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Cooperation Strategy Between Large Agricultural Households and Farmers' Market Based on Evolutionary Game

Wang Xiao-ping[1,a,*], Wei Zhi-qi[1], and Wang Ya-bo[1]

[1]*College of Logistics, Beijing Materials University, Beijing, 101149, China*
a. Bjwxp2004@163.com
**corresponding author*

Abstract: With the continuous development of China's agriculture, individual farmers are increasingly integrating into the supply chain of agricultural products, leading to the emergence of "large agricultural households" in the agricultural market. These large households monopolize the local market by purchasing agricultural products from individual farmers, thereby greatly influencing the diversity of product types and brand image in the agricultural market. In this study, we utilize evolutionary game theory to construct a model that explores the cooperative evolution between large agricultural households and agricultural markets under limited rationality. We analyze the evolutionary process of the cooperative strategies between the two parties and validate the game results through Matlab simulation. The findings reveal that the decision of whether or not large agricultural households cooperate with agricultural markets is affected by various factors, such as the benefits and costs associated with cooperation, as well as the potential losses resulting from non-cooperation. As a result, agricultural markets can implement measures, such as establishing effective information sharing and communication coordination mechanisms, and reducing cooperation costs with large agricultural households, to attract and retain them.

Keywords: circulation of agricultural products, evolutionary game between the two sides, large agricultural households, brand competitiveness of farmers' market

1. Introduction

In the supply chain of agricultural products in China, various stakeholders, including individual farmers, agricultural product buyers, wholesale markets, farmers' markets, retailers, and consumers, play vital roles. Recently, a unique type of agricultural buyer, referred to as "large agricultural households," has emerged. These large households purchase significant quantities of specific agricultural products from individual farmers and then concentrate their sales in farmers' markets. Due to the substantial quantities of agricultural products bought by large agricultural households, they often establish a local monopoly for these products. This monopoly can have implications for the diversity of agricultural products available in farmers' markets. Therefore, to maintain their brand value and ensure the integrity of the products they sell, farmers' markets strive to attract and retain large agricultural households.

This study aims to investigate the game relationship and cooperation mechanism between large agricultural households and farmers' markets, building upon the aforementioned observations. By assuming limited rationality, we develop a game model that captures the evolutionary behavior of both parties. The model aims to explore the changes in the behavioral choices of large agricultural households and farmers' markets, as well as the stability of the supply chain system, as key parameters such as cooperation costs, cooperation benefits, and potential losses from non-cooperation are varied. The study seeks to understand how these changes influence the system dynamics and lead to the attainment of a stable state in the supply chain.

From a theoretical standpoint, this study introduces a novel participant in the agricultural supply chain, namely "large agricultural households", and investigates the game relationship and strategic decision-making between these and farmers' markets. This research not only the diversity of agricultural product channels but also expands the research scope of evolutionary game theory. Additionally, as large agricultural households often establish local monopolies due to their significant holdings of agricultural products, their decision to cooperate or not with farmers' markets has a direct impact on the brand management of these markets. Consequently, understanding the factors that influence the cooperation strategy between large agricultural households and farmers' markets can provide valuable insights on how farmers' markets can effectively attract and retain these large agricultural households.

2. Literature Review

Within the realm of agricultural supply chain systems, understanding the strategic decision-making of the involved stakeholders has garnered significant interest among scholars. Both domestic and international researchers have approached this topic from various perspectives, with the main areas of research being as follows:

Firstly, research has focused on the perspective of agricultural product circulation, yielding notable findings and contributions. For example, Ma Li [1] highlights the broader development opportunities brought by the big data era for agricultural product circulation, emphasizing how the optimization of the agricultural product circulation system can be achieved through the utilization of big data technology. Li Jiyan [2] emphasizes that the efficiency of agricultural product circulation, acting as the connection between the agricultural production and consumption fields, significantly affects the quality of agricultural products and market turnover. Based on the reality of infrastructure construction, production and circulation management standardization, and circulation system development, strategies to enhance the efficiency of agricultural product circulation are proposed. Xu J [3] and others argue that government supervision and consumer awareness of rights protection influence the decision-making behavior of participating subjects within the agricultural supply chain. Zhou Shuanglei [4] examines the behavior of farmers by dividing the game between farmers and traders into three stages. Employing an integrated rationality perspective and considering the social context, the study finds a "rational" behavior pattern among farmers, meaning a causal relationship exists between the means employed and the desired outcomes. Liu Xiaoli [5] suggests that farmers can choose to sell their agricultural products through agricultural e-commerce enterprises. Srimanee [6] and others analyze the distribution channels of fruit and vegetable agricultural products in Thailand, investigating the differences between traditional and modern distribution models, and proposing ideas to promote changes in the distribution of fresh agricultural products.

The second area of research centers around the application of evolutionary game models to behavioral evolution. Key findings and perspectives include: Zhu Lilong and Guo Pengfei [7] introduce a consumer incentive mechanism, constructing an evolutionary game model between government regulators and agricultural product producers, and analyzing the evolutionary trend of strategy selection between the two parties. The study further examines the impact of changes in parameters on the evolutionary strategies of both actors and presents stable equilibrium solutions for the evolution game under different circumstances. Yang Song [8] and other scholars develop an evolutionary game model for the quality and safety inputs of suppliers and producers. The study finds a significant correlation between the quality and safety input strategies of agricultural product suppliers and producers and the cost-benefit conversion rate of input from both parties. The evolution equilibrium of the system constantly changes based on the cost-benefit conversion rate of quality inputs from both parties. Huo Hong [9] and other scholars establish an evolution game model for agricultural product suppliers and processors based on blockchain technology inputs. The study explores the suitability of blockchain technology inputs for the two actors, analyzes the dynamics of the system and the stability of the strategy through system simulation, and provides insights into relevant factors impacting the upstream and downstream behavior of agricultural product suppliers and processors. Xu Xiuchuan [10] and other scholars construct a three-party evolution game model involving the government, farmers, and consumers to explore the mechanism of green agriculture development. It is concluded that the government can maximize the benefits of green agriculture development by changing farmers' and consumers' preferences from the perspectives of material, beliefs, values, and mental models. Wang Xuping [11] and other scholars establish a network evolutionary game model for the upstream behavior of farmers and cooperatives. By employing evolutionary game theory to describe the decision-making mechanism of the game's main actors and utilizing complex networks to depict interactions within the system, the study comprehensively examines the influence of relevant factors on the upstream behavior of farmers and cooperatives.

