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Research on Competitive and Cooperative Strategies of Agricultural Product Marketing Based on Game Theory

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ABSTRACT

In the face of the traditional agricultural marketing model is difficult to continue the status quo, agricultural marketing competition - cooperation relationship for agricultural enterprises of commodity marketing and long-term development is also increasingly important. In this paper, game theory is introduced into the study of competition and cooperation strategy of agricultural products marketing, the strategic behavior of two agricultural products enterprises in the agricultural products industry cluster is constructed into the corresponding matrix, and evolutionary dynamic stability analysis is carried out to establish the replication dynamic equations and Jacobi matrix to solve the evolutionary stability strategy (ESS), so as to provide reference for the formulation of the competition and cooperation strategy of the enterprise's agricultural products marketing. Using simulation to explore the influencing factors of the evolutionary direction of the marketing competition and cooperation strategy of agricultural products enterprises. When the probability of winning the joint bidding is greater than 0.8, it will evolve into a cooperative strategy, and when it is less than 0.7, it will evolve into a competitive strategy, and with the increase of the allocation coefficient of the investment amount of the project construction, the agricultural products enterprise 1 and the agricultural products enterprise 2 will gradually shift from a competitive strategy to a cooperative strategy. The lower the cost allocation coefficient is, the higher the probability that enterprises will evolve to cooperative strategy. The increase of cooperative transaction cost then accelerates the evolution of enterprise 1 and enterprise 2 to competitive state.

Keywords: evolutionary game theory, replication dynamic equation, Jacobi matrix, agricultural marketing

1. Introduction

Globalization and information flattening make the competition among enterprises more and more intense, and the expansion of the overall scale of the market in some industries has become more

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limited with the development of resources, technology, market environment and other factors [1-2]. Increasing market competition has also prompted enterprises to enhance the supply chain integration capabilities and improve the supply chain toughness, the supply chain is gradually mature, the industry standards tend to be unified [3-4]. Based on this situation, businesses can provide consumers with products and services are gradually becoming homogenized. At the same time, the rise of the Internet and new media has brought a large amount of product information, along with a large amount of information influx and the fierce competition of homogenized products, consumer expectations have been gradually raised, so the competitive situation faced by enterprises is more complex [5-7]. In the face of such a situation, enterprises will face whether to choose a new way and what new way to choose to meet the challenges and increase market share and realize profit growth.

In the face of the increasingly competitive market, enterprises pay more and more attention to technological innovation, product development and personnel training, etc., looking forward to using new ways to find new profit growth points, but enterprises will have to bear huge operating costs and time costs, the effect is often difficult to be reflected in a short period of time [8-10]. Therefore, marketing has become an important way for enterprises to seek new growth in a short period of time, and this way has been skillfully applied by enterprises in various industries, especially in the agricultural industry where market competition is becoming increasingly fierce, and an endless variety of marketing methods have become the front-end tool for enterprises and farmers to occupy the consumer market and reach consumers [11-12]. Enterprises and farmers also fully recognize the importance of marketing for the operation and development of enterprises and personal income. Enterprise marketing investment often occupies more than half of the total investment in business operations, in this process, enterprises have gradually found that cooperation has become an effective way to develop markets, reduce costs and improve profits, and cooperative marketing is an effective and popular form of cooperation [13-15]. Farmers are also aware of the limitations of independent marketing in the era of networking and information technology, and cooperation with agribusinesses or organizations to carry out marketing can maximize returns [16-17]. Under the competition of all kinds of marketing strategies for agricultural products, enterprises in different industries have reached long-term or short-term cooperation in marketing relationships to help realize the complementary advantages of resources between enterprises, enhance market development, penetration, and competitiveness, and create conditions for breaking through the development bottlenecks to further develop and utilize market opportunities [18-19]. Therefore, this puts forward high requirements for the win-win model of competition and cooperation in the marketing of enterprise products or services.

In this paper, the research on competition and cooperation strategy of agricultural marketing is based on the combination of theoretical analysis and simulation verification. In the theoretical analysis module, the relevant theories of game theory and evolutionary game are firstly explained to clarify the definition and nature of evolutionary stable strategy. The theory of evolutionary game is applied to the competitive and cooperative strategy selection of agricultural products marketing, by calculating the equilibrium point of the differential equation, establishing the payment matrix between different participants, obtaining the replicated dynamic equations, and carrying out the analysis of dynamic stability of evolution, solving the evolutionary stable strategy, and obtaining the dynamic evolutionary process of the competitive and cooperative strategies of the enterprises within the agricultural products industrial clusters. In the simulation verification module, the proposed evolutionary game model of competition and cooperation in agricultural product marketing is used to analyze the evolutionary paths of the strategy choices of the competing and cooperating parties. At the same time, numerical simulation is carried out for the same-traveling enterprises in the agricultural products manufacturing industry to explore the evolutionary game process of the agricultural products enterprises and verify the validity of the model in this paper.

2. Evolutionary game principle

2.1. Evolutionary game theory

Game theory, refers to a kind of individual or group, under the relevant constraints, by virtue of mastering the information of other participants in the game, to adopt a certain strategy to be able to overcome or surpass the opponent, and the winning party can get the corresponding payment, while the other party can only bear the corresponding payment of the struggle process [20]. It is a branch of applied mathematics, early used to study the struggle between species, in recent years with the wide application of game theory, has gradually involved in the field of agricultural economy.

Evolutionary game theory is a new theory that combines the analysis of game theory and dynamic evolutionary process [21]. In methodology, it is different from game theory is that it emphasizes a dynamic equilibrium and the comparison of static equilibrium, it is not the game player as a rational, but the game as a number of games gradually converge to the equilibrium of a game, and Darwin's theory of biological evolution has commonality. The equilibrium of the evolutionary game is a function of the equilibrium state of the game parties, and its equilibrium is affected by the history, the system and some details of the equilibrium process will be changed to some extent.

The applied research of evolutionary game theory never stops from the day of its birth. At first, it was first introduced into the field of economics by economists, mainly used to analyze the change of social system, financial securities, stock market, etc., and gradually carried out in-depth research on symmetric game to asymmetric game, and achieved corresponding results. In this paper, we will apply the evolutionary game theory to the study of agricultural products economy, and discuss the competition and cooperation of agricultural products marketing.

