

A Study on Evolution Game of Accounts Receivable Pledge Financing in Supply Chain Finance Model

Yiyu Xia¹

¹ Rosedale Academy, Beijing, 100000, China

Correspondence: Yiyu Xia, Rosedale Academy, Beijing, 100000, China. E-mail: operations@rosedaleedu.com

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Abstract

In practice, due to information asymmetry and the bounded rationality of game participants, most of the actions taken by game participants are irrational. The evolutionary game theory is based on bounded rationality and looks at the adjustment process of group behavior through the perspective of system theory. Therefore, this paper will use the idea of evolutionary game to discuss the issue of SMEs' accounts receivable pledge financing under the supply chain finance model. This paper builds the model on the basis that both sides of the game are bounded rationality. In real life, the behavior of individuals tends to be more bounded rationality. By constructing an evolutionary game model under bounded rationality, we can see that the final evolution result between banks and loan companies is related to many factors. From the phase diagram of the evolutionary game, it can be seen that the area on both sides of the dotted line of the phase diagram is mainly determined by the profit matrix, but the direction of the final evolution is mainly determined by the initial state of the game.

Keywords: pledge financing; evolutionary game, accounts receivable, supply chain finance model

1. Introduction

Small and medium-sized enterprises have gradually become an important force in China's economic and social development in the process of economic development. How to create a good environment for the development of small and medium-sized enterprises has become an important issue to ensure the steady and rapid economic development and social stability (Hu et al., 2022). However, Chinese smes still face many obstacles in their development process, the most important of which is the difficulty of financing. The financing problem of small and medium-sized enterprises has become the biggest obstacle to their sustainable and stable development and industrial transformation and upgrading (Sun, He & Su, 2021).

China's credit system is still not perfect. Under the traditional financing mode, smes are generally regarded as high-risk and high-cost customers by banks due to their small scale and insufficient collateral, which makes it difficult for such enterprises to obtain loans (Yan et al., 2021). As for small and medium-sized enterprise financing difficult problem solution to continuously explore, the concept of the supply chain finance is raised, in recent years due to the popularity of credit sales mode, there are many small and medium-sized enterprise supply chain upstream accounts receivables, and by its operations due to the existence of the accounts receivable process there is a big gap, in order to reduce the pressure on the cash flow, to ensure its continuing operations. Small and medium-sized enterprises urgently need to solve the problem of their source of funds, in this case, supply chain finance model accounts receivable pledge financing business emerged (Yunhang et al., 2021; Zhou et al., 2021).

The birth of supply chain finance can effectively alleviate the financing difficulties of small and medium-sized enterprises and the increasingly fierce competition among banks. It can also enable core enterprises to further reduce costs, improve efficiency and enhance market competitiveness by participating in this business (Abbasi et al., 2017). Therefore, the research content of this paper has important theoretical and practical significance.

Theoretical significance: First, using the static game theory of complete information, this paper expounds that the supply chain finance model of accounts receivable pledge financing has more advantages than the traditional model of accounts receivable pledge financing, which proves the necessity of carrying out the accounts receivable pledge financing business under the supply chain finance model. Secondly, under the condition of asymmetric information and incomplete rationality of participants, this paper makes a quantitative study on how

to reach the result of loan and keep the contract between banks and enterprises by using evolutionary game theory, which provides a theoretical basis for the operation of this business.

Practical significance: This paper has important practical significance to study supply chain finance. First, in the traditional financing mode, the credit standard of banks is usually limited, and it is difficult for ordinary small and medium-sized enterprises to meet the credit standard of banks. However, the core enterprises are introduced into the bank credit system in the supply chain finance mode, and the rigorous model derivation proves that the supply chain finance mode has more advantages. This is of great significance to small and medium-sized enterprises with small scale, weak strength and internal cash flow that cannot meet their own development needs. Secondly, the evolutionary game theory is used to quantitatively analyze the conditions for banks and enterprises to reach loans and keep promises, which provides two specific strategies for promoting the development of receivables pledge financing business in supply chain finance model: improving the policy environment and building a bank-dominated supervision system, so as to ensure the smooth development of this business.