While the aforementioned studies have contributed valuable insights, only a small number of scholars have applied evolutionary game theory to investigate the cooperative relationships between participating subjects such as farmers' markets, with even less research conducted on the agricultural supply chain involving entities such as large agricultural households, farmers' markets, and cooperative mechanisms. Furthermore, research on the recent emergence of these "large agricultural households" and their behavioral choices has been relatively limited. By employing an evolutionary game model, this study seeks to analyze the behavioral logic of participating subjects within the system, simulate and calculate the factors affecting the system's stability, and construct a behavioral game model for agricultural households and farmers' markets. This analysis will explore the behavioral evolution of participating subjects in reaching a stable state within the system, as well as the factors influencing their behavioral choices.

Compared to previous literature, this paper's major contributions lie in:

(1) Introducing the concept and nature of large agricultural households as a new participating entity, and investigating the game relationship and cooperation mechanism between these households and farmers' markets.

(2) Enhancing the realism of the game model by incorporating factors such as the cost of losing the opportunity for cooperation within farmers' markets, and the costs of providing additional services to attract large farmers. The study also analyzes the effects of parameter changes in costs and additional benefits on the evolutionary stability of both sides' strategies and equilibrium states.

3. Agricultural Products Circulation Model and the Behavior of Each Participating Subject Description

The agricultural product supply chain that encompasses large agricultural households is illustrated in Figure 1. Individual farmers engage in planting agricultural products and subsequently sell them to large agricultural households once they reach maturity. These large households procure significant quantities of agricultural products from farmers. As a consequence of their substantial purchases, there are fewer agricultural products available in the local market, thus resulting in a relative monopoly for these products by the large agricultural households.

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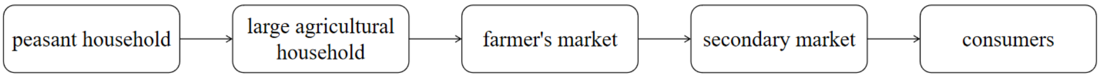

Figure 1: Agricultural supply chain flow diagram.

To maintain their brand value and ensure product integrity while avoiding any disadvantage in market competition resulting from a limited product range, farmers' markets employ strategies to attract and retain large agricultural households. This includes reducing the cost of stalls for these households or providing them with value-added services. Additionally, secondary markets may visit farmers' markets to purchase a diverse range of agricultural products in bulk and subsequently sell them to retail consumers in their own markets. It is worth noting that the agricultural products mentioned in this particular supply chain refer to cash crops that farmers can directly obtain through cultivation. Conversely, products such as rice and wheat, which have prices uniformly regulated by the state, are generally excluded.

The roles of the relevant subjects in this supply chain are positioned as follows:

Farmers: Farmers primarily engage in selling their agricultural products either wholesale or retail to large agricultural households. Depending on market price changes, they may also sell their remaining agricultural products in smaller markets instead of large farmers' markets.

Large Agricultural Household: These buyers concentrate on purchasing substantial quantities of specific agricultural products at specific locations. Following their purchases, they sell these products in large quantities at farmers' markets. Due to their substantial ownership of agricultural products, large agricultural households can create local monopolies for these products after achieving a significant scale.

Farmers' markets: These markets predominantly prioritize wholesale sales, with a smaller portion dedicated to retail. As farmers' markets strive to ensure the integrity of their agricultural products, they employ various means to attract and retain large agricultural households.

4. Evolutionary Game Model Construction

In aforementioned agricultural product circulation model, which involves farmers' markets and large agricultural households, the characteristics of large agricultural households, including their substantial quantity of agricultural products, imply a specific sales methodology, sales locations, and bargaining power. Consequently, attracting and retaining these large agricultural households has become crucial for enhancing the competitiveness of the farmers' market brand.

Based on the aforementioned scenario, this study presents the model assumptions and provides a description of the notation.

4.1. Model Assumptions and Explanations

Assumption 1: This study is grounded on the assumption of limited rationality, hypothesizing that the behavior of large agricultural households and farmers' markets is primarily driven by their own self-interests.

Assumption 2: It is assumed that large agricultural households possess a significant quantity of specific agricultural products, potentially even establishing a local monopoly to some extent. Farmers' markets depend on the opportunity to sell such agricultural products. If these large agricultural households choose not to sell their agricultural products at the farmers' market, there will be a shortage of these products, which would hinder the establishment of the farmers' market brand and hinder its market competitiveness.

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Assumption 3: It is assumed that the farmers' market discussed in this study is a large farmers' market. The profit model of this market relies on providing stalls, warehouses, quality testing, and other services to farmers and agricultural households, and collecting fees for stalls and additional services. In order to establish its brand value and enhance market competitiveness, the farmers' market may opt to offer more value-added services to large agricultural households or reduce the cost for these households in order to attract and retain them.

Hypothesis 4: It is hypothesized that there exists a probability, denoted as x, that a large agricultural household chooses to sell its agricultural products at the farmers' market. Conversely, there is a probability of 1-x that a large agricultural household chooses not to sell its agricultural products at the farmers' market. Additionally, the farmers' market has a probability denoted as y of choosing to reduce the cost for large agricultural households to attract them, and a probability of 1-y of choosing to provide value-added services to attract them.

Hypothesis 5: It is hypothesized that the behavioral strategy for large agricultural households choosing the farmers' market is denoted as 1, while the behavioral strategy for choosing other markets is represented as 0. Meanwhile, the farmers' market has a behavioral strategy of selecting 1 when it chooses to reduce the cost for large agricultural households to attract them, and a behavioral strategy of 0 when it selects to provide value-added services to attract them.