2.2. Theory of Evolutionary Stabilization Strategies

Evolutionary stabilization strategy was proposed in the study of ecological phenomena, it is regarded each population as a strategy, all the populations as a large group, due to the symmetric game between the populations, so the early evolutionary stabilization strategy is only effective for the symmetric game of mixed strategies [22]. However, through the continuous hypothesis verification by researchers, the evolutionary stabilization strategy which is not only applicable to mixed strategies but also to pure strategies is finally found and defined as follows.

If strategy $s \in S$ is an evolutionarily stable strategy, then it satisfies that there exists $u \notin (0,1)$ such that inequality $f(s,h) > f(s^{'},h)$, holds for all $u \le u^{*}$ if and only if for any strategies $s^{'} \in S$ and $s^{'} \ne s$.

where: S denotes the large population; s is the small and optimal strategy in the large population; s' is the small population of the chosen mutation strategy; $u(u \in (0,1))$ denotes the share of the mutation small population in the large population; h is the mixed strategy adopted by two-two repetitively playing opponents in the population, where $h = (1-\mu)s + \mu s^{'}$; $f(s^{'},h)$ denotes the expectation of the payout obtained by the mutator's selection of strategy s'; and $f(s,h)$ denotes the expectation of the payout obtained by the participant's selection of strategy s in the game. If the participant adopts strategy s and the opponent adopts strategy s' when the acquired payment is $f(s,s^{'})$, based on the definition of ESS it can be seen that the evolutionary stable strategy has the following properties:

Property 1, if strategy s is an evolutionarily stable strategy, then there must be $f(s,s) > f(s^{'},s)$ for any $s^{'} \in S$.

Property 2, if strategy s is an evolutionarily stable strategy and satisfies $f(s,s) = f(s^{'},s)$ for any s', then there must be $f(s,s') > f(s',s')$.

Property 3, if strategy $s \in S$ satisfies (1) for any $s^{'} \ne s$ and $s^{'} \in S$ there must be

$f(s,s) > f(s',s)$

$f(s,s) = f(s',s)$ implies $f(s,s') > f(s',s')$, then strategy s is an evolutionarily stable strategy. Properties 1 and 2 are sufficiently necessary conditions for evolutionarily stable strategies. Property 3 (1) shows that if strategy s is an evolutionary stable strategy, then the individual who chooses mutation strategy s' has a smaller expectation compared to the individual who chooses strategy s, so it is impossible to invade the group that chooses the evolutionary stable strategy; (2) shows that the evolutionary stable strategy s is able to invade the group that chooses the mutation strategy, and the player who chooses the mutation strategy will eventually perish in the large group.

1) The connection between evolutionary stable equilibrium and Nash equilibrium. For a Nash equilibrium, if strategy combination $s^* = (s_1^*, s_2^*, \cdots, s_n^*)$ is a Nash equilibrium, then for each i, s_i^* is the best response of the ith player given the other players' choices $s_i^* = (s_1^*, s_2^*, \cdots, s_{i-1}^*, s_i^*, s_{i+1}^*, \cdots, s_n^*)$, i.e., $f_i(s_i^*, s_{-i}^*) \ge f(s_i, s_{-i}^*), \forall s_i \in S_i, \ \forall i$. From this, it follows that a Nash equilibrium strategy is the best strategy for its own response, and vice versa, its own best strategy must necessarily be a Nash equilibrium strategy, i.e., if strategy $s \in S$ satisfies $\forall s' \ne s$ and $s' \in S$ has $f(s,s) > f(s',s)$, then the former is able to introduce that the latter is an equilibrium strategy, while through the evolutionary stable strategy property 3 in (2) can be seen that the latter can not necessarily be introduced to the former is a stable strategy, this is due to the Nash equilibrium in the existence of inferior equilibrium, its equilibrium is not necessarily the evolutionary stable equilibrium.

The correctness of this theoretical analysis can be proved by a counterfactual, that is, assuming that the inferior strategy s is an evolutionary stable strategy, that is to say, there exists a strategy s' weakly superior to s, then there are $f(s,s) = f(s',s)$ and $f(s,s') \ge f(s',s')$, obviously contradicting (2) in the nature of the evolutionary stable strategy 3, so the inferior strategy s must not be an evolutionary stable strategy.

From the definition of the two equilibrium can be seen, the evolutionary stable equilibrium, although it is in a static state, but can effectively reflect the local dynamic changes in the system, the size of its impact lies in the degree of its description of the nature of the system. While the Nash equilibrium strategy is also static, but can not react to the dynamic nature of the system, so the general nature of the game can be completed by the Nash equilibrium, but for slightly more complex dynamics need to be completed by the evolutionary stable equilibrium.

2) Evolutionary game replicates the dynamic equations. The “replication dynamic equation” is a dynamic differential equation that describes the proportion of an individual's strategy that is adopted in the group. From evolutionary theory, it is known that if an individual adopts a strategy that yields a higher expected payoff than the average expected payoff of the group's adopted strategy, that strategy will be retained in the group and will be continuously learned and imitated, i.e., the law of survival in nature. The rate of change of the imitated strategy can be expressed by the differential equation $\frac{d_{s_k}}{d_t} = s_k[g(k,s) - g(s,s)]k = 1,2,\cdots K$, where s_k denotes the proportion of the group that adopts the strategy k, $g(k,s)$ denotes the expected payment for an individual adopting the strategy k, $g(s,s)$ denotes the average expected payment for the strategy adopted by the group; and k denotes the different strategies.

3. Evolutionary game model of competition and cooperation in agricultural marketing

In the above article, this paper has made a brief introduction to the related knowledge theory of classical game and evolutionary game. In this chapter, based on the theory of evolutionary game, we will analyze the marketing competition and cooperation strategy between agricultural enterprises from the perspective of evolutionary game, establish the evolutionary game model of agricultural marketing competition and cooperation, and provide some feasible decision-making references for decision-makers of agricultural enterprises.

