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Blockchain-Driven Optimal Strategies for Supply Chain Finance Based on a Tripartite Game Model

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Abstract: Applying blockchain to supply chain financing is an effective way to solve the problems of financing difficulties, high financing costs, and slow financing for small and medium-sized enterprises (SMZEs). Using evolutionary game theory, this study constructs a tripartite game model and analyzes the influence of blockchain technology on the evolutionary stability strategies for financial institutions (FIs), core enterprises (CEs), and SMZEs, in which the default losses of CEs and SMZEs are assumed to be dynamic. The results of this study are as follows: (1) When CEs and SMZEs' default losses are lower than some critical value, they tend to break their promises. (2) When accounts receivable are greater than some critical value, CEs cannot repay on time because they can make a relatively large profits from delayed repayment, whereas SMZEs can be constrained to be trustworthy. Finally, the results using numerical simulation show that both relatively large default losses and enough large, trustworthy income sources can make CEs and SMZEs tend to keep their promises; in turn, CEs would be non-paying and the SMZEs tend to be trustworthy for relatively large accounts receivable. The results provide theoretical support for realizing healthy and sustainable development for supply chain finance.

Keywords: supply chain finance; enterprises financing; blockchain; tripartite evolutionary game model



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1. Introduction

As the backbone of the economic development of China's private-owned enterprises, small and medium-sized enterprises (SMZEs) are facing the problems of financing difficulties [1,2]. Supply chain finance is more inclusive and open to SMZEs, which provides a solution to the financing problems of SMZEs. However, at present, some serious problems exist, such as lack of trust in the supply chain, asymmetric information among enterprises [3], imperfect access to information, and the reliability of information that cannot be guaranteed [4], making it impossible for all parties in the supply chain to cooperate smoothly; indeed, the effect of the supply chain is greatly reduced. There is a natural fit between the credibility of blockchain technology (BT) and the essence of finance [5]. It is worthwhile to apply BT to innovative supply chain financing models and solve the dilemma that supply chain financing cannot be used as a direct financing model [6].

Generally, there are three supply chain financing modes: accounts receivable, prepayment, and inventory pledge financing [7]. Accounts receivable are the main source of enterprise repayment in the upstream financial business, while the main source of enterprise repayment in the downstream financial business is the sales income of pledged goods, and banks and other FIs will comprehensively evaluate the financing risks of upstream and

downstream enterprises according to the transactions of accounts receivable and pledged goods [8]. Obviously, the quality of accounts receivable and sales quota of upstream and downstream enterprises determine their financing quota and financing risks. However, in the actual evaluation process, the disorderly judgment and misjudgment of the real trade situation for the upstream and downstream enterprises above “secondary” happen because the credit endorsement from core enterprises (CEs) is lacking [1]. Therefore, the current supply chain credit mechanism restricts the access of “secondary” and upstream and downstream enterprises at the end of the supply chain to obtain financial financing services.

Blockchain has immense potential to transform supply chain functions, including supply chain provenance, business process reengineering, and security enhancement [9]. The endogenous innovative features of blockchain, such as decentralization, consensus trust, collective supervision, smart contracts, being tamper proof, and traceability [4,10,11], can effectively fit the characteristics of multi-agent participation and the transmission of upstream and downstream credit levels by the level of supply chain finance in transactions and operations [12]. Supply chain finance using BT can ensure the tightness and integrity of the transaction data provided by each node of the supply chain, which, meanwhile, also avoids the influence of human factors in the transaction process, and then effectively ensure the efficient operation of supply chain finance [4]. Supply chain finance using BT is an innovative way to realize the financing mode of supply chain finance, which can solve the current problems of financing difficulties and slow financing of SMZEs, as well as the poor flow of financing information and the destruction of isolated islands of financing information in the supply chain, so as to reduce the risks of various financing participants [13].

The information asymmetry among the participants in the current supply chain finance, such as in FIs such as banks, upstream and downstream CEs, and SMZEs, is the most important reason for the financing difficulties for the upstream and downstream SMZEs on the financial platform [14]. The key to solving this blockage is whether the CEs and the FIs abide by the contract and lend money, respectively. With the empowerment of the BT, the SMZEs complete transactions by data on the chain in real time, and the credit of CEs can penetrate the whole chain. Then, the cooperation and credit transmission among all upstream and downstream enterprise nodes of supply chain finance can be achieved, which makes up for the shortcomings of supply chain financing for SMZEs [4]. From a theoretical perspective, with the increasing number of supply chain financial nodes, especially with the embedding of traditional FIs, Internet finance, blockchain system platforms, and other subjects, it will be better to obtain a trade background of supply chain financial nodes and verify the authenticity of the transactions. However, since the power mechanism for CEs to participate in supply chain finance is insufficient and there are few excellent CEs, how to construct a participation power mechanism to encourage CEs to participate in supply chain finance is one of the restrictive factors [2]. Using evolutionary game theory and assuming bounded rationality for all parties, the utilities or benefits of all parties involved in the game reach an equilibrium in a process of continuous learning and adaptation, which compensates for the deficiency in traditional game theory in that all parties involved in the game are completely rational. Due to the bounded rationality of all participants, one of the parties participating in the game often adjusts its own behavior strategy based on observing and learning other parties' behavioral strategies.

Based on the above analysis, although the existing literature provides a rich theoretical reference on supply chain finance, the following aspects still need further research: (1) Compared to the static default losses of SMZEs and CEs in existing research, the default losses are essentially dynamic for SMZEs and CEs in supply chain financing, which needs to develop new approaches to reflect the dynamic characteristics of default losses of SMZEs and CEs in supply chain financing. (2) Evolutionary game theory is used to study supply chain financing strategies, which mainly consider two or three game subjects, and an in-depth discussion on supply chain financing strategies among more game subjects should be enriching.

Therefore, to solve the above problems, this study aims to develop a tripartite dynamic game model and analyze the supply chain financing strategies of FIs, SMZEs, and CEs. The main objectives of this study are as follows. Firstly, this study constructs a supply chain financing framework for the behavior strategies of FIs, SMZEs, and CEs. Second, this study develops a dynamic game model integrated with blockchain technology among FIs, SMZEs and CEs. Finally, this study analyzes the influences on the behavior strategies of FI, SMZE, and CE for supply chain financing using BT.

The rest of this study is organized as follows. Section 2 provides a literature review of supply chain finance, “blockchain + supply chain” finance, and evolutionary game theory. The problem description is stated in Section 3. Section 4 constructs the game theory model, including the basic assumptions, and the various analyses of the proposed models. Section 5 provides the simulation analysis and implications of the results, with the conclusions given in Section 6.

2. Literature Review

This section mainly involves three aspects: supply chain finance, “blockchain + supply chain” finance, and evolutionary game theory, which provide a rich theoretical basis for the rest of this study.

2.1. Supply Chain Finance

The supply chain finance business has developed rapidly, which is showing a rising trend year by year [15]. Supply chain finance mainly involves SMZEs, CEs, and FIs. Based on the operations of enterprises in the supply chain, supply chain finance optimizes the capital flow and promotes the overall development of the supply chain through the innovation and management of financial business. It not only alleviates the financing pressure of SMZEs but also strengthens the trade relations between enterprises, which realizes the common flow of information, logistics, and capital among upstream and downstream enterprises in the supply chain, so as to provide a new development path for solving the financing difficulties of SMZEs and reducing the financing risks of FIs [2].

