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Study on the evolutionary game theory of the psychological choice for online purchase of fresh produce under replicator dynamics formula

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Abstract

First, the research results of using game theory in the field of agricultural product quality and safety at home and abroad are reviewed and summarised, and the shortcomings of classical games theory are pointed out in most studies. The evolutionary game theory is used to explore the strategic space and evolution trend of agricultural product supply chain. Through the construction and analysis of a game model for the evolution of agricultural product quality and safety, the evolutionary phase diagram of the agricultural product supply chain market and evolutionary stability characteristics at each equilibrium point are obtained, which well reveal the evolutionary process of the agricultural product supply chain and effectively formulate related policies. Scientific basis for ensuring the quality and safety of agricultural products is provided.

Keywords: agricultural product quality and safety, evolutionary game, agricultural product supply chain, evolutionary phase diagram, game theory

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1 Introduction

In recent years, the quality and safety of agricultural products has become an issue of increasing concern. Researchers have also tried to use various advanced management technologies to explore theories and methods to ensure the quality and safety of agricultural products. Many scholars have focussed on applying game theory to guarantee research on agricultural product quality and safety. The earliest related research originated from Mazé and other analysis of the relationship between agricultural product quality and safety and agricultural product governance structure based on the characteristics of European agricultural product supply chains and for the first time proposed the rational use of game theory to comprehensively improve the quality of agricultural products. The role and mechanism of the leadership of the food industry in the supply of food explain the quality guidance of the oligopoly game in the food industry; Vetter and others have used game theory to verify that food has a

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trust product that consumers cannot identify with quality and safety. There is a certain moral hazard problem in the process of vertical integration of the food supply chain; Weaver et al. and Hudson conducted a detailed theoretical and empirical analysis of the contract cooperation game in the food supply chain.

One of the most prominent contributions in China has studied the strategic choices among actors in the food supply chain under one game, repeated games and dynamic games with incomplete information. Research shows that in one-off market transactions that are common in the market, food supply chain actors will choose uncooperative opportunistic behaviours for the motivation of maximising their own interests. However, in the indefinite repeated game, the actors in the food chain will reach a cooperative equilibrium, thereby achieving the quality and safety of food supply. In addition, the literature addresses the abuse of food quality and safety labels (such as pollution free, green, organic food labels, etc.), uses food producers and consumers as game players, establishes game models and analyses the three Bayesian equilibriums. Under these conditions, the government's strategy to control food quality and safety under asymmetric conditions was derived. The literature aims at a series of problems such as sales difficulties, malicious competition among enterprises and difficulties in developing international markets in China's agricultural product processing enterprises. Using three classic game theory models, a reasonable explanation of the current economic behaviours of agricultural product processing enterprises in China is proposed, and corresponding responses are proposed. Policy recommendations to ensure the quality and safety of agricultural products are proposed. The research shows that there is a game relationship between the government authorities and food companies in the protection and supervision of food quality and safety. By analysing its static game model and dynamic game model, it is believed that to ensure food quality and safety, the government and its supervisors departments, food companies, etc. must retain a game relationship among themselves.

The replication dynamic equation proposed by Taylor and Jonker [1] is the most widely used dynamic equation of selection mechanisms in evolutionary game theory. One of the main problems in studying complex non-linear dynamical systems and chaos is the judgement of chaos. At present, one of the statistical eigenvalues showing significant significance in characterising chaotic motion is the Lyapunov exponent [2], which is a measure of the average convergence or average divergence of similar orbits in phase space. The more mature algorithms for calculating the Lyapunov exponent include the Jacobian method, the p-norm method and the small data volume method proposed by Rosenstein and Kantz [3]. Compared with other methods, the small data volume algorithm is more robust to phase space embedding dimensions, delay time and observation noise. While calculating the Lyapunov exponent, it can also obtain the important feature quantities of other chaotic systems such as the correlation dimension. From the theoretical value of research, the combination of dynamic system games and chaos theory is a cutting-edge subject in interdisciplinary research. This research not only promotes and develops the basic theories of dynamics and chaos but also broadens the generalisation. The stone-scissor-cloth game is considered as a dynamic system, and the chaotic theory is used to study whether the dynamic system evolves over time and chaos will occur over time. The dynamics is improved by applying a small amount of the data method. The system's Lyapunov exponent is calculated to conclude that, under replication dynamics, chaotic behaviour occurs when the parameter 'a' is <0 in the generalised stone-scissor-cloth game system [4].