3.1. Modeling assumptions of the game

3.1.1. Assumptions of the game model environment. For the sake of discussion, it is assumed that there are only two firms, Firm 1 and Firm 2, in a particular agricultural products cluster, and that they compete with each other, but there is also some cooperation between them. Assume that each firm has the following three choices of behavioral strategy combinations: (cooperation, competition), (cooperation, competition-cooperation), and (competition, competition-cooperation), and it must be one of them. For the sake of research convenience, it is assumed that when both firms have selected their behavioral strategy space, the likelihood that Firm 1 will choose the former strategy is x and the likelihood that it will choose the latter strategy is $1-x$, and similarly, the likelihood that Firm 2 will choose the former strategy is y, and the likelihood that it will choose the latter strategy is $1-y$.

3.1.2. Parameter assumptions of the game model. Suppose that when firm 1 and firm 2 choose competition at the same time, the payments received are a_1, a_2, respectively, and when both firm 1 and firm 2 choose cooperation, the payments will increase from when they choose competition at the same time $b_1(b_2)$, and when both firm 1 and firm 2 choose competition-cooperation, the payments will increase from when they choose competition at the same time $f_1(f_2)$, and when firms 1 and 2 adopt different behaviors. Payments by firms using cooperative behavior will decrease compared to when they also choose competitive $c_1(c_2)$, Payments by firms using competitive behavior will increase compared to when they also choose competitive $d_1(d_2)$, Payments by firms using competitive-cooperative behavior will increase compared to when the other firm chooses cooperative $e_1(e_2)$, Payments by firms using competitive-cooperative behavior will decrease compared to when they also choose competitive 6, Payments by firms using competitive-cooperative behavior will increase compared to when the other firm chooses competitive $e_1(e_2)$, and $a_i, b_i, c_i, d_i, e_i, f_i > 0, f_i > d_i, f_i > e_i, b_i > d_i, b_i > e_i, d_i > e_i, e_i > c_i, i = 1,2$.

3.2. Game Model Analysis

3.2.1. Analysis of replicated dynamic equations and evolutionary stabilization strategies. The following is an example of scenario 4 (one firm chooses a strategy space of (cooperation, competition-cooperation) and the other firm chooses a strategy space of (competition, competition-cooperation):
1) Firm 1's gain. Expected gains from choosing a competitive strategy:

$$U_1 = y(a_2 + d_2) + (1-y)(a_2 + d_2) \tag{1}$$

Expected benefits of choosing a competitive-cooperative strategy:

$$U_2 = y(a_2 + e_2) + (1-y)(a_2 + f_2) \tag{2}$$

Average earnings:

$$U = xU_1 + (1-x)U_2 \tag{3}$$

Then the equation for the replication dynamics of firm 1 is:

$$\frac{dx}{dt} = x(1-x)[f_2 - d_2 + (e_2 - f_2)y] \tag{4}$$

2) Benefits for Business 2. Expected gains from choosing a cooperative strategy:

$$V_1 = x(a_1 - c_1) + (1-x)(a_1 - c_1) \tag{5}$$

Expected benefits of choosing a competitive-cooperative strategy:

$$V_2 = x(a_1 - e_1) + (1-x)(a_1 + f_1) \tag{6}$$

Average earnings:

$$V = yU_1 + (1-y)U_2 \tag{7}$$

Then the equation for the replication dynamics of firm 2 is:

$$\frac{dy}{dt} = y(1-y)[f_1 + c_1 - (f_1 + e_1)x] \tag{8}$$

The system of differential equations consisting of (4), (8) has five equilibrium points:

$$A(0,0); B(0,1); C(1,0); D(1,1); E(\frac{f_1 + c_1}{f_1 + e_1}, \frac{f_2 - d_2}{f_2 - e_2}) \tag{9}$$

The partial derivatives of the differential equations (4), (8) with respect to x, y, respectively, yield the corresponding Jacobi matrices [23]:

$$J = \begin{pmatrix} (1-2x)[f_2 - d_2 + (e_2 - f_2)y] & x(1-x)(e_2 - f_2) \\ -y(1-y)(f_1 + e_1) & (1-2y)[f_1 + c_1 - (f_1 + e_1)x] \end{pmatrix} \tag{10}$$

Substituting the five equilibrium points into the Jacobi matrix respectively, we get the value and sign of the corresponding determinant, and the value and sign of the corresponding matrix trace, and carry out the local stability analysis of these five equilibrium points, and the results are shown in the table below:

It can be seen that only B(0, 1), C(1, 0) is the evolutionary stable strategy (ESS) of this evolutionary game model, i.e., (Cooperation, Competition-Cooperation) or (Competition, Competition-Cooperation) is the evolutionary stable strategy for this situation. That is, one party always chooses the strategy of competition-cooperation, and this stabilization does not last, because when the two firms have different combinations of strategies, there is always a party whose gain is greater than the gain when they simultaneously choose the competition strategy. And the other party's gain is less than the simultaneous choice of competitive strategy, which is consistent with the reality of the economy, so the two enterprises will learn from each other, each other to imitate, and ultimately the benefits converge, that is, not complete cooperation and not complete competition, but competition in cooperation, cooperation in competition.

Similarly, respectively, the other three cases to establish the replication dynamic equation, and local stability analysis to obtain the following results.

The five equilibrium points of scenario I are A(0, 0); B(0, 1); C(1, 0); D(1, 1); and E$(\frac{c_1}{b_1 + c_1 - d_1}, \frac{c_2}{b_2 + c_2 - d_2})$, where points A and D are ESS, B and C are unstable points, and E is a saddle point, i.e., (cooperation, cooperative) or (competition, competitive) is an evolutionary stable strategy of the game.

The five equilibrium points of situation two are: A(0, 0); B(0, 1); C(1, 0); D(1, 1); E$(\frac{c_1 + f_1}{b_1 + c_1 + f_1 - e_1}, \frac{c_2 + f_2}{b_2 + c_2 + f_2 - e_2})$, in which point A and D are ESS, point B and C are unstable points, and point E is the saddle point, i.e., (Cooperation, Cooperation) or (Competition-Cooperation, Competition-Cooperation) is an evolutionary stabilization strategy of the game.

