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Evolutionary Game Analysis of Pig Supply Chain Financing under Order Financing Model: Based on the Perspectives of Quality Default and Bank Loan

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Abstract

Chinese hog farmers have long been troubled by the challenge of obtaining costly and hard-to-get finance.The emergence of big data and internet has led to the advancement of agricultural supply chain finance, offering a novel and efficient solution to address the financial limitations faced by hog farmers. This paper examines a two-party evolutionary game involving a hog farmer without financial limitations and a pork producer in the case of a hog quality default within the hog supply chain order financing framework. It also analyzes a three-party stationary sport model involving a hog farmer, a pork producer, and a bank following the bank's provision of a loan with financial restrictions. The study revealed that the fulfillment of contracts by hog farmers and the acceptance of substandard quality hogs by pork producers are influenced by market prices, information costs, and default losses. The trustworthiness of hog farmers and pork producers is impacted by bank pledge rates and creditworthiness losses. Additionally, the lending decisions of banks are influenced by pledge rates and government incentives. To improve the hog supply chain financing model, it is recommended to lower the threshold for hog farmers to join and establish a comprehensive hog supply chain financing platform.

Keywords

Pig Supply Chain; Order Financing; Tripartite Evolutionary Game.

1. Introduction

China is a major consumer of pork, with pork making up around 65% of the country's total meat consumption. The per capita pork consumption by people is increasing annually. The hog business in China is a longstanding sector that plays a crucial role in the agricultural economy and significantly boosts farmers' income. In 2021, China produced 52,959,000 tons of pork and 12,116,000 tons of cattle, sheep, and poultry combined, with pork production representing around 80% of the overall meat production. China's hog sector has a substantial volume.

Currently, China's hog farming model consists of two primary types: small-scale backyard farming by individual farmers and large-scale farming, which includes "company + farmers" and corporate-owned operations. Currently, retail farming still makes up over 50% of the sector. Retail households primarily obtain financing from policy banks, financial institutions, government subsidies, and private loans. Among them, financial institutions provide the largest source of funds for hog farming operations. Financial institutions mostly depend on the creditworthiness of the primary entity in hog farming to grant loans. In 2020, about 60% of all small- and medium-scale hog farmers will have a herd size of less than 500 hogs, as reported by the Ministry of Agriculture and Rural Development. Financial institutions often deny loans to hog farming major bodies because of their tiny farming scale, lack of credit self-certification, and absence of collateral. By the end of the third quarter of 2019, loans to farmers and

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agricultural loans had both increased, with loan volumes reaching 5.23 trillion RMB and 4.06 trillion RMB, respectively. However, their proportion in the total loan balance of financial institutions remained low, at only 3.4% and 2.7%. Credit rationing in the hog breeding business is a significant issue, as the standard financing methods are insufficient to cover the capital needs of the primary hog breeders. The 2020 Central Document No. 1 emphasizes the need to expedite the restoration of hog production and promptly address credit constraints to ensure timely achievement of comprehensive prosperity in rural areas. Constraint. Agricultural supply chain finance is a novel financing approach that offers a solution for the hog industry's funding challenges.

2. Literature Review

2.1. The Advantages of Agricultural Supply Chain Finance

The Small and medium-sized enterprises (SMEs), core enterprises, and financial institutions in the agricultural supply chain are interconnected through financing. Core enterprises provide credit endorsements for SMEs, enabling them to access loans from financial institutions. This creates a closely connected community of interest between SMEs and core enterprises, facilitating risk sharing [1, 2, 3]. Agricultural supply chain finance facilitates the shift from traditional independent farming to a collaborative model involving both companies and farmers. Participating in supply chain finance and collaborating with the company allows farmers to connect directly with the market, effectively addressing the company's land resource limitations and challenges related to costly financing and outdated breeding practices among retail households, thus fostering the advancement of the hog industry.

Agricultural supply chain finance is better suited for the current rural situation than other financial models and can effectively ease rural credit limitations [4]. Thus, it is crucial to prioritize the advancement of the agricultural supply chain financial service model and speed up agricultural supply chain financial innovation [5, 6]. In 2023, The People's Bank of China and five other departments collaborated to release the Guiding Opinions on Financial Support for Comprehensively Promoting Rural Revitalization and Accelerating the Construction of a Strong Agricultural Country. This document urges core supply chain companies to offer credit guarantees and enhancements to both upstream and downstream enterprises using methods like white list confirmation, accounts receivable confirmation, and the creation of a purchasing and marketing fund. firms aim to ensure credit enhancement and enhance finance availability for firms and farmers throughout the chain.

