Improving supply chain resilience : Development of a decentralized trust mechanism in the supply chain

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Yu Cui

1. Introduction

At present, with the rapid development of information technology, substantial changes have taken place in the business models and concepts of enterprises. In order to adapt to the fierce market competition environment in current era, the best business development pattern for modern enterprises is mutual cooperation among enterprises (Lian et al., 2017). Supply chain, as one of the multiple cooperation modes, is the one that aims at win-win status (Chen et al., 2017).

Through the cooperation among enterprises, supply chain members can enhance their core competitiveness, accordingly, competitiveness of supply chain is also raised. However, such cooperation among enterprises is also accompanied by risks, due to information asymmetry, cooperative members may perform disruptive behaviors when they are driven by interests, which indicates that on the one hand, supply chain can assist members of supply chain to adapt to the market in no time, on the other hand, it may also cause irreparable losses to supply chain members (Zhang et al., 2014; Wang et al., 2017; Kerkkamp et al., 2018).

These problems can be analyzed mainly from two aspects: The first one is from external environmental factors, especially the blows and harm on supply chain that caused by natural irreversible emergencies or geopolitics, terrorist attacks (Behzadi, et al., 2017). Examples include the 2011 Tohoku Earthquake and tsunami, floods in Thailand, the unstable situation in the Middle East, or supply chain fracture induced by large-scale fires and public transport accidents. The second one is from intentional or unintentional human-made actions, such as tampering production test data, hacking and the poor commu-

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nication among and within organizations which result in huge losses to the whole supply chain (Brusset, et al., 2017).

For the former one, there has been a great deal of valuable research and practice on how to respond promptly after an incident and resume production and operation as soon as possible (Ribeiro, et al., 2018). In practice, however, the means by which forecasts or preventive measures can be made in advance are very limited.

The most effective way to improve supply chain resilience is to make a detailed record in advance and grasp clear and real-time supply chain related enterprises at each node. While at most, these measures can merely minimize the damage and loss of supply chain and cannot completely avoid or solve the essential problems of supply chain management.

For the latter, although there have been a large number of research findings for our reference, as technology advances and environment continues to change, new methodologies still need to be constantly introduced in research and practice for innovative and transformative breakthrough (Gill, et al., 2016). In addition, researches concerning how to improve supply chain resilience with the latest technology and innovative management methods and eventually to solve the inherent weakness and complexity of supply chain is still little. It can be said that upon solving the latter problem, transparency of supply chain can be fully enhanced, accordingly, the former problem can be solved indirectly.

2. Factors affecting supply chain resilience

After decades of development since the 1980s, supply chain is increasingly grown. In the meantime, some fundamental problems existing in it are still apparent and unavoidable, which are reflected in the following aspects:

2.1 Distortions of information transfer lead to bullwhip effect

There is always a two-way flow of information among suppliers, manufacturers, distributors and customers in supply chain. Since information cannot be effectively shared, information regarding supply and demand is often distorted or amplified step by step, resulting in greater demand information fluctuations, which is also the typical bullwhip effect in supply chain (Udenio, 2015). Due to the multi-level information transfer in supply chain, it is impossible to eliminate the bullwhip effect, which inevitably raises supply chain cost and lowers supply chain efficiency.

2.2 Counterfeit and shoddy products undermine the market order

Counterfeit and shoddy products appear in market ceaselessly; product quality problems frequently occur; and supply chain members lack basic trust (Capaldo, et al., 2015). When problems occur, suppliers and manufacturers usually tend to clarify their responsibilities and attribute fault to upstream or downstream suppliers, resulting serious disruption of market order (Singh, et al., 2016). To eliminate counterfeit and shoddy goods and ensure the rights and interests of customers being protected, every link of supply chain have to be strictly inspected and supervised so as to establish a supply chain which is transparent, mutual trust, and take the initiative to comply with agreement.

2.3 Information asymmetry and crisis of trust reduce supply chain efficiency

In essence, supply chain is to achieve earnest cooperation and coordinated development among enterprises through information sharing (Khan, et al., 2016). Nevertheless, as a result of the short-term and temporary interests among the nodes in supply chain, information can barely be shared among the members in supply chain (Kim, et al., 2017). The crisis of trust among supply chain members is reflected in the asymmetry of trust between upstream and downstream enterprises and the absence of trust mechanism in supply chain.