The five equilibrium points of scenario 3 are A(0, 0); B(0, 1); C(1, 0); D(1, 1);

$E(\frac{f_1-d_1}{f_1-d_1+e_1},\frac{f_2-d_2}{f_2-d_2+e_2})$, where point A is the ESS, point D is the unstable point, and points B, C and E are the saddle points, i.e., (Competition-Cooperation, Competition-Cooperation) is the evolutionary stabilization strategy of the game.

3.2.2. Analysis of replicated dynamic equilibrium results. The benefits of cooperation are greater than the benefits of simultaneous competition, so the two firms will choose to cooperate; if the two strategies are not the same. If the strategies of the two enterprises are different, the revenue of the enterprise adopting competition strategy is greater than that of the enterprise adopting cooperation strategy, so the enterprise adopting cooperation strategy in order to maximize its own interests will gradually turn to competition strategy through learning and imitation, and finally the strategy of the inter-firms will evolve into two stable strategy combinations, namely (cooperation, cooperation) or (competition, competition). Obviously, these two stable strategy combinations do not meet the real economic situation.

When the strategy space of two enterprises is (cooperation, competition-cooperation), if the strategies of two enterprises are the same, the revenue of both enterprises will increase; if the strategies of two enterprises are not the same, the revenue of the enterprise adopting cooperation will be reduced, and the revenue of the enterprise adopting competition-cooperation will be increased, so the strategies of the two enterprises are constantly converging to the same level of evolution. That is, the evolutionary stable strategies of the firms are (cooperation, cooperation) or (competition-cooperation, competition-cooperation). And the equilibrium outcome of (competition-cooperation, competition-cooperation) is pareto better than (cooperation, cooperation).

When the strategy space of the two firms is (Competition, Competition-Cooperation), since the gains from simultaneously adopting Competition-Cooperation are greater than the gains from simultaneously adopting Competition. And there is always one firm's gain increasing and the other firm's gain decreasing when the strategies are inconsistent. So the evolutionarily stable strategy of a firm is (competition-cooperation, competition-cooperation).

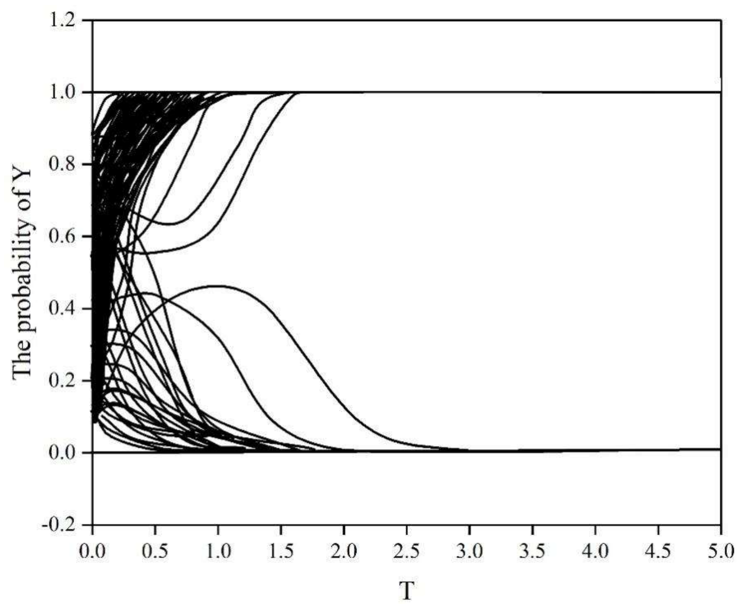
When one firm's strategy space is (competition, competition-cooperation) and the other firm's strategy space is (cooperation, competition-cooperation), when the two firms' strategies are not the same, there is always one of the firms whose returns are higher than those when they compete together and the other firm's returns are lower than those when they compete together, it is clear that (competition-cooperation, competition-cooperation) is the evolutionary stable strategy, and this strategy combination is more consistent with the real economy.

4. Simulation Experiment on Competitive and Cooperative Strategy Selection in Agricultural Product Marketing

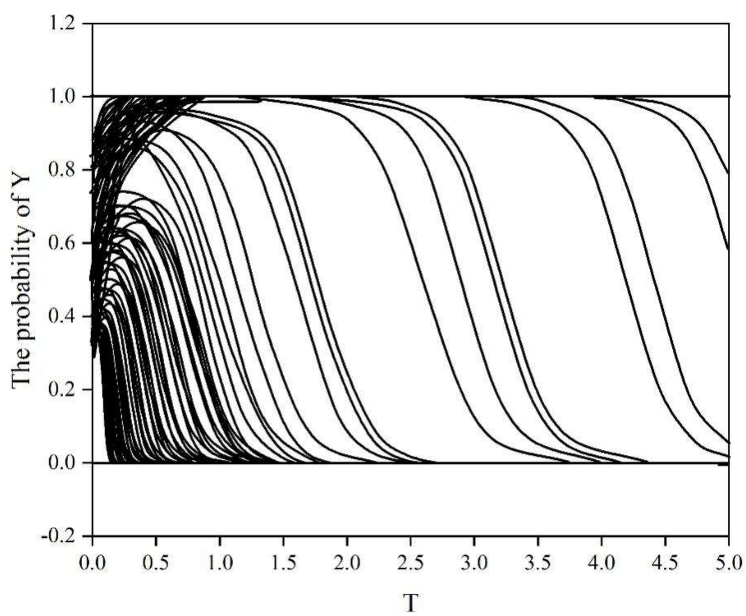
In this chapter, the proposed evolutionary game model of competition and cooperation in agricultural marketing will be utilized to analyze the evolutionary paths of strategic choices of both competitive and cooperative parties using the numerical simulation of agricultural enterprises as an example.

1) Analysis of the evolutionary path of strategic choices of agricultural enterprise 1 and agricultural enterprise 2 in the case of the same input cost in the early stage and different returns in the later stage.