4.2. Explanation of Symbols and Parameters

(1) It is assumed that the base cost of large agricultural households is Ca1, which includes acquisition costs, facility and equipment costs, agricultural storage costs, and so on. The base gain of large agricultural households is Pa1, which refers to the revenue obtained when these households sell their agricultural products to sales channels, such as other farmers' markets, at market prices higher than the acquisition costs. However, the gain may be volatile and unstable.

(2) When a large agricultural household chooses to cooperate with the farmers' market, their costs increase to Ca1+Ca2. The cooperation cost Ca2 includes stall fees, costs associated with quality testing of agricultural products, storage costs, transportation costs, and other additional services. The gain for the large agricultural household becomes Pa1+Pa2, where the cooperation gain Pa2 refers to the value-added services provided by the farmers' market or the reduced costs.

(3) Assuming that when the large agricultural household chooses not to cooperate with the farmers' market, their costs increase to Ca1+Ca3. The additional costs Ca3 include expenses related to seeking other farmers' markets, negotiation time, stall fees, costs of quality testing of agricultural products, costs of additional services such as storage, and logistical costs. At this time, the income for the large agricultural household becomes Pa1+Pa3, where the other benefits Pa3 include additional costs provided by other markets to attract the large agricultural household. These additional benefits are also included in Pa2, which refers to the benefits brought by value-added services or reduced costs offered by the farmers' market.

(4) The base cost of the farmers' market is denoted as Cm1, which includes expenses for the construction of market sites, warehouses, equipment maintenance, and more. The gain for the farmers' market is denoted as Pm1, which includes basic stall fees and other additional service revenues.

(5) Assuming that the farmers' market reduces costs for large agricultural households to attract them, the cost for the farmers' market becomes Cm1+Cm2. The cooperation cost Cm2 includes expenses associated with reducing costs for large agricultural households. At this time, the revenue for the farmers' market becomes Pm1+Pm2. The cooperation gain Pm2 results from successfully attracting and retaining the large agricultural households, which enhances the market competitiveness and brand influence of the farmers' market and brings in additional revenue.

(6) Assuming that the farmers' market provides value-added services to attract large agricultural households, the cost for the farmers' market becomes Cm1+Cm3. The cooperation cost Cm3 includes

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expenses associated with providing value-added services to large agricultural households. The revenue for the farmers' market becomes Pm1+Pm3. The cooperation gain Pm3 results from successfully attracting and retaining the large agricultural households, enhancing the market competitiveness and brand influence of the farmers' market, and bringing in additional revenue from value-added services.

(7) Assume that when large agricultural households do not cooperate with the farmers' market, both parties incur certain losses. The loss for the large agricultural household, denoted as Ea, includes costs related to storage and product freshness, negotiation time, and costs associated with searching for other markets. The loss for the farmers' market, denoted as Em, includes the shortage of agricultural products in the market due to large agricultural households supplying these products elsewhere, leading to a decrease in consumer demand and potentially requiring the farmers' market to offer more favorable conditions to attract other agricultural farmers for cooperation.

Table 1: Description of symbols.

Symbol	Meaning
Ca1	Base costs of large agricultural households, including acquisition costs, facility and equipment costs, storage costs of agricultural products, and so on
Ca2	Cooperation costs when large agricultural households cooperate with farmers' markets
Ca3	Other costs when large agricultural households do not cooperate with farmers' markets
Pa1	Base income of large agricultural households
Pa2	Cooperative benefits of large agricultural households when they cooperate with farmers' markets
Pa3	Other benefits when large agricultural households do not cooperate with farmers' markets
Cm1	Base cost of farmers' markets
Cm2	Cost of cooperation when farmers' markets take a way to reduce the cost of large agricultural households to attract large agricultural households
Cm3	Cost of cooperation when farmers' markets provide value-added services to large agricultural households to attract them
Pm1	Base income of farmers' markets
Pm2	Benefits of cooperation when farmers' markets attract large farmers by lowering their costs
Pm3	Cooperative benefits when farmers' markets provide value-added services to large agricultural households to attract large agricultural households
Ea	Losses of large agricultural households when they do not cooperate with farmers' markets
Em	Losses of farmers' markets when large agricultural households do not cooperate with farmers' markets

4.3. Payment Matrix

Based on the assumptions and parameter descriptions mentioned above, the evolutionary game payoff matrix for both agricultural producers and farmers' markets can be obtained, as shown in Table 2.

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Table 2: Mixed strategy payoff matrix for both sides of the game.

Game Participants		Farmers' Markets	
		Reduce costs to attract large agricultural households (y)	Provide value-added services to attract large agricultural households (1-y)
Large agricultural household	Cooperation (x)	Pa1+Pa2-Ca1-Ca2;Pm1+Pm2-Cm1-Cm2	Pa1+Pa2-Ca1-Ca2;Pm1+Pm3-Cm1-Cm3
	Uncooperative (1-x)	Pa1+Pa3-Ca1-Ca3-Ea;Pm1-Cm1-Em	Pa1+Pa3-Ca1-Ca3-Ea;Pm1-Cm1-Em

5. Analysis of the Evolutionary Game Path and Stability of the Behavioral Subjects

In the evolutionary game, each participant continuously adjusts the probability values x and y a series of games to achieve evolution towards the optimal state. This process is referred to as the replication dynamic process. In this section, replication dynamic equations are utilized to investigate the evolutionary trends in strategy selection for the agricultural households and farmers' markets. This analysis aims to provide a foundation for examining the attainment of the optimal state later in the study.