2.2. Order Financing Model of Agricultural Supply Chain

There are four common financing modes in agricultural supply chain finance: accounts receivable financing, inventory financing, prepaid account financing, and order financing. The hog supply chain is a segment of the agricultural supply chain that revolves around the sale of hog products. It involves upstream suppliers of hog breeding enterprises, core enterprise slaughtering and processing enterprises, and downstream sales enterprises working together to achieve mutual benefits. This chain includes logistics, capital flow, and information flow to deliver hog products to consumers [7].

Order financing is a financial service provided by banks to enterprises with good credit, allowing them to secure loans to purchase materials and fulfill product orders. The loan is repaid by the enterprise once payment is received [8]. In 2020, Cao et al. studied how hog farming enterprises facing financial constraints seek loans from banks. They discovered that banks evaluate the creditworthiness of the entire supply chain rather than individual enterprises to determine whether to grant credit. This approach aims to enhance the accuracy of assessing credit for small and medium-sized micro-enterprises [9]. In their 2021 study, Wang

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et al. discovered that financial institutions prioritize the creditworthiness of the entire hog supply chain over traditional bank loans in risk management under the order financing model. They use the order contract for credit assessment and rely on the cash flow from the order contract as the repayment source, unlike traditional bank loans that rely on the assets of hog farmers for repayment. financial flow produced by the contractual agreement [10].

In conclusion, at present, the papers about agricultural supply chain mainly focus on the static game analysis under the accounts receivable model, and rarely see the evolutionary game analysis under the order financing model. At present, the papers about tripartite game of supply chain mainly focus on small and medium-sized enterprises, core enterprises and financial institutions in the macro, and rarely see the tripartite game of agricultural supply chain. Based on this, this paper adopts an evolutionary game model to consider the two-party game between pig farmers and pork producers in the case of quality default and the three-party game between pig farmers, pork producers and banks in the case of bank loans. There are two main marginal contributions in this paper. Firstly, an evolutionary game model was used to consider the game between pig farmers and pork producers under the order financing model of agricultural supply chain, and a stable equilibrium point was found. Secondly, by using static game theory, the three-party game model of pig farmers, pork producers and financial institutions is considered.

3. Model Construction and Evolution Analysis

3.1. The Two-party Game in the Case of Quality Defaults by Hog Farmers

3.1.1. Modeling Assumptions

Firstly, consider the situation where hog farmers have no financing constraints. In the order-oriented hog supply chain, hog farmers establish order partnerships with pork producers to ensure hog marketability and mitigate risks associated with excessively low market prices. Pork producers, on the other hand, aim to form order partnerships with hog farmers to mitigate market volatility and provide a steady supply of processing raw materials in terms of quantity and quality. Hog farmers will typically execute orders, deliver items, and pay interest when the market price at the order's expiration p_0 is less than the contract price p_1. Conversely, there is a much greater chance that they may default on the order if the market price at the time of order expiration is higher than the contract price.

Suppose a contract is signed between a hog farmer and a pork producer for the delivery of a quantity of Q and at the price of p_1 per kilogram. If processing losses are not taken into account, the pork producer's price per kilogram of hog being sold is p_2, the cost of processing is C_1, and the cost of endeavor to put the processed product on the market is C_2, then the pork producer's net return per kilogram of hog is R_b, $R_b = (p_2 - p_1)Q - C_1 - C_2$. The return to the hog farmer is the difference between sales revenue and input cost C_3, i.e. $R_a = p_1 Q - C_3$.

The following theories are put out by the article in order to build the model:

Assumption 1: hog farmers who default incur a penalty of M.

Assumption 2: Pork producers penalize hog farmers at the expense of increased expenses; the higher the penalty, the higher the associated costs. When punishing, assume that C_5 is the price that must be paid.

Assumption 3: In the event of a hog farmer's default, the pork producer and the hog farmer must both visit the instantaneous market to locate a buyer and a seller. Assume that both parties will incur C_4 in information acquisition costs.

Assumption 4: Since there would be a significant financial and reputational cost associated with the pork producer's default, the default is not taken into account at the time the deal is signed.

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3.1.2. Model Construction

If a hog farmer delivers a quantity of hogs Q that fulfills the acceptable quantity standards but lacks the necessary quality, they are deemed to be in default of quality. Pork producers currently have two choices: either agree to receive the subpar batch of hogs or refuse them to impose a penalty on the hog farming households. A two-party game matrix can be generated as a result, as shown in Table 1. The return functions for hog farmers and pork producers are listed from top to bottom.