Different returns in the case of agricultural marketing competition and cooperation strategy selection evolution path is shown in Figure 1. Figures (a) and (b) correspond to the two situations. Figure (a) is the case that both sides of the game are able to recover costs in the cooperation process, but the return of enterprise 2 is higher than the return of enterprise 1. Figure (b) is the case when the return of an agricultural product project is positive in the early stage, and then gradually decreases in the later stage as the market competition becomes more intense. When both firms 1 and 2 are able to recover their costs and firm 2's returns are higher than firm 1's, most of the curves in Fig. (a) converge to 1 in probability over time, i.e., firm 2 will be more willing to cooperate. In addition, when the initial willingness to cooperate is higher than 0.3, there will be a high probability of forming a stable cooperative relationship after 1.5 years; conversely, there is a high probability of forming a competitive relationship. When the positive returns of the agricultural project gradually decline, as shown in Fig. (b), the vast majority of the curve probability first tends to 1 and then an inflection point gradually tends to 0. That is, Firm 2 will tend to choose the cooperation strategy at first, but may give up the agricultural project and re-select the competition strategy with the passage of time. In addition, although no matter how the initial willingness changes, firm 1 and firm 2 in that case will finally evolve into a competitive relationship. However, an elevated initial willingness to cooperate can effectively delay the formation of competitive constraints, and this marginal utility of a longer period of cooperation due to an increase in initial willingness is significantly incremental.



(a)When the income of enterprise 2 is higher than the income of enterprise 1

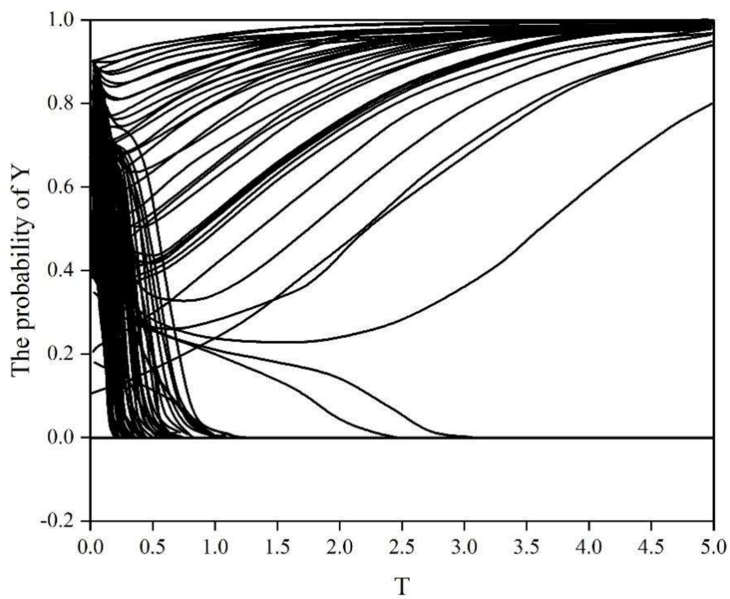


(b)When the income of agricultural products projects gradually declines

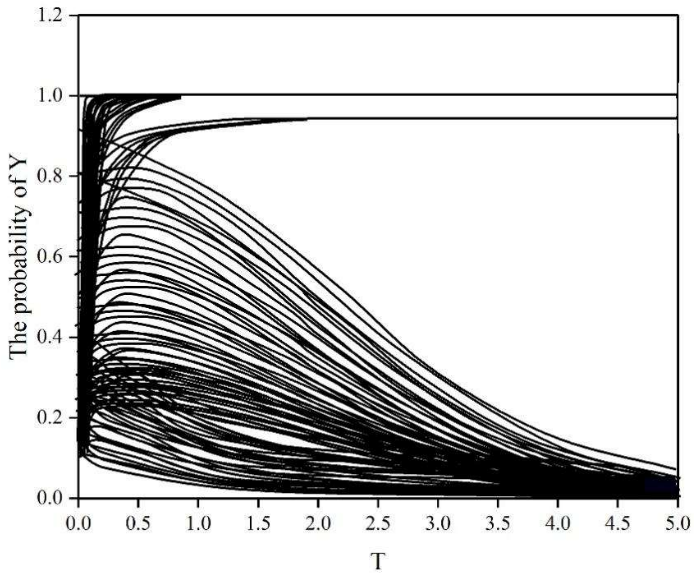
Fig. 1. The evolutionary path of strategy selection under different returns

2) Analysis of the evolution path of strategy selection between agricultural enterprise 1 and agricultural enterprise 2 under the situation that both sides of the game have equal late gains and different input costs in the early stage.

Different cooperation costs under the agricultural marketing competition and cooperation strategy selection evolution path is shown in Figure 2, in which Figure (a) corresponds to the two sides of the game produce late gains are positive, enterprise 2's input cost is obviously more than enterprise 1, Figure (b) corresponds to the enterprise 1's input cost is obviously more than enterprise 2's situation. As can be seen from the figure, when the late returns are all positive and the input cost of firm 2 is higher than that of firm 1, the probability of most curves gradually decreases to 0, i.e., there is a higher probability that firm 2 will terminate the cooperation and choose the competitive strategy. When the input cost of enterprise 1 is higher than that of enterprise 1, the probability of most curves gradually tends to 1. At this time, although enterprise 2 tends to choose the cooperation strategy, whether the two sides can reach cooperation depends on the cooperation willingness of enterprise 1. When the initial willingness to cooperate is greater than 0.5, the two sides will rapidly evolve to a stable cooperative relationship; conversely, although the two sides have a tendency to cooperate in the initial period, they usually turn to a competitive strategy within 1 year.



(a)When the input cost of enterprise 2 is more than that of enterprise 1



(b)When the input cost of enterprise 1 is more than that of enterprise 2

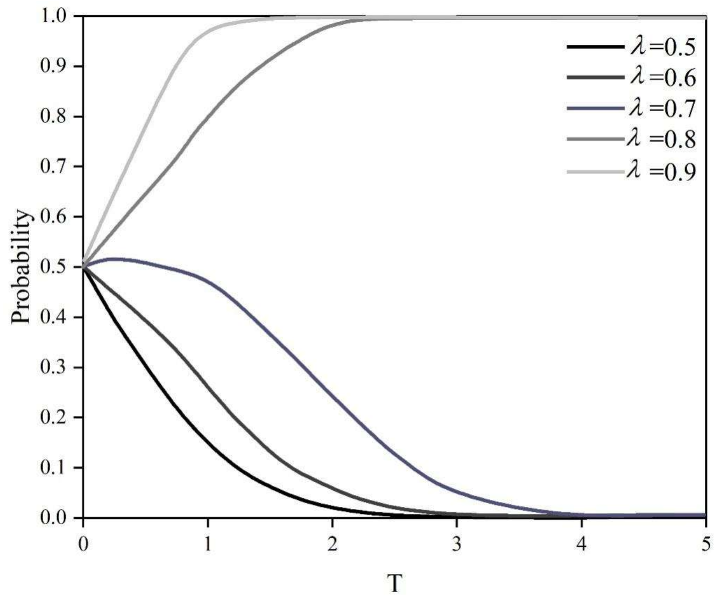
Fig. 2. The evolution path of strategy selection under different cooperation costs