5.1. Replication Dynamic Equations for Large Agricultural Households

The large agricultural households to choose "cooperation with the farmers' market" and "non-cooperation with the farmers' market" strategy when the expected return were recorded as U11 and U12, at this time, the average expected return of the large agricultural households were recorded as U1, then there are

$$U11 = y * (Pa1 + Pa2 - Ca1 - Ca2) + (1 - y) * (Pa1 + Pa2 - Ca1 - Ca2), \tag{1}$$

$$U12 = y * (Pa1 + Pa3 - Ca1 - Ca3 - Ea) + (1 - y) * (Pa1 + Pa3 - Ca1 - Ca3 - Ea), \tag{2}$$

$$U1 = x * U11 + (1 - x) * U12, \tag{3}$$

According to the Malthusian replication dynamic equation, the growth rate of the number of large agricultural households choosing the strategy of "cooperating with the farmers' market" is U11-U1, and the replication dynamic equation of large agricultural households under the continuation of time t is:

$$F(x) = dx/dt = x * (U11 - U1) = -x * (x - 1) * (Ca3 - Ca2 + Ea + Pa2 - Pa3), \tag{4}$$

5.2. Dynamic Equations for Farmers' Market Replication

The expected returns of the farmers' market when it chooses the strategies of "reducing costs to attract large farmers" and "providing value-added services to attract large farmers" are denoted as U21 and U22, respectively, and the average expected return of the large farmers at this time is denoted as U2, then there are

$$U21 = x * (Pm1 + Pm2 - Cm1 - Cm2) + (1 - x) * (Pm1 - Cm1 - Em), \tag{5}$$

$$U22 = x * (Pm1 + Pm3 - Cm1 - Cm3) + (1 - x) * (Pm1 - Cm1 - Em), \tag{6}$$

$$U2 = y * U21 + (1 - y) * U22, \tag{7}$$

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According to the Malthusian replication dynamic equation, the growth rate of the number of farmers' markets choosing the strategy of "reducing costs to attract large farmers" is U21-U2, and the replication dynamic equation of the farmers' markets under the continuation of time t is

$$F(y) = dy/dt = y * (U21 - U2) = x * y * (y - 1) * (Cm2 - Cm3 - Pm2 + Pm3), \quad (8)$$

5.3. Evolutionary Equilibrium Points As Well As Jacobi Matrix

The above replicated dynamic equation describes the dynamic adjustment process of the strategy choices of the large agricultural farmers and the farmers' market. Both parties reach a steady state in the process of continuous learning and imitation. The joint equation makes F(x) and F(y) equal to 0 at the same time, so that the three evolutionary game equilibrium points of the system can be solved as: O (1, 0), E (1, 1), G(0, 0).

According to the theory proposed by Friedman, the stability of each equilibrium point of the evolutionary game needs to be analyzed to determine the local stability of the Jacobi matrix of the system, then the replicated dynamic equations can be derived from the Jacobi matrix of the system as:

$$J = \begin{bmatrix} -x * (Ca3 - Ca2 + Ea - Pa3) & 0 \\ -(x-1) * (Ca3 - Ca2 + Ea - Pa3) & x * y * (Cm2 - Cm3 - Pm2 + Pm3) \\ y * (y-1) * (Cm2 - Cm3 - Pm2 + Pm3) & x * (y-1) * (Cm2 - Cm3 - Pm2 + Pm3) \end{bmatrix}, \quad (9)$$

Based on the local stability analysis of the Jacobi matrix, it can be seen that the equilibrium point of the dynamic equations is locally stable, i.e., the equilibrium point is the stabilization strategy of the evolution, if the traces of the matrix tr(J)<0 and the eigenvalues of the determinant of the matrix det(J)>0 are satisfied at the same time. Substituting each of the above three equilibrium points, the tr(J) and det(J) of this Jacobi matrix can be obtained, as shown in Table 3.

Table 3: Calculation of different traces Tr(J) and eigenvalues Det(J) of Jacobi matrix J.

Equilibrium	Tr(J)	Det(J)
E1(1,0)	(Ca2-Ca3-Ea-Pa2+Pa3)+(Cm3-Cm2+Pm2-Pm3)	(Ca2-Ca3-Ea-Pa2+Pa3)(Cm3-Cm2+Pm2-Pm3)
E2(1,1)	(Ca2-Ca3-Ea-Pa2+Pa3)+(Cm2-Cm3-Pm2+Pm3)	(Ca2-Ca3-Ea-Pa2+Pa3)(Cm2-Cm3-Pm2+Pm3)
E3(0,0)	(Ca3-Ca2+Ea+Pa2-Pa3)	0

5.4. Stability and Result Analysis of the Evolutionary Game Between Large Agricultural Households and Farmers' Markets

According to Table 3, the sign of Tr(J) and Det(J) of Jacobi matrix at each equilibrium point is calculated, from which the stability of each equilibrium point is judged, as shown in Table 4. Accordingly, the stability strategy situation of the system and the analysis of the factors affecting the cooperation between the two parties are shown in the conclusion.

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Table 4: Equilibrium Point Stability Analysis.

Condition	Equilibrium point	Tr(J)	Det(J)	Stability	Strategy combination
Pa3-Ca3-Ea<Pa2-Ca2 and Pm2-Cm2<Pm3-Cm3	E1(1,0)	-	+	ESS	(cooperation, providing value-added services)
Pa3-Ca3-Ea<Pa2-Ca2 and Pm3-Cm3<Pm2-Cm2	E2(1,1)	-	+	ESS	(cooperation, cost reduction)
Pa2-Ca2<Pa3-Ca3-Ea	E3(0,0)	-	0	instability	(no cooperation, provide value-added services)

As can be seen, E3 is not an evolutionarily stable strategy. The following discussion addresses the other 2 equilibria in turn.

5.4.1. E1 (1, 0)

At this stage, if the condition Pa3 - Ca3 - Ea < Pa2 - Ca2 is satisfied, it means that the profit for large agricultural households to choose not to cooperate with farmers' markets is lower than the profit for them to cooperate with farmers' markets. Consequently, large agricultural households are more likely to opt for cooperation with the farmers' market. This cooperative arrangement is beneficial for the farmers' market to establish a strong brand image and enhance its competitiveness in the market.