Scholars at home and abroad have done a lot of research on supply chain finance. Blackman et al. [16] studied the development model of supply chain finance under the background of globalization and found that the supply chain finance model can accelerate payment efficiency and weaken the supply chain financial risk. Sang-Bing Tsai [17] pointed out that banks can link CEs and upstream and downstream enterprises with the help of supply chain finance and provide them with a variety of supply chain products and services. Wang et al. [18] thought that supply chain finance has always been regarded as an important intersection of supply chain management and trade finance. Fu et al. [19] explained that the endogenous risk in supply chain finance mainly refers to the imperfect information in the supply chain and the information asymmetry among users in the supply chain. Information asymmetry will cause enterprises to choose between trustworthiness and defaults, which leads to unsuccessful cooperation. It is inevitably accompanied by risks, since supply chain finance is a credit model. For the risk prevention of supply chain finance, Gomm Moritz Leon [13] considered that the principal agent problem is one of the main reasons for the financial risk in the supply chain. According to Gomm Moritz Leon [13], the principal agent problem is one of the primary causes of financial risk in the supply chain. Sang [20] used genetic algorithms, support vector machines, and the BP neural network to assess the financial credit risk of the supply chain. Wang [21] studied the credit risk prevention of SMZEs financing from the perspective of supply chain finance. The existing research provides powerful theoretical support for banks to reduce the probability of profit damage and improve profitability.

At present, although much research on supply chain finance has solved the problems of financing difficulties for SMZEs to a certain extent, supply chain finance also has many restrictive factors, such as difficult authorization of CEs, low transparency of business processes, difficult accurate positioning and traceability of responsibilities, cumbersome

transaction procedures, and so on. It is obvious that some new methods and technologies are needed to overcome these constraints.

2.2. "Blockchain + Supply Chain" Finance

The blockchain platform plays an active role in solving problems, such as information asymmetry, and will gradually become an important business strategic deployment of FIs in the future [1]. At present, research enterprises using BT have reached strategic cooperation intentions with many banks, small loan companies, trusts, insurance, and guarantee companies to jointly build an alliance chain, providing rich soil for the smooth application of BT to supply chain financial business.

At present, BTs have four main ways to promote the development of supply chain finance, including a distributed ledger to solve information asymmetry, data traceability to help enterprise supervision, decentralization to improve clearing and settlement efficiency, and smart contract technology to solve operational risks [1,22]. For the current disassembled credit problems of the inability of CEs in China's supply chain financial market, Chen et al. [12] provided a new perspective for the bottleneck of supply chain financial development by introducing BTs. Omran et al. [23] developed a conceptual framework for a blockchain-driven supply chain financial solution, which aims to promote the coordination of the relationship between buyers and sellers and improve the efficiency of supply chain finance. Jang [24] believed that banking has become the core technology of the global financial market due to the financial trend with BT, and blockchain will be most actively applied to the financial industry, and its growth potential will be very large in the future. Hofmann et al. [25] pointed out that the blessing of BT can benefit all participants in the supply chain, which is not only conducive to improving the transaction efficiency of financial businesses but also in reducing the financing cost of enterprises. Through the research and analysis of the technical characteristics of blockchain, Malik Nida et al. [26] clearly pointed out that information encryption, distributed storage, and decentralized structure are conducive to improving the security factor of the supply chain system.

In a word, the existing research on blockchain in supply chain finance mainly focuses on mechanism design [10,27], application optimization [28], and technology optimization. However, it is not sufficient that the analyses coordinate evolutionary financing strategies based on tripartite game theory for supply chain finance using BT.

2.3. Evolutionary Game Theory

All parties involved in the game are assumed to have bounded rationality in evolutionary game theory [29], and they dynamically reach equilibrium through the process of continuous learning and adaptation, which compensates for the deficiency in traditional game theory that all parties involved in the game are completely rational. Since the game participants are bounded by rationality, one of them in the process of the evolutionary game often adjusts its own behavior strategy through observing and learning other participants' behavioral strategies [30]. Therefore, the behavioral strategy selection of each participant in the game is uncertain. One of the most important features in evolutionary games is the adaptability of their strategies with time [31].

Recently, game theory has been widely used in supply chain finance. On the one hand, the default loss in SMZEs will have an impact on whether the CEs continue to cooperate with them in the later stage and then affect the selection of strategies for SMZEs; on the other hand, whether FIs are willing to make loans depends not only on the credit situation of CEs and whether they prefer to vouch for SMZEs, but also on the early credit situation of SMZEs. Yan et al. [32] studied a supply chain financed by retailers, manufacturers, and commercial banks with limited funds and formulated a two-tier Stackelberg with banks as leaders. Based on the game model, a sensitivity analysis of the manufacturer's guarantee coefficient and the retailer's initial capital was carried out. In order to explore the impact of capital constraints and loss avoidance on supply chain operation decisions, Zhang et al. [33] discussed a supply chain with capital constraints and determined the

optimal pricing and ordering decisions through the Stackelberg game. By constructing an asymmetric evolutionary game model, Zhang et al. [34] analyzed the evolutionary stability strategies of banks, suppliers, and retailers. By introducing CEs into the traditional accounts receivable financing model, Yan et al. [35] constructed an evolutionary game model and analyzed the strategic decisions of banks, SMZEs, and CEs.

Based on the above analysis of the literature, it is obvious that evolutionary games are able to analyze the evolutionary strategies of FIs, CEs, and SEZMs. The existing research on supply chain financing mainly focuses on the game between FIs and CEs, or between CEs and SEZMs, which can not comprehensively characterize the interactive influence of strategies among all game subjects. Therefore, combining the advantages of evolutionary games theory and BTs, this study will try to develop an evolutionary game model through considering FIs, CEs, and SEZMs, and analyze the tripartite strategies of supply chain finance empowering BTs. The research will provide insights into the long-term development of the accounts receivable financing mode.

3. Problem Descriptions

Based on the above analysis, this section will give the descriptions of problem. The terminologies and symbols used in this study are also explained before constructing the evolutionary game model.

3.1. Basic Descriptions of Problem

To explore this conveniently, this study assumes that the supply chain for SMZEs financing includes a FI, a CE, and a SEZM, which were obtained by selecting representative ones in groups of FIs, CEs, and SEZMs. For traditional supply chain financing, the default records can not be shared in real time across the entire network or even be tampering or denial, since the enterprise credit information is asymmetric [36]. Furthermore, each loan issued by the FI needs to pay the marginal credit audit cost. If the FI chooses to supply chain financing with BT, automatic credit review can be realized based on its consensus mechanism, which can not only improve the efficiency of the transactions and coordination in the whole supply chain but also reduce the occurrence of the enterprises' defaults, so as to promote the win-win cooperation of all participants. Considering the existence of the debt relationship between CE and FI, if the CE fails to repay, the FI will claim against the SMZE for the principal and interest on the loan.