2. Rationality Analysis of the Application of Evolutionary Game Theory

2.1 Evolutionary Game Theory

In traditional game theory, game players are assumed to be completely rational, but it is difficult for them to be completely rational in real life, because the cognitive level of most players is limited and the information they have is impossible to be complete (Zeng & Geng, 2022). Because of this, on the basis of traditional game theory, some scholars have carried out further research, and evolutionary game theory was born and developed rapidly (Wang, Yu & Wang, 2019).

The evolutionary game theory is based on the assumption of bounded rationality of the participants and describes the process of human cognition of the real world by using genetic theory and evolutionary theory (Jiang et al., 2022). From the point of view of system theory, the adjustment process of group behavior is regarded as a dynamic system. Based on the study of the influence of bounded rationality of a large number of individuals in a group on group behavior, the relevant factors are analyzed. The analysis of evolutionary game emphasizes the dynamic process of equilibrium evolution, and the equilibrium result is not the result of one-time selection, but gradually improved in constant adjustment. Through such long-term adjustment and improvement, the system may reach the equilibrium strategy, or it may always be in the process of approaching a certain equilibrium strategy, which is called "evolutionary-stable strategy" (Liu, Hu & Zhang, 2022). If the system has more than one equilibrium strategy, which strategy the system will eventually evolve to depends on the initial state of evolution and the path of evolution.

Specifically, the advantages of evolutionary game theory are as follows:

(1) In evolutionary game theory, it is assumed that participants are bounded rational in the process of behavior and only have a limited cognitive level of the external environment. Therefore, the behavior of the players can not maximize their income, but each strategy choice of the players will have an impact on the subsequent strategy choice of the other party. Therefore, for a long period of time, the strategic choice of both players in the game includes the consideration of the history of the other party's strategy choice (Li & Pan, 2019). At the same time, participants also improved their decision-making ability by observing the history of the other party's strategic choices.

(2) The evolution game theory can be used to study how the interaction between different individuals within the population of mutual influence, will their behavior choice as a dynamic system, the evolution process of the game participants think as an individual can be constantly in the process of strategy selection, based on the historical choice of learning constantly adjust their behavior to make better decisions eventually reach equilibrium.

2.1.1 Single Population Evolution Stabilization Strategy

When the players' strategies are pure strategies, each player can choose a pure strategy at the same time. When the players' strategy choices are mixed, for a single population, these individuals may play different strategies at different times depending on the probability (Huang et al., 2022).

When an individual in a group chooses S^* , the benefit of any individual choosing other strategies will not be higher than that of S^* . In this case, S^* can be called an Evolutionary Stable Strategy (ESS). Specifically, suppose that when a player chooses strategy S , the expected return obtained by the player who chooses strategy S^* is denoted as $E(S^*, s)$. A is the payoff matrix of the player who chooses strategy S , then $E(S^*, s) = S^* \cdot A_s$, which is the inner product of vector S^* and vector A_s . A_s represents the product of the matrix A with the transpose of S , and it should be noted that the transpose is omitted, and represents a column vector.

2.1.2 Evolution Stabilization Strategy of Two Populations

In the game between two populations, we only consider the evolutionary game behavior between individuals of different species, and do not consider the evolutionary game behavior between individuals of the same population.

In THE two-POPULATION EVOLUTION game, the row player and the column player represent population 1 and population 2 respectively, their payoff matrices are payoff matrix A and payoff matrix B respectively, and X and Y represent their alternative strategies respectively.

For all (x, y) in the neighborhood of (x*, y*) among all strategy combinations of both parties in the game, if:

$$x^* \bullet Ay > x \bullet Ay \quad (1)$$

Or there is:

$$y^* \bullet Bx > y \bullet Bx \quad (2)$$

Then (x*, y*) is an ESS. If (x*, y*) is an ESS of the two-population evolution game, then x* and y* are pure strategies in Δ_m and Δ_N , where m and n represent the pure strategies of row and column players, respectively. So we can say that a mixed strategy cannot be an ESS.

