply chain, and ultimately the supply chain synergistic effect can not be played [25].

3.2 Risk assessment methods

After identifying the risk of supply chain finance, it is necessary to further assess the risk to facilitate further security risk management, this paper will be in-depth elaboration of hierarchical analysis method, fuzzy comprehensive evaluation method of these two methods.

The first step is to assess the risk associated with decision-making, which involves the hierarchical analysis method (AHP), which is a decision-making method that qualitatively and quantitatively analyzes the elements associated with decision-making. In the security risk assessment of supply chain finance, the introduction of hierarchical analysis involves first determining the level of security risk in supply chain finance, and then the construction of a hierarchical model, a step that is designed to categorize risk factors hierarchically, such as the development of specific assessment indicators corresponding to each type of risk, and determining the importance weights of the elements at each level by comparing the types of risks involved two by two.

In addition, there is also a class of fuzzy comprehensive evaluation method, which refers to the comprehensive evaluation method of fuzzy data, through the use of fuzzy transformation principle and the principle of maximum affiliation degree, each relevant element of the transaction is evaluated comprehensively. In supply chain finance security risk assessment, it is necessary to determine the set of evaluation factors (including credit risk, information security risk and other risk factors) and then determine the evaluation level. Experts can then determine the affiliation degree of each factor to different evaluation levels based on the above information, so as to construct a fuzzy relationship matrix, and finally carry out the comprehensive evaluation results of the evaluated object through fuzzy synthesis operation.

3.3 Risk Transmission Mechanism

Security risks in supply chain finance can affect all links in the supply chain. For example, from the perspective of trading relationship, if some suppliers in the supply chain have credit risk and cannot deliver goods on time, it will affect the normal production of some production enterprises, which may lead to the production enterprises not being able to deliver the products to the customers on time, and then lead to the risk of default, and ultimately affect the cash flow and credit status of the enterprises.

In addition, in terms of information transmission, risks to information security may cause information distortion or information leakage. For example, if the information system of an enterprise in the supply chain suffers from hacking, the transaction data may be tampered with or leaked, and the downstream enterprises are likely to make decisions based on the previous erroneous information, which may lead to errors in procurement planning. The above problems will further affect the capital turnover and operational effects of the enterprise, and ultimately transfer the risk to the supply chain amount system.

In addition to the risk transmission mentioned above there is also the risk transmission of capital flow. Once the market risk triggered the stagnation of enterprise products, it will lead to a reduction in sales revenue, the enterprise's capital recovery will be difficult, unable to repay the supply chain financial loans on time. In order to reduce the risk, the corresponding financial institutions will take the tightened credit policy, and the loan amount or loan interest rate of other enterprises in the supply chain will be increased, which will affect the financing cost of other enterprises, and ultimately lead to the capital tension in the whole supply chain.

4. Mechanisms of the impact of blockchain technology on security risks in supply chain finance

4.1 Reducing Credit Risk

The previous section has elaborated in detail the relevant forms of risk that exist in supply chain finance, and in this section we will introduce blockchain technology with the aim of reducing the supply chain finance risks mentioned above.

Firstly, at the credit risk level, the emergence of blockchain technology can enhance the degree of information transparency of the upstream and downstream of the supply chain, in addition, blockchain technology has decentralization and distributed ledger technology, and can also build a highly credible transaction environment. In the blockchain transaction environment, every transaction information in the supply chain will be recorded in the distributed ledger, and many nodes will be maintained together, and all the enterprises in the upstream and downstream can view the transaction data and verify it in real time, which guarantees the transparency of the transaction, and effectively reduces the situation of unequal information. Another advantage of the introduction of blockchain technology is that financial institutions can directly obtain real and reliable data, so that they can more accurately assess the repayment ability of SMEs and reduce the credit risk caused by inaccurate information.

In addition the non-tampering feature in blockchain technology also provides a solid foundation for credit assessment. In credit assessment, it is necessary to verify historical transaction data, which is an important criterion for assessing the creditworthiness of enterprises. Under the traditional financial model, even if the financial transactions of enterprises are recorded, they are easily tampered with, which will increase the difficulty of credit assessment. The hash algorithm and encryption technology in blockchain technology, on the other hand, will ensure that transaction records cannot be tampered with once they are uploaded to the chain. It is guaranteed that each transaction will be linked to the previous transaction through hash values, forming a complete chain structure, so the transaction data is difficult to be tampered with. Such tamperability will ensure that

financial institutions will be able to assess the creditworthiness of a business based on authentic and reliable records.

In terms of credit record sharing, blockchain can share credit information between various participants in the supply chain, thereby breaking down information silos. Financial institutions, core enterprises, small and medium-sized enterprises and other institutions can access the credit records on the blockchain with authorization, and the introduction of blockchain technology can provide a more comprehensive understanding of the credit status of enterprises upstream and downstream in the supply chain.

At the level of default tracing, blockchain technology also has significant advantages. Once a default occurs in a certain link on supply chain finance, blockchain can help financial institutions quickly locate the source of the default and the relevant person in charge. Traceability can clearly understand the transaction records, capital flow and other related information of the defaulting enterprise through the transaction records on the blockchain, and the blockchain technology can provide strong support when recovering funds.

4.2 Guarantee information security

The encryption algorithm in blockchain technology can encrypt the data in supply chain finance to ensure the security of the data. For example, in the process of data transmission, the sender uses the public key of the receiver to encrypt the data, and it requires the receiver's own key to decrypt the data, which effectively prevents the data from being altered or stolen in the process of transmission. In terms of data storage, the distributed ledger technology of blockchain can decentralize the data storage in multiple nodes, and each node will keep the complete data or part of the data copy. This kind of storage method can effectively avoid many risks brought by data centralization, for example, if a node suffers from data destruction or loss, the data of other nodes can still guarantee that the data is complete.