With the help of the BT, all transaction information for CE and SMZE in the supply chain is verified and distributed by the whole network. If the CE and SMZE keep the contract, they will obtain cooperative and trustworthy benefits. On the contrary, once they are found to have default behaviors, they need to pay large default losses. In addition, through empowering BT in the supply chain, the SMZE in the supply chain can directly borrow from the FI through digital vouchers, which can not only alleviate the difficulties in credit investigation and guarantee their financing but also improve the financing efficiency. So, it virtually increases the benefits of SMZE. The flow chart of the supply chain financing using BT is shown in Figure 1.

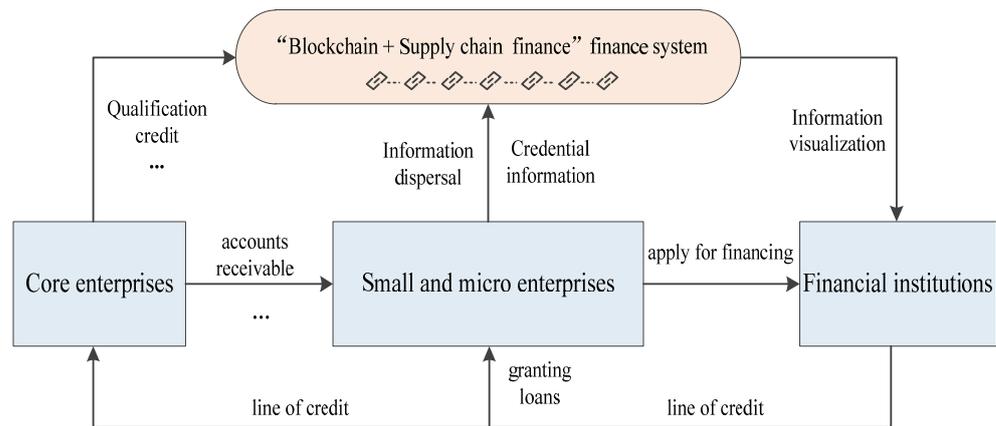


Figure 1. The flow chart of supply chain financing using BT.

3.2. Basic Descriptions of Terminologies and Symbols

In this subsection, the following will first explain the main terminologies used in this study.

- (I) Supply chain finance: Supply chain finance is a mode in which two or more internal and external entities in the supply chain circulate financial resources within the supply chain organization through the design and implementation of management activities to create value through collaboration.
- (II) Pledge rate: Pledge rate refers to the ratio of loan principal to the market value of the standard warehouse receipt, which is generally determined fairly based on the price difference between the futures and spot, the price fluctuation range, the trend, and other factors.
- (III) Accounts receivable: Accounts receivable refers to the amount that an enterprise should collect from the purchasing unit due to the sale of goods, products, services, and other businesses in the normal course of business.
- (IV) Loan interest rate: The loan interest rate refers to the ratio of the interest amount to the principal amount during the loan term. The level of the loan interest rate directly determines the proportion of profits between the borrowing enterprises and banks, thus affecting the economic interests of both the borrowers and lenders.
- (V) Return on investment: Return on investment refers to the value that should be returned through investment; that is, the economic return of an enterprise from an investment activity. It covers the profit objectives of enterprises.

Additionally, the parameter symbols and their meanings used in this study are shown in Table 1.

Table 1. The parameter symbols and their meanings.

| | Symbols | Meanings |
|--------------------|---------|---|
| decision variables | a | Pledge rate required by the FI, which is a constant |
| | R | Accounts receivable held by the SMZE |
| | i | Loan interest rate of the FI |
| | r_s | Investment return rate of the SMZEs after obtaining accounts receivable pledge financing |
| | C | Marginal credit audit cost of the FIs under traditional supply chain financing |
| | G | The blockchain and supply chain collaborative and trustworthy incentive income with both the SMZE being trustworthy and the CE choosing repayment |

Table 1. Cont.

| | Symbols | Meanings |
|------------------|---------|---|
| plain parameters | k | Proportion of collaborative and trustworthy incentive income for the SMZE |
| | G | The blockchain and supply chain collaborative and trustworthy incentive income with both the SMZE being trustworthy and the CE choosing repayment |
| | r_h | Return rate of reinvestment after deferred payment of accounts payable by the CE |
| | M, m | Default loss of the SMZE under supply chain financing using BT and the traditional way (TW) |
| | N, n | Default loss of the CE under supply chain financing using BT and TW |
| | G_1 | The extra benefits of the SMZE under supply chain financing using BT |

4. Model Development

This section will build a game model among the FI, CE, and SMZE using evolutionary game theory and will thoroughly discuss how all participants can achieve a stable cooperation state of evolutionary and coexistence with every participant’s bounded rationality. Some assumptions using the construction of the tripartite game model of FI, CE, and SMZE are given first.

4.1. Basic Assumptions

Assumption 1: Assume that the FI, CE, and SMZE are three participants in the game, and, under the condition of incomplete information, all parties seek to maximize their own benefits or utility [30].

Assumption 2: The strategy selection of the SMZE is trustworthiness (A1) or defaults (A2); the strategy selection of the FI is supply chain financing using BT (B1) or supply chain financing using TW (B2); and the strategy selection of the CE is repayment (C1) or non-repayment (C2).

Assumption 3: Assume that the SMZE will obtain an extra benefit due to the improvement in financing efficiency when the FI selects the supply chain financing using BT. Otherwise, if the SMZE breaches the contract, then the SMZE will be paid by the FI according to the principal of the pledge financing.

Assumption 4: The probabilities of the supply chain financing using BT (B1) and using TW (B2) selected by the FI are x and $1 - x$; the probabilities of trustworthiness (A1) and defaults (A2) selected by the SMZE are y and $1 - y$; and the probabilities of repayment (C1) and non-repayment (C2) selected by the CE are z and $1 - z$.

Assumption 5: Assume that the FI chooses supply chain financing using BT, and the default loss of the SMZE and non-repayment loss of the CE are adversely related to their probabilities of keeping their promises. Naturally, the default losses of the SMZE and non-repayment of the CE have changed from the fixed constants M and N to $\bar{M}(y) = (1 - y)M$ and $\bar{N}(z) = (1 - z)N$, respectively.

Based on the above assumptions, the profit matrix of the tripartite game is shown in Table 2.

Table 2. The profit matrix of the tripartite game.

| Strategies | | | FI | | |
|------------|-----------|------|-----------|--|--|
| | | | B1 x | B2 1-x | |
| CE | C1 z | SMZE | A1 y | aRi $Rr_h + (1-k)G$ $aR(r_s - i) + G_1 + kG$ | $aRi - C$ Rr_h $aR(r_s - i)$ |
| | | | A2 1-y | R 0 $aR(1 + r_s) - \bar{M}$ | R - C 0 $aR(r_s + 1) - m$ |
| | C2 1-z | SMZE | A1 y | $aR(1 + i)$ $R(1 + r_h) - \bar{N}$ $aR(r_s - i - 1)$ | $aR(1 + i) - C$ $R(1 + r_h) - n$ $aR(r_s - i - 1)$ |
| | | | A2 1-y | 0 $R(1 + r_h) - \bar{N}$ $aR(1 + r_s) - R - \bar{M}$ | -C $R(1 + r_h) - n$ $aR(1 + r_s) - R - m$ |

4.2. Evolutionary Analysis of Tripartite Game Model with the Dynamic Default Losses of Enterprises

This subsection will analyze the reliability of the evolutionary game model based on the stability analysis of equilibrium points [37]. The replicated dynamic equation (RDE) is first constructed according to the profit matrix of the tripartite game. Then, whether the equilibrium points are evolutionary stable strategies need to be discussed, as it depends on the local stability of the Jacobian matrix corresponding to the tripartite evolution system. Specifically, the evolutionary stable strategy is judged by the determinant and trace of the Jacobian matrix at the corresponding equilibrium point. If the determinant at one equilibrium point is larger than zero and the trace at the same equilibrium point is smaller than zero, then, simultaneously, this equilibrium point is an evolutionary stable strategy.