Similarly, if the condition Pm2 - Cm2 < Pm3 - Cm3 holds true, it indicates that the profit for the farmers' market to reduce the cost of large agricultural households is lower compared to the profit obtained by providing value-added services.

5.4.2. E2 (1, 1)

At this stage, if the condition Pa - Ca3 - Ea < Pa2 - Ca2 holds true, it means that the profit for large agricultural households choosing not to cooperate with the farmers' market is less than the profit for them to cooperate with the farmers' market. Therefore, large agricultural households are more likely to opt for cooperation with the farmers' market. This cooperative arrangement is beneficial for the farmers' market to establish a strong brand image and enhance its competitiveness in the market.

Similarly, if the condition Pm3 - Cm3 < Pm2 - Cm2 is satisfied, it indicates that the profit for the farmers' market to provide value-added services to large agricultural households is less compared to the profit obtained by reducing the cost for these households. As a result, the farmers' market tends to choose to reduce the cost of large agricultural households to attract and retain them.

6. Data Simulation Analysis

In this paper, simulations are conducted using MATLAB software. A set of parameter values is assumed, such as Pa2 = 40, Pa3 = 40, Ca2 = 8, Ca3 = 10, Ea = 5, Pm2 = 60, Pm3 = 62, Cm2 = 17, and Cm3 = 15. Initially, the probabilities for the large agricultural households and farmers' market are set to (0.5, 0.5). The simulation is performed over a time period of [0, 1]. The effect of changing each parameter on the system's evolutionary path is examined while keeping the other parameters constant.

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6.1. The Effect of Each Factor When Large Agricultural Households Do Not Cooperate with Farmers' Markets

6.1.1. The Impact of Other Benefits of Large Agricultural Households Pa3

In order to investigate the impact of different values for Pa3 on the strategy evolution of both parties when large agricultural households do not cooperate with the farmers' market, three are considered: Pa3 = 40, 47 and 55. The simulation results are displayed in Figure 2.

When Pa3 = 40, indicating a smaller value, it can be observed that the net benefit of cooperation (Pa3 - Ca3 - Ea) is greater than the net benefit of non-cooperation (Pa2 - Ca2). Consequently, large agricultural households tend to choose cooperation (1), i.e., to cooperate with the farmers' market. Furthermore, the farmers' market is inclined to choose the strategy of 0, aiming to attract cooperation from large agricultural households by providing them with value-added services. At this stage, the game system reaches a stable state.

In the case of Pa3 = 47, where the net benefit of cooperation and non-cooperation is equal (Pa3 - Ca3 - Ea = Pa2 - Ca2), the behavioral choice probabilities for large agricultural households remain neutral. Conversely, the farmers' market exhibits a tendency towards a behavioral choice probability of 0.1, indicating its preference to attract cooperation from large agricultural households by offering value-added services.

When Pa3 = 55, signifying a larger value, it can be observed that the net benefit of non-cooperation (Pa3 - Ca3 - Ea) surpasses the net benefit of cooperation (Pa2 - Ca2). Consequently, large agricultural households are more inclined to choose the strategy of 0, signifying non-cooperation with the farmers' market, while the farmers' market tends to choose the strategy of 0.4, aiming to attract large agricultural households through value-added services.

These results highlight that large agricultural households tend to cooperate with the farmers' market when the other benefits of not cooperating are smaller (Pa3 = 40). As a result, reducing the other benefits associated with non-cooperation can incentivize the establishment of a cooperative relationship between the two parties, leading to enhanced stability within the system.

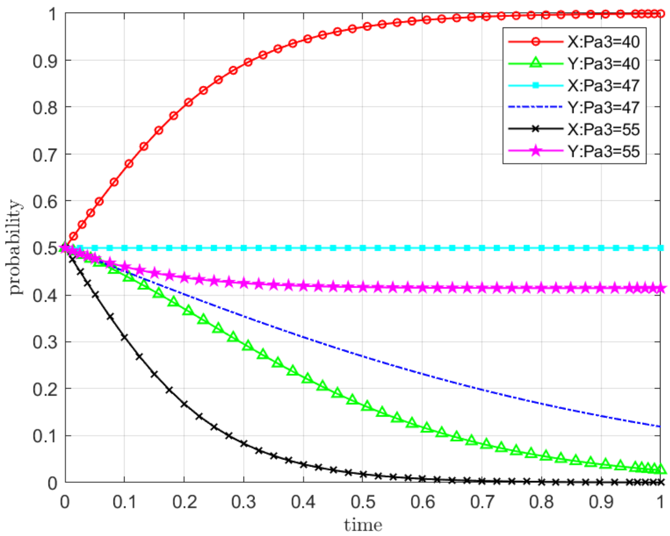

Figure 2: Impact of Other Benefits of Large Agricultural Households (Pa3) on Strategic Choices of Both Parties.

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6.1.2. Influence of Other Costs Ca3 of Large Agricultural Households.

To analyze the impact of different values for Ca3 on the stability of the system when large agricultural households do not cooperate with the farmers' market, three scenarios are considered: Ca3 = 0, 3, and 10. The simulation results are presented in Figure 3.

When Ca3 = 10, indicating larger costs, it can be observed that the net benefit of cooperation (Pa3 - Ca3 - Ea) is smaller than the net benefit of non-cooperation (Pa2 - Ca2). As a result, large agricultural households tend to choose cooperation (1), i.e., to cooperate with the farmers' market. Meanwhile, the farmers' market tends to choose the strategy of 0, aiming to attract large agricultural households through value-added services. At this stage, the game system reaches a stable state of (1, 0).

When Ca3 = 3, the net benefit of cooperation and non-cooperation is equal (Pa3 - Ca3 - Ea = Pa2 - Ca2). Consequently, the probability of the behavioral choice for large agricultural households remains neutral (0.5), while the behavioral choice for the farmers' market tends towards 0.1, indicating the farmers' market's intention to attract cooperation from large agricultural households through value-added services.