However, the above relevant summary documents rely on classic game theory for research and analysis. Nash equilibrium is the most important concept in classic game theory. The premise of achieving Nash equilibrium is the 'complete rationality' assumption, which requires game participants to have 'infinite regression reasoning'. In fact, in real economic life, we cannot assume that participants can always calmly make completely rational decisions, but we must consider that the decisions of game participants may be disturbed by many temporary irrational factors. Temporary interference may undermine other participants' rational expectations of the participants, suggesting that the equilibrium may not be achieved. Then, in this case, the 'evolutionary game theory' based on the adaptability of strategy in generational changes seems particularly important. In repeated games, individuals with only limited information continuously and marginally respond to them based on their vested interests. The strategy is adjusted to pursue the improvement of their own interests and finally reaches

a dynamic equilibrium. In this state of equilibrium, any individual is no longer willing to unilaterally change its strategy. The strategy in this state of equilibrium is called an evolutionary stable strategy and so said such a game process is an evolutionary game. This article is an attempt to use evolutionary game theory to analyse the strategic space and evolution trend of agricultural product supply chains in detail so as to derive the evolutionary phase diagram of the agricultural product supply chain market and the evolutionary stability characteristics at each equilibrium point in order to reveal the evolution of agricultural product supply chains. A process to provide a more objective scientific basis for the effective formulation of relevant policies to ensure the quality and safety of agricultural products is proposed.

2 Game model description of agricultural product quality and safety evolution

The improved maximum Lyapunov exponent algorithm is as follows: Based on the small data volume method [5] commonly used to calculate the maximum Lyapunov exponent, the auto-correlation method and GP method are applied to the small data volume method, and the minimum Lyapunov exponent is calculated. The improved algorithm of data volume method [6, 7] and its calculation steps are as follows:

1. fast Fourier transform of time series $x(i), i = 1, 2, \dots, N$ to calculate the average period p ;
2. using the autocorrelation method and G-P method, respectively, to obtain delay time τ and the embedding dimension m ;
3. reconstruct the phase space based on the time delay τ and the embedding dimension $m: x(j), j = 1, 2, \dots, M$;
4. find the best neighbouring point x_j of each point x_i in the phase space and limit the short separation, which is as follows:

$$dt(0) = \min_j \|Xi - Xj\|, |i - j| > p, j = 1, 2, \dots, M, i \neq j \quad (1)$$

5. For each point $x(t)$ in the phase space, calculate the distance $d_t(i)$ after the i discrete time step of the neighbourhood point pair. The calculation formula is given as follows:

$$d_t(i) = \|X(t+i) - X(\hat{t}+i)\|, i = 1, 2, \dots, \min(M-t, M-\hat{t}) \quad (2)$$

6. $y(i)$, find the mean of $\ln d_t(i)$ for all t for each i , $y(i) = \frac{1}{q\Delta t} \sum_{t=1}^q \ln d_t(i)$, that is, $y(i) = \frac{1}{q\Delta t} \sum_{t=1}^q \ln d_t(i)$, where q is the number of non-zero $d_t(i)$;
7. Make a curve $y(i)$ and find the linear relationship in the curve and use the least square method to perform a straight line fitting [8].

First determine the utility function of the impact of agricultural products on consumers. There are various effects of agricultural products on consumers, such as satiety, taste enjoyment, nutrition, health care, etc. The product dual value theory proposed in this section considers that agricultural products have dual value, and consumers can obtain basic information from agricultural product consumption. For value functions, such as satiety, taste enjoyment, etc., and transcend value functions, such as quality and safety, the utility of the binary value is binary utility. When the demand is determined, the dual utility U of the unit agricultural product is equal to the following equation:

$$U = w_1 u(p) + w_2 v(p, s) \quad (3)$$

$$\frac{\partial u}{\partial p} < 0, \frac{\partial v}{\partial p} < 0, \frac{\partial v}{\partial s} > 0 \quad (4)$$

w_1 and w_2 represent the weight of the two attributes in the minds of consumers. The values are non-negative and satisfy the following equation:

$$w_1 + w_2 = 1 \quad (5)$$

Due to the characteristics of trusted products in agricultural products, consumers cannot modify the probability of quality and safety characteristics of agricultural products after consumption, but the probability of safe and non-safe agricultural products can be obtained through some channels before consumption, such as through a third party (such as the government), investigation and announcement, as well as advertising, news, etc.