For their own interests, individual enterprise strictly keep their own business information confidential or even share false information, resulting in information asymmetry between upstream and downstream enterprises in the supply chain, poor communication, coordination difficulties in business activities, high costs, the lack of controllability, and the reduction of supply chain efficiency.

Hence it is imperative to solve these problems existing in the development of supply chain, rebuild supply chain system through Blockchain technology, and make profound changes in the context of Internet of Things (IoT).

3. Introducing blockchain

3.1 Definition of blockchain

Blockchain technology and its application is currently a topic in the spotlight. It generally refers to the application platform based on blockchain technology. Each functional entity of the blockchain (including blockchain application and blockchain service platform) jointly maintains one or more distributed peer-to-peer ledgers, and the data in the distributed ledger is encrypted and stored, making it hard to be rewritten or forged (Swan, et

al., 2015). Blockchain technology is highly anticipated and considered to be a trusted, accountable, transparent and efficient trading application (Maria-Lluïsa, 2017). It can be applied in the fields of financial services, healthcare, government, manufacturing, retail, media and entertainment, supply chain and logistics.

In this section, some characteristics of blockchain technology and blockchain thinking will be briefly analyzed, and approaches to optimize IoT network and service platform through utilizing blockchain will be introduced.

Bitcoin is a source code based on peer-to-peer and decentralized networks (Nakamoto, 2008). Blockchain, as the underlying technology of bitcoin, is a new distributed architecture and computing paradigm that applies cryptography to encrypt data transmission and access (Noguchi, 2017). In Bitcoin system, the problem of double payment and Byzantine issues are innovatively fixed. In detail, the double payment problem refers to utilizing the digital nature of money to complete multiple transactions by paying "one sum of money"; the problem of Byzantine general refers to the fact that in the absence of third-party trust institutions, it is difficult to establish mutual trust mechanism. And in Bitcoin system, the above two problems are both resolved.

Blockchain technology builds a trustworthy decentralized system through distributed consensus algorithms and digital encryption, accomplishes information transfer and value transfer synchronously, and reaches consensus and establishes mutual trust mechanism in distributed nodes (Tapscott, et al., 2016). Through the utilization of cloud services and Security Keeper, information resources such as smart government and think tank are integrated to provide relatively neutral platform for members of blockchain, meanwhile, transparency of data transmission is enhanced; regulatory functions and social supervision functions of government can be fully exerted, and diversity of information resource accesses can be realized.

3.2 Characteristics of blockchain

Blockchain involves Hash function, Merkel tree, asymmetric encryption, data block, chain structure, timestamp, P2P network, transmission mechanism, PoS, blockchain finance, block supply chain and etc. Combined with the connotation, technology and framework of blockchain, we summarize its basic characteristics as follows.

Distributed node in decentralizing blockchain system form pedigree distribution. Trust between each other is built through mathematical methods rather than an obligatory management authority so as to ensure that each node has equal rights and

obligations. Data performs redundant backup at node and the data loss of a single node will not damage the integrity of the entire network system, in other words, individual node cannot freely manipulate data, thus forming a decentralized distributed network system. The storage, repair, delivery and inspection of blockchain data all depends on decentralized distribution system, which renders blockchain-based data and information more resistant to transform.

The principle of data encryption in a secure and transparent blockchain network originates from asymmetric cryptography. In the process of encryption, asymmetric Public Key and Private Key are applied, so as to satisfy the security demand and ownership verification demand. In the meantime, the operating process and rules of blockchain system are safe and transparent, and update of the network data is in need of joint support of multiple users.

Intelligent contract blockchain has a transformable programming system that allows nodes to set up efficient smart contracts. Intelligent contract can automatically tell the conditions for the implementation of contract and the obligations to perform, automatically execute the contractual matters that meet the conditions, and guarantee orderly execution of the contract without the supervision of central authority. Accordingly, execution efficiency is enhanced, and resource waste is diminished.

Verifiable blockchain system uses timestamping technology to extend time dimension of data and to ensure the verification of its data storage and exchange. Timestamp is called the PoW (Proof of Work) of block data, and the blockchain database composed of it cannot be forged and tampered with, so that blockchain can be applied into the field with higher time series requirements, and the chain structure can be used to trace any data.