Replicating the dynamic equation can help us to accurately judge whether a pure strategy combination is evolutionarily stable or not. Take row player for example, its specific meaning can be interpreted as, the growth rate $\dot{p}/p$ is equal to his fitness $e_1 \bullet A(q, 1 - q)$ minus his average fitness $(p, 1 - p) \bullet A(q, 1 - q)$, where $e_1 = (1, 0)$ means that row player chooses strategy H with probability 1, A is the payoff matrix of the row player. Then, the replicator dynamics of the row player can be obtained:

$$\dot{p} = p[e_1 \bullet A(q, 1 - q) - (p, 1 - p) \bullet A(q, 1 - q)] \quad (3)$$

2.2 Rationality Analysis

In the supply chain financial accounts receivable pledge financing model, the Banks have is asymmetric information on supply chain enterprise, due to the scale and management level of supply chain enterprise itself, etc, the effect of lead to excessive dependence on its decision-making management personnel's subjective judgment. Banks in the judging process of supply chain enterprise credit level is "limited rationality".

In the process of the bank by investigating other cooperated with the enterprise on supply chain, on the basis of real transaction background to provide loans, after many times with supply chain enterprises credit in the bank, the two sides will continue to learn in the process of long-term repeated game and adjust their strategies, policies and the change of market environment in response to each other. It can be seen that the behavior of both parties has very obvious characteristics of evolutionary game. Due to the above reasons, this study will use evolutionary game theory to analyze the game process between banks and enterprises.

3. Evolutionary Game Model Construction and Analysis of Banks and Supply Chain Enterprises

3.1 Evolutionary Game Model Construction of Banks and Supply Chain Enterprises

The two sides of the evolutionary game are the supply chain and the bank, which are composed of smes and core enterprises. Both of them are bounded rational, and due to the information asymmetry, neither the bank nor the supply chain enterprises can accurately choose the most favorable decision for themselves. Therefore, the bank's strategy choice space is {loan, no loan}; the strategy choice space of small and medium-sized enterprises is {breach, keep agreement}.

In addition, because of the core enterprise credit level has a significant impact on bank decision-making, in order to facilitate analysis, we assume that the core enterprise of the default situation whether to conduct joint to small and medium enterprises loan fraud, is its possible strategy for {joint loan fraud, no joint loan fraud} (not joint loan fraud is also money to the designated bank account). To be sure is a traditional game model for the sake of symmetry in the third chapter takes into consideration the core corporate defaults, small and medium-sized enterprise credit situation, in this study to closer to the real situation in the evolution game model we do not consider this kind of situation, because of financial supply chain model is the key to using the core enterprise credit, so we don't consider the core enterprise default alone here. Instead, the case that the core enterprise uses its credit to cheat on loans jointly with small and medium-sized enterprises is considered as the case that the core enterprise defaults.

In order to facilitate the research, without changing the essence of the problem, we further put forward the following assumptions: Assuming that smes still take receivables with total amount of B to the bank for receivables pledge loan, the bank determines the financing rate of receivables as λ ($0 < \lambda < 1$), that is, the total

amount of credit that smes can obtain is λB . The loan interest rate of the bank is R (the payoff of the bank is 1 year and I'll call it λBr). Assume that the bank's supervision cost for this business is C ($\lambda br > C$); the reproduction rate of smes is R_1 ($0 < R_1 < 1$), the reproduction rate of core enterprises is R_2 ($0 < R_2 < 1$), the probability that smes and core enterprises jointly cheat banks for loans is α ($0 < \alpha < 1$), and the ratio of the income obtained by smes from this behavior to the total income is L (the ratio obtained by the core enterprise is $1-L$; small and medium-sized enterprises unilateral default can bring economic loss to the core enterprise and core business to other enterprises will therefore to boycotts, leading to the loss of future opportunities for cooperation, the losses can be considered a punishment for small and medium-sized enterprises of supply chain, remember to F , at this time due to the provisions of the loan contract, core enterprise need payment to the bank. In this case, assume that the fee paid to the bank is D ($0 \leq D \leq \lambda b(1+r_0)$). At the beginning of the game, it is assumed that the probability of banks choosing "loan" is X ($0 \leq x \leq 1$), the proportion of banks choosing "no loan" is $1-x$, and the probability of smes defaulting is Y ($0 \leq Y \leq 1$).

