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Article

Multi-Party Evolutionary Game Analysis of Accounts Receivable Financing under the Application of Central Bank Digital Currency

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Abstract: Accounts receivable financing is one of the most prominent financing approaches in supply chain finance; nevertheless, in the actual financing process, financial institutions and SMEs have credit risk and information asymmetry risk, which leads to frequent nonpayment and collaboration fraudulent loans. This paper introduces central bank digital currency into traditional accounts receivable financing and solves the credit risk and information asymmetry risk using two technologies of central bank digital currency: digital technology and blockchain technology; digital technology enables the supervision of capital flow, and blockchain technology enables for access to logistics and information flow. In the context of using central bank digital currency technology, this paper builds an evolutionary game model of whether financial institutions use central bank digital currency and whether SMEs repay the loan, compares the evolutionary stabilization strategies of financial institutions and SMEs, calculates and analyzes the model's impact, investigates changes in the decision-making and evolutionary paths of both parties, and then conducts numerical simulation analysis using Matlab and Python to verify the model's reliability further. According to the results, adding central bank digital currency to the traditional accounts receivable financing model can reduce the loan risk of financial institutions, increase the credibility of accounts receivable financing, expedite the implementation of accounts receivable financing, and alleviate the financing concerns of SMEs.

Keywords: supply chain finance; accounts receivable financing; central bank digital currency

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1. Introduction

In recent years, pandemic fluctuations, financial market instability, supply chain disruptions, and shrinking global trade have seriously impacted the development of the world economy, particularly the survival and growth of SMEs, which play an irreplaceable and massive role in increasing jobs, improving people's living standards, and promoting economic development [1]. Thus, there is an urgent need to find effective ways to address the predicament of SMEs. Accounts receivable financing is one of the more mature financing approaches in existing supply chain finance, primarily involving core enterprises, SMEs, and financial institutions. The three supply chain finance entities establish a collaborative framework to provide financial services with lower interest rates and flexible payment terms, assisting SMEs in obtaining loans [2]. It can not only effectively relieve the capital pressures of SMEs but also keep improving the trade connection between supply chain enterprises, realize the smooth flow of logistics, capital, and information between upstream and downstream supply chain enterprises, and promote the overall development of the supply chain [3]. However, the three entities do not achieve a win-win-win scenario in the specific financing process due to credit risks and information asymmetry risks among them, especially accounts receivable financing. As a result of these risks, financial institutions increase SMEs' financing threshold. Financial institutions do not have the transaction information between core enterprises and SMEs for accounts receivable financing under the traditional supply chain finance platform. Therefore, credit given to SMEs still has to rely on core enterprises to complete. Financial institutions first extend credit to core enterprises, then core enterprises extend credit to SMEs [4]. Due to the lack of property evidence and credit proof, financial institutions classify SMEs as having poor credit ratings, even if core enterprises give credit. Additional issues will arise due to the slow access to credit information, high credit costs, and fraudulent loans and subsidies [5]. Before making loans to SMEs, financial institutions must pay specified credit costs to evaluate SMEs' credit standing and reduce financial risks.

The risks of accounts receivable financing have become more potentially avoidable in recent years owing to blockchain technology. Blockchain technology's attributes, such as distributed ledger, decentralization, traceability, tamper-evident, and smart contracts, among others, make it possible to effectively lower the informational barrier between SMEs and financial institutions [6]. Distributed ledger technology has been shown to solve the information asymmetry risk, reduce credit collection costs, assist financial institutions in monitoring, and improve clearing and settlement using smart contracts [7]. Research on blockchain technology mainly focuses on three areas: conceptual innovation, mechanism design, and technological optimization in the context of the present supply chain finance system. Whether for analysis within the more general framework of supply chain finance or the specific study of accounts receivable financing, these sectors lack obvious application entry points and fail to adequately illustrate their worth; consequently, this paper introduces central bank digital currency inspired by blockchain technology to the accounts receivable finance model in the traditional supply chain finance. Compared to existing research, an innovation and a change would be using central bank digital currency for accounts receivable financing. It possesses some characteristics of blockchain technology and can successfully address the credit risk and information asymmetry risk between financial institutions and SMEs, thereby reducing the regulatory burden on financial institutions and limiting SMEs' non-repayment behavior and joint fraudulent lending behavior. The general blockchain technology is the generalized blockchain technology, while the blockchain technology used by the central bank digital currency is the narrow blockchain technology, which the central bank has optimized; in addition, central bank digital currency also has digital characteristics compared to traditional paper currency, it also maintains its status as a sovereign credit currency, and in specific transactions, it acts as a cryptocurrency, an algorithm-based currency, or a smart currency, all of which are compatible with the fundamental principles of accounts receivable finance. Therefore, credit risk and information asymmetric risk in accounts receivable finance may be eliminated using central bank digital currency.

The following three aspects reflect the primary contributions of this paper: First, this paper highlights the basic framework for integrating central bank digital currency technology into the established supply chain financing model to further the knowledge base on blockchain technology's use in supply chain financing. Second, focusing on using digital currency technology and blockchain technology in accounts receivable financing, this article explains how central bank digital currency may control credit risk and information asymmetry risk using these technologies. Third, this paper analyzes the specific factors influencing the accounts receivable financing model, explores the dynamic behavior of financial institutions and SMEs in the model using evolutionary game theory, and employs Matlab and Python simulations to test the correctness of the findings.

The rest of the essay is structured as follows: in Section 2, the research on supply chain finance, central bank digital currency, and related literature addressing supply chain risks is reviewed; in Section 3, a theoretical model for the use of central bank digital currency technologies in accounts receivable financing is presented; in Section 4, the model formulation and game analysis for SMEs and financial institutions are established; in Section 5, numerical analysis is performed; and in Section 6, conclusions are drawn.

2. Literature Review

This paper focused on using central bank digital currency in the "M + 1 + N" supply chain finance platform's accounts receivable financing mode to address credit risk and information asymmetry risk. It also analyzed the effect evolution of financial institutions and SMEs as the key variables. Consequently, The literature pertinent to this paper falls under two subcategories: supply chain finance and central bank digital currency.

2.1. Supply Chain Finance

Supply chain financing differs from traditional commercial finance, which does not consider the supply chain as an important factor [8]. Financial institutions analyze individual enterprise's credit ratings by considering factors such as company size, economic status, business performance, existing collateral, and social trust and make loans of varying amounts without considering the supply chain. Companies with ambiguous information may have issues when applying for loans from financial institutions and have incredible difficulty when financial institutions investigate them. SMEs may go bankrupt due to this situation, endangering the integrity of present global production chains in the event of a catastrophic global crisis [9]. The emergence of supply chain finance has changed the conventional logic of financial institutions assessing loans. It now considers the supply chain instead of only analyzing individual SMEs. Financial institutions provide financial services by evaluating transaction information between core enterprises and SMEs and relying on the credit ratings of core enterprises [10]. As a result, supply chain finance aims to integrate logistics, information flow, and capital flow throughout the supply chain and assist core enterprises, SMEs, and financial institutions in reducing costs and increasing value via planning, direction, and management. Due to credit risk and information asymmetric risk that may quickly occur since financial institutions do not have access to transaction data between businesses in the supply chain, financial institutions struggle to decide whether financing for SMEs is in their best interests. How to solve the credit risk and information asymmetry risk in supply chain finance directly affects whether SMEs can complete financing. For example, Accounts receivable financing will go smoothly if financial institutions can obtain accurate transaction information from the supply chain, including logistics, information flow, and capital flow, which may assist in assessing financing risk. Zhou et al. suggested that a field programmable gate array and an internet of things solution for logistics information cooperation enhance the veracity of logistics information for supply chain management [11]. Zhang et al. employed a multimodal learning technique to combine data from several supply chain sources and then used the cascaded vectors produced by data fusion as the input to a feedforward neural network to estimate the credit risk of SMEs [12]. Additionally, Kang et al. developed a supply chain financing credit risk assessment index selection method for SMEs using the 5C approach [13]. Some other scholars improved the support vector machine (FA-SVM) with the firefly algorithm and utilized it to evaluate supply chain finance with various information options [14]. There is still a significant issue: while verifying information flow and logistics is relatively simple, it is relatively challenging to verify capital flow, and verification costs are relatively high. This is true even though scholars are constantly proposing new methods to improve supply chain management, increase the authenticity of supply chain information, and decrease financial risk.