When Ca3 = 0, implying lower costs, the net benefit of non-cooperation (Pa3 - Ca3 - Ea) exceeds the net benefit of cooperation (Pa2 - Ca2). As a result, large agricultural households are more prone to choosing the strategy of 0, i.e., not cooperating with the farmers' market. At the same time, the farmers' market tends to choose a strategy of 0.3, which indicates a lower level of stability within the game system.

It can be concluded that when large agricultural households choose not to cooperate with the farmers' market, they are more likely to cooperate when the other costs (Ca3) are larger. Therefore, appropriately increasing the other costs for large agricultural households when they do not cooperate with the farmers' market aids in achieving a stable cooperative state of (1,0) within the system.

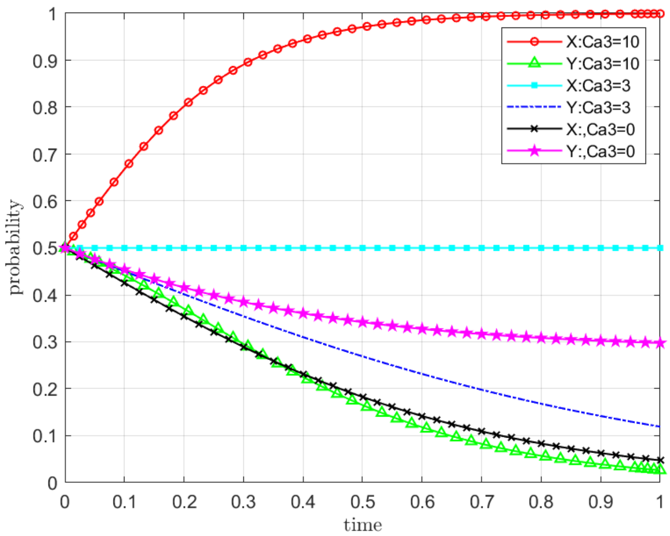

Figure 3: Impact of Other Costs of Large Agricultural Households (Ca3) on the Stability of the System.

6.1.3. The Effect of the Loss Ea of Large Agricultural Households

To investigate the impact of the magnitude of loss Ea for large agricultural households on the strategy evolution of both parties when these households do not with the farmers' market, three scenarios are examined: Ea = 5, 8, and 15. The simulation results are presented in Figure 4.

In all three scenarios, Ea = 5, 8, and 15, the behavioral choices of large agricultural households tend towards 1, while the behavioral choices of the farmers' market tend towards 0. In all cases, the system reaches a stable state, with large agricultural households choosing to cooperate with the

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farmers' market, and the farmers' market opting to attract these households by providing value-added services.

It can be observed that the magnitude of the loss Ea for large agricultural households has a limited influence on the strategy choices of both parties. However, in terms of the speed of reaching an evolutionary steady state, a larger loss Ea results in a faster convergence towards a cooperative strategy for both large agricultural households and the farmers' market. Therefore, appropriately increasing the loss Ea for large agricultural households can facilitate a quicker attainment of the steady state within the system.

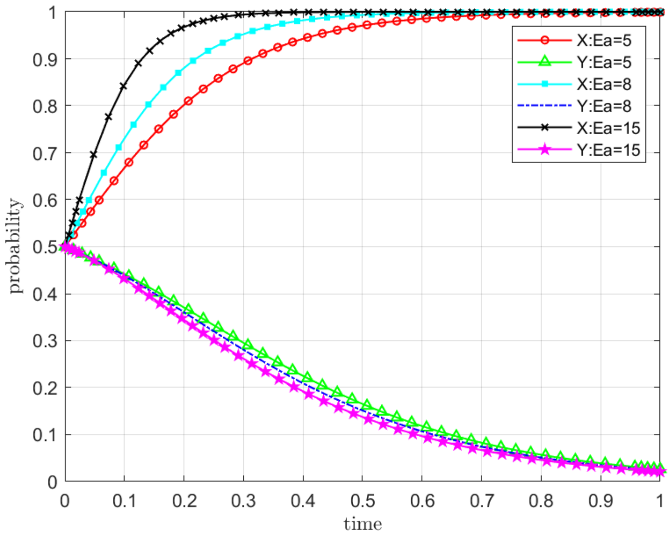

Figure 4: Impact of Loss (Ea) of Large Agricultural Households on Strategy Evolution.

6.2. The Influence of Factors When Large Agricultural Households Cooperate with Farmers' Markets

6.2.1. The Impact of the Agricultural Big Tenant's Gain Pa2

From Figure 5, it can be observed that when the large agricultural household cooperates with the farmers' market, the value of Pa2, which represents the cooperation benefit for large agricultural households, significantly influences the stability of the game system.

When Pa2 = 40, indicating larger benefits, it can be observed that the net benefit of cooperation (Pa3 - Ca3 - Ea) is smaller than the net benefit of non-cooperation (Pa2 - Ca2). Consequently, large agricultural households tend to choose cooperation (1), i.e., to cooperate with the farmers' market. Meanwhile, the farmers' market tends to choose the strategy of 0, aiming to attract large agricultural households by providing them with value-added services. At this stage, the game system reaches a stable state.

When Pa2 = 33, the net benefit of cooperation and non-cooperation is equal (Pa3 - Ca3 - Ea = Pa2 - Ca2). Consequently, the probability of the behavioral choice for large agricultural households remains neutral (0.5), while the behavioral choice for the farmers' market tends towards 0.1, indicating the farmers' market's intention to attract cooperation from large agricultural households through the provision of value-added services.

When Pa2 = 20, signifying lower benefits (Pm2 is small), the net benefit of non-cooperation (Pa3 - Ca3 - Ea) exceeds the net benefit of cooperation (Pa2 - Ca2). As a result, large agricultural households are more inclined to choose the strategy of 0, i.e., not to cooperate with the farmers' market, while the farmers' market tends to choose 0.4. At this stage, the stability of the game system is compromised.