Table 1. Benefits Matrix for Hog Farmers in Case of Quality Defects.

Revenue		Hog farmers	
		trustworthiness r_1	Default $1-r_1$
Pork producers	Acceptance r_2	p_1Q-C_3 $(p_2-p_1)Q-C_1-C_2$	$p_0Q-C_3-C_4$ $(p_2-p_0)Q-C_1-C_2-C_4$
	Penalty $1-r_2$	none	$p_0Q-C_3-C_4-M$ $(p_2-p_0)Q-C_1-C_2-C_4+M-C_5$

3.1.3. Evolutionary Analysis of Hog Farmers

The anticipated rewards and mean anticipated rewards of farmers selecting the "trustworthy" and "default" strategies are denoted as $E_{\alpha 1}$, $E_{\alpha 2}$, and $\overline{E_\alpha}$, correspondingly, based on the game payoffs outlined in Table 1.

$$E_{\alpha 1} = r_2(p_1Q - C_3) \tag{1}$$

$$E_{\alpha 2} = r_2(p_0Q - C_3 - C_4) + (1-r_2)(p_0Q - C_3 - C_4 - M) \tag{2}$$

$$\overline{E_\alpha} = r_1E_{\alpha 1} + (1-r_1)E_{\alpha 2} \tag{3}$$

The replication dynamics equation for hog farmers is determined by the expected return function.

$$\begin{aligned} F(r_1) &= \frac{dr_1}{dt} = r_1(E_{\alpha 1} - \overline{E_\alpha}) = r_1(1-r_1)(E_{\alpha 1} - E_{\alpha 2}) \\ &= r_1(1-r_1)[r_2(p_1Q - C_3 - M) + C_3 + C_4 + M - p_0Q] \end{aligned} \tag{4}$$

$$\begin{aligned} F'(r_1) &= \frac{d\left[F(r_1)\right]}{dt} \\ &= (1-2r_1)[r_2(p_1Q - C_3 - M) + C_3 + C_4 + M - p_0Q] \end{aligned} \tag{5}$$

$$F'(r_1)\Big|_{r_1=0} = r_2(p_1Q - C_3 - M) + C_3 + C_4 + M - p_0Q \tag{6}$$

$$F'(r_1)\Big|_{r_1=1} = -r_2(p_1Q - C_3 - M) - C_3 - C_4 - M + p_0Q \tag{7}$$

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The stability theorem of repeated dynamic equations and the evolutionary stabilization strategy indicate that an evolutionary stabilization strategy can be established when $F(x)=0,\ F'(x)<0$. When Equation (4) $F(r_1)=0$ is considered, the solution is $r_1=0,\ r_1=1$.

$$r_2^*=\frac{p_0Q-M-C_3-C_4}{p_1Q-C_3-M} \tag{8}$$

Three possibilities are now being analyzed using equations (5) through (8).

(1) If $r_2=r_2^*$ occurs, $F(r_1)\equiv 0$ can be obtained, suggesting that the strategy choice remains constant over time. Any value of r_1 is considered an evolutionary stable strategy, and the pork producer has the option to either accept or penalize.

(2) If $r_2<r_2^*$ occurs, $F'(r_1)\big|_{r_1=0}<0,\ F'(r_1)\big|_{r_1=1}>0$ can be obtained, and $r_1=0$ represents the globally evolutionarily stable approach. When the likelihood of a pork producer accepting is below r_2^*,the hog farmer opts for the "default" method.

(3) When $r_2>r_2^*$, we get $F'(r_1)\big|_{r_1=0}>0,\ F'(r_1)\big|_{r_1=1}<0$. $r_1=1$ is currently the predominant global evolutionary stabilization method. If the likelihood of acceptance by the pork producer exceeds r_2^*, the hog farmer opts for the "trustworthy" option.

This study presents the following based on the analysis provided above:

Proposition 1: When the market price p_0 exceeds the contract price p_1, an increase in the order quantity Q leads to a higher likelihood of default among pork producers. When the market price p_0 is less than the contract price p_1, hog farmers are more likely to honor their word as the order quantity Q increases.

Proposition 2: Increased penalties from pork producers lead to greater compliance among hog farms.

Proposition 3: As the information-seeking cost C_4 increases, pork producers are more likely to be trustworthy.