2.2. Central Bank Digital Currency

Cryptographic digital currencies such as Bitcoin, Ether, Dogecoin, and Litecoin have had a meteoric rise in popularity over the past five years due to their extraordinarily high investment value. It all started with Bitcoin, which emerged as the result of Satoshi Nakamoto's 2008 paper "Bitcoin: A Peer-to-Peer Electronic Cash System," which describes the blockchain technology and the working system of Bitcoin. Policymakers, regulators, and academics quickly became interested in Bitcoin and blockchain technology. However, some countries have banned the circulation and trading of cryptographic digital currencies, such as China, the UK, Singapore, and Turkey, due to their highly speculative nature, high risk, limited quantity, and lack of regulation. Nevertheless, as a replacement for current paper currencies and in reaction to decentralized cryptographic digital currencies, many nations around the world have declared the formation of centralized digital currencies based on national sovereignty, commonly known as central bank digital currencies [15]. Central bank digital currency is a recent technical development, although its concept is distinct from that of digital currency, virtual currency, and electronic currency. It is a new form of currency that is fundamentally the same as traditional paper money; it is still a central bank liability to the public whose value is backed by sovereign credit. It is issued by the nation's central bank using particular encryption technology. It has the same intrinsic value as traditional paper currency, including a measure of value, circulation, storage, and world currency. Central bank digital currency is distinct from Bitcoin in that it lacks Bitcoin's "Decentralization" feature, making it subject to financial regulation [16].

Generalized blockchain technology is described as a decentralized distributed ledger system with qualities like traceability, invariance, anonymity, transparency, and security. It accomplishes decentralization through the use of smart contracts and encryption [17]. Incompatible with central bank digital currency's concept, function, and placement, generalized blockchain technology cannot be used to create central bank digital currency directly from paper currency. For example, While central bank is the most important nodes in central bank digital currency system, generalized blockchain technology has no centralized nodes. As a result, existing central bank digital currencies tend to be based on a limited amount of blockchain technology—narrow blockchain technology. Narrow blockchain technology usually does not contain decentralized features, and each central bank will optimize it so that the issued central bank digital currency includes one or some parts of the comprehensive blockchain technology. For example, The Bank of England and University College London have invented a cryptocurrency—RSCoin. With RSCoin, the central bank is able to keep complete control over the money supply, while double spending is prevented via a dispersed system of authority. It ensures the centralization of monetary policy while maintaining high levels of transparency and auditability, and it illustrates both theoretically and empirically the advantages of moderate centralization [18]. Project Ubin, a central bank digital currency launched by the Monetary Authority of Singapore, aims to investigate the use of blockchain to clear and settle payments and securities. Five phases have been completed: In the first phase, R3, a distributed ledger technology company, has partnered with financial institutions to design a distributed ledger technology that best fits the settlement system and details the design principles; In the second phase, they developed software prototypes of three different models for interbank payments and settlements with liquidity savings mechanisms; In the third phase, together with the Singapore Exchange, MAS created delivery and payment capabilities for settling tokenized assets on various blockchain platforms; In the fourth phase, they conducted cross-border settlement payment experiments; In the fifth phase, they explored the development of multi-currency payment models to enable collaboration across a broad ecosystem [19]. In contrast to the decentralization that the initial cryptocurrency promised, China's central bank digital currency, the digital yuan, is centralized because the government controls the blockchain-distributed ledger of the digital yuan. This system enables the economic system [20]. Additionally, many central banks, including Lionrock of the Hong Kong Monetary Authority, are working to create a central bank digital currency based on distributed ledger technology and blockchain technology [21]. Nonetheless, it is a real-world application of blockchain technology and retains some characteristics, including distributed ledger technology, an asymmetric encryption algorithm, and smart contracts. In the field of supply chain finance, Fegatelli et al. examine and elucidate the conditions for the large-scale introduction of the digital euro without leading to bank disintermediation or a credit crunch. The two main points are that the central bank must regulate the total volume and user costs of CBDC in the financial markets and that it must continue to make loans easier to get and to provide commercial banks with enough sources of finance [22]. Compared with central bank digital currency, blockchain technology has more research achievements in supply chain finance. Chang et al. investigated distributed ledger technology and smart contracts to allow a decentralized business process, reorganize the supply chain financing framework, and boost the multilateral cooperation network [23]. Guo et al. also proposed an information management framework based on blockchain and IoT to coordinate and integrate information flow, logistics, and capital flow in the supply chain using distributed ledger technology to improve information transparency in the process and address information asymmetry in transactions [24]. Saberi et al. discovered that blockchain technology creates a highly trusted transaction environment for core enterprises, SMEs, and banks to reach mutual trust mechanisms and consensus in the supply chain. At the same time, the decentralized advantage of distributed ledgers can weaken the reliance on the credit guarantor endorsement of core enterprises [25]. According to research, blockchain technology has many advantages, such as rebuilding the supply chain finance framework, sharing logistics, information flow, and capital flow, developing a new model of core enterprise credit transmission, and overcoming the traditional supply chain finance model's lack of trust. By offering additional transaction transparency and a single fact to all supply chain network members, it can also reduce uncertainty, insecurity, and ambiguity in transactions.

2.3. Contribution to the Literature

According to the published research, firstly, supply chain finance may assist SMEs and financial institutions, but it has risks. For example, accounts receivable financing entails credit risk and information asymmetry risk. Only a small portion of risk control research begins with the premise that the topic is boundedly rational and uses evolutionary game theory. The majority of risk control research assumes that the subject is entirely reasonable. Secondly, most studies on using blockchain technology to reduce financial risks in the supply chain focus on qualitative analysis and technical design, including conceptual innovation, mechanism design, and technological optimization, while only a few examine using blockchain technology from a quantitative angle. Finally, there is less research on using central bank digital currency for supply chain financing. Central bank digital currency introduced in this paper is applied to the wholesale system, while the application of central bank digital currency to retail ecosystems will not be explored. The present study then considers applying central bank digital currency and evolutionary game theory to the accounts receivable financing model of supply chain finance, studying the strategic choices of financial institutions and SMEs under various factors and analyzing the impact of various factors on both parties' strategy decisions.

3. Accounts Receivable Financing Issues

3.1. Accounts Receivable Financing

The traditional supply chain finance platform has undergone three changes. Initially, it was the "1 + N" model, where "1" refers to the core enterprise and "N" refers to core enterprise's upstream and downstream suppliers and distributors. The second evolution is to lessen the danger of SMEs manipulating or tampering with transaction information by adding "L" (logistics) to the original "1 + N" model, resulting in the "1 + N + L" model. Logistics acts as an intermediary between SMEs and financial institutions to improve the authenticity of supply chain transactions. Financial institutions rely on the credit and guarantee of core enterprises to complete financing through actual supply chain transactions involving SMEs. With the fast growth of information technology such as big data, cloud computing, and the internet of things in recent years, supply chain finance has entered the third evolution, producing a new "M + 1 + N" supply chain financial platform [26]. "M" is financial institutions, such as banks, core enterprises, and fintech companies, "N" is the financing body of enterprises, including core enterprises and SMEs, and "1" is a professional supply chain financial platform. Supply chain financial platforms are classified into three types: core enterprise-led, fintech company-led, and bank-led [27]. The "M + 1 + N" supply chain financial platform depends on the core enterprises' strong business credit. It integrates the supply chain network's logistics, information flow, and capital flow through the core enterprises to subtly raise the level of trust among the upstream and downstream SMEs [28]. Financial institutions primarily provide accounts receivable financing, future cargo right financing mode, warehouse financing, and other loan modes to SMEs on the supply chain financial service platform. Figure 1 below shows the "M+1+N" supply chain finance platform.