This paper ignores the interactions within populations and only considers the interactions between populations, that is to say, only the interactions between banks, smes and core enterprises are considered.

First, when banks lend to smes, smes and core enterprises perform their contracts as scheduled, and the earnings of banks, smes and core enterprises are respectively: $\lambda br - C$, $\lambda b(R_1 - R)$, Br_2 .

Second, when the bank does not lend to smes, and smes deliver goods to them and receive payment as required by the core enterprises, the income of the three parties is respectively: $0, 0, Br_2$.

Third, when the bank loans to small and medium-sized enterprises, small and medium-sized enterprises unilateral default, no production shall be carried out in accordance with the contract, the small and medium-sized enterprises in the core enterprise can't normal production, the core enterprise to the bank according to the contract production, still result in core enterprise can't normal production, the core enterprise still make payment to the bank D . The rest of the payment may be refused, and the core enterprise will punish the small and medium enterprises, then the income of the three parties is: $-\lambda b(1+R) - C + D$, $\lambda b(1+R) - B - F$, $-D - Br_2$.

Fourth, when the bank loans to small and medium-sized enterprises, small and medium-sized enterprises unilateral default, no production shall be carried out in accordance with the contract, the small and medium-sized enterprises in the core enterprise can't normal production, the core enterprise will not pay the small and medium-sized enterprise receivables, at the same time also will punish for small and medium-sized enterprises, the tripartite benefits are: $0, -B - F, -Br_2$.

Fifthly, when banks lend to smes and smes and core enterprises unite to cheat loans from banks, there is no real transaction background between smes and core enterprises, and the sales contract between them is a fake contract. The profits of the three parties are as follows: $-\lambda B(1+R) - C$, $\lambda B(1+R)L$ and $\lambda B(1+R)(1-L)$.

Sixth, when banks do not lend to smes and there is no real transaction background between smes and core enterprises, the income of the three parties is 0 .

3.2 Analysis of Evolutionary Game Model between Banks and Supply Chain Enterprises

Through the long-term evolution of the system, it is possible to achieve a stable equilibrium state in which both banks and enterprises choose to make loans and do not default. The reasons are as follows:

First, the probability α of joint loan fraud between small and medium-sized enterprises and core enterprises and the interest distribution ratio L when joint loan fraud occurs. If α is small and close to 0 , the risk avoidance mechanism of supply chain finance model is strong and effective. In this case, banks are more likely to choose to provide loans to smes. However, this is not the case in reality. It is undeniable that there is the possibility of joint loan fraud between smes and core enterprises in real life, and the probability of joint loan fraud between smes and core enterprises is related to the overall economic situation. Therefore, the risk prevention mechanism based on the supply chain finance model will have a huge loophole in this case. At the same time, when small and medium-sized enterprises collude with core enterprises, the larger the income distribution ratio, the more incentive small and medium-sized enterprises have to cooperate or cheat core enterprises and conspire with them, the higher the probability of contract violation (Ronchini, Moretto & Caniato, 2021).

Second, the bank's regulatory cost C and the lending rate R . The supervision cost and loan interest rate of banks have a great influence on whether banks choose loans. The higher the regulatory cost and the lower the loan ratio, the more banks tend not to provide loans to smes. Among them, the supervision cost mainly depends on the supervision demand and technical level of the bank in a certain period, so the supervision cost is a fixed number

in the short term, so the loan interest rate determines whether the system can reach equilibrium (Liu, 2020). If bank in pursuit of higher yields, improve sme lending rates, while can improve the profits in the short term, but easy to lead to moral hazard, increase the proportion of default potential small and medium-sized enterprises, so if higher lending rates by state is not stable, due to the increase of bank of credit risk is bound to lower loan interest rates gradually in the game, the system can reach evolutionarily stable strategy equilibrium.