5. Simulation Experiments of Competitive and Cooperative Games in Marketing of Agricultural Products Enterprises

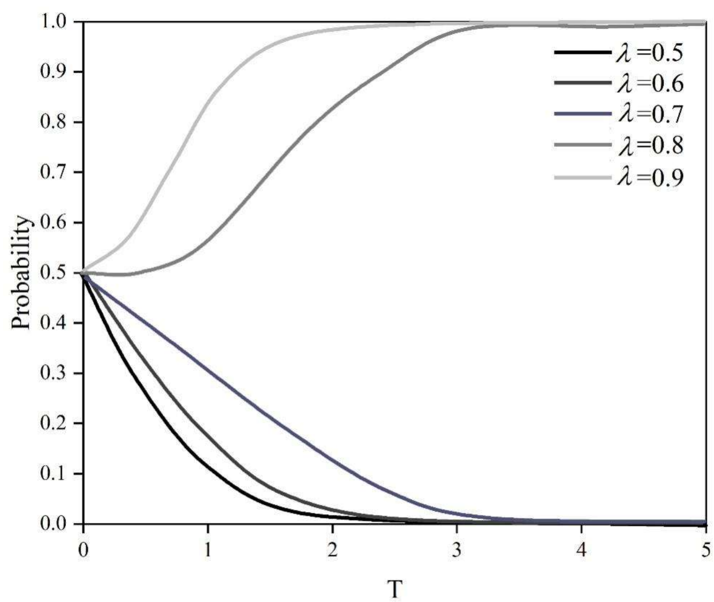
In this chapter, we will take the agricultural products manufacturing industry as an example, conduct numerical simulation for the same-traveling enterprises, and use the evolutionary game model of competition and cooperation in agricultural products marketing proposed in this paper to explore the evolutionary game process of agricultural products enterprises and factors affecting the game results, and to further validate the validity of the model in this paper.

5.1. Probability of winning a joint bid

The evolution trajectory diagrams of the probability of winning bids for agricultural enterprise 1, agricultural enterprise 2 and joint bidding are specifically shown in Fig. 3, with diagrams (a) and (b) corresponding to enterprise 1 and enterprise 2. λ in the diagram is the probability of winning bids when enterprises bid jointly. The change of the joint bid winning probability will significantly affect the evolution speed and direction of enterprise 1 and enterprise 2. As the probability of winning the joint bid increases, the two enterprises gradually shift from a competitive strategy to a cooperative strategy. A larger value of the joint bid winning probability corresponds to a shorter time required for the firms to evolve into a cooperative state. When the joint bid winning probabilities of firm 1 and firm 2 are 0.8 and 0.9, respectively, they will evolve into cooperative strategies. However, they will evolve to a competitive state if the joint bid winning probability is 0.5, 0.6 or 0.7. For firm 1, an increase of more than 30% in the probability of winning the joint bid will tend to favor the cooperative strategy, while an increase of less than 20% will tend to favor the competitive strategy. For firm 2, an increase of more than 40% in the probability of winning a joint bid will tend to favor the cooperative strategy, while an increase of less than 30% will tend to favor the competitive strategy.



(a)Influence of joint bidding probability on the evolution results of enterprise 1

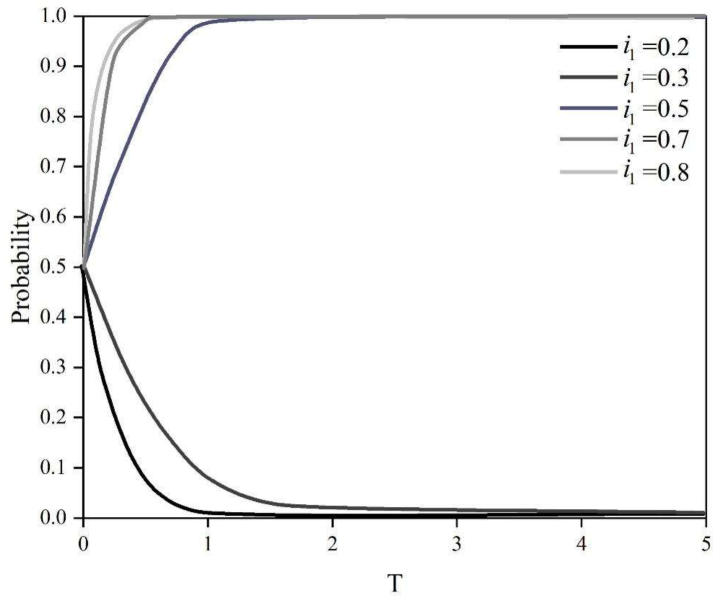


(b)Influence of joint bidding probability on the evolution results of enterprise 2

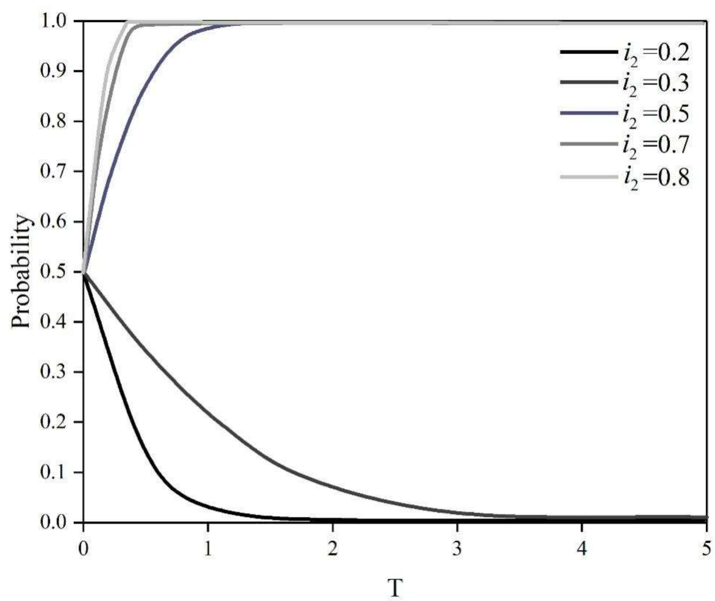
Fig. 3. Influence of joint bidding probability on the evolution results