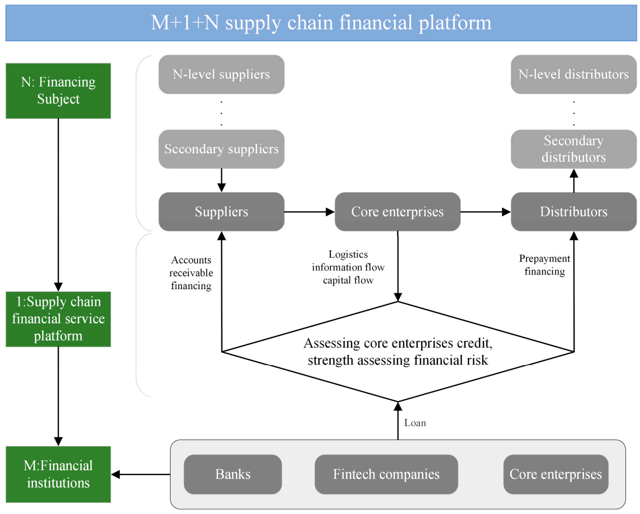

Figure 1. "M + 1 + N" supply chain financial platform.

In the accounts receivable financing business of the "M + 1 + N" supply chain financial platform, SMEs sign transaction contracts with core enterprises to create accounts receivable, but core enterprise does not immediately pay accounts receivable. In addition, both parties agree that accounts receivable will be paid at a future date. In the event of insufficient funds, SMEs will initiate accounts receivable financing service to supply chain financial platform, transfer the accounts receivable to financial institutions, and notify core enterprises that the accounts receivable debt is transferred. As soon as core enterprises receive the notice, core enterprises confirm the transfer with financial institutions, and financial institutions verify contracts, invoices, shipping documents, and other transactional information, as well as the legitimacy of the accounts receivable and transfer, before making a loan to SMEs. On the due date of the accounts receivable contracts, core enterprises must make complete payments [3]. Accounts receivable financing can be generally divided into recourse and non-recourse. Non-recourse means that financial institutions have no right to demand that the lender repay the loan when core enterprises do not repay the loan, while recourse has the right to request that the lender repay the loan [29]. For developed countries such as the United States and Italy, non-recourse is more prevalent when the bearers of credit risk and financing risk are financial institutions, and SMEs do not bear the corresponding risk. In contrast, in developing countries, where credit risk and financing risk are more difficult to measure, recourse is more prevalent when the primary risk bearers are financial institutions and SMEs. In the "M + 1 + N" supply chain finance platform, the risk of each link is more rational and predictable, so this paper will explore non-recourse accounts receivable financing.

Credit from core enterprises and actual logistics, information flow, and capital flow are the keys to the regular functioning of accounts receivable financing for financial institutions and SMEs. Accounts receivable financing in the "M + 1 + N" supply chain financial platform is functional. However, there are specific unresolved issues: Firstly, the "M + 1 + N" supply chain financial platform can only deal with the issue of accounts receivable financing for first-level SMEs, leaving second-level, third-level, and even N-level SMEs in the supply chain with little credit transmission. Secondly, for SMEs after the second level, core enterprises lack credit incentives because production and sales of the first-level

SMEs are more likely to affect the business of core enterprises, whereas second-, third-, and even N-level suppliers and distributors are less likely to affect the business of core enterprises. Thirdly, credit risk exists in accounts receivable financing. In the process of crediting receivables by core enterprises, core enterprises and SMEs may deliberately collude to conceal their genuine cooperation relationship and fraudulently obtain loans by forging false contracts, invoices, and transportation documents [12]. Fourthly, in accounts receivable financing, the lack of transparency and sharing of logistics, information flow and capital flow of SMEs make it more difficult for financial institutions to obtain transaction information, and financial institutions still need to spend certain credit costs when processing corresponding applications for loans for SMEs' accounts receivable, which reduces the willingness of financial institutions to finance. Generally speaking, financial institutions, SMEs, and core enterprises must face credit risk and information asymmetry risk. In particular, the bullwhip effect between N-level SMEs and financial institutions increases the risks of credit and information asymmetry between levels, creating a fragile-trust environment and high-trust risk.

3.2. Accounts Receivable Financing Using Central Bank Digital Currency Technology

Essentially a sovereign credit-based currency, central bank digital currency is a new kind of money that primarily uses blockchain technology and digital currency technology. When used for accounts receivable financing, we refer to the two technologies as central bank digital currency technology. In terms of technology, it is a cryptocurrency; in terms of implementation, it is an algorithm-based currency; and in terms of use applications, it is a smart currency [30]. Digital currency technology will increase the timeliness of their receivables monitoring. Moreover, blockchain technology, which offers complete transactions and factual certainty, will minimize uncertainty, insecurity, and ambiguity in transactions [31]. As a result, central bank digital currency can be applied to accounts receivable financing in supply chain finance to address SMEs' credit risk and information asymmetry risk under the short-credit transmission regime.

3.2.1. Digital Currency Technology

Corporations in supply the chain financial platform will transfer money whenever it does business. Central bank digital currency, a cryptocurrency, and algorithmic currency is based on the nation's sovereign credit and uses digital technology. In Accounting and Industry 4.0, Fülöp et al. point out the current status, trends, and importance of fintech, such as central bank digital currencies, in the digitalization of accounting. In addition, combining the Technical Success Model (TAM) with trust and risk as a theoretical basis for the analysis, the results show that users trust and use the collected information and verify the availability of digital services [32]. When compared to traditional paper currency, central bank digital currency reduces the need for financial institutions to spend transportation, storage, and security of cash throughout the accounts receivable financing process. At the same time, sophisticated physical anti-counterfeiting technology is not used, and additional expenses are not required to increase printing quality and anti-counterfeiting capabilities. Simply said, digital currency technology enables central bank digital currency to be optimized to a considerable degree without incurring the expenses associated with paying for paper currency, both in the existing currency operating system and the accounts receivable financing procedure.

Central bank digital currency has changed traditional paper currency payment mechanisms, improving the payment's security and dependability. It uses the "anonymous front-end and real-name back-end" methodology so that it can be used and recorded for payment transactions in the supply chain financial platform [33]. Financial institutions are also permitted to access the transaction information records of the supply chain financial platform and use the invoice information records of SMEs to confirm the authenticity and legitimacy of capital flow. The payment transaction records of central bank digital currency technology may be a reliable source of evidence of the credit of SMEs when requesting accounts receivable financing from financial institutions. In contrast to traditional paper currency, digital currency technology effectively shows the trajectory of money circulation and links lending behavior to corporate credit; implements a broad coverage network supervision; effectively lowers illegal and criminal acts; and aids in the financial security of receivables and the protection of SMEs' and core enterprises' rights and interests.

Using traditional paper currency necessitates relying on the equipment or branches of financial institutions, which costs money and takes time. Central bank digital currency uses digital currency technology that combines capital flow and information flow in a very efficient manner. As a result, transactions and settlements may be completed simultaneously, achieving the benefits of peer-to-peer payment and instant settlement. The effectiveness of loan and the smooth functioning of the loan system are enhanced by using central bank digital currency for accounts receivable financing rather than traditional forms of paper currency. Additionally, as central bank digital currency circulates among businesses, core enterprises' credit is gradually passed down. For example, first-tier suppliers get payment from core enterprises in the form of digital currency from the central bank, which first-tier suppliers then use to pay for raw materials from second-tier suppliers, and so on, the credit of core enterprises is transmitted downward step by step through the actual payment transactions of central bank digital currency, solving the issue that the traditional supply chain finance platform relies too heavily on the credit of core enterprises and lacks sufficient incentive for core enterprises to grant credit [34]. Central bank digital currency can track the flow of funds, further verify the transaction's authenticity, and help SMEs solve their credit risk and information asymmetry risk. For another example, subsequent payment transactions initiated with central bank digital currency must be coordinated with financial institutions, which will use digital features of central bank digital currency to implement oversight after an SME obtains a loan to pay its accounts receivable financing in central bank digital currency. When an SME is discovered to be using central bank digital currency for improper transactions or transactions with illegal content, financial institutions can identify these transactions and content, correct them if necessary, or close the relevant transactions to control risk and, if necessary, ensure compliance. This will allow the loan to flow appropriately, such as for regular business operations. The credit risk and information asymmetry risk that SMEs are facing may be addressed with the aid of the aforementioned strategies.