3.1.4. Evolutionary Study of Pork Producers

The anticipated rewards and mean anticipated rewards for pork producers that opt for the "accept" and "penalize" strategies are denoted as $E_{\beta 1}$, $E_{\beta 2}$, and $\overline{E_\beta}$, respectively, according to the game payoffs outlined in Table 1.

$$E_{\beta 1}=r_1[(p_2-p_1)Q-C_1-C_2]+(1-r_1)[(p_2-p_0)Q-C_1-C_2-C_4] \tag{9}$$

$$E_{\beta 2}=(1-r_1)[(p_2-p_0)Q-C_1-C_2-C_4+M-C_5] \tag{10}$$

$$\overline{E_\beta}=r_2E_{\beta 1}+(1-r_2)E_{\beta 2} \tag{11}$$

The following is the equation for the replication dynamics of pork producers based on the expected return function:

$$\begin{aligned}F(r_2)&=\frac{dr_2}{dt}=r_2(E_{\beta 1}-\overline{E_\beta})=r_2(1-r_2)(E_{\beta 1}-E_{\beta 2})\\&=r_2(1-r_2)[r_1(p_2Q-p_1Q-C_1-C_2-C_5+M)+C_5-M]\end{aligned} \tag{12}$$

ISSN: 2692-7608 DOI: 10.6981/FEM.202405_5(5).0003

$$F'(r_2)=\frac{d\left[F(r_2)\right]}{dt} \tag{13}$$
$$=(1-2r_2)[r_1(p_2Q-p_1Q-C_1-C_2-C_5+M)+C_5-M]$$

$$F'(r_2)\big|_{r_2=0}=r_1(p_2Q-p_1Q-C_1-C_2-C_5+M)+C_5-M \tag{14}$$

$$F'(r_2)\big|_{r_2=1}=-r_1(p_2Q-p_1Q-C_1-C_2-C_5+M)-C_5+M \tag{15}$$

The stability theorem of repeated dynamic equations and the evolutionary stabilization strategy indicate that an evolutionary stabilization strategy can be established when $F(x)=0,\ F'(x)<0$. When Equation (12) $F(r_2)=0$ is satisfied, the result is $r_2=0,\ r_2=1$.

$$r_1^*=\frac{M-C_5}{(p_2-p_1)Q-C_1-C_2-C_5+M} \tag{16}$$

Currently, there are three potential outcomes derived from Equation (13) to Equation (16).

(1) If $r_1=r_1^*$ occurs, $F(r_2)\equiv 0$ can be obtained, suggesting that the strategy choice will remain constant over time. Any value of r_2 is considered an evolutionarily stable strategy, allowing the hog farmer to decide whether to honor his commitment or not.

(2) If $r_1<r_1^*$ occurs, $F'(r_2)\big|_{r_2=0}<0,\ F'(r_2)\big|_{r_2=1}>0$ is obtained, with $r_2=0$ being the globally stable evolutionary strategy. If the likelihood of hog farmers honoring their word is below r_1^*, the pork producer opts for the "punishment" method.

(3) If r_1^*, then $F'(r_2)\big|_{r_2=0}>0,\ F'(r_2)\big|_{r_2=1}<0$. $r_2=1$ is currently the worldwide evolutionary stabilization strategy. The pork producer opts for the "acceptance" method when the likelihood of the hog farmer being trustworthy exceeds r_1^*.

According to the analysis provided, this paper suggests:

Proposition 4: When the pork producer's selling price p_2 exceeds the contract price p_1, the pork producer prefers the acceptance approach more when the order quantity Q is higher.

Proposition 5: The pork producer is more likely to opt for the "acceptance" method when penalized based on the higher cost C_5.

Proposition 6: The hog producer is more likely to choose for the "accept" method if the contract price p_1 is lower.

Proposition 7: (Performance, performance) is the set of best practices for hog farmers and pork producers to work together on ordering. In the event that hog farmers fail to meet quality standards, the set of Nash equilibrium methods for order cooperation between hog farmers and pork producers is (default, penalty).

3.1.5. Solve the Equilibrium Point of the Evolutionary Game Model

By $F(r_1)=dr_1/dt=0$ and $F(r_2)=dr_2/dt=0$, it can be obtained that the equilibrium point of the evolutionary game model is $E_1(1,1)\ E_2(0,1)$, $E_3(0,0)$, $E_4(r_1^*,r_2^*)$. In an asymmetric game, the mixed strategy equilibrium must not be an evolutionary stable equilibrium, so only the asymptotic stability of the pure strategy equilibrium needs to be discussed.