5.2. Distribution of benefits under the cooperative construction model

The evolutionary trajectory of the revenue allocation between enterprise 1 and enterprise 2 under the cooperative construction mode is specifically shown in Fig. 4, with Figs. (a) and (b) corresponding to enterprise 1 and enterprise 2. i_1 and i_2 in the figure are the coefficients for the allocation of the project construction investment amount between enterprise 1 and enterprise 2. With the increase of i_1 and i_2, enterprise 1 and enterprise 2 gradually shift from competitive strategy to cooperative strategy. The larger the values of i_1 and i_2, the faster the two enterprises evolve into cooperation. The larger the values of i_1 and i_2, the longer it takes Enterprise 1 and Enterprise 2 to evolve into competition.



(a)The impact of income distribution on the evolution results of enterprise 1

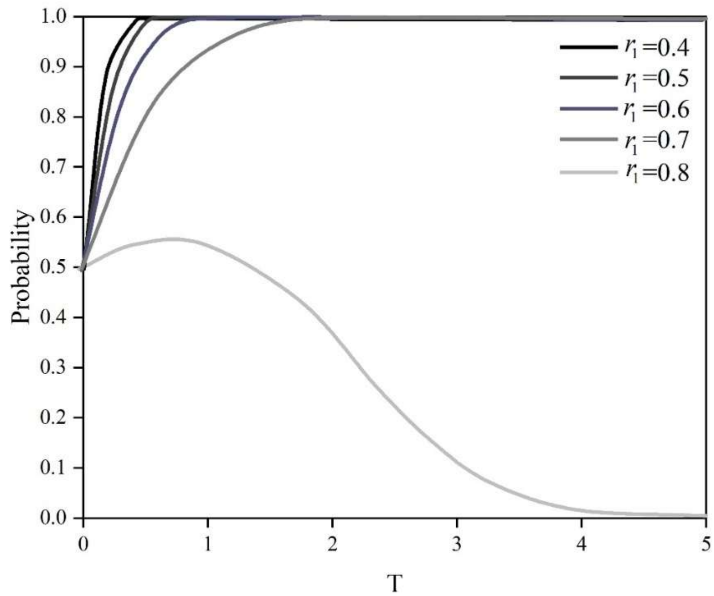


(b)The impact of income distribution on the evolution results of enterprise 2

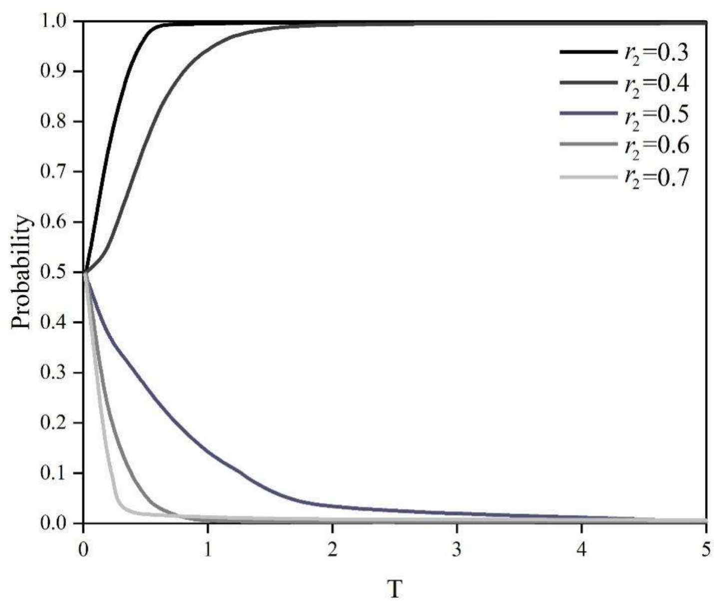
Fig. 4. The impact of income distribution on the evolution results

5.3. Cost allocation under the cooperative construction model

In this section, the relationship between cost allocation under the cooperative construction model and the competitive and cooperative strategies of agricultural firms will be explored. The evolution trajectory diagrams of enterprise 1 and 2 with cost allocation under cooperative construction mode are specifically shown in Fig. 5, with diagrams (a) and (b) corresponding to enterprise 1 and enterprise 2, respectively. r_1 and r_2 in the diagrams are the cost allocation coefficients of project construction for enterprise 1 and enterprise 2, respectively. The lower the cost allocation coefficients of Enterprise 1 and Enterprise 2 in cooperative construction mode, the greater the benefits the enterprises get from cooperation, and the greater the probability that the enterprises evolve to cooperative strategy. When the values of r_1 and r_2 are large, the firms will gain only a small benefit from it, and Firm 1 and Firm 2 will eventually evolve to a competitive state. As r_1 and r_2 decrease, the firms' profits gradually increase, and the time for Firm 1 and Firm 2 to evolve into cooperation gradually decreases. At r_1 = 0.8, firm 1 tends to evolve to cooperation first, but eventually chooses a competitive strategy.