3.2.2. Blockchain Technology

Blockchain technology is a component of a system behind central bank digital currency technology. Prior to now, dual payments and the Byzantine General issue had been cryptographic digital currencies' two most significant issues. The expression "double payment issue" refers to making payments in two or more transactions with an "identical amount of money." The Byzantine General issue is the problem of consensus and mutual trust in distributed systems in the absence of a trusted central node. These issues can be successfully solved due to the advancement of generalized blockchain technology. A blockchain is a form of a shared ledger that joins data blocks into a specific data structure in a chain in chronological order. It is cryptographically guaranteed to be tamper-proof and unfalsifiable—a reliable, decentralized system without relying on a single node. With blockchain technology under central bank digital currency, the central bank is always one of the most prominent trusted nodes in the system. In other words, the distributed ledger of the central bank digital currency is always owned by the central bank, so there is no need to worry about this issue.

For accounts receivable financing on the "M + 1 + N" supply chain finance platform, with blockchain technology, purchase orders, logistics, information flow, and capital flow movement may all be integrated into a distributed ledger-based data flow. Order transaction information and related transportation data of third-party logistics companies, such as delivery and receipt data, are contained in the order, while third-party logistics companies will also provide supervisory roles, billing information, third-party transportation information, and partnership records of historical transactions are also included in the order. Information flow is the integration of purchase order, logistics, and capital flow, while capital flow comprises information about buyer-seller invoices, as well as records of payment methods and bank account information [24]. In addition, the central bank owns the general ledger of the capital flow at the moment, giving it complete reliability and granting the financial institution access to the capital flow for that receivable upon request. After asymmetric encryption, blockchain technology is used to broadcast information flow to pertinent supply chain financial platform players, such as broadcasting to financial institutions.

Blockchain technology can improve the control and accessibility of logistics, information flow, and capital flow of supply chain financial platform, facilitate the review of financial institutions, strengthen trust between the subjects of the supply chain financial platform, and effectively resolve credit risk and information asymmetry risk. Blockchain technology can also digitize the workflow through smart contracts to reduce the operational risk of the platform. For instance, in traditional accounts receivable financing, there is a possibility of intentional collusion between SMEs and core enterprises to obtain loans by forging fake contracts, invoices, and fake transportation documents, but blockchain technology ensures information invariance and traceability in the supply chain to guarantee the authenticity and reliability of the relevant information of enterprises in need of loans and thus eliminates this possibility [35]. There is no theoretical way for SMEs to manipulate the transaction data stored in the supply chain finance platform using blockchain technology, either before or after default. The only possible behavior is general non-repayment, which will result in credit loss for SMEs And lose the confidence of financial institutions.

3.2.3. Simplified Accounts Receivable Financing and Comments

Central bank digital currency provides the confirmation for each transaction, producing a set of tamper-evident digital payment vouchers for use in core enterprises and SMEs' accounts receivable financing, in the "M + 1 + N" supply chain finance platform to make full use of smart contracts. Smart contracts reduce the cost of negotiating between parties to a transaction and prevent unforeseen abnormalities or malicious behavior during contract fulfillment by translating contract terms into code and embedding them in software or hardware so that they are automatically performed [36]. Not only may smart contracts be used, but a small number of them can also be locally implemented—that is, signed and performed by the participants for that accounts receivable financing.

A simplified accounts receivable financing should include the following stages:

In the initial stage, financial institutions sign cooperation agreements with core enterprises and immediately transfer crucial data from the ERP systems of core enterprises to the "M + 1 + N" supply chain finance platform blockchain, including logistics, information flow, and capital flow. Financial institutions will grant credit of a certain amount according to the assets of core enterprises; In the secondary and multiple credit stage, when relevant receivables are present, core enterprises upload information on the first-tier suppliers (or distributors) and verify it with financial institutions. Financial institutions check core enterprises' distributors (or suppliers). Additionally, first-tier suppliers (or distributors) that have received approval from financial institutions may promote their upstream second-tier suppliers (or distributors) to those institutions; In the financing application stage, the first-tier suppliers (or distributors) whose accounts receivable have been established and verified by core enterprises may submit a loan application to financial institutions or divide the verified accounts receivable to secondary suppliers (or distributors). After verifying with core enterprises, financial institutions request that the supplier (or distributor) supply logistics, information flow, capital flow, and other relevant contract documentation. Then, after additional verification of the particular supervisory account, loans can be provided in central bank digital currency; In the repayment stage, when the loan is due, core enterprises use a smart contract to pay the lending immediately. Financial institutions will send out a demand letter in the event of overdue payments and freeze the associated assets until full repayment is received.

Accounts receivable financing using central bank digital currency technology differs from accounts receivable financing of traditional supply chain financial platforms in the following ways:

- Digital currency technology provides cheaper transaction costs, safer payments, and improved payment efficiency in the accounts receivable financing process. Compared to traditional paper currency, it is enabled to show the flow of loan and record the date, location, and recipient of the loan, making it much easier for financial institutions to comprehend and monitor, whether for forwarding supervision or backward monitoring.
- Blockchain technology is used by the central bank digital currency technology system to reduce credit costs for financial institutions, avoid traditional supply chain finance, and improve the ability to share logistics, information flow, and capital flow in accounts receivable financing among various supply chain financial platform topics. Additionally, built on smart contracts, information invariance, and traceability, it prevents fraudulent collaborative lending and boosts financial security.
- The service platform's dispersed and trading information of variable quality for accounts receivable financing prevents the development of information barriers. Furthermore, core enterprises' credit does not transfer well. Central bank digital currency technology enables the multi-level transmission of core enterprise credit through capital circulation, enhances the penetration of core enterprise credit throughout the entire supply chain, and facilitates credit access for SMEs at all levels.

The central bank digital currency technology effectively addresses the credit risk and information asymmetry risk of traditional accounts receivable financing; enhances trust between secondary and subsequent SMEs, core enterprises, and financial institutions; enables financial institutions to only access actual supply chain transaction information; increases in operational efficiency; and lowers financing risks with a very modest introduction of central bank technology, currency technology expenses, and capital flow supervisory costs.

4. Descriptions of the Parameters and Model Presumptions

4.1. Descriptions of the Parameters

The primary considerations for financial institutions when deciding whether to loan SMEs in accounts receivable financing are credit risk and information asymmetry risk. There is little research on this topic since central bank digital currency technology is a new technology. Financial institutions have difficulty figuring out if their choices optimize their interests. As a result, financial institutions may decide to "use" or "not use" central bank digital currency technology depending on their judgments and benefits. Moreover, SMEs have the option of "repay" or "not repay" the loan based on their profitability, capability for repayment, and risk of default. When financial institutions do not use central bank digital currency technology, SMEs may conspire with core enterprises to maximize their profits, conceal the genuine cooperation relationship between the two sides, and fabricate the logistics, information flow, and capital flow to obtain loans, which may easily cause losses if there is no supervision. However, after using central bank digital currency technology, the transaction in question is completed in a transparent and safe manner. SMEs are unable to falsify any logistical, information, or capital flow due to the non-traceability, and capital flow oversight by financial institutions.