(I) Analysis of the evolutionary equilibrium for the FI.

From Table 2, the expected profits of the FI selecting strategies (B1) and (B2) are

$$\Phi_{11} = zy aRi + z(1 - y)R + (1 - z)y(aR(1 + i)), \tag{1}$$

$$\Phi_{12} = zy(aRi - C) + z(1 - y)(R - C) + (1 - z)y(aR(1 + i) - C) - C(1 - z)(1 - y), \tag{2}$$

and the average profits in both cases is

$$\bar{\Phi}_1 = x\Phi_{11} + (1 - x)\Phi_{12}. \tag{3}$$

Thus, the RDE of the FI selecting strategy (B1) is

$$C(x) = \frac{dx}{dt} = x(\Phi_{11} - \bar{\Phi}_1) = x(1 - x)C$$

Taking the first-order derivative with respect to x in C(x), the following equation can be obtained:

$$\frac{dC(x)}{dx} = C(1 - 2x)$$

Obviously, $\frac{dC(x)}{dx} > 0$ when $x = 0$, and $\frac{dC(x)}{dx} < 0$ when $x = 1$. Therefore, $x = 1$ is an evolutionary stable strategy.

(II) Analysis of evolutionary equilibrium for the CE.

From Table 2, the expected profits of the CE selecting strategies (C1) and (C2) are

$$\begin{aligned} \Phi_{21} &= yx(Rr_h + (1 - k)G) + y(1 - x)Rr_h \\ \Phi_{22} &= yx(R(1 + r_h) - \bar{N}) + y(1 - x)(R(1 + r_h) - n) \\ &+ x(1 - y)(R(1 + r_h) - \bar{N}) + (1 - y)(1 - x)(R(1 + r_h) - n) \end{aligned}$$

and the average profits in both cases is

$$\bar{\Phi}_2 = z\Phi_{21} + (1 - z)\Phi_{22}$$

Thus, the RDE of the CE selecting strategy (C1) is

$$C(z) = \frac{dz}{dt} = z(\Phi_{21} - \bar{\Phi}_2) = z(1 - z)(xy(1 - k)G + x(N - Ny - n) - R - Rr_h + Rr_hy + n)$$

Let $x_0 = \frac{(1+r_h-r_hy)R-n}{((1-k)G-N)y+N-n}$, and for the case of $x = x_0$, no matter what value of z is taken, the strategic choices of CE are stable, since $C(z) = 0$. Otherwise, for the case of $x \neq x_0$, two stable points $z = 0$ and $z = 1$ are obtained through setting $C(z) = 0$.

Taking the first-order derivative with respect to z in $C(z)$, the following equation can be obtained:

$$\frac{dC(z)}{dz} = (1 - 2z)(xy(1 - k)G + x(N - Ny - n) - R - Rr_h + Rr_hy + n)$$

Obviously, for the case of $x > x_0$, when $z = 0$, $\frac{dC(z)}{dz} > 0$; and when $z = 1$, $\frac{dC(z)}{dz} < 0$. So $z = 1$ is the evolutionary stable strategy. Similarly, for the case of $x < x_0$, the evolutionary stable strategy is $z = 0$.

From the evolutionary equilibrium analysis for the CE, it was found that the CE's profits increase with the collaboration and trustworthiness income obtained by empowering blockchain to supply chain finance, and then the CE will be increasingly keen to choose repayment. Meanwhile, if the probability of trustworthiness chosen by the SMZE is large, then the CE will get relatively large profits as long as it chooses repayment. Furthermore, when the accounts receivable from the SMZE are relatively few and the default losses of non-repayment is relatively large, the CE also chooses repayment.

Additionally, the same argument is also discussed for $y_0 = \frac{R+Rr_h-(N-n)x-n}{Gx-Gxk-Nx+Rr_h}$, but which will not be discussed in detail here.

(III) Analysis of evolutionary equilibrium for the SMZE

From Table 2, the expected profits of the SMZE selecting strategies (A1) and (A2) are

$$\begin{aligned} \Phi_{31} &= zx(aR(r_s - i) + G_1 + kG) + z(1 - x)aR(r_s - i) \\ &+ (1 - z)x(aR(r_s - i - 1)) + (1 - z)(1 - x)aR(r_s - i - 1) \\ \Phi_{32} &= zx(aR(1 + r_s) - \bar{M}) + z(1 - x)(aR(r_s + 1) - m) \\ &+ x(1 - z)(aR(1 + r_s) - R - \bar{M}) + (1 - z)(1 - x)(aR(1 + r_s) - R - m) \end{aligned}$$

and the average profits in both cases is

$$\bar{\Phi}_3 = y\Phi_{31} + (1 - y)\Phi_{32}$$

Thus, the RDE of the SMZE selecting strategy (B1) is

$$\begin{aligned} C(y) &= \frac{dy}{dt} = y(\Phi_{31} - \bar{\Phi}_3) \\ &= y(1 - y)(G_1zx + z x k G + Mx - Myx - mx - aRi - zaR - Rz + R + m) \end{aligned}$$

Let $x_0 = \frac{aRi+zaR+Rz-R-m}{(G_1+kG)z-My+M-m}$, and for the case of $x = x_0$, no matter what value of y is taken, the strategic choices of SMZE are stable since $C(y) = 0$. Otherwise, for the case of $x \neq x_0$, two stable points $y = 0$ and $y = 1$ are obtained through setting $C(y) = 0$.

Taking the first-order derivative with respect to y in $C(y)$, the following equation can be obtained:

$$\frac{dC(y)}{dy} = (1 - 2y)((G_1z + zkG + M - My - m)x - aRi - (aR + R)z + R + m) - Mxy(1 - y)$$

Obviously, for the case of $x > x_0$, when $y = 0$, $\frac{dC(y)}{dy} > 0$; when $y = 1$, $\frac{dC(y)}{dy} < 0$. So, $y = 1$ is the evolutionary stable strategy. Similarly, for the case of $x < x_0$, the evolutionary stable strategy is $y = 0$.

From the evolutionary equilibrium analysis of SMZE, it was found that the SMZE tends to choose trustworthiness when both its extra income and the collaboration and trustworthiness income obtained by empowering blockchain to supply chain finance increase. The SMZE also chooses trustworthiness if CE prefers repayment.

Additionally, the same argument is also discussed for $z_0 = \frac{mx - Mx + Myx + aRi - R - m}{G_1x + xkG - aR - R}$, but which will not be discussed in detail here.