(a)The impact of cost allocation on the evolution results of enterprise 1

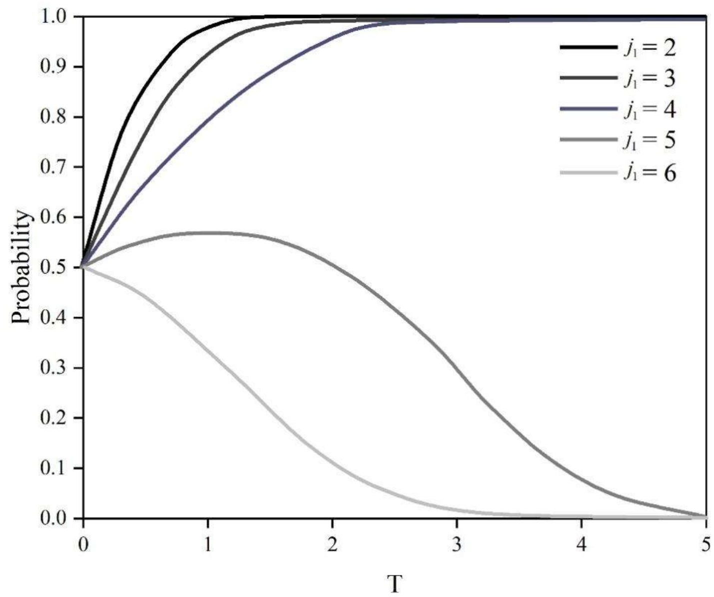


(b)The impact of cost allocation on the evolution results of enterprise 2

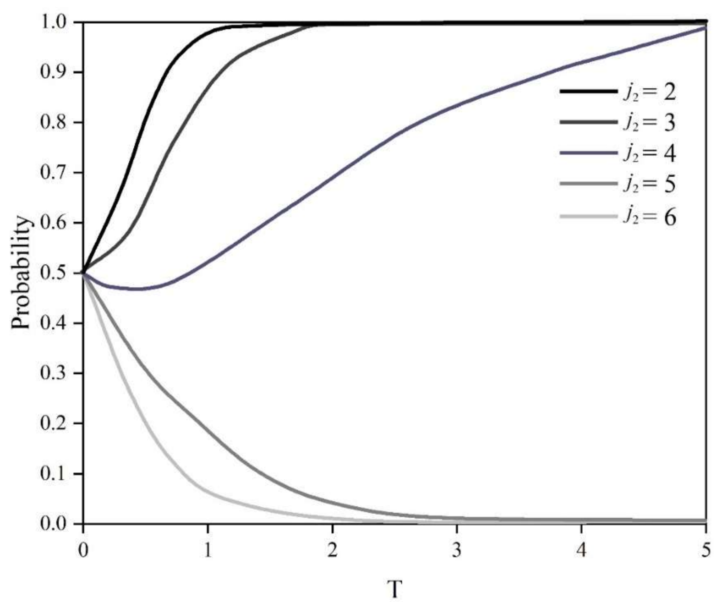
Fig. 5. The impact of cost allocation on the evolution results

5.4. *Transaction costs*

The evolutionary trajectory diagrams of enterprise 1 and enterprise 2 with transaction costs are specifically shown in Fig. 6, with diagrams (a) and (b) corresponding to enterprise 1 and enterprise 2, respectively. j_1 and j_2 in the diagrams are the transaction costs paid by enterprise 1 and enterprise 2, respectively, when they reach cooperation. Changes in transaction costs have an impact on the evolutionary speed and direction of the firms. Higher transaction costs motivate firm 1 and firm 2 to evolve in the direction of competition. When firms evolve in the competitive direction, transaction costs are positively related to the speed of evolution. Lower transaction costs of cooperation promote firms 1 and 2 to evolve in the direction of cooperation, where transaction costs are negatively related to the speed of evolution. Thus, it can be seen that the transaction costs have an important impact on the strategic choices and evolutionary paths of enterprises when choosing the competition and cooperation strategies among co-traveling enterprises, and enterprises need to consider them carefully in order to realize their own best interests.



(a)The impact of transaction costs on the evolution of enterprise 1



(b)The impact of transaction costs on the evolution of enterprise 2

Fig. 6. The impact of transaction costs

6. Conclusion

This paper discusses the competition and cooperation strategies of agricultural product marketing through evolutionary game theory, and establishes an evolutionary game model of competition and cooperation in agricultural product marketing to provide some feasible decision-making references for decision-makers in agricultural product enterprise sales.

Using the proposed evolutionary game model, we analyze the evolutionary paths of competition and cooperation in strategy selection in agricultural products enterprises. It is assumed that agricultural products enterprise 1 and agricultural products enterprise 2 have the same input cost in the early stage and different returns in the later stage. When both enterprises 1 and 2 are able to recover their costs, and the return of enterprise 2 is higher than that of enterprise 1, enterprise 2 will be more willing to cooperate. When the positive returns of the agricultural program are declining, firm 2 will be more willing to cooperate in the early stage, but as the returns decline, it may abandon the agricultural program and compete with firm 1. Suppose that firms 1 and 2 have different input costs in the early stage but equal returns in the later stage. When the input cost of enterprise 2 is higher than that of enterprise 1, enterprise 2 will probably choose to terminate the cooperation and switch to the competitive strategy. When the input cost of enterprise 1 is higher than that of enterprise 2, whether the two sides can reach cooperation depends on the cooperation willingness of enterprise 1. If Enterprise 1's initial willingness to cooperate is greater than 0.5, Enterprises 1 and 2 will quickly evolve into a cooperative relationship. If the willingness to cooperate is less than 0.5, the two parties will usually evolve into a competitive strategy in 1 year despite their initial intention to cooperate.

Numerical simulation is carried out as an example of agricultural products manufacturing industry, and the evolutionary game process of agricultural products enterprises and the factors affecting the game are further explored through simulation experiments. When the probability of winning the joint bid increases, enterprise 1 and enterprise 2 will gradually shift from competitive strategy to cooperative strategy. When the probability of winning the joint bid increases more than 30%, enterprise 1 will tend to choose the cooperative strategy, and enterprise 2 will tend to choose the cooperative strategy when the probability of winning the joint bid increases more than 40%. The increase of project construction investment allocation coefficient also pushes enterprise 1 and enterprise 2 to gradually shift from competitive strategy to cooperative strategy. Under the cooperative construction mode, the lower the cost allocation coefficient is, the more profitable the enterprise is, and the higher the probability that enterprise 1 and enterprise 2 will evolve to the cooperative strategy. On the contrary, when the cost allocation coefficient is higher, the profitability of the firms is smaller, and Firm 1 and Firm 2 will eventually evolve to a competitive state. Higher transaction costs also cause firms 1 and 2 to shift to a competitive strategy, while lower cooperative transaction costs promote cooperation between firms 1 and 2.

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