Hypothesis 1 (H1): *The probability of financial institutions choosing to "use" central bank digital currency technology is*$x(0 < x < 1)$*, and the probability of choosing "not use" is* $1 - x$*; the probability of SMEs choosing to "repay" loan after receiving it is* $y(0 < y < 1)$*, the probability of choosing "non repay" is* $1 - y$*. Financial institutions provide loans R to SMEs at interest rates of* r_1 *for loan and* r_2 *for investment.*

Hypothesis 2 (H2): *SMEs will produce the loans they get legitimately and earn receivable income B if they do not conspire with core enterprises to cheat on loans. P represents the usual production costs. The benefit distribution ratio attained when SMEs band together with core enterprises to forge loans is k. To avoid financial institutions' investigation, the costs of forging F must be paid before making the loan, and G is the revenue used for investment after the receipt of fraudulent loans.*

Hypothesis 3 (H3): *Financial institutions can now access transaction data from SMEs at a much lower costs thanks to the "M + 1 + N" supply chain financial platform, which is powered by central bank digital currency technology. Only central bank digital currency technology costs c_2, and capital flow supervision costs c_3 ; there is no need to pay the credit costs c_1 without using central bank digital currency technology, so $c_1 > c_2 + c_3$. If repaid, SMEs will get the credit block incentive v_1 and direct trust from financial institutions, establishing a track record for future business, while financial institutions receive credible income v_2. Instead, if they fail to pay back loans or cheat on loans together, they will be charged a penalty of u_1 for non-payment by SMEs using of central bank digital currency technology and u_2 for non-payment by SMEs not using it.*

Table 1 shows the basic parameters.

Table 1. Basic parameters descriptions.

Parameters	Meaning of Parameters
$x/1-x$	Probabilities of financial institutions using or not using central bank digital currency technology
$y/1-y$	Probabilities of SMEs repayment or non-repayment
R	Loans provided to SMEs
r_1	Accounts receivable loan interest rates
r_2	Financial institutions investment rates
B	Receivables income for SMEs
c_1	Financial institutions' credit costs
c_2	Technology costs for central bank digital currency technology
c_3	Costs for supervision capital flow
F	SMEs share the expenses of loan fraud and counterfeiting.
G	SMEs illegally acquired loans and exploited them to generate investment revenue.
P	SMEs production costs
k	Joint fraudulent loan allocation rate to SMEs
v_1	Credit block incentives
v_2	Financial institutions benefit from trust.
u_1	Non-payment penalty for SMEs that use central bank digital currency technology
u_2	Non-payment penalty for SMEs that no-use central bank digital currency technology

4.2. Model Presumptions

Model 1: Financial institutions use central bank digital currency technology and incur no credit costs c_1. It must pay central bank digital currency technology costs c_2 and capital flow supervision costs c_3. In addition, it creates an interest gain Rr_1 and loses an additional investment gain Rr_2.

If SMEs repays the loan normally and in accordance with the contract time, they will receive receivable gain B, and credit block incentives v_1, but must also pay production costs P and repayment interest Rr_1. At this point, SMEs gain is $B - P - Rr1 + v1$; Financial institutions are repaid the loan when it matures, earn a respectable gain v_2, the technical cost of central bank digital money technology c_2 and capital flow supervision costs c_3, and at that point its net gain is $Rr1 + v2 - c2 - c3 - Rr2$. If SMEs refuse to pay, they will still need to produce regularly, spend on production expenses P, get the receivables revenue B, and return the loan R, but it will not receive the credit block incentive v_1 and will be subject to the non-repayment penalty u_1, so the net benefit is $B + R + Rr1 - P - u1$.

Financial institutions cannot recover the loan R and will also lose the interest on the financed account Rr_1 but will get the non-repayment penalty u_1 from the SMEs since the financed loan turns into bad debt when it matures. Financial institutions now have a net gain of $-R - Rr1 - Rr2 - c2 - c3 + u1$.

Model 2: Financial institutions do not use central bank digital currency technology; they only need to pay for credit collection c_1, but not for central bank digital currency technology costs c_2 or capital flow supervision cos c_3.

If SMEs repay the loan in accordance with the terms of the contract, it will receive a receivable gain B, be required to pay production costs P and interest Rr_1, but it will not be able to receive credit block incentives v_1, and its net gain will be $B - P - Rr1$; in contrast, if financial institutions recover loan at maturity, it will incur credit costs c_1 and receive a credible gain v_2, and will realize a net gain of $Rr1 + v2 - c1 - Rr2$. Due to the limitations of conventional financial institutions' credit collection practices and their lack of control over the supply chain finance's logistics, information flow, and capital flow, SMEs will jointly cheat on the loan with core enterprises if they fail to return the loan. The necessity to create the necessary items and the accompanying production costs P are not now present in SMEs and core enterprises. As a result, SMEs are prohibited from receiving credit block incentives v_1 and will suffer the consequences of non-repayment u_2, while also incurring the costs of counterfeiting F, sharing the financing kR of accounts receivable, and earning investment income G. Consequently, the net profit is $kR + Rr1 + G - F - u2$. Financial institutions will only get the non-payment penalty u_2 since the funded loan is a bad debt at maturity and cannot be collected. Additionally, financial institutions will lose the interest on the financed account Rr_1 and be unable to collect the financed loan R. At this moment, financial institutions have a net gain of $-R - Rr1 - Rr2 - c1 + u2$.

4.3. Evolutionary Game Analysis

4.3.1. Financial Institutions and SMEs' Strategic Stability Analyses

For financial institutions: Based on the revenue matrix of both financial institutions and SMEs in Table 2, it is possible to determine the anticipated revenue function for financial institutions when using the central bank digital currency technology and the expected revenue function when not using it.

$$Ex = y(Rr1 + v2 - c2 - c3 - Rr2) + (1 - y)(u1 - R - Rr1 - Rr2 - c2 - c3) \quad (1)$$

$$E(1 - x) = y(Rr1 + v2 - c1 - Rr2) + (1 - y)\ (u2 - R - Rr1 - Rr2 - c1) \quad (2)$$

Table 2. Benefit matrix for SMEs and financial institutions.

		SMEs	
		Repay	**Non-Repay**
Financial institutions	use	$B - P - Rr1 + v1$ $Rr1 + v2 - c2 - c3 - Rr2$	$B + R + Rr1 - P - u1$ $-R - Rr1 - Rr2 - c2 - c3 + u1$
	not use	$B - P - Rr1$ $Rr1 + v2 - c1 - Rr2$	$kR + Rr1 + G - F - u2$ $-R - Rr1 - Rr2 - c1 + u2$

The average expectation of financial institutions is determined by Equations (1) and (2) and is: $\overline{Ex} = xEx + (1 - x)E(1 - x)$.

As a result, the replication dynamic differential equation for financial institutions using central bank digital currency technology is obtained as follows:

$$F(x) = \frac{\mathrm{d}x}{dt} = x(1 - x)[y(u2 - u1) + c1 - c2 - c3 + u1 - u2] \quad (3)$$

The following conditions must be satisfied for the probability of using central bank digital currency technology of financial institutions to be in a stable state in accordance with the differential equation's stability theorem: $F(x) = 0$ let $F(x) = 0$, then:

$$x1 = 0, x2 = 1, y^* = \frac{c1 - c2 - c3 + u1 - u2}{u1 - u2} \tag{4}$$

For SMEs: Based on the revenue matrix of both financial institutions and SMEs in Table 2, the expected return function when the loan is repaid and the expected return function when the loan is not repaid:

$$Ey = x(B - P - Rr1 + v1) + (1 - x)(B - P - Rr1) \tag{5}$$

$$E(1 - y) = x(B + R + Rr1 - P - u1) + (1 - x)(kR + Rr1 + G - F - u2) \tag{6}$$

The average expectation of SMEs is determined by Equations (5) and (6) and is: $\overline{Ey} = y\ Ey + (1 - y)E(1 - y)$.