4. Applications of blockchain technology in both supply and demand sides transaction authentication

In recent years, the credit problems caused by both supply and demand sides in supply chain make the supply chain resilience is greatly challenged. The blockchain technology's high reliability proof mechanism has brought new directions and hopes for supply chain to solve the credit problems of both sides. The key features of the blockchain are credible, transparent, secure, low cost and decentralized, all of which are tremendous changes to the existing infrastructure and principles of the supply chain trading system, especially the belief that blockchain does not require credit data proof mechanism to

completely solve the problem of the traditional credit system can be denied.

Based on the basic theory and technology of blockchain, this section proposes to reshape the credit mechanism and the dynamic multi-center collaborative authentication model based on the transaction structure of the supply chain.

4.1 Blockchain transaction structure applied in supply chain

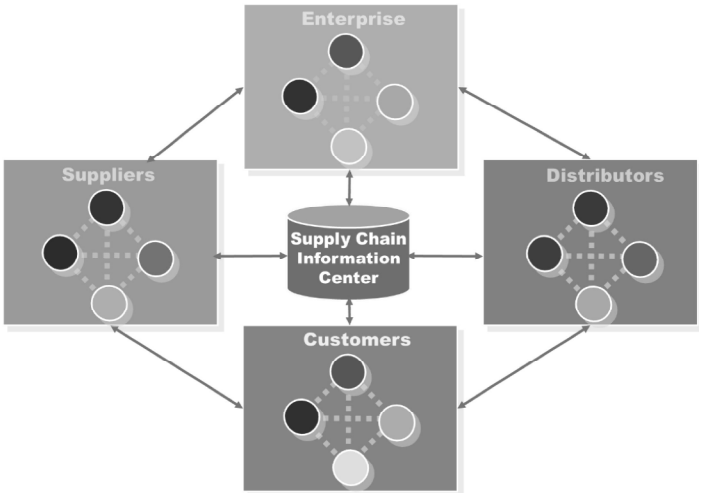
Supply chain transaction is the main mode of network transaction. In real life, it is faced with serious problem regarding transaction credit. Although the development of big data technology has brought a turn for the better to transaction credit issue of supply chain, parties participating in the transaction can adopt big data technology to check transaction big data of each other and acquire transaction data and information proof of each other.

Due to the data source being limited, complete transaction credit data cannot be acquired, meanwhile, as a result of the independence of data source and data information, big data technology also provides a higher possibility for criminals to modify, destroy, steal and trade data (Luo, 2012). Therefore, fundamentally speaking, Big Data technology is still unable to completely solve the data proof problem in supply chain transaction.

From raw materials to finished products, supply chain is the entire chain throughout the whole process, involving multiple transaction entities such as suppliers, manufacturers, distributors and sellers, and customers. Part of supply chain is contained in ERP, which is a complex management information system of manufacturing enterprises. Therefore, for an enterprise with certain scale, its transactional relationship of supply chain is also complicated, leading to the difficulty of trading behavior authentication among transaction entities. The advent of blockchain technology can precisely solve the difficulty of authentication existing in the transactions among various trading entities in supply chain.

Based on the analysis of blockchain technology and supply chain structure, this paper constructs the transaction structure of all the transaction entities in supply chain on the basis of blockchain. In Figure 1, the transaction structure of supplier, internal transaction body of enterprise, distributor and customer constitutes a supply chain. Transaction process of main entities is realized on the basis of supply chain information center, hence the transaction process within the supply chain which involves large transaction body is proof-based.

Figure 1. Traditional transaction structure in supply chain



Source: Created by Author.

4.2 Authentication model of blockchain technology in supply chain

In traditional transactions, usually a single central agency is adopted to complete the transaction of authentication. And generally, authentication center has a certain degree of independence, authority and fixedness. Through analyzing the transaction behavior of transaction entities in supply chain, we can find out that transaction entity in supply chain is dynamically changing, and in particular, the client entity is more liquid and the degree of randomness is high.

Nevertheless, the main internal transaction body of enterprises in supply chain is generally fixed, and upstream suppliers and downstream sellers also reflect a great degree of stability in a certain period of time, meanwhile, in the transaction behavior authentication mechanism based on blockchain, the main internal transaction body of enterprise, suppliers and sellers are also the main authentication body of supply chain. Therefore, it is possible to consider the construction of a dynamic multi-center collaborative authentication model of supply chain which integrates internal transactions body, suppliers and sellers as authentication integration. In the meantime, clients, as an entity of blockchain transaction, also conduct transaction behavior authentication rather than serving as an authentication center. The role of client in the authentication is to make further proof when multi-center collaborative authentication cannot prove the transaction behavior.