The Jacobian matrix of the two-party evolutionary game system is:

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$$J=\begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix}=\begin{bmatrix} \frac{\partial(F(r_1))}{\partial r_1} & \frac{\partial(F(r_1))}{\partial r_2} \\ \frac{\partial(F(r_2))}{\partial r_1} & \frac{\partial(F(r_2))}{\partial r_2} \end{bmatrix}$$

Using Lyapunov's first method, all the eigenvalues of the Jacobian matrix have negative real parts, and the equilibrium point is an asymptotic stable point; If at least one of the eigenvalues of the Jacobian matrix has a positive real part, then the equilibrium point is an unstable point; The Jacobian matrix has a negative real part except for the eigenvalue with zero real part, then the equilibrium point is in a critical state, and the stability cannot be determined by the eigenvalue sign.

When the equilibrium point is $E_1(1,1)$, the eigenvalues λ_1 and λ_2 are $(p_0-p_1)Q-C_4$ and $(p_1-p_2)Q+C_1+C_2$, and the real part symbol is $(\times,\times)$. So $E_1(1,1)$ is a point of instability. Only if the conditions $(p_0-p_1)Q-C_4<0$ and $(p_1-p_2)Q+C_1+C_2<0$ are met, $E_1(1,1)$ will become ESS(Evolutionarily Stable Strategy). When the equilibrium point is $E_2(0,1)$, the eigenvalues λ_1 and λ_2 are $(p_1-p_0)Q+C_4$ and $M-C_5$, and the real part symbol is $(\times,+)$. So $E_2(0,1)$ is a point of instability. When the equilibrium point is $E_3(0,0)$, the eigenvalues λ_1 and λ_2 are $C_3+C_4+M-P_0Q$ and C_5-M, and the real part symbol is $(-,-)$ .So $E_3(0,0)$ is ESS.

3.2. Simulation Analysis

3.2.1. Simulation Analysis in Array 1 $p_0<p_1$

In order to verify the effectiveness of the evolutionary stability analysis, the model was numerically simulated with numerical values according to the actual situation. In this article, the default value of array 1,namely when $p_0<p_1$, is set as $Q=100$, $p_0=20$, $p_1=25$, $p_2=35$, $C_1=500$, $C_2=100$, $C_3=1000$, $C_4=100$, $C_5=100$, $M=200$. On the basis of array 1, the influence of Q, C_1 on the process and outcome of the evolutionary game is analyzed.

Firstly, in order to analyze the influence of the change of order volume on the process and result of the evolutionary game, we take Q as some numbers, namely $Q=50,100,150$. The simulation results for replicating the evolution of the dynamic equation 50 times over time are shown in Figure 1. As can be seen from Figure 1, when $p_0<p_1$ is established, as Q increases, pig farmers tend to keep their promises faster and faster, and pork producers will also choose the "accept" strategy, and finally reach the equilibrium point ESS, namely $(1,1)$.

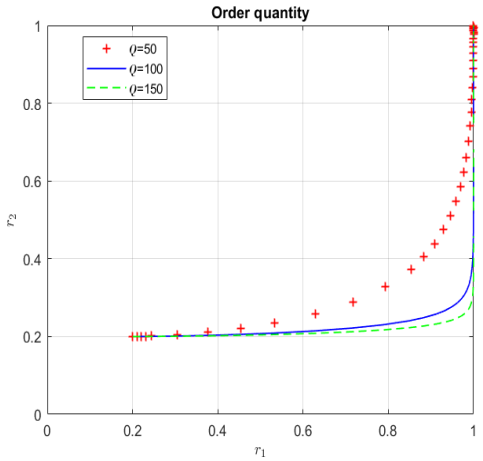

Figure 1. The impact of order quantity

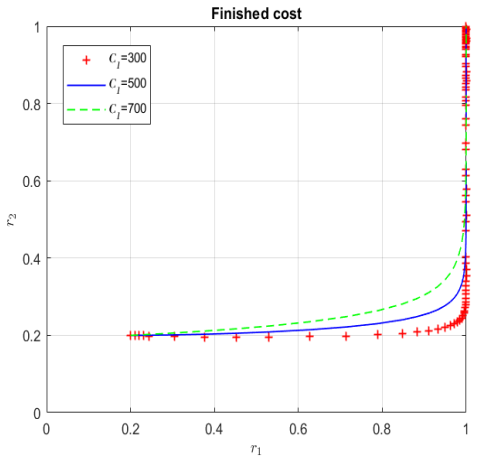

Figure 2. The impact of finished cost

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Secondly, in order to analyze the influence of the change of finished cost on the process and result of the evolutionary game, we take C_1 as some numbers, namely $C_1 = 300, 500, 700$. The simulation results for replicating the evolution of the dynamic equation 50 times over time are shown in Figure 2. As can be seen from Figure 2, when $p_0 < p_1$ is established, as C_1 decreases, Pork producers tend to accept it more and more quickly, and hog farmers will also opt for the "keep the word" strategy, and finally reach the equilibrium point ESS, namely $(1,1)$.