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In conclusion, if large agricultural households choose to cooperate with the farmers' market, they are more likely to do so when their benefits are higher (Pa2 = 40). Therefore, appropriately increasing the benefits of cooperation for large agricultural households helps the system achieve a stable state of cooperation (1,0). In turn, the farmers' market is inclined to provide value-added services to retain large agricultural households. This optimal scenario maximizes the interests of all parties involved.

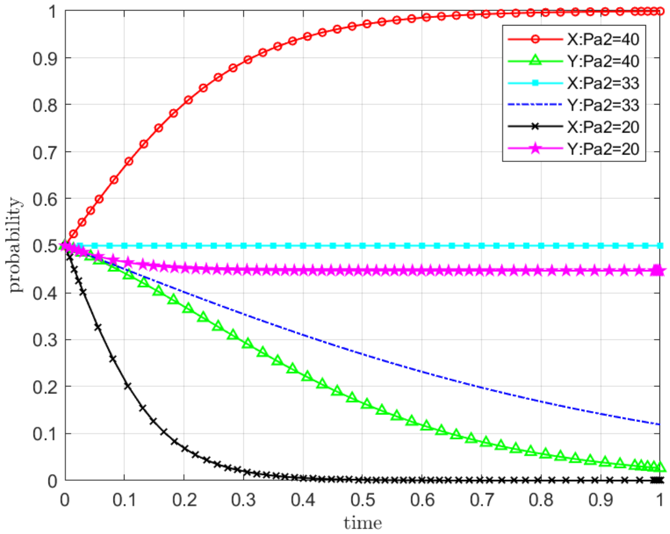

Figure 5: Impact of Pa2 (Cooperation Benefit for Large Agricultural Households) on Strategic Choices of Both Parties.

6.2.2. The Effect of the Cost of Large Agricultural Households Ca2

In order to analyze the impact of the cost for large agricultural households on the strategy evolution of both parties when the large agricultural household cooperates with the farmers' market, three scenarios are examined: Ca2 = 8, 15, and 20. The simulation results are illustrated in Figure 6.

When Ca2 = 8, indicating a smaller cost, the net benefit of cooperation (Pa3 - Ca3 - Ea) is greater than the net benefit of non-cooperation (Pa2 - Ca2). As a result, large agricultural households tend to choose cooperation (1), i.e., to cooperate with the farmers' market. Additionally, the farmers' market tends to choose the strategy of 0, aiming to attract large agricultural households by providing value-added services. At this stage, the game system reaches a stable state.

When Ca2 = 15, the net benefit of cooperation and non-cooperation is equal (Pa3 - Ca3 - Ea = Pa2 - Ca2). Consequently, the probability of the behavioral choice for large agricultural households remains neutral. Conversely, the behavioral choice for the farmers' market tends towards 0.1, indicating the farmers' market's intention to attract cooperation from large agricultural households by providing value-added services.

When Ca2 = 20, indicating a larger cost, the net benefit of non-cooperation (Pa3 - Ca3 - Ea) exceeds the net benefit of cooperation (Pa2 - Ca2). In this scenario, large agricultural households tend to choose the strategy of 0, i.e., not to cooperate with the farmers' market, while the farmers' market tends to choose a strategy of 0.4, implying the farmers' market's inclination to provide value-added services to attract large agricultural households.

It can be observed that when the cost of cooperation for large agricultural households is smaller, they tend to cooperate with the farmers' market. Therefore, reducing the cost of cooperation for large agricultural households can facilitate the establishment of a cooperative relationship between the two parties and improve the stability of the system.

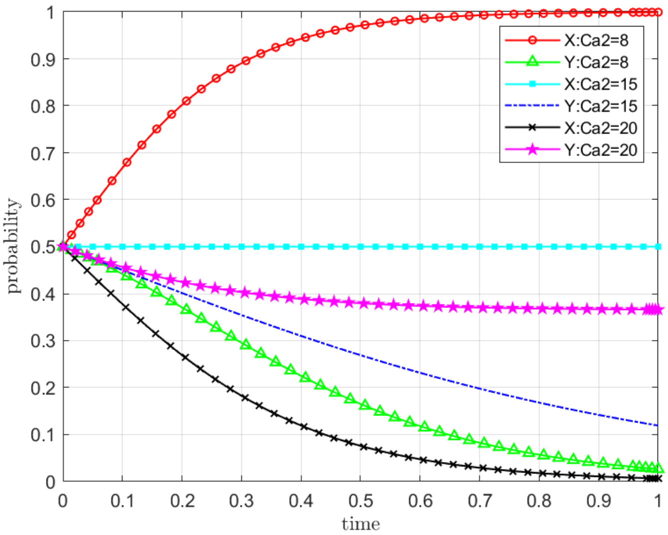

Figure 6: Impact of Cooperation Cost (Ca2) for Large Agricultural Households on Strategic Choices of Both Parties.

6.3. Influence of Factors When Farmers' Markets Choose to Reduce Costs to Attract Large Agricultural Farmers

6.3.1. The Impact of the Farmers' Market's Cooperation Benefit Pm2

In order to analyze the impact of different values for Pm2, the cooperative gain for the farmers' market, on the strategy evolution of both parties when the farmers' market chooses to reduce costs to attract large agricultural households, three scenarios are considered: Pm2 = 60, 64, and 77. The simulation results are shown in Figure 7.

When Pm2 = 60, indicates a smaller value, it can be observed that the net benefit of the farmers' market choosing to reduce costs for large agricultural households (Pm2 - Cm2) is smaller than the net benefit of choosing to provide value-added services (Pm3 - Cm3). As a result, the choice of large agricultural households tends towards 1, i.e., to cooperate with the farmers' market. Additionally, the choice of the farmers' market tends towards 0, indicating their preference for attracting large agricultural households by reducing costs.

When Pm2 = 64, the net benefit of reducing costs for large agricultural households (Pm2 - Cm2) is equal to the net benefit of providing value-added services (Pm3 - Cm3). Consequently, the probability of the behavioral choice for both large agricultural households and the farmers' market remains neutral. However, the choice of the farmers' market tends towards 1, indicating a propensity to attract large agricultural households by reducing costs.