(IV) Equilibrium analysis of the tripartite evolutionary game.

The critical conditions and paths of the evolutionary strategies of the tripartite subjects were analyzed, as well as the influence of the relevant factors on their evolutionary stable strategies. The evolutionary stable strategies and different equilibrium states under the joint action of tripartite subjects are discussed below. The replication dynamic equations for the FI, CE and SMZE are

$$\begin{cases} C(x) = \frac{dx}{dt} = x(1 - x)C \\ C(z) = \frac{dz}{dt} = z(1 - z)(G(1 - k)yx + ((1 - z)N - n)x - R - Rr_h + Rr_hy + n) \\ C(y) = \frac{dy}{dt} = y(1 - y)((G_1 + kG)zx + (a - 1)Rz + (1 - ai - 2a)R + (1 - y)Mx - mx + m) \end{cases}$$

Afterwards, the Jacobian matrix of the tripartite evolutionary system is as follows:

$$J_1 = \begin{pmatrix} \frac{\partial C(x)}{\partial x} & \frac{\partial C(x)}{\partial z} & \frac{\partial C(x)}{\partial y} \\ \frac{\partial C(z)}{\partial x} & \frac{\partial C(z)}{\partial z} & \frac{\partial C(z)}{\partial y} \\ \frac{\partial C(y)}{\partial x} & \frac{\partial C(y)}{\partial z} & \frac{\partial C(y)}{\partial y} \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix}$$

where

$$\begin{aligned} a_{11} &= (1 - 2x)C; a_{12} = 0; a_{13} = 0; \\ a_{21} &= z(1 - z)(G(1 - k)y + (1 - z)N - n); \\ a_{22} &= (1 - 2z)(G(1 - k)yx + (1 - z)Nx - nx - R - Rr_h + Rr_hy + n) - zNx(1 - z); \\ a_{23} &= z(1 - z)(G(1 - k)x + Rr_h); \\ a_{31} &= y(1 - y)((G_1 + kG)z + (1 - y)M - m); \\ a_{32} &= y(1 - y)((G_1 + kG)x + (a - 1)R); \\ a_{33} &= (1 - 2y)((G_1 + kG)zx + (a - 1)Rz + (1 - ai - 2a)R + (1 - y)Mx - mx + m) - y(1 - y)Mx. \end{aligned}$$

The evolutionary stable strategies obtained from the above RDE can be determined by the determinant and trace of the corresponding Jacobian matrix J_1 . Specifically, the determinant and trace of the Jacobian matrix J_1 need to simultaneously satisfy $\det(J_1) > 0$ and $Tr(J_1) < 0$ [38]. Through calculating the determinant and trace of the Jacobian matrix at the eight local equilibrium points, namely, $E_1(0, 0, 0)$, $E_2(0, 0, 1)$, $E_3(0, 1, 0)$, $E_4(0, 1, 1)$, $E_5(1, 0, 0)$, $E_6(1, 0, 1)$, $E_7(1, 1, 0)$ and $E_8(1, 1, 1)$, and substituting the eight equilibrium points into the Jacobian matrix J_1 , respectively, the eigenvalues of the Jacobian matrix J_1 corresponding to the equilibrium weight points were obtained, as shown in Table 3.

Table 3. System equilibrium points and eigenvalues.

| Equilibrium Points | Eigenvalue λ_1 | Eigenvalue λ_2 | Eigenvalue λ_3 |
|--------------------|------------------------|------------------------|---------------------------|
| $E_1(0, 0, 0)$ | C | $n - R - Rr_h$ | $(1 - ai - 2a)R + m$ |
| $E_2(0, 0, 1)$ | C | $n - R$ | $aRi + 2aR - R - m$ |
| $E_3(0, 1, 0)$ | C | $R + Rr_h - n$ | $-aiR - aR + m$ |
| $E_4(0, 1, 1)$ | C | $R - n$ | $aiR + aR - m$ |
| $E_5(1, 0, 0)$ | -C | $N - R - Rr_h$ | $R - aiR - 2aR + M$ |
| $E_6(1, 0, 1)$ | -C | $G(1 - k) + N - R$ | $2aR - R + aiR$ |
| $E_7(1, 1, 0)$ | -C | $R + Rr_h$ | $G_1 - aiR - aR + M + kG$ |
| $E_8(1, 1, 1)$ | -C | $R - (1 - k)G$ | $(1 + i)aR - (G_1 + kG)$ |

4.3. Influence Analysis of Blockchain on the Parameters and Equilibrium Results

This section will further analyze the influence of blockchain technology on the parameters and evolutionary stable strategies based on the results in Table 3.

(1) Blockchain affects the equilibrium by increasing the default losses, and relatively large default losses make the CE and SMZE tend to keep their promises.

From the above results, for the conditions $N < R + Rr_h$ and $R + M < aiR + 2aR$, the stable strategy of the system corresponds to the equilibrium point $E_5(1, 0, 0)$. Specifically, the financial institution prefers supply chain finance using BTs, and CEs and SMZEs tend towards non-repayment and default, respectively. From the results, it can be seen that, for the smaller non-repayment and default losses, M and N simultaneously, the CEs and SMZEs tend to break their promises in the financing process.

(2) Blockchain affects the equilibrium by decreasing the accounts receivable, and the CEs would be non-payment and the SMZEs tends to be trustworthy for relatively large accounts receivable.

For $G(1 - k) + N < R$ and $2aR + aiR < R$, the stability strategy of the system corresponds to the equilibrium point $E_6(1, 0, 1)$; that is, the CEs and SMZEs tend to be non-repayment and trustworthy, respectively, when FI prefers supply chain finance using BTs. For a relatively large accounts receivable, the CEs can obtain a relatively large income from delayed payment of accounts receivable, which would make it impossible to make the repayment chosen by the CEs in time. Meanwhile, a relatively large accounts receivable, which is greater than the principal and interest of a loan from FI, can constrain the choice of the SMZEs to be trustworthy.

(3) Blockchain affects the equilibrium by increasing the trustworthy incentive profits, and enough large trustworthy incentive profits from the supply chain using BTs would make the CEs and SMZEs tend to keep their promises.

If $R < (1 - k)G$ and $(1 + i)aR < G_1 + kG$, the stability strategy of the system corresponds to the equilibrium point $E_8(1, 1, 1)$. FI prefers supply chain financing using BT, and CEs and SMZEs tend towards repayment and trustworthy, respectively. Obviously, the sufficiently large trustworthy incentive income from the supply chain finance using BT gives enough large benefits for the CEs and SMZEs, which would generate a strong drive to keep their promises. Specifically, the trustworthy incentive income is larger than accounts receivable for CEs, and meanwhile, the sum of the extra benefit and trustworthy incentive income is larger than the principal and interest of the loan from the financial institution for the SMZEs.

5. Simulation Analysis and Implications of the Results

This section will analyze the impact path of evolutionary game strategies under the different main parameters for the results obtained in Section 4, and some implications of the results are also given.