As a result, the dynamic replication equation of SEMs' repayment is obtained as:

$$F(y) = \frac{\mathrm{dy}}{dt} = y(1 - y)[x(kR - B - F + G + P - R + u1 - u2 + v1) + B + F - G - P + u2 - kR - 2Rr1\Big] \tag{7}$$

The following conditions must be satisfied for the probability of repayment of the SMEs to be in a stable state in accordance with the differential equation's stability theorem. $F(y) = 0$, let $F(y) = 0$, then:

$$y1 = 0, y2 = 1, x^* = -\frac{B + F - G - P + u2 - kR - 2Rr1}{kR - B - F + G + P - R + u1 - u2 + v1} \tag{8}$$

4.3.2. Equilibrium Point Stability Analysis

The game between financial institutions and SMEs can be described by a system consisting of Equations (3) and (7). This system has five equilibrium positions: E_1(0,0), E_2(0,1), E_3(1,0), E_4(1,1), E_5(x^*,y^*). When the range of x^*, y^* is (0,1), E_5 is likewise the system equilibrium point. In order to make the study of the parameters easier, we assume the following assumptions, such that:

$$a = -(B + F - G - P + u2 - kR - 2Rr1)$$

$$b = kR - B - F + G + P - R + u1 - u2 + v1$$

$$c = c1 - c2 - c3 + u1 - u2$$

$$d = u1 - u2$$

$$\mathrm{I}\begin{cases} a > 0 \\ b > 0 \\ a - b < 0 \end{cases} \mathrm{II}\begin{cases} a < 0 \\ b < 0 \\ a - b > 0 \end{cases} \mathrm{III}\begin{cases} c > 0 \\ d > 0 \\ c - d < 0 \end{cases} \mathrm{IV}\begin{cases} c < 0 \\ d < 0 \\ c - d > 0 \end{cases}$$

The four combination strategies for the E_5 equilibrium points are Condition1 (I, III), Condition2 (I, IV), Condition3 (II, III), and Condition4 (II, IV) based on the above-mentioned four cases. After determining the partial derivatives for the two replicated dynamic differential Equations (3) and (7), a Jacobi matrix is the output. The stability of the system's equilibrium point may be ascertained using the local stability analysis of the Jacobi matrix: $deJ = a11a22 - a12a21, trJ = a11 + a22$. The four strategy combinations are introduced into the Jacobi matrix to get the results. ESS has to meet these requirements: $deJ > 0, trJ < 0$. Table 3 is the stability analysis of equilibrium point.

$$J = \begin{pmatrix} \frac{\partial F(x)}{\partial x} \frac{\partial F(x)}{\partial y} \\ \frac{\partial F(y)}{\partial x} \frac{\partial F(y)}{\partial y} \end{pmatrix} = \begin{pmatrix} a11a12 \\ a21a22 \end{pmatrix}$$

Table 3. Analysis of equilibrium point stability.

		(0,0)	(0,1)	(1,0)	(1,1)	(x^*,y^*)
Condition1	deJ	−	−	−	−	/
	trJ	−	Unknown	+	Unknown	0
	Evolutionary Results	×	×	×	×	×
Condition2	deJ	+	+	+	+	/
	trJ	−	+	Unknown	−	0
	Evolutionary Results	ESS	×	×	ESS	×
Condition3	deJ	+	−	+	+	/
	trJ	+	−	Unknown	+	0
	Evolutionary Results	×	×	×	×	×
Condition4	deJ	−	−	−	−	/
	trJ	+	Unknown	−	Unknown	0
	Evolutionary Results	×	×	×	×	×

According to the findings of the above table, it can be inferred that when Condition 2 is satisfied, in other words, when the molecular denominator values are all negative, the final balance will be stable. This indicates that financial institutions use central bank digital currency technology; SMEs repay and financial institutions do not use central bank digital currency technology; and SMEs do not repay as the final evolutionary stability strategy. Figure 2 shows the phase diagram of the results of the evolutionary process. Figure 3 shows the use of central bank digital currency technology for accounts receivable financing.

Figure 4 indicates that the development of points O (0,0) and B (1,1) yields two stable findings, suggesting that the replication dynamic curves of both financial institutions and SMEs have the propensity to converge to points O and B. When both game subjects' dynamic curves converge to point O (0,0), financial institutions decide to not use central bank digital currency technology, and SMEs decide to not repay the loan. However, when both game subjects' dynamic curves converge to point B (1,1), financial institutions decide to use central bank digital currency technology, and SMEs decide to repay the loan. The critical point for calculating the likelihood that the two replicated dynamic curves will converge to points O and B is point E. The quadrilaterals AECB and AECO comprise the two regions of the square OABC that are separated by the line AC. The size of these two areas determines the final direction of game participant, so that the quadrilateral AECB's area is S_1 and the quadrilateral AECO's area is S_2. When $S_1 > S_2$, both sides of the game will tend toward the evolution of financial institutions using central bank digital currency technology and SMEs repayment. When $S_1 < S_2$, both sides of the game will tend toward the evolution of financial institutions not using central bank digital currency technology and SMEs´ non-repayment. Additionally, S_1, S_2 is dependent on the variables x^*, y^*, where AECB's area is $S_1 = \frac{1}{2}[(1-y^*)+(1-x^*)]$ and AECO's area is $S_2 = \frac{1}{2}(x^*+y^*)$.

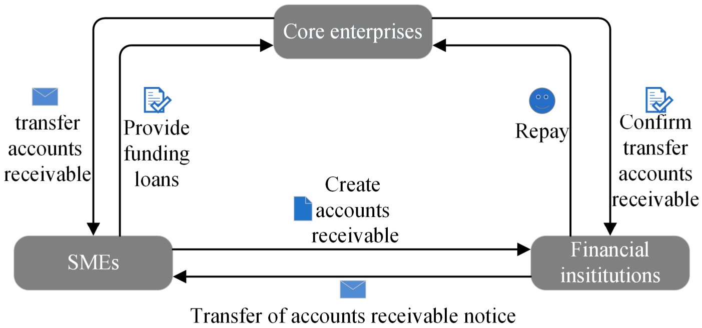

Figure 2. Accounts receivable financing.

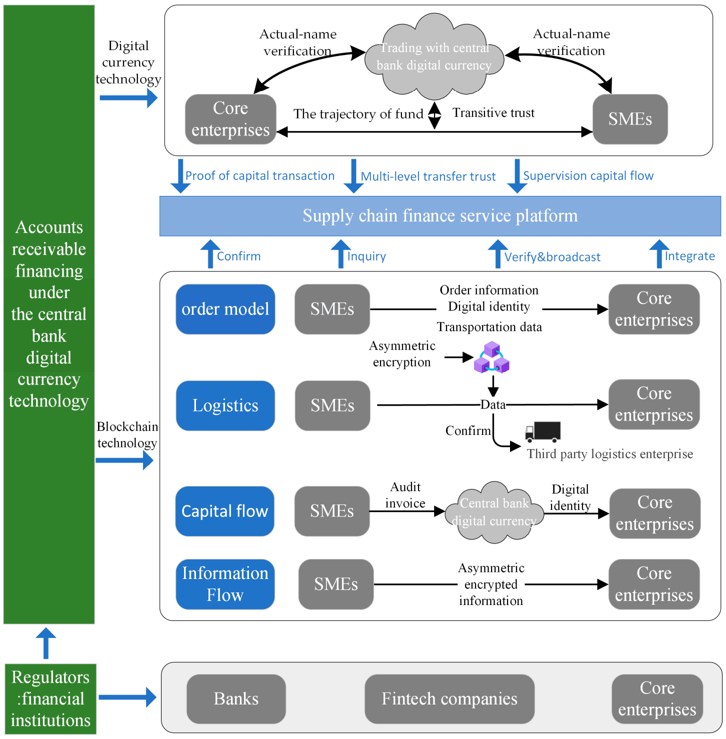

Figure 3. Accounts receivable financing using central bank digital currency technology.

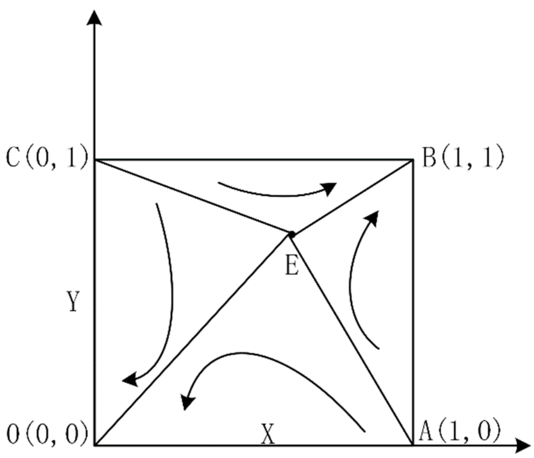

Figure 4. Evolutionary game between SMEs and financial institutions.