Finally, observing the results of replicating the dynamic equation 50 times over time under different initial states, as shown in Figure 3, it is found that no matter what the initial state is, it will eventually be the stable point of evolution to $(1,1)$, and the larger the initial probability, the faster the evolution speed.

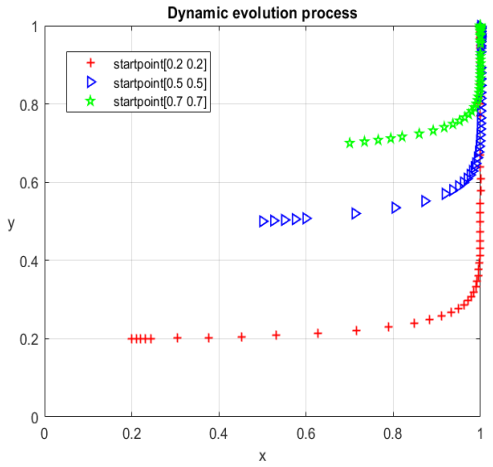

Figure 3. The result of the evolution of the initial state differently

3.2.2. Simulation Analysis in Array 2 $p_0 > p_1$

In order to verify the effectiveness of the evolutionary stability analysis, the model was numerically simulated with numerical values according to the actual situation. In this article, the default value of array 1,namely when $p_0 > p_1$, is set as $Q = 100$, $p_0 = 25$, $p_1 = 15$, $p_2 = 35$, $C_1 = 500$, $C_2 = 100$, $C_3 = 1000$, $C_4 = 100$, $C_5 = 100$, $M = 200$. On the basis of array 2, the influence of Q, C_1 on the process and outcome of the evolutionary game is analyzed.

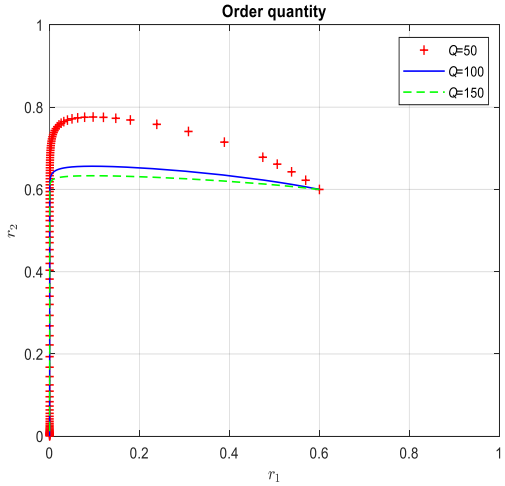

Figure 4. The impact of order quantity

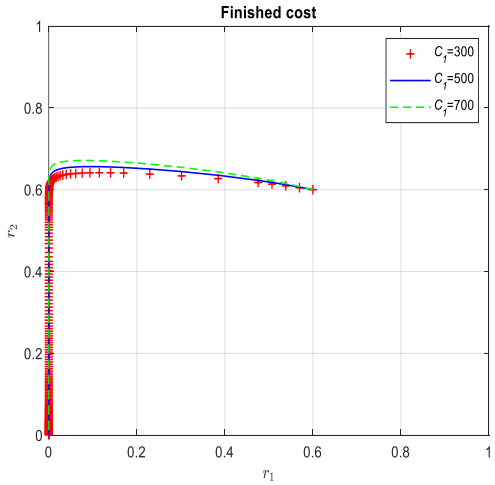

Figure 5. The impact of finished cost

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Firstly, in order to analyze the influence of the change of order volume on the process and result of the evolutionary game, we take Q as some numbers, namely $Q=50,100,150$. The simulation results for replicating the evolution of the dynamic equation 50 times over time are shown in Figure 4. As can be seen from Figure 4, when $p_0 > p_1$ is established, as Q increases, pig farmers tend to keep their promises faster and faster, and pork producers will also choose the "accept" strategy, and finally reach the equilibrium point ESS, namely $(0,0)$.

Finally, observing the results of replicating the dynamic equation 50 times over time under different initial states, as shown in Figure 6, it is found that no matter what the initial state is, it will eventually be the stable point of evolution to $(0,0)$, and the lower the initial probability, the faster the evolution speed.