Third, the reproduction of small and medium-sized enterprises (smes) yields and default penalties F for small and medium-sized enterprises of supply chain. The higher the small and medium-sized enterprises in the process of production and operation to obtain the higher yield, the lower the probability of default will; the larger F is, the lower the default probability of smes. Among them, the default penalty F of the supply chain for smes will play a key role in the formation of the stability strategy. If the punishment is large enough, the final evolution strategy will become loan and contract keeping, so as to achieve ESS stability.

4. Strategies to Reduce the Implementation Risks of Accounts Receivable Pledge Financing Business in Supply Chain Finance

4.1 Reduce the Cost of Bank Supervision

Through the analysis, we know that the lower the regulatory cost C of the bank for smes, the higher the probability of providing loans to smes. Since the supervision cost of banks is relatively fixed in the short term, banks can improve the efficiency of risk assessment by improving the level of risk control system and strengthening the training of employees in a period of time. Specifically, improvements should be made from the following aspects:

(1) Strengthen the supervision of the process from the perspective of business process control. In the supply chain finance receivables pledge business, it is very expensive for banks to conduct comprehensive and detailed examination on smes (Zhu et al., 2019). Therefore, when smes apply for loans from banks, banks need to focus on the most critical aspects to reduce supervision costs and improve work efficiency. Among them, the authenticity of transaction contracts and accounts receivable provided by small and medium-sized enterprises should be examined most by the bank, so as to make a clear judgment on whether the real daily transactions between small and medium-sized enterprises and core enterprises are behind the accounts receivable, and exclude the collusion of the two to cheat the bank. After passing the above examination, the bank also needs to review the data indicators of smes and core enterprises in the supply chain, especially the business status and credit level of both parties. It should review the changes of the indicators regularly not only before the loan but also after the loan, so as to re-evaluate the changes of the risk level.

(2) Establish a unified standard risk assessment system. Banks can establish a unified standard risk assessment system through cooperation with third-party logistics companies to measure the risks of supply chain enterprises (Ioannou & Demirel, 2022). On the one hand, the establishment of the evaluation system is to improve the efficiency of bank lending, simplify the audit process, reduce the risk of the bank, on the other hand, it can also strengthen the credit consciousness of supply chain enterprises, and form a self-disciplined credit environment.

(3) Prevent moral hazard of practitioners. Good system and perfect system can help small and medium-sized enterprises successfully obtain loans and reduce bank credit risks, but business operations need relevant personnel to handle, so it is very important to strengthen the skills training and industry ethics of employees (Lu & Chen, 2022). On the one hand, we can rely on strict punishment mechanism and reasonable incentive measures to strengthen the supervision of practitioners. On the other hand, the legal level and professional accomplishment of practitioners should be improved through training.

4.2 Strengthen Supervision over Small and Medium-Sized Enterprises

For small and medium-sized enterprises, the probability α of joint loan fraud with core enterprises is one of the main sources of bank risks. In this regard, banks should start from the following aspects:

(1) Review whether there is a real transaction background of accounts receivable. To reduce the probability of small and medium-sized enterprises with the core of the syndicated loan fraud, banks need to investigate both the trading history of the past, to understand the relationship between, and then to apply for a loan of this contract amount of accounts receivable and to judge whether there is a correlation, guarantee the authenticity of its transactions, effectively reduce the joint probability of loan fraud α . Then there is the need to pay extra attention to whether the transaction amount matches the amount on the documents, and whether the repayment date is before the maturity date of the loan.

(2) Set up a special repayment account to supervise the repayment capital flow of the core enterprise. In the supply chain finance accounts receivable pledge financing business, the general loan contract will require the core enterprise to repay the accounts receivable into the account designated by the bank to serve the sub-business (He et al., 2021). So they have to bank for small and medium-sized enterprises with the core enterprises of both sides payment account of regulation, to be specified in the provisions in the contract to the outside of the core enterprise accounts for payment, otherwise the payment behavior invalid provision, and clearly told that the two sides, with the person this, prevent malicious fraud, reduce the probability of joint fraud for alpha, ensure the business smoothly.