5.1. Analysis the Impact Path of Evolutionary Game Strategies under Different Main Parameters

(I) Effects of different default losses on evolutionary game strategies

The collective supervision and maintenance and consensus trust mechanism of BT enable SMZEs to deposit and share their bad credit records across the network once they breach the contract, which cannot be denied or tampered with, and may even permit no longer obtain financing, so as to achieve the joint dishonesty punishment effect of “one dishonesty, everywhere blocked”. Under supply chain finance using BTs, excessive default losses make CEs and SMZEs obtain smaller profits, respectively. As shown in Figure 2, for the relatively small default losses, SMZEs and CEs naturally tend to choose the default strategy, such as satisfying the conditions $N < R + Rr_h$ and $R + M < aiR + 2aR$, for which the stable strategy of the system is $E_5(1, 0, 0)$, whose strategy set is (B1, C2, A2).

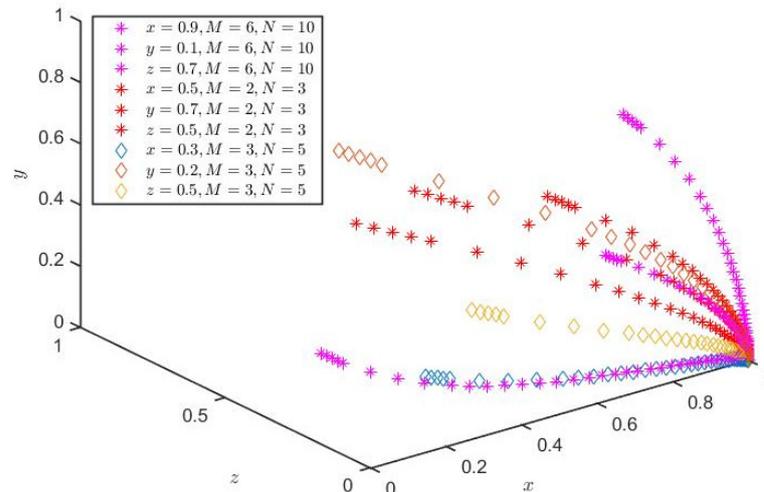


Figure 2. Effects of different default losses on evolutionary game strategies.

(II) Effects of different accounts receivable on evolutionary game strategies

With the application of blockchain in supply chain finance, the electronic voucher of accounts receivable is split and circulated many times, which can place enterprises further away from the supply chain for obtaining more credit. The smaller the single accounts receivable held by the SMZEs, the lower the single amount of loans from FIs. Therefore, the “speculative” income of the SMZEs obtained from debt evasion may be less than the default cost, which leads to a reduction in the possibility of default. Thus, a relatively small accounts receivable, for example, the conditions $(1 + i)aR < G_1 + kG$ or $R + M < aiR + 2aR$, will give SMZEs the motivation to keep their promises, as shown in Figure 3. With supply chain finance using BTs, FIs have more power to carry out small and decentralized inclusive financial services, so as to expand the coverage of supply chain financial services, form a virtuous circle, and meet the financing needs of more SMZEs on the premise of effective risk control.

(III) Effects of different trustworthy incentive incomes on evolutionary game strategies

Supply chain finance using BT can help the whole supply chain to establish a reliable information system and an efficient credit-sharing mechanism. The CEs and SMEs are more likely to keep their promises if they receive a relatively large share of the trustworthiness incentive income, such as, if the condition $R < (1 - k)G$ or $(1 + i)aR < G_1 + kG$ is satisfied, the stable strategy of the system is $E_8(1, 1, 1)$, whose strategies set is (B1, C1, A1) for three participants. On the basis of the credit-sharing mechanism, the trustworthiness incentive is finally reflected in the improvement in financing efficiency and the reduction in financing costs, so that SMEs with good credit can truly enjoy inclusive financial services, and CEs can also share the benefits of improving supply chain synergy efficiency, and FIs can expand the coverage of supply chain financial services and promote win-win cooperation among all parties (Figure 4).

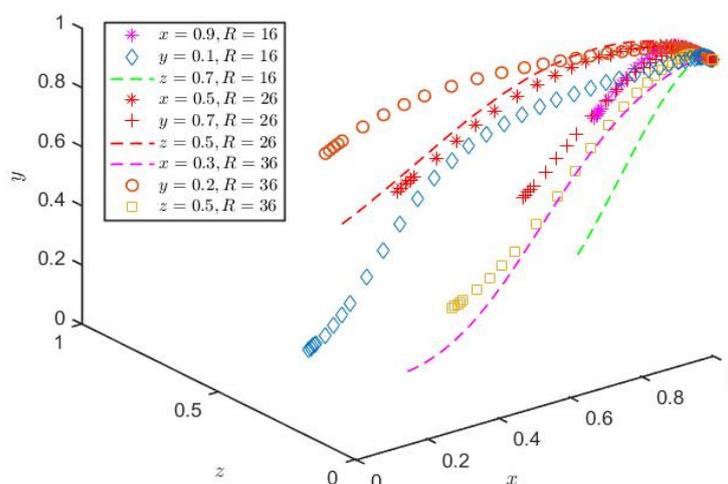


Figure 3. Effects of different accounts receivables on evolutionary game strategies.

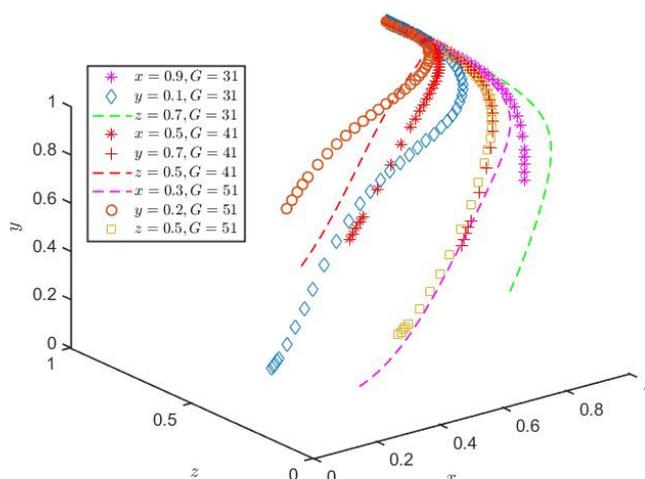


Figure 4. Effects of different trustworthy incentive incomes on evolutionary game strategies.

5.2. Implications of the Results

From the results obtained above, some implications are given:

(1) FIs actively carry out small and decentralized inclusive financial services, which will help them achieve the goal of digital inclusive finance and meet the financing needs of short, small, frequent, and urgent for SMZEs. The application of BT has realized the effective splitting and credible circulation of CEs with the electronic vouchers of accounts receivable as the carrier, so that the credit of CEs is transmitted to the far end without attenuation, which can solve the financing problems of more SMZEs and expand the coverage of supply chain financial services [39]. Thus, financing services with small, high-frequency, and low-cost to SMZEs holding accounts receivable after multiple splits and circulation are provided to FIs.

(2) Incentive compatibility mechanisms should be designed to promote the evolution of the tripartite game system for FIs, CEs, and SMZEs to an ideal “tripartite trustworthiness” equilibrium. To encourage CEs and SMZEs to keep their promises, the collaborative and trustworthy income incentive should be increased and obtained at a reasonable distribution [40]. The characteristics of a perfect incentive compatibility mechanism are reflected in that the trustworthy incentive income plays an important role in the SMZEs’ financing process, while the cost of credit management in the supply chain for CEs is reduced and their willingness to participate in supply chain finance using BT is improved.