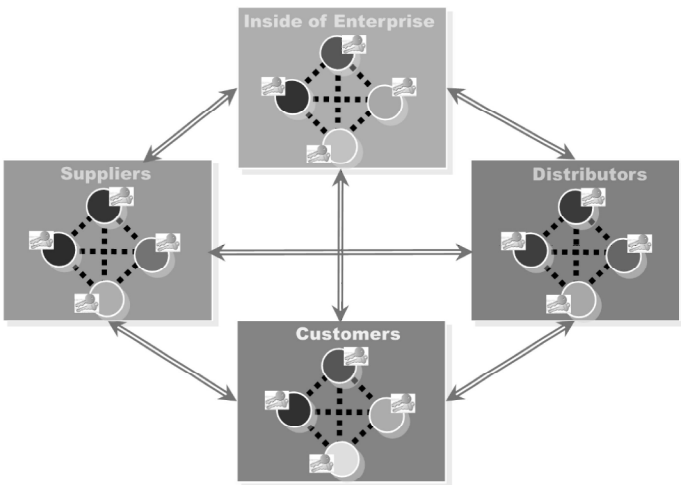
Compared with traditional independent central authentication, there is no need for

blockchain based dynamic multi-center collaborative authentication model to entrust a third party to act as an independent authentication center, and multiple transaction entities act as different authentication centers to jointly verify supply chain transactions. In the long run, upstream suppliers and downstream distributors and sellers are dynamically changing, accordingly, the number of authentication centers participating in authentication transactions are ensured, and the formation of collusion is prevented.

Due to the interest game, individual authentication center, as the main transaction entity in supply chain, tends to proactively comply with the credit mechanism. Accordingly, the dynamic multi-center collaborative authentication model based on blockchain possesses a high degree of transactional stability and proof. And this dynamic multi-center collaborative authentication model based on blockchain supply chain is shown in Figure 2.

As can be seen from Figure 2, any main transaction entity among the main internal entity of transaction in enterprise, suppliers, and distributors possesses the ability to prove transaction behavior. If a main entity of transaction alone or in conjunction with other transaction entities attempt to tamper transaction record, other transaction entities can prove this wrongdoing on the basis of their own records of the transaction, and kick it out of supply chain. If one or more transaction entities of distributors attempt to deceive consumer, the consumer may report this to other entities that as authentication center as a result of the customer's own transaction prove ability. After the verification

Figure 2. Blockchain-based multi-center transaction structure in supply chain



Source: Created by Author.

of multiple authentication centers, the unscrupulous seller will be kicked out of supply chain. In the situation that customer attempts to cheat seller, after the co-verification of multiple transaction center, the unscrupulous consumer will be recorded, and its eligibility of transaction will be cancelled.

Blockchain-based supply chain dynamic multi-center collaborative authentication model can ensure that the integrated authentication body composed by a number of transaction centers possesses certain degree of stability, enabling the internal transaction entities, suppliers and distributors to grasp the sales of goods and customer behavior, and cooperate the supply chain with ease. Additionally, high degree of transparency, consistency and authenticity of transaction information can be ensured, meanwhile, collective decision-making among internal transaction entities, suppliers, and distributors is promoted.

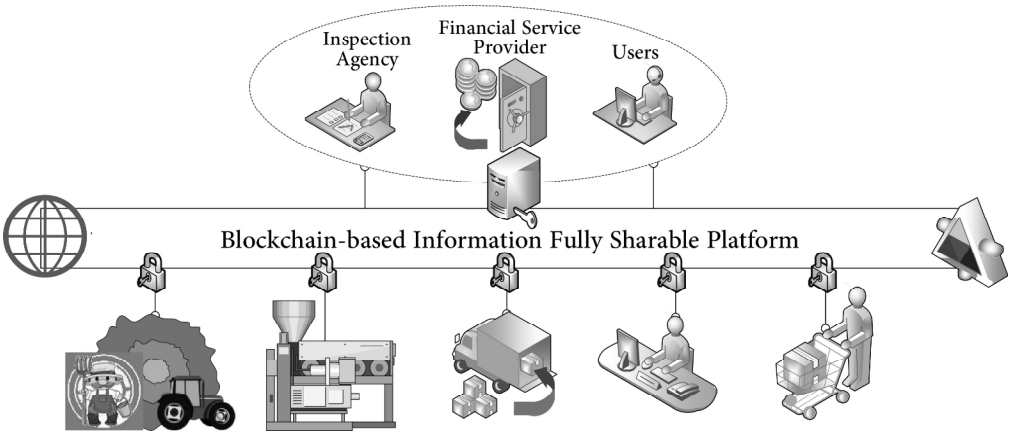
5. Building blockchain-based trust mechanism for improving supply chain resilience