In order to further reduce the probability of default, Banks need to strengthen the reproduction of small and medium-sized enterprises (smes) yields regulation:

(1) Banks should conduct in-depth investigation on the industries and operational capabilities of smes. When an industry is on the rise, enterprises generally lack funds for investment, reproduction and research and development, so such enterprises can consider lending to them. But when some enterprises in the sunset industry, although its production and operation capacity is stronger than the former, its loan still need to be considered carefully. Because industry in the rising stage, the reproduction yield in the future is likely to continue to improve, will reduce the risk of the bank.

(2) Banks should strengthen their investigation into the risks in the industries operated by smes. Some small and medium-sized enterprises due to the management risk of the industry is very high, its investment return rate is also high, such an enterprise often due to the current economic environment is good or because at the stage of emerging industries, good operating condition, earnings data is also very good, but this kind of enterprise management state is the biggest characteristic changes prone to volatility. Therefore, in the face of such high-risk and high-yield enterprises, banks should make a judgment on whether to issue loans in combination with the development trend of the industry and the change of the economic environment.

4.3 Strengthen the Supervision of Core Enterprises

Banks should strengthen the training of their business personnel. For the accounts receivable pledge financing business under the supply chain finance mode, the most important part of the business risk source is the comprehensive strength of the core enterprise (Yang et al., 2021). Because core enterprises are the key to the whole supply chain finance credit system, strengthening the supervision of core enterprises plays a crucial role in the smooth development of supply chain finance business. In this regard, we should proceed from the following aspects:

(1) Strengthen the supervision of the credit level of core enterprises

In the process of supply chain finance business development, banks should focus on selecting the middle and lower enterprises that cooperate with core enterprises with higher credit level, higher industry reputation and stronger comprehensive strength to carry out receivables pledge financing business (Xiao et al., 2022). The core enterprises with major bad credit records and weak strength should be considered carefully, because the probability α of such enterprises to cheat loans jointly with small and medium-sized enterprises is high. On the other hand, the penalty F received by small and medium-sized enterprises due to their weak strength and the possibility of losing cooperation with them is also relatively small.

(2) Strengthen the supervision of the operation of core enterprises

Generally, the contracts signed between the bank and the lending smes and the core enterprises clearly stipulate that the core enterprises are the debtors in the business, so it is very important to supervise their operation conditions (Markets, 2020). When the loan is due, if the core enterprise still fails to pay the loan amount, the bank will have a greater risk. So in addition to strengthen the supervision of core enterprise operating conditions, should also be in the loan stipulated in the contract, if there is a core enterprise insolvent, the loans to small and medium-sized enterprise is responsible for the notification of core enterprise receivables transfer matters. However, considering the small and medium-sized enterprise bankruptcy due to mismanagement, you can't through its connection to the core enterprise. When lending to small and medium-sized enterprises, it can be stipulated in the contract that the creditor's right assignee can issue the loan to the core enterprise if necessary.

(3) Supervise whether the core enterprise is informed about the mortgage of the accounts receivable

In the process of supply chain finance receivables pledge financing business, bank employees should conduct field examination and get written approval of the authenticity of the transaction background between smes and core enterprises before proceeding with the next process of this business. Information provided by small and medium-sized enterprises or core enterprises should not be trusted unilaterally. If both parties cheat banks in this

case, it will be very difficult for banks to defend their rights and interests with legal weapons, which will bring high risks to banks.

5. Conclusion

Small and medium-sized enterprises have made great contributions to China's economic development, but due to their own reasons, there are certain difficulties in the financing process, which hinder their development. Accounts receivable as a large number of small and medium-sized enterprises generally existing current assets, if can properly use it, to promote the long-term healthy development of small and medium-sized enterprises will be of great significance. This paper studies the supply chain finance model of receivables pledge financing, and concludes that the supply chain finance financing model has more advantages than the traditional financing model, which is easier to facilitate banks to lend money to small and medium-sized enterprises, help small and medium-sized enterprises to solve the financing problems, and promote the vigorous development of small and medium-sized enterprises. Under the condition of information asymmetry and bounded rationality of participants, an evolutionary game model between banks and enterprises is constructed by using the theory of evolutionary game. The influence of various factors on the evolution direction of game results between banks and smes is analyzed qualitatively.

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