5. Discussion

5.1. Parameters Analysis

Financial institutions and SMEs will continuously modify their strategies in response to changes in parameter values as the game progresses, which can be directly reflected by the coordinate of point E and can also be further analyzed through point E to analyze parameters that affect the outcome of the evolutionary game. The purpose of this paper is to investigate how central bank digital currency technology affects accounts receivable financing offered by the "M + 1 + N" supply chain finance platform. Accordingly, the primary research parameters are $c_1, c_2, c_3, k, v_1, u_1, u_2$. As for parameters $R,\ r_1,\ r_2,\ B,\ F,\ G,\ P$, this paper does not undertake much research since accounts receivable financing is involved. We can observe that the evolutionary game's outcome and the saddle point's coordinates are closely associated with the values of E(x^*,y^*).

Since central bank digital currency technology enables information sharing between financial institutions and SMEs in the "M + 1 + N" supply chain financial platform, it modifies the traditional approach taken by financial institutions to collecting credit, which has some bearing on accounts receivable financing. The parameters of the aforementioned study are split into two categories in this paper: he first category is concerned with the credit method of financial institutions and includes c_1, c_2 *and* c_3, whilhe second category relates to sanctions and rewards both before and after the use of central bank digital currency technology, and includes k, v_1, u_1 and u_2.

The stability condition of the equilibrium point, Condition 2, informs us that $a > 0, b > 0, a - b < 0, c < 0, d < 0, c - d > 0$. The partial derivatives of each significant parameter with respect to the area S_1 are separately obtained, assuming that all other parameters are kept constant. From these partial derivatives, we can infer the contribution of each parameter to the influence of both parties' decisions, with a positive correlation denoted by +, and a negative correlation denoted by.

Therefore, the following inferences may be drawn from Table 4:

Table 4. Impact analysis of parameters.

Parameters	Partial Derivatives' Positivity and Negativity	Result for S_1
c_1	+	positive
c_2	−	negative
c_3	−	negative
k	+	positive
v_1	+	positive
u_1	+	positive
u_2	−	negative

Corollary 1: Related to credit that financial institutions collect: The relationship between c_1 and S_1 is positive, while c_2, c_3 and S_1 are negative. When financing receivables, if financial institutions have to pay a greater c_1, S_1 will also be higher, indicating that the higher credit costs will drive them to choose to use central bank digital currency technology. However, S_1 is lesser when c_2, c_3 are greater. It makes sense that financial institutions will not use central bank digital currency technology if the expenses associated with both supervision capital flows and technology are higher. The primary problems preventing financial institutions from using central bank digital currency technology to supervise accounts receivable financing are the costs of the technology and capital flow supervision. The costs of using central bank digital currency technology will continue to decline, and financial institutions will be more willing to accept the technology for financing supervision as a result of the rapid development and research of central bank digital currency technology in significant countries around the world.

Corollary 2: Penalties and incentives related to the use of central bank digital currency technology: The relationship between v_1, u_1 and S_1 is positive, while k, u_2 and S_1 are negative. If the credit block incentive v_1 and the non-repayment penalty u_1 for SMEs using central bank digital currency technology are higher, S_1 is also higher, suggesting that the credit block incentive will encourage SMEs to repay and also trend SMEs to repay due to the increased non-repayment penalty. As a result, financial institutions will choose to use central bank digital currency technology. However, without using central bank digital currency technology, the greater k, u_2 is, the smaller S_1 is, and the higher SMEs' joint fraud allocation rate and non-repayment penalty would lead SMEs to non-repayment. For example, when financing the receivables from secondary suppliers, if the allocation rate for joint fraudulent loans is higher, the secondary suppliers may decide to take the risk of making joint fraudulent loans to SMEs and defaulting on the loans even though the penalty for non-repayment is also higher.

5.2. Simulation Analysis

In this chapter, numerical simulations of the repeated dynamic equations in the evolutionary game model are carried out using Matlab and Python in order to confirm further the accuracy of the parameters, models, and analytical corollaries in the preceding section. It is difficult to use accurate data to test accounts receivable financing model since comprehensive information on the accounts receivable financing process is not readily accessible from publicly available sources. However, many researchers now simulate accounts receivable financing using numerical simulations in order to do more research [37]. We should initialize the assignment of variables in accordance with the limitations of the evolutionary stabilization approach before starting the simulation analysis [38].

Let: $R = 600, r1 = r2 = 0.05, B = 100, c1 = 80, c2 = 5, c3 = 5, F = 200, G = 100, P = 300, k = 0.5, v1 = 50, v2 = 20, u1 = 400, u2 = 600$. At the original value setting, the value of E_5 may be calculated to be around (0.467,0.65). The results of the initial value simulation are shown in the following Figure 5.

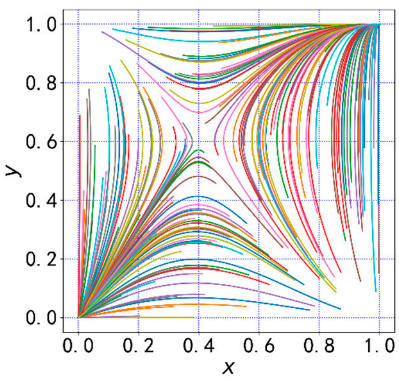

Figure 5. Initial Simulation Chart.

About the financial institutions' credit costs c_1: When c_1 increases from 90 to 130 while controlling the other parameters to take the same value, the simulation results are shown in Figure 6 below. When compared to Figure 5, the E point moves to the bottom left corner, at which point it becomes apparent that $S_1 > S_2$. Therefore, it is known that when the costs of credit for financial institutions rise, more initial points converge to the point (1,1). It suggests that financial institutions favor using central bank digital currency technology, while SMEs favor the repayment strategy. Due to the "M + 1 + N" supply chain financial platform, financial institutions often undertake actual offline investigations of the credit and qualification of SMEs, which is time-consuming and expensive. However, central bank digital currency technology has caused financial institutions to consider the possibility of significantly lowering the costs of loans to SMEs. To put it another way, the more expensive it is to solve credit risk and information asymmetry risk, the less interest financial institutions make, and the more likely it is that there will be a need to use central bank digital currency technology to rectify the situation. For SMEs, using central bank digital currency technology may improve relationships with financial institutions, build trust and make it easier to acquire loans. It can also provide access to more information about the regulatory policies and motivations of financial institutions. Therefore, SMEs will decide to pay back the loan.

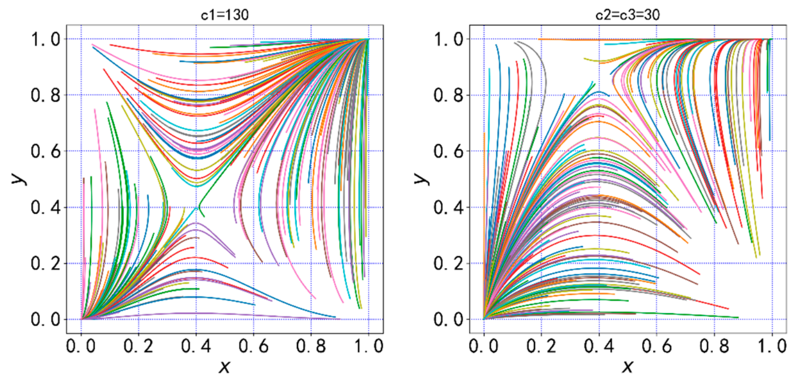

Figure 6. Simulation results chart for $c_1 = 130$ and $c_2 = 30$, $c_3 = 30$.