(3) The default losses in CEs and SMZEs should be increased, and a new ecosystem of trust network among participants should be built. Through the innovative characteristics

of blockchain, the default losses in CEs and SMZEs are greatly increased, which will also improve the level of supervision for FIs and the efficiency of financing and lending. Furthermore, it is more helpful to promote the deep integration of blockchain and supply chain finance, and then break the trustworthy “shackles” among all subjects [14,41].

6. Conclusions

Supply chain finance using BT provides a new way to solve the financing difficulties and expensive problems of SMZEs to some extent. This study aimed at developing a dynamic evolutionary game model among a FI, CE, and SMZE. Combining with MATLAB, optimal equilibrium strategies of the tripartite game were simulated, so as to provide theoretical significance for the benign development of supply chain finance.

The results of this study are as follows. Firstly, whether the CE and SMZE break their promises depends on the relationship between the default losses and accounts receivable. When default losses of the CE and SMZE are lower than some critical value, such as $N < R + Rr_h$ or $R + M < aiR + 2aR$, they tend to break their promises, and the converse is also true. Secondly, the optimal strategies of the CE and SMZE mainly depend on whether the accounts receivable are large. A relatively large accounts receivable will make SMZEs tend to be trustworthy, while the CE will tend towards non-payment. Third, the difference between the accounts receivable and trustworthy incentive income motivates CEs and SMZEs to choose whether to keep their promises or not. When the shared trustworthy incentive income is larger than the accounts receivable for the CE and SMZE, such that $R < (1 - k)G$ and $(1 + i)aR < G_1 + kG$, both of them will choose to keep their promises actively. Actually, these results are consistent with the realistic situation, in which FIs, CEs, and SMZEs would choose “tripartite-win” strategies.

Meanwhile, the main contributions of this study are as follows: (1) To reveal the internal mechanism of influence on supply chain financing strategies, an innovative framework integrated with blockchain technology and the behaviors of FIs, SMZEs, and CEs was constructed. The problem of supply chain financing strategies is transformed into a tripartite game problem, which can broaden the thinking and approach to solving the problem of supply chain financing. (2) The dynamic game model among FI, SMZE, and CE was developed to discuss the restraint and incentive mechanisms of supply chain financing for participants in the game process. In this study, we analyzed the influences on the supply chain financing strategies of a FI, SMZE, and CE under different key factors and explained the dynamic evolution paths of supply chain financing strategies. It eases the financing pressure of SMZEs and CEs, and also provides a new theoretical reference to realize the financing innovation of empowering blockchain to supply chain financing for SMZEs and CEs.

Although this study has achieved some results, it still has the following limitations: (1) The parameters influencing the selection of financing strategies for CEs and SMZEs are not fully considered. Other factors, such as enterprises’ reputation and the uncertainty of the market environment, should be considered for the supply chain financing strategy selection. (2) When considering the tripartite game, this study chose a representative FI, CE, and SMZE as the main game subjects, while the interaction influences within groups of the FIs, CEs, and SMZEs on the financing strategies were ignored. Additionally, a dynamic incentive mechanism needs to be designed due to the uncertainties of the economic environment and potential risks. Meanwhile, other blockchain-related works, such as autonomy and protection [42], privacy [43], smart payment [44], and user spectra [45], should be taken into account in future research. Additionally, other new technologies, such as 5G, the Internet of Things, and big data, also need to be integrated with supply chain finance. These are some future research needs that need to be explored from the perspective of this study.

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Abbreviations

| | |
|-------|------------------------------------|
| SMZEs | Small and medium-sized enterprises |
| FIs | Financial institutions |
| CEs | Core enterprises |
| BT | Blockchain technology |
| TW | Traditional way |
| RDE | Replicated dynamic equation |

References

- Sun, R.; He, D.; Su, H. Evolutionary game analysis of blockchain technology preventing supply chain financial risks. *J. Theor. Appl. Electron. Commer. Res.* **2021**, *16*, 2824–2842. [[CrossRef](#)]
- Wu, S.; Mu, P.; Shen, J.; Wang, W. An incentive mechanism model of credit behavior of SMEs based on the perspective of credit default swaps. *Complexity* **2020**, *2020*, 1–8. [[CrossRef](#)]
- Li, Q.; Ji, H.; Huang, Y.M. The information leakage strategies of the supply chain under the block chain technology introduction. *Omega* **2022**, *110*, 102616. [[CrossRef](#)]
- Li, J.; Zhu, S.C.; Zhang, W.; Yu, L. Blockchain-driven supply chain finance solution for small and medium enterprises. *Front. Eng. Manag.* **2020**, *7*, 500–511. [[CrossRef](#)]
- Liu, L.; Li, Y.; Jiang, T. Optimal strategies for financing a three-level supply chain through blockchain platform finance. *Int. J. Prod. Res.* **2021**. Early Access. [[CrossRef](#)]
- Yin, Y. Analysis of revenue incentive dynamic mechanism of financial supply chain from the perspective of the inter-net of things. *Complexity* **2021**, *2021*, 5595979. [[CrossRef](#)]
- Li, X. Debt financing cost evaluation method of shipping enterprises. *J. Coast. Res.* **2020**, *103*, 744–748. [[CrossRef](#)]
- Wang, X.; Han, L.; Huang, X. Bank market power and SME finance: Firm-bank evidence from European countries. *J. Int. Financ. Mark. Inst. Money* **2020**, *64*, 101162. [[CrossRef](#)]
- Dutta, P.; Choi, T.M.; Somani, S.; Butala, R. Blockchain technology in supply chain operations: Applications, challenges and research opportunities. *Transp. Res. Part E: Logist. Transp. Rev.* **2020**, *142*, 102067. [[CrossRef](#)]
- Gayialis, S.P.; Kechagias, E.P.; Papadopoulos, G.A.; Masouras, D. A Review and Classification Framework of Traceability Approaches for Identifying Product Supply Chain Counterfeiting. *Sustainability* **2022**, *14*, 6666. [[CrossRef](#)]
- Gayialis, S.P.; Kechagias, E.P.; Konstantakopoulos, G.D.; Papadopoulos, G.A.; Tatsiopoulou, I.P. An approach for creating a blockchain platform for labeling and tracing wines and spirits. In *IFIP International Conference on Advances in Production Management Systems, 5–9 September 2021, Nantes, France*; IFIP Advances in Information and Communication Technology; Springer: Berlin, Germany, 2021; pp. 81–89.
- Chen, J.; Chen, S.; Liu, Q.; Shen, M. Applying blockchain technology to reshape the service models of supply chain finance for SMEs in china. *Singap. Econ. Rev.* **2021**, 1–18. [[CrossRef](#)]
- Gomm, M.L. Supply chain finance: Applying finance theory to supply chain management to enhance finance in supply chains. *Int. J. Logist. Res. Appl.* **2010**, *13*, 133–142. [[CrossRef](#)]
- Du, M.; Chen, Q.; Xiao, J.; Yang, H.; Ma, X. Supply chain finance innovation using blockchain. *IEEE Trans. Eng. Manag.* **2020**, *67*, 1045–1058. [[CrossRef](#)]
- Xu, X.; Chen, X.; Jia, F.; Brown, S.; Gong, Y.; Xu, Y. Supply chain finance: A systematic literature review and bibliometric analysis. *Int. J. Prod. Econ.* **2018**, *204*, 160–173. [[CrossRef](#)]
- Blackman, I.D.; Holland, C.P.; Westcott, T. Motorola's global financial supply chain strategy. *Supply Chain. Manag. Int. J.* **2013**, *18*, 132–147. [[CrossRef](#)]