Far distance between production place of agricultural products and consumption, consumers' very little understanding of the pesticides and fertilizers used by producers as well as the information on transportation, the additives used in processing, and etc, resulting in the diminishment of consumers' trust in products. The agricultural product traceability system based on blockchain technology can record all the data on the ledger and realize the full-course traceability of the quality of agricultural products and the main entities of transactions, hence enable the information to be more transparent, and the traceability service on quality and utility can be actualized.

On the one hand, the safety of agricultural products is ensured, with the resilience of agricultural supply chain being enhanced and fake and shoddy products being cracked down and eliminated. On the other hand, the quality, price fairness and effectiveness of agricultural supply chain itself are ensured. Meanwhile, the level of innovation and R&D of entire agricultural supply chain, as well as the quality and efficiency of utility can also be improved.

The introduction of blockchain technology enables all supply chain node companies to accurately grasp data and information, forming a smooth and transparent information flow in blockchain-orientated supply chain trust mechanism, and problems existing in operation process can also be timely detected and solved. At the same time, the time-stamped blockchain data and information can resolve the disputes among entities in

Figure 3. Blockchain-based trust mechanism in supply chain



Source: Created by Author.

supply chain and improve supply chain resilience by absolute information sharing among entities (see Figure 3).

With the development of big data, IoT and cloud computing, blockchain technology is expected to be applied to all walks of life. The research on blockchain technology is also in full swing in the industry and academia. The application of supply chain resilience based on blockchain technology will further enhance the security of member enterprises, their capital flow, information flow and logistics and present a more efficient and robust supply chain with a wide range of applications. From the overall development of its process, the development of agricultural supply chain based on blockchain technology is still in its infancy. On the one hand, with the standardization of data based on blockchain technology platform, can the interconnection of values be realized and the problems regarding standardization of embedded technologies, business and various interface data be solved, and it is possible to actualize large-scale application and promotion in future. On the other hand, issues such as whether the performance of supply chain resilience based on blockchain technology is stable, whether the capacity can be expanded, whether traceability can be guaranteed, and so on, still need to be explored in applications and be verified by practice constantly.

6. Conclusion

The competition in 21st century is no longer the one between individual enterprises, but the one among supply chains. In recent years, with environmental pollution, lack of

resources and frequent occurrences of product quality problems, supply chain is in urgent need of enhanced resilience. Meanwhile, as blockchain technology gradually develops and booms, nearly all the industries are embarking on the development and application of this technology. In the era of big data and IoT, how to apply blockchain technology to solve problems in order to improve supply chain resilience? This is one of the trends in the development and innovation of supply chain.

In this paper, firstly, through analyzing the case of supply chain damage caused by human factors, we conclude a conception which enhances and strengthens supply chain resilience through reshaping trust mechanisms. After that, based on this conception, we propose a solution to reshape blockchain-orientated supply chain trust mechanism in the context of IoT. Hence, the advantages of the existing cooperation mechanism of supply chain can be fully exerted. In the event of natural irreversible emergencies, the allocation of resources of entities in supply chain can be promptly and orderly adjusted so as to maximize the effect of supply chain resilience.

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Summary

In this paper, firstly, through analyzing the case of supply chain damage caused by human factors, we conclude a conception which enhances and strengthens supply chain resilience through reshaping trust mechanisms. After that, based on this conception, we propose a solution to reshape blockchain-orientated supply chain trust mechanism in the context of IoT.

Furthermore, the analysis on blockchain and its practical application clearly indicates the great effect of this framework on the improvement of supply chain resilience. At last, the discussion demonstrates that how blockchain-orientated trust mechanism in agricultural supply chain assist supply and demand sides to enhance its resilience while increasing productivity and reducing transaction costs. Hence main transaction entities of supply chain can minimize the human-induced supply chain crisis and fundamentally solve the problems regarding the complexity and transparency of supply chain.

Accordingly, the advantages of the existing cooperation mechanism of supply chain can be fully exerted. In the event of natural irreversible emergencies, the allocation of resources of entities in supply chain can be promptly and orderly adjusted so as to maximize the effect of supply chain resilience.