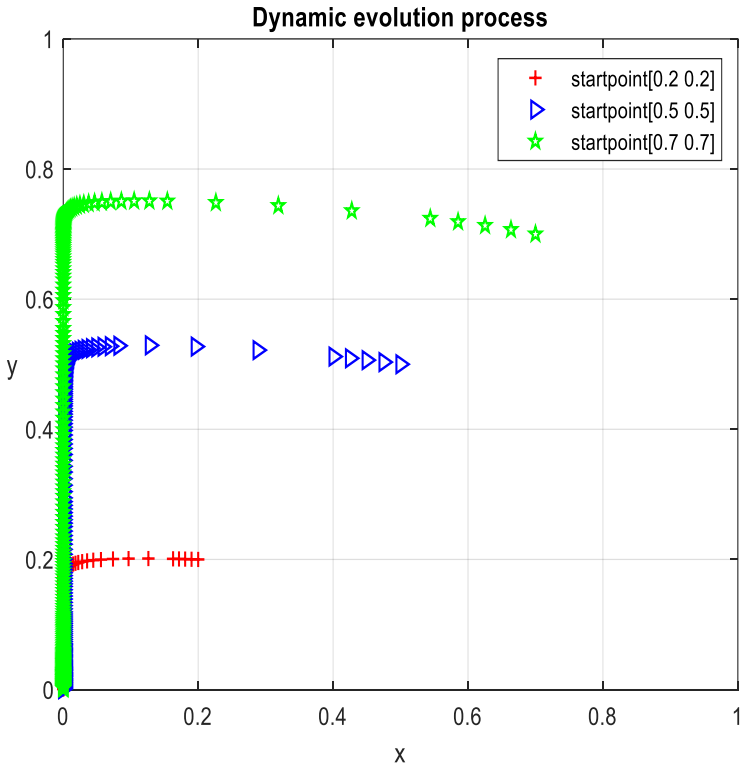

Figure 6. The result of the evolution of the initial state differently

3.3. Three-party Game under Bank Loan Conditions

3.3.1. Model Assumptions

Now, consider a scenario in which hog farmers are limited by financial restraints. The pork producer reserves a specific number of hogs from the hog farmer at the start of the period. The hog farmer then uses this booking order as collateral to secure a loan from a financial institution. Once the hogs are set free, the hog farmer sends the designated number of hogs to the pork producer and pays interest to the financial institution, which then repays the loan to the financial institution.

3.3.2. Configuring Parameters

To build the game model and assess the stability of each party's strategy and equilibrium point, as well as the interplay between the influence of each factor, we introduce the pertinent parameters (included in Table 2) and make the following assumptions.

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Table 2. Description of the Three Parameters in the Order Finance Model Game.

Item	Symbol
Hog farmers' accounts receivable	R
Hog supply chain accounts receivable pledge rate	α
Loanable amount	αR
When hog farmers are not trustworthy, pork producers do not fully enjoy the benefits of account extensions due to bank debt collection, this parameter is the percentage parameter of reinvested earnings of pork producers.	β
Pork producer's return on investment when hog farmers are trustworthy	β_1
Hog farmers' return on investment	β_2
Bank loan interest rate	β_0
Bank deposit rate	β_3
Bank monitoring costs	C_0
Positive incentives of bank loans to hog farmers in government appraisals	G_1
Costs of searching for alternative suppliers when pork producers fail to repay	S_3
Impairment of goodwill of the pork producer when it defaults on its loans	C_6
Creditworthiness value added to hog farmers for keeping their word	A
Increased future financing costs of a defaulting hog farmer	S_2
Additional utility that the bank gains from being glad it did not lend when the pork producer does not repay and the hog farmer defaults	U

3.3.3. Model Construction

The revenue matrix for the three parties in the hog supply chain order financing model may be derived based on the definitions of each variable provided above, as displayed in Table 3. The revenue functions of hog farmers, pork producers, and banks are displayed in descending order.

Table 3. Matrix of Benefits for Financing Orders in the Hog Supply Chain.

Revenue		Hog farmers	
		trustworthiness r_1	Default $1-r_1$
Pork producers	repayment r_2	$\alpha R(\beta_2-\beta_0)+A$ $R\beta_1+C_6$ $\alpha R(\beta_0-\beta_3)-C_0+G_1$	$\alpha R(1+\beta_2)-S_2-A$ $\beta R\beta_1+R(1-\alpha)+C_6$ $-\alpha R\beta_3-C_0+G_1$
	non-repayment $1-r_2$	$\alpha R(\beta_2-\beta_0)-R+A$ $R(1+\beta_1)-S_3-C_6$ $\alpha R(\beta_0-\beta_3)-C_0+G_1$	$\alpha R(1+\beta_2)-R-S_2-A$ $R(1+\beta_1)-S_3-C_6$ $-\alpha R(1+\beta_3)-C_0+G_1+U$

Based on the above analysis, this paper proposes:

Proposition 8: The higher the pledge rate α is, the higher the probability of default of hog farmers.