Suppose that several consumers of agricultural products choose x with safety labels (such as pollution-free agricultural product labels) and those who choose general agricultural products without safety labels account for $1 - x$ (these two probabilities can also be It is understood as the possibility of a consumer choosing safe agricultural products. For several consumers, the probability represents their expected value. In the absence of constraints, due to the asymmetric information, the supplier of agricultural products may charge inferiorly and label in violation of regulations to obtain excess profits. Therefore, consumers who choose safe agricultural products may not get the safety effect. In order to facilitate the analysis, it is assumed that the basic functional utility of the same agricultural product is constant. The consumers who purchase a unit of a certain type of safe agricultural product, general agricultural product and counterfeit and ‘safe agricultural product’, respectively, obtain the utility U_1 , U_2 and U'_2 , as follows:

$$U_1 = w_1 u_1 + w_2 v_1 \quad (6)$$

$$U_2 = w_1 u_2 + w_2 v_2 \quad (7)$$

$$U'_2 = w_1 u'_2 + w_2 v_2 \quad (8)$$

Among them, $U_1 > U_2 > U'_2$.

Then, the utility obtained by a consumer who purchases a unit of the same type of agricultural product with a safety label is represented by $U_1(s)$:

$$U_1(s) = \begin{cases} w_1 u_1 + w_2 v_1 & s = 1 \\ w_1 u'_2 + w_2 v_2 & s = 0 \end{cases} \quad (9)$$

Assume that s is independent and identically distributed and obeys a two-point distribution. Among them, $s = 1$ indicates that consumers have purchased genuine and safe agricultural products, and $s = 0$ indicates that consumers have purchased safe agricultural products counterfeited by general agricultural products, and their probability changes with the evolution process.

After determining the utility function of the impact of agricultural products on consumers, the next step is to analyse the possible benefits caused by different strategic choices between the supplier and the consumer. Due to the characteristics of agricultural product trust products, even with government supervision, it is impossible to constantly monitor agricultural product enterprises due to input-output considerations. Only regular inspections can be used to punish, and the inspection results can be made public. It is assumed that if this punishment is insignificant (the enterprise can even avoid punishment by some means), then the government’s adjustment of the agricultural product market will be more reflected in the regular survey of consumers’ authoritative survey data. This model does not consider the risk cost of agricultural products produced by the government’s punishment for counterfeiting and establishes a general evolutionary game model. In the subsequent analysis of the model, it further considers and analyses the impact of government supervision on the evolutionary game model. According to the above description, the benefits of various scenarios of supply and consumer choices are summarised in Table 1.

Table 1 Possible benefits of different strategic choices between suppliers and consumers

Yield function of agricultural product supplier and consumer in period t			Consumer (B)	
			Select with probability $1 - xt$ General agricultural products (B1)	Select by probability xt General agricultural products (B2)
Agricultural Product Supplier (A)	Provide authentic safe agricultural products with probability yt (A1)		-C1, 0	PH -C1, $U_1(s)$
	With probability $1 - yt$	Label safe agricultural products with probability μ , and Selling at Safe Farm Prices (A21)	-C2, 0	PH -C2, $U_1(s)$
	Provide general Agricultural products (A2)		PL-C2, U_2	-C2, 0

3 Analysis of the stability of agricultural product markets and their evolutionary phase diagrams

The following is a stability analysis of the equilibrium point obtained from the above analysis, and then, the evolution phase diagram of the agricultural product market is drawn.

1. Consider the equilibrium point $(0,0)$, $\det J = \Delta_2 \Delta_4$, $tr J = -\Delta_4 - \Delta_2$. According to the stability conditions of the discrete dynamic system, if and only if $\begin{cases} \det J > 0 \\ tr J < 0 \end{cases}$, the equilibrium point is ESS stable. Because $\Delta_4 > 0$, only Δ_2 needs to be verified. When $\Delta_2 > 0$ is $U_2 - \mu U_2 - \mu U_2' > 0$, it can be seen that as long as $\mu < 1 - \frac{U_2'}{U_2 + U_2'}$, $(0,0)$, is ESS stable. When $\mu > 1 - \frac{U_2'}{U_2 + U_2'}$, $(0,0)$ is the saddle point.
2. Consider the balance $(0,1)$, $\det J = (\Delta_1 - \Delta_2) \Delta_4$, $tr J = \Delta_1 - \Delta_2 + \Delta_4$, because $\Delta_1 - \Delta_2 = U_1 > 0$, $\Delta_4 > 0$, and so $\det J > 0$, $tr J > 0$; therefore, $(0,1)$ is the point of instability. When $\mu > 1 - \frac{C_1 - C_2}{P_H} > 1 - \frac{U_2'}{U_2 + U_2'}$, the system has four equilibrium points: $(0,0)$, $(0,1)$, $(1,0)$, $(1,1)$. Among them, $(1,0)$ is ESS stable, $(0,0)$ and $(1,1)$ are saddle points and $(0,1)$ is the unstable point. The evolution phase diagram is shown in Figure 1.