About central bank digital currency technology costs c_2, the capital flow supervision costs c_3: When c_2 and c_3 increase from 5 to 30, while controlling the other parameters to take the same value, the simulation results are shown in Figure 6 below. When contrasted to Figure 5, the E point of the simulation result moves to the upper right corner, where it becomes clear that $S_1 < S_2$. Therefore, it is known that when central bank digital currency technology costs and the capital flow supervision costs rise, more initial points converge to the point (0,0). This demonstrates both the unwillingness of financial institutions to choose the approach of using central bank digital currency technology and SMEs choose not to repay their loans. Despite the fact that central bank digital currency technology would lower the costs of accounts receivable financing generally, it will still suffer certain expenses, such as fixed costs and variable costs, as a result of the imperfect implementation and early adoption of the technology [39]. Financial institutions are less likely to decide to use central bank digital currency as a mechanism of regulation when c_2, c_3 are too high. Additionally, as a result of decreased regulatory pressure, there is a higher likelihood that SMEs may decide not to return the loan.

About the joint fraudulent loan allocation rate to SMEs k and the credit block incentives v_1: When maintaining the other parameters' values and increasing the combined fraudulent loan allocation rate of SMEs from 0.5 to 0.7, the simulation results are shown in Figure 7 below. The E point shifts to the bottom left corner of Figure 7, where it is discovered that $S_1 > S_2$ in comparison to Figure 5. Therefore, it is well known that when the allocation rate of joint fraudulent loans to SMEs rises, more initial points converge towards the point (1,1). This suggests that financial institutions favor the using central bank digital currency technology strategy, while SMEs favor the repayment strategy. The probability of credit risk and information asymmetry risk will be considered if financial institutions do not supervise SMEs and core enterprises; these risks mostly rely on how benefits and penalties are related. For example, the profits of SMEs would be much more than the penalties from financial institutions, the higher the distribution ratio of joint loan fraud. SMEs and core enterprises are therefore ready to take risks and choose joint loan fraud, even if it means receiving penalties. Therefore, financial institutions are increasingly willing to control accounts receivable financing using central bank digital currency technology to prevent this problem. When the credit block incentives are increased from 50 to 100 while controlling the other parameters to take the same value, the simulation results are shown in Figure 7 below. When compared to Figure 5, the E point shifts to the top right corner, at which point it becomes apparent that $S_1 > S_2$. Therefore, it is known that when the credit block incentives rise, more beginning points converge to the point (1,1). When financial institutions use central bank digital currency technology, credit block incentives are an incentive for SMEs with greater credit and regular repayment. Thus, SMEs will adopt repayment strategies in order to keep high credit and obtain credit block incentives.

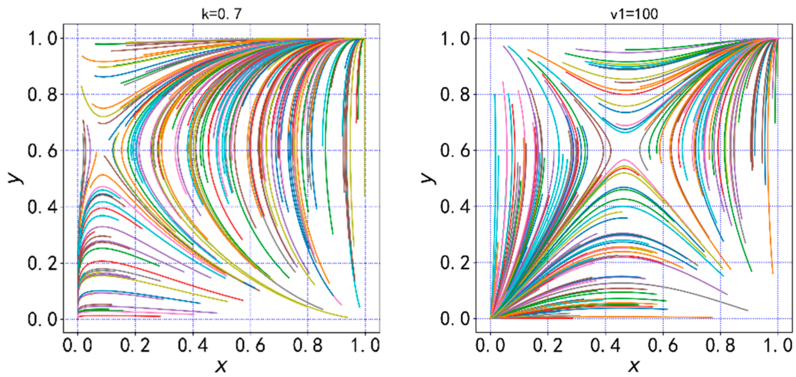

Figure 7. Simulation results chart for $k = 0.7,\ v_1 = 100$.

With regard to the non-payment penalties for SMEs that use central bank digital currency technology u_1, the non-payment penalties for SMEs that no-use central bank digital currency technology u_2: Figure 8 shows the simulation results when u_1 is increased from 400 to 500 while the other parameters remain constant. When u_2 increases from 600 to 700, the E point moves to the left and $S_1 > S_2$, indicating that more initial points converge towards point (1,1) when the penalty for non-repayment by SMEs using central bank digital currency technology increases. When u_2 increases from 600 to 700, the E point moves to the right and $S_1 < S_2$, indicating that more initial points converge towards the point (1,1). More starting points converge on the point as the penalty rises (0,0). The larger the penalties when using central bank digital currency technology, the higher proportion that SMEs will choose to repay the loan since they will be impacted by the counterfeiting costs of joint fraudulent lending. The existence of u_1 thereby monitors timely repayment of loans by SMEs, thus serving as a facilitator. However, without the use of central bank digital currency technology, the larger the penalties for default, rather than simply choosing not to return the loan, the more SMEs will choose not to repay the loan in order to maximize their own interests.

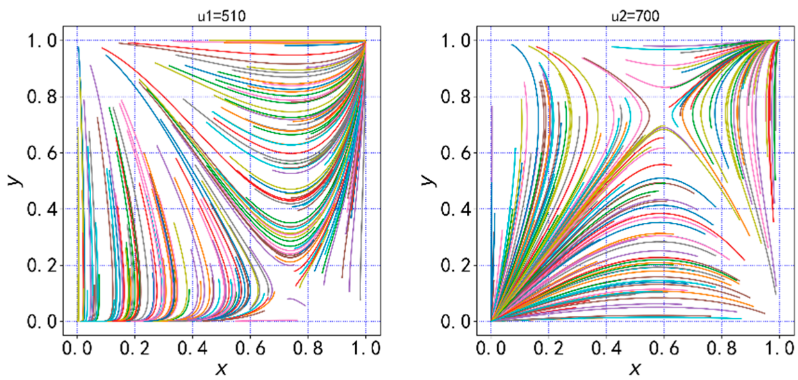

Figure 8. Simulation results chart for u_1 = 510 $u_2 = 700$.

6. Conclusions

A supply chain financial platform based on central bank digital currency will emerge as more and more nations study and speed up the application process of central bank digital currency, as well as the rapid development of financial technology like blockchain technology and distributed ledger technology. Central bank digital currency technology will be used to finance businesses like accounts receivable financing, which will significantly facilitate the financing of SMEs and bring new ideas for financial institutions to exclude the credit risk and information asymmetry risk existing in traditional accounts receivable financing, as well as reduce the losses brought to financial institutions by the occurrence of accounts receivable financing falsification. In order to assess the effects of each parameter on the process of financing receivables from financial institutions and SMEs, this paper uses game analysis to examine the dynamic evolution of central bank digital currency technology. It then draws the following conclusions:

(1) Central bank digital currency technology can decrease the costs of credit collection for financial institutions, increase the convenience of financing transactions, and remove credit barriers in the traditional accounts receivable financing process. It can also strengthen the authenticity and sharing of logistics, capital flow, and information flow, promote the transmission of core enterprise credit, and assist SMEs at multiple levels in obtaining a loan.
(2) The costs of supervising capital flow may be seen in central bank digital currency technology costs. Central bank digital currency technology's high costs are a significant barrier to its adoption and promotion. However, as technology advances and the concept of central bank digital currency is gradually adopted, it will become more mature and less expensive, making it possible for more financial institutions and enterprises to adopt it.
(3) Central bank digital currency technology has a specific technical threshold and necessitates a high level of enterprise digitization, so initial acceptance will typically be limited. As a result, it needs more industry promotion and popularization. In addition, because the supervision of the flow of funds must be safe, it is best to support the enactment of laws to prevent the leakage of information by SMEs.
(4) Financial institutions are crucial in providing incentives for repayment and punishing for non-repayment. In order to protect the interests of financial institutions, they can act as a deterrent to SMEs while guiding them to adhere to contracts and make payments on time. Financial institutions can also entice SMEs to participate by offering incentives that will result in a situation where everyone wins.

There are still many further lines of inquiry that need to be researched in the future, especially in light of the limitations of this paper. First, new directions for future research could compare other supply chain financing models, such as the financing model for future cargo rights, to understand the effects of various financing models on financial institutions, SMEs, and core enterprises. Second, central bank digital currency technology leads to current monetary technology; the new method may be used in future research to compare different finance strategies. Third, it may take into account the collaboration and fraud of both parties involved in the multiple games, including the cooperation and fraud of SMEs, core enterprises, and financial institutions, as well as what steps should be taken to stop the negative consequences.

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