Proposition 9: The larger the positive incentive G_1 of bank loans to hog farmers in the government assessment, the larger the probability of bank loans.

Proposition 10: The larger the future financing cost S_2 increased by default of the hog farmer, the larger the probability that the hog farmer is trustworthy; the larger the cost S_3 of searching for other suppliers when the pork producer does not repay, the larger the probability that the pork producer repays.

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Proposition 11: The larger the credibility value-added A that a hog farmer can get by keeping its word, the larger the probability that the hog farmer will keep its word; the larger the goodwill impairment C_6 that the pork producer will get when it defaults, the larger the probability that the pork producer will pay back the loan.

Proposition 12: The optimal set of strategies for hog farmers, pork producers, and banks under the hog supply chain order financing model in the presence of hog farmers' financing constraints is (trustworthiness, repayment, and loan).

4. Conclusion and Countermeasure Recommendations

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4.1. Conclusion of the Study

As a result of the recent effects of the COVID-19 pandemic, numerous hog farmers are in the passive penning state, with small and medium-sized enterprises struggling to repay their loans. Banks have increased their scrutiny on loan risks, adding pressure to the survival of hog farmers. This paper examines the way banks' order financing supply chain finance business affects hog farmers and pork producers. It analyzes a two-party game between hog farmers and pork producers without capital constraints under order financing, and a three-party game involving hog farmers, pork producers, and banks with capital constraints. The study builds a three-party game model to investigate the influence of banks' order financing supply chain finance business on hog farmers and pork producers. A tripartite game model is created including hog farmers, pork producers, and banks. The study's primary findings are as follows:

Firstly, the order finance approach for hog farming has partially eased the financing challenges faced by hog farming organizations. Hog supply chain order financing differs from standard bank loans by not necessitating collateral, instead using the order contract as the loan's foundation. Enhancing financing efficiency and credit visibility for hog farming entities, specialized financial support is provided to establish strong business relationships. The increasing capital needs and financing challenges faced by hog farming entities have led to a greater inclination towards utilizing order financing, thereby easing the financing obstacles encountered by these entities to some extent.

Secondly, the order financing method in hog supply chain finance can enhance the borrowing capacity of hog farming businesses. Due to the impact of the COVID-19 pandemic, banks have tightened loan risk management. Order financing allows businesses to increase loan amounts by pledging orders. This method, compared to traditional commercial loans, enables banks to utilize funds from pork producers and hog farmers to expand financing for hog farmers, addressing the issue of financial support limitations due to their own circumstances. It can successfully resolve the dilemma faced by hog farmers who are unable to secure financial assistance from banks for various reasons.

4.2. Recommendations for Countermeasures

Order finance can efficiently address the financing challenges faced by the primary entity in the hog supply chain. Based on the conclusions mentioned above, the following policy proposals are proposed.

Firstly, reduce the finance need for hog producers and promote their involvement in hog supply chain financing. The government should incentivize hog farmers to engage in agricultural supply chain financing, expedite the enhancement of the registration system for hog farmers to facilitate the implementation of large-scale management in China's hog farming sector, define the legal standing of hog farmers, and establish a framework to support the adoption of the hog farming order financingmodel. Pork companies should take the initiative in offering credit

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guarantees to hog farmers facing financial limitations. Banks can offer lower lending rates to hog farmers in the agricultural supply chain by raising the pledge rate.

Secondly, raise the standard loss for hog farmers and pork producers. Once a hog farmer or pork producer fails to meet their obligations, their reputation will suffer, leading to higher costs associated with finding a new manufacturer or supplier. Avoiding collaboration with a hog farmer or pork producer with a history of several defaults can raise the risk of default.

Thirdly, encourage the development of an order financing platform for the hog supply chain. Promoting the funding model for hog farming based on specific local circumstances. To establish cooperatives tailored to the decentralized breeding traits of hog farmers and unite hog farmers with similar traits to minimize expenses. Government departments standardize the business procedure of hog farming order finance to ensure its smooth application.

China's hog farmers are still mainly small-scale farming. To enhance the efficiency of the "company + farmers" scale farming order finance model in China, it is crucial to incorporate retail homes into the service platform.

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