17. Tsai, S.B. A study on the service quality and competitive strategies of internet financing and FinTech from the perspective of internet finance law. In *Economics and Management Innovations (ICEMI)*; Volkson Press: Cyberjaya, Malaysia, 2017; pp. 378–380.
18. Wang, Z.; Wang, Q.; Lai, Y.; Liang, C. Drivers and outcomes of supply chain finance adoption: An empirical investigation in China. *Int. J. Prod. Econ.* **2020**, *220*, 107453. [[CrossRef](#)]
19. Fu, Y.; Zhu, J. Big production enterprise supply chain endogenous risk management based on blockchain. *IEEE Access* **2019**, *7*, 15310–15319. [[CrossRef](#)]
20. Sang, B. Application of genetic algorithm and BP neural network in supply chain finance under information sharing. *J. Comput. Appl. Math.* **2021**, *384*, 113170. [[CrossRef](#)]
21. Wang, Y. Research on supply chain financial risk assessment based on blockchain and fuzzy neural networks. *Wirel. Commun. Mob. Comput.* **2021**, *2021*, 5565980. [[CrossRef](#)]
22. Kim, K.; Lee, G.; Kim, S. A study on the application of blockchain technology in the construction industry. *KSCE J. Civ. Eng.* **2020**, *24*, 2561–2571. [[CrossRef](#)]
23. Omran, Y.; Henke, M.; Heines, R.; Hofmann, E. Blockchain-driven supply chain finance: Towards a conceptual framework from a buyer perspective. In Proceedings of the 26th Annual IPSERA Conference, Budapest, Hungary, 9–12 April 2017.
24. Jang, K.J. The a study on innovative financial services of business models using blockchain technology. *E-Bus. Stud.* **2017**, *18*, 113–130. [[CrossRef](#)]
25. Hofmann, E.; Strewé, U.M.; Bosia, N. *Supply Chain Finance and Blockchain Technology*; Springer: Berlin, Germany, 2018.
26. Malik, N.; Alkhatib, K.; Sun, Y.; Knight, E.; Jararweh, Y. A comprehensive review of blockchain applications in industrial internet of things and supply chain systems. *Appl. Stoch. Model. Bus. Ind.* **2021**, *37*, 391–412. [[CrossRef](#)]
27. Thurner, T. Supply chain finance and blockchain technology—the case of reverse securitisation. *Foresight* **2018**, *20*, 447–448. [[CrossRef](#)]
28. Babich, V.; Hilary, G. Distributed ledgers and operations: What operations management researchers should know about blockchain technology. *Manuf. Serv. Oper. Manag.* **2019**, *22*, 223–240. [[CrossRef](#)]
29. Friedman, D. Evolutionary games in economics. *Econometrica* **1991**, *59*, 637–666. [[CrossRef](#)]
30. Wang, J.; Peng, X.; Du, Y.; Wang, F.; Dnes, A. A tripartite evolutionary game research on information sharing of the subjects of agricultural product supply chain with a farmer cooperative as the core enterprise. *Manag. Decis. Econ.* **2021**, *43*, 159–177. [[CrossRef](#)]
31. Sun, H.; Wan, Y.; Zhang, L.; Zhou, Z. Evolutionary game of the green investment in a two-echelon supply chain under a government subsidy mechanism. *J. Clean. Prod.* **2019**, *235*, 1315–1326. [[CrossRef](#)]
32. Yan, N.; Sun, B.; Zhang, H.; Liu, C. A partial credit guarantee contract in a capital-constrained supply chain: Financing equilibrium and coordinating strategy. *Int. J. Prod. Econ.* **2016**, *173*, 122–133. [[CrossRef](#)]
33. Zhang, B.; Wu, D.; Liang, L.; Olson, D.L. Supply chain loss averse newsboy model with capital constraint. *IEEE Trans. Syst. Man Cybernetics: Syst.* **2016**, *46*, 646–658. [[CrossRef](#)]
34. Zhang, B.; Ye, Y.; Yue, X. Evolutionary strategies of supply chain finance from the perspective of a return policy. *IEEE Access* **2019**, *7*, 110761–110769. [[CrossRef](#)]
35. Yan, B.; Chen, Z.; Yan, C.; Zhang, Z.; Kang, H. Evolutionary multiplayer game analysis of accounts receivable financing based on supply chain financing. *Int. J. Prod. Res.* **2021**. Early Access. [[CrossRef](#)]
36. Li, X.Y. Analysis of SME financing model from the perspective of supply chain finance. *Int. Core J. Eng.* **2020**, *6*, 115–117.
37. Aimin, D.; Bo, Y. Research overview of risk management of SMEs accounts receivable financing based on supply chain finance. *World J. Res. Rev.* **2017**, *4*, 16–20.
38. Khalil, H.K.; Grizzle, J.W. *Nonlinear Systems*; Michigan State University: Prentice Hall, NJ, USA, 2002.
39. Zhang, T.L.; Li, J.J.; Jiang, X. Analysis of supply chain finance based on blockchain. *Procedia Comput. Sci.* **2021**, *187*, 1–6. [[CrossRef](#)]
40. Jiang, R.; Kang, Y.; Liu, Y.; Liang, Z.; Duan, Y.; Sun, Y.; Liu, J. A trust transitivity model of small and medium-sized manufacturing enterprises under blockchain-based supply chain finance. *Int. J. Prod. Econ.* **2022**, *247*, 108469. [[CrossRef](#)]
41. Paliszkievicz, J.; Chen, K. *Trust, Organizations and the Digital Economy: Theory and Practice*; Routledge: London, UK, 2021.
42. Corradini, E.; Nicolazzo, S.; Nocera, A.; Ursino, D.; Virgili, L. A two-tier Blockchain framework to increase protection and autonomy of smart objects in the IoT. *Comput. Commun.* **2022**, *181*, 338–356. [[CrossRef](#)]
43. Nicolazzo, S.; Nocera, A.; Ursino, D.; Virgili, L. A privacy-preserving approach to prevent feature disclosure in an IoT scenario. *Future Gener. Comput. Syst. - Int. J. Escience* **2020**, *105*, 502–519. [[CrossRef](#)]
44. Wu, L.; Lu, W.; Xu, J. Blockchain-based smart contract for smart payment in construction: A focus on the payment freezing and disbursement cycle. *Front. Eng. Manag.* **2022**, *9*, 177–195. [[CrossRef](#)]
45. Bonifazi, G.; Corradini, E.; Ursino, D.; Virgili, L. Defining user spectra to classify Ethereum users based on their behavior. *J. Big Data* **2022**, *9*, 1–39. [[CrossRef](#)]