Fig. 1 Evolutionary phase diagram 1

When the rate of general agricultural products' excessive labelling turning into 'safe agricultural products' is too high, the interests of true safe agricultural product manufacturers is also high. After being violated, they turned to produce general agricultural products and faked them as safe agricultural products. Eventually, all

agricultural product manufacturers produced general agricultural products and labelled them ‘safe agricultural products’. For consumers, although $U_2 > U'_2$, consumers have higher utility in purchasing general agricultural products than in counterfeit and inferior ‘safe agricultural products’, but because $\Delta_2 < 0$ that is, $(1 - \mu)U_2 < \mu U'_2$, consumers know that they are likely to be deceived, but it is possible to counteract counterfeiting by reducing the consumption of agricultural products. At this time, consumers cannot guide the market direction through their own utility preferences. Instead, the safety of agricultural products is completely determined by the producers of agricultural products. The final evolution result is that agricultural product manufacturers only produce counterfeit and inferior ‘safe agricultural products’, which consumers accept as counterfeit and ‘safe agricultural products’.

When $1 - \frac{U'_2}{U_2 + U'_2} < \mu < 1 - \frac{C_1 - C_2}{P_H}$, the system has five equilibrium points: (0,0), (0,1), (1,0), (1,1), and $(\frac{\Delta_2}{\Delta_1}, \frac{\Delta_3}{\Delta_4})$, where (1,1) is ESS stable and (0,0), (1,0) and $(\frac{\Delta_2}{\Delta_1}, \frac{\Delta_3}{\Delta_4})$ are saddle points and (0,1) is unstable. The evolutionary phase diagram is shown in Figure 2.

Fig. 2 Evolutionary phase diagram 2

When $\mu < 1 - \frac{U'_2}{U_2 + U'_2} < 1 - \frac{C_1 - C_2}{P_H}$, the system has five equilibrium points: (0, 0), (0, 1), (1, 0), (1, 1) and $(\frac{\Delta_2}{\Delta_1}, \frac{\Delta_3}{\Delta_4})$, where (0, 0) and (1, 1) ESS are stabled, $(\frac{\Delta_2}{\Delta_1}, \frac{\Delta_3}{\Delta_4})$ is the saddle point and (1, 0) and (0, 1) are the unstable points. The evolutionary phase diagram is shown in Figure 3.

Fig. 3 Evolutionary phase diagram 3

When μ is smaller than both, the agricultural product market considers the (0, 1) – (1, 0) dividing line. When the initial state of the agricultural product market is in the upper half plane, the final evolution result is (1, 1), that is, the agricultural product manufacturer chooses produce genuine and safe agricultural products (labelled), and consumers choose agricultural products with security labels; the final result of evolution when in the lower half of the plane is (0, 0), that is, the agricultural product manufacturer chooses to produce general agricultural products (not according to the full label), and consumers choose general agricultural products without labels.

When $1 - \frac{C_1 - C_2}{P_H} < 1 - \frac{U'_2}{U_2 + U'_2}$ is $P_H < \frac{U_2 + U'_2}{U'_2} (C_1 - C_2)$, the system equilibrium point, the evolutionary stability of the equilibrium point and the system evolution phase diagram of the agricultural product market in (1) and

(3) are the same as those of the previous one. The only difference is the evolutionary stability condition. Only (2) the stability points are different; so, there are three cases:

First, when $\mu > 1 - \frac{U'_2}{U_2+U'_2} > 1 - \frac{C_1-C_2}{P_H}$, the system has four equilibrium points: (0, 0), (0, 1), (1, 0) and (1, 1) where (1, 0) is ESS stable, (0, 0) (1, 1) is the saddle point and (0, 1) is the unstable point. The evolutionary phase diagram is shown in Figure 4, and its economic meaning is the same as (1). Second, when $1 - \frac{C_1-C_2}{P_H} < \mu < 1 - \frac{U'_2}{U_2+U'_2}$, the system has five equilibrium points: (0,0), (0, 1), (1, 0), (1, 1) and $(\frac{\Delta_2}{\Delta_1}, \frac{\Delta_3}{\Delta_4})$, where (0, 0) is ESS stable, (1, 1), (1, 0) and $(\frac{\Delta_2}{\Delta_1}, \frac{\Delta_3}{\Delta_4})$ are saddle points and (0, 1) is the unstable point, and the evolution phase diagram is shown in Figure 4; combining (2) shows that when the size of μ is between the two, the profit is damaged when producing safe agricultural products at $1 - \frac{C_1-C_2}{P_H} < 1 - \frac{U'_2}{U_2+U'_2}$, and the production of fake and inferior agricultural products is gradually unprofitable because of the small demand. Consumers tend to buy general agricultural products; so, the evolution result is F (0, 0); $1 - \frac{C_1-C_2}{P_H} > 1 - \frac{U'_2}{U_2+U'_2}$ The situation is exactly the opposite, and its evolution result is (1, 1). Only in this case is the size between $\frac{C_1-C_2}{P_H}$ and $\frac{U'_2}{U_2+U'_2}$ decisive. Third, when $\mu < 1 - \frac{C_1-C_2}{P_H} < 1 - \frac{U'_2}{U_2+U'_2}$, the system has five equilibrium points: (0, 0), (0, 1), (1, 0), (1, 1) and $(\frac{\Delta_2}{\Delta_1}, \frac{\Delta_3}{\Delta_4})$, where (0, 0) and (1, 1) are stable, $(\frac{\Delta_2}{\Delta_1}, \frac{\Delta_3}{\Delta_4})$ is the saddle point and (1, 0) and (0, 1) are unstable points. The evolutionary phase diagram is shown in Figure 3, and its economic meaning is the same.

Fig. 4 Evolutionary phase diagram 4

4 Kinetic model

Let us consider a well-known two-player game in evolutionary game theory under replication dynamics [9]: the generalised stone-scissor-cloth game, whose payment is represented by the matrix $A = \begin{bmatrix} 1 & 2+a & 0 \\ 0 & 1 & 2+a \\ 2+a & 0 & 1 \end{bmatrix}$: (where a is the real parameter) by replication The kinetic equation [1] can be obtained as its replication kinetic equation is as follows:

$$\begin{cases} \dot{x} = [x + (2+a)y - a(xy + yz + xz) - 1]x \\ \dot{y} = [y + (2+a)z - a(xy + yz + xz) - 1]y \\ \dot{z} = [z + (2+a)x - a(xy + yz + xz) - 1]z \end{cases} \quad (10)$$

When the parameter is set $a = 1$, the initial values are as follows: $x = 0.5$; $y = 0.3$; $z = 0.2$; the limit point currently is $x = 0.33314$; $y = 0.3324$ and $z = 0.3362$. It can be seen from the figure that the dynamic solution converges to the Nash equilibrium point of the game [10].

5 Chaos in the stone-scissor-cloth game under replication dynamics

1. When the initial value of $a = -0.5$ is $x = 0.6$, $y = 0.3$ and $z = 0.1$, $dt = 0.005$ the graph is shown in Figure 5. The limit points currently are $x = 0.8851$, $y = 0.1142$ and $z = 5.0267e-004$. That is, its strategy will be biased towards a purely strategic solution. Through the improved small data method, when $a = -0.5$, take the delay time $\tau = 1$ and the embedding dimension $m = 1$, the average period $P = 3$ and the data point $N = 1629$ to get the Lyapunov index $\lambda = 0.8474$ so as to judge. At this time, the game will appear chaotic with the evolution of time [11].

Fig. 5 Orbital solution when parameter $a = 1$

Fig. 6 Parameter $a = -0.5$ o'clock orbit map

2. When $a = 0$, the initial value is as follows: $x = 0.35$, $y = 0.35$ and $z = 0.3$; the graph is shown in Figure 7. When taking 6,000 points, its trajectory fluctuates cyclically at points $(x = 0.3333, y = 0.3634, z = 0.3319)$.
3. When $a = 0$, the initial value is as follows: $x = 0.35$, $y = 0.35$ and $z = 0.3$; the graph is shown in Figure 8. When taking 10,000 points, the convergence to the points is $x = 5.1406e-007$, $y = 4.4578e-007$ and $z = 5.2891e-007$.