4.3 Reducing Operational Risks

Operational risk is a common supply chain risk, in order to reduce the occurrence of such risks, the smart contract technology of blockchain can provide an effective ending solution. Smart contract refers to an automatically executed contract, the terms of which exist on the blockchain in the form of code. When the preset conditions are met, the smart contract can automatically complete the specified operations, which can reduce human errors in operations and reduce operational risks.

In addition, in the automatic lending scenario of supply chain finance, smart contract technology can also perform automatic lending operations according to preset lending conditions. For example, in the accounts receivable financing project, when the core enterprise confirms the receipt of goods, the smart contract can automatically trigger the lending instruction and release the financing amount to the SME. Compared with the traditional payment method, the above operation not only reduces the payment and audit process, but also reduces the errors of manual operation, such as reducing the delay of disbursement and the problem of lax audit. At the same time, the addition of smart contract technology can reduce the factors of human intervention and prevent fraudulent behavior of internal personnel.

In addition smart contracts can also be applied in the repayment reminder scenario of supply chain finance. The smart scenario can automatically send repayment information to the borrowing enterprise before the repayment date according to the agreement of the loan contract, which plays the role of reminding the SMEs, and at the same time, avoids overdue repayment caused by negligence.

4.4 Cope with market risk

Market risk is also an important factor that cannot be ignored in supply chain finance, and the introduction of blockchain technology can help participants in the supply chain chain link to actively cope with market risk by virtue of its unique advantages.

Firstly, blockchain technology can realize real-time capture of market data and information sharing, which provides accurate and timely market information for participants in the upstream and downstream of supply chain finance. Under the traditional financial model, the ability of enterprises in each link of the supply chain to obtain market information is limited, and the captured information is not real-time and effective. With the introduction of blockchain technology, the data generated in the supply chain can be captured in real time through a sophisticated combination with the Internet of Things and big data, helping enterprises to better cope in the face of market fluctuations. The collected data will also be uploaded and stored on the blockchain in a timely manner, which ensures the data's ineradicability and increases the transparency of the data.

Blockchain technology also plays an important role in market volatility and detection. Blockchain technology can analyze a large amount of data and set up detection and warning devices. Corresponding thresholds can be set on smart contracts, and when market data reaches or exceeds the threshold range, an early warning is automatically issued, helping upstream and downstream enterprises in supply chain finance to monitor the market environment in real time.

5. Supply Chain Finance Security Risk Management Strategy Based on Blockchain Technology

5.1 The construction of risk early warning system based on blockchain

In the above narrative, we mentioned that after joining blockchain technology, in theory supply chain finance has decreased in all kinds of risks, so in this chapter, we design a set of supply chain finance risk early warning system based on blockchain technology in theory. This system, firstly, starting from the credit risk dimension, should incorporate indicators such as enterprise repayment records, credit rating changes, counterparty credit status, etc. Secondly, in terms of information security risk, indicators such as the number of

data leaks, the number of system vulnerabilities, and the strength of encryption algorithms should be taken into account. The above indicators are then used to complete the real-time collection of data with the help of blockchain's distributed ledger technology, which guarantees the reliability and non-tamperability of the data source.

The early warning system can be divided into a data collection layer, a data processing layer and an early warning release layer. And the blockchain nodes in the data collection layer and the information systems within each link of the supply chain should be docked and automatically acquire various types of risk data. Machine learning algorithms should be introduced into the data processing layer to build risk prediction models, for example, in the model for predicting credit risk, historical data can be introduced to make predictions. The early warning dissemination layer is to convey the occurrence of risk warning to financial institutions, core enterprises in the supply chain, etc. in a timely manner.

After the data is collected, it is also subjected to data cleansing, removal of duplicates, erroneous data, etc., and then standardized to help format uniformity. In this step, correlation analysis can be introduced to explore the intrinsic connection between the data. And add time series analysis methods to predict the trend of risk development. When the risk indicator reaches the early warning indicator, the emergency plan will be activated quickly.

5.2 Blockchain-enabled risk control measures

One of the advantages of blockchain technology is distributed storage, where it can be used to strengthen enterprise identity authentication in the supply chain by constructing a distributed identity authentication system. Identity information is stored in encrypted form in the blockchain at the time of initial enterprise registration to generate a unique digital identity. In this way, identity authentication is required before future transactions to ensure the authenticity and reliability of the identities of both parties.

In addition, Internet of Things technology can be introduced to combine blockchain technology with it to establish a blockchain-based pledge supervision mechanism. First, sensors will be installed before the pledges are provided to collect real-time information on location, status, quantity, etc., so that an alarm will be issued as soon as any abnormality occurs in the pledges and subsequent financial transactions will be frozen, thus safeguarding the security of the pledges and reducing the risks of financial institutions.

6. Conclusion

This study provides an in-depth analysis of the application of security risk management in supply chain finance empowered by blockchain technology. Since supply chain finance occupies an important position in economic development, it hides many risks in credit, information security, operation and market. And blockchain technology can show significant advantages in reducing credit risk, guaranteeing information security, reducing operation risk and coping with market risk by virtue of its decentralization, tampering and traceability characteristics. Therefore, this paper provides new research ideas for supply chain finance at the level of risk management with the help of blockchain technology.

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