From (2) to (3), when the parameter $a = 0$, the game fluctuates at the equilibrium point in the beginning time period, but its solution trajectory will jump out of the Nash equilibrium point over time. Cyclic waves tend to be unstable. Therefore, we can get inspiration from this phenomenon. When engaging in economic decision-making like this, we must be more careful not to simply use the short-term static Nash equilibrium point as the long-term prediction result of the game.

Fig. 7 Orbital diagram of parameter = 0 and evolution time of 6000-unit time points

Fig. 8 Orbital diagram of parameter $a = 0$ and evolution time of 10000-unit time points

6 Conclusion of game model for evolution of agricultural product quality and safety

By establishing a game model for the evolution of agricultural product quality and safety, the evolution trend of the agricultural product market, the evolutionary stability characteristics at each equilibrium point and the evolution phase diagram of the agricultural product market have been scientifically described. The following conclusions are drawn:

1. In this model, there is no comparability between the consumer's utility payment and the agricultural product supplier's benefit payment, but it does not affect the conclusion; the size between $\frac{P_H}{C_1 - C_2}$ and $\frac{U_2 + U'_2}{U'_2}$ affects the agricultural product by affecting the value range of μ , that is, the evolutionary stability of the market;
2. The evolution stability of the agricultural product market depends on the size or range of μ . In the first and third cases, the size relationship between $\frac{P_H}{C_1 - C_2}$ and $\frac{U_2 + U'_2}{U'_2}$ only affects the evolutionary stability range and does not affect the final evolutionary stable phase diagram. In the second case, the size relationship between $\frac{P_H}{C_1 - C_2}$ and $\frac{U_2 + U'_2}{U'_2}$ determines whether the security situation of the agricultural product market is going to be better or worse.
3. Because consumers are in a weak position of information, in the first and second cases, that is, when μ is relatively large and there are many counterfeits, the evolution trend of the agricultural product market is dominated by the agricultural product producer, and the agricultural product producer is based on its own. To determine whether to produce safe agricultural products and whether to label in violation of regulations, in the third case, that is, when μ is relatively small, the initial state of (x_t, y_t) determines the final evolution trend of the agricultural product market.

4. In addition, consider another situation: the government punishes counterfeit and inferior agricultural products, if the penalty function is D , and the return function is shown in Table 2 below.

Table 2 Possible benefits of different strategic choices between suppliers and consumers

Yield function of agricultural product supplier and consumer in period t			Consumer (B)	
			Select with probability $1 - xt$ General agricultural products (B1)	Select by probability xt General agricultural products (B2)
Agricultural Product Supplier (A)	Provide authentic safe agricultural products with probability yt (A1)		-C1, 0	PH -C1, $U_1(s)$
	With probability $1 - yt$	-C2, 0	PH -C2, $U_1(s)$	PH -C2 -D, $U_1(s)$
	Provide general Agricultural products (A2)	PL-C2, U_2	-C2, 0	-C2, 0

The government's punishment function only affects Δ_4 . To change the evolutionary stability of the agricultural product market through the government's punishment for counterfeiting, only the value of Δ_4 needs to be changed. In the case of agricultural product market $\Delta_4 > 0$ without government constraints, Δ_4 may be less than zero with government constraints. Combining the previous analysis, it can be deduced that when $\Delta_4 < 0$ is $D > (1 - \mu)P_L + (C_1 - C_2)$, regardless of the value of μ , (0,0) is an unstable point or saddle point, (0,1), (1,0) and $(\frac{\Delta_2}{\Delta_1}, \frac{\Delta_3}{\Delta_4})$ are saddle points and (1,1) is stable for ESS.

7 Conclusion

Consider the generalised stone-scissor-cloth game in evolutionary game theory as a dynamic system and apply chaos theory to study whether the long-term evolution of the dynamic system will cause chaos over time. Improve the small data through application. The quantitative method is used to calculate the Lyapunov exponent of the dynamic system. It is concluded that under the replication dynamics, chaos occurs in the generalised stone-scissor-cloth game system when the parameter 'a' is < 0 .

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