When Pm2 = 77, indicating larger benefits, the net benefit of reducing costs for large agricultural households (Pm2 - Cm2) exceeds the net benefit of providing value-added services (Pm3 - Cm3). As a result, the choice of large agricultural households tends towards 1, i.e., to cooperate with the farmers' market. Meanwhile, the choice of the farmers' market tends towards 1 as well, expressing a desire to attract large agricultural households by reducing costs.

It can be observed that when the farmers' market chooses to reduce costs to attract large agricultural households, the magnitude of the cooperative gain Pm2 significantly influences the stability of the game system. Enhancing cooperation between the farmers' market and large agricultural households helps improve the market competitiveness and brand effect of the farmers' market, and also contributes to the establishment of a stable cooperative relationship between the two parties, thereby enhancing the overall stability of the system.

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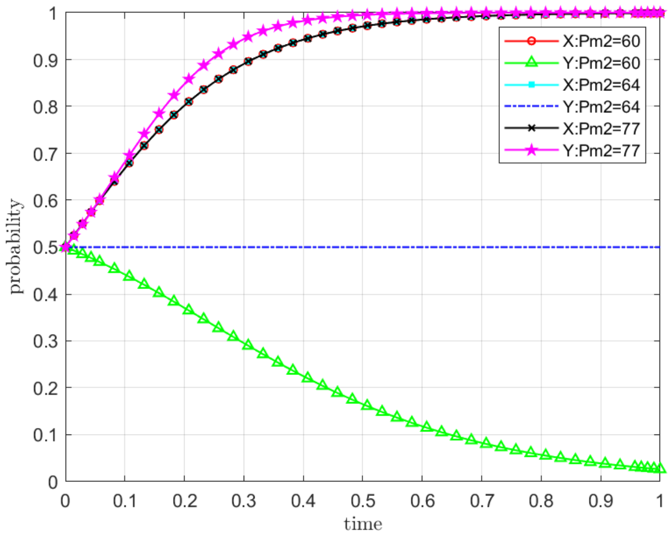

Figure 7: Impact of Cooperative Gain (Pm2) for the Farmers' Market on Strategic Choices of Both Parties.

6.3.2. The Impact of the Farmers' Market's Cooperation Cost Cm2

In order to analyze the impact of cooperation cost size on the strategy evolution of both parties when the farmers' market reduces the cost to attract large agricultural households, simulations were conducted with different values of cooperation cost (Cm2 = 5, 13, 17). The results are presented in Figure 8.

When Cm2=17 (i.e., when Cm2 is larger), the farmers' market attracts large agricultural households by reducing their cost. In this case, Pm2-Cm2<Pm3-Cm3, indicating that the net benefit for large agricultural households to cooperate with the farmers' market is higher than that of pursuing individual strategies. Consequently, the choice of large agricultural households tends to be 1, i.e., to cooperate with the farmers' market. On the other hand, the farmers' market tends to choose 0, i.e., to attract large agricultural households by providing value-added services.

When Cm2=13, (i.e., when Pm2-Cm2=Pm3-Cm3), the net benefit for the farmers' market to reduce the cost of attracting large agricultural households and providing value-added services is the same. Therefore, the farmers' market remains neutral in its choice at this point, resulting in a non-linear relationship between the cooperation benefit of large agricultural households and the farmers' market, and the evolution path of the two parties' strategies.

When Cm2=5 (i.e., when Cm2 is small), Pm2-Cm2>Pm3-Cm3. This implies that the net benefit for large agricultural households to cooperate with the farmers' market is higher than that of pursuing individual strategies. Consequently, the choice of large agricultural households tends to be 1, i.e., to cooperate with the farmers' market. Meanwhile, the farmers' market tends to choose 1, i.e., to attract large agricultural households by reducing their cost.

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It can be inferred that when the farmers' market aims to reduce the cost of attracting large agricultural households, it is more inclined to choose this approach when the cooperation cost is smaller. By reducing the cooperation cost between farmers' markets and large agricultural households, the probability of cooperation between the two parties can be enhanced. Moreover, it also helps enhance the competitiveness of farmers' markets.

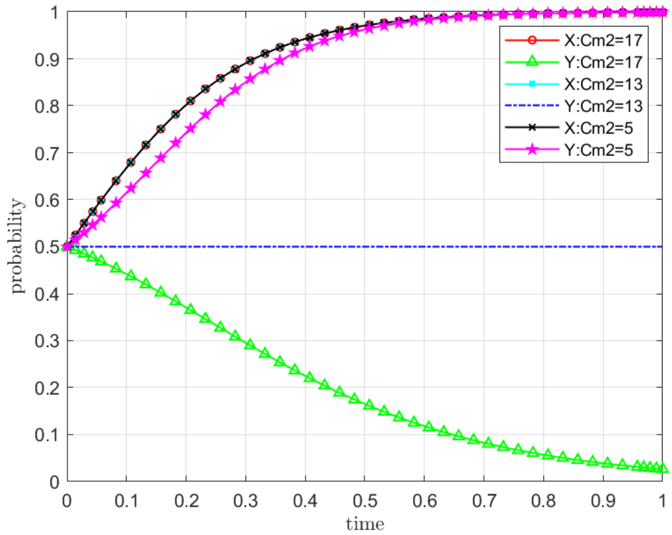

Figure 8: Impact of Cooperation Cost (Cm2) for the Farmers' Market on Strategic Choice of Both Parties.

6.4. The Impact of Factors When Farmers' Markets Choose to Provide Value-Added Services to Attract Large Agricultural Households

6.4.1. Influence of Farmers' Market's Cooperation Benefit Pm3

In order to analyze the impact of the cooperative gain of the farmers' market on the strategy evolution of both parties, simulations were conducted with different values of cooperative gain (Pm3 = 50, 58, 62). The results are presented in Figure 9.

When Pm3=62 (i.e., when Pm3 is larger), the net benefit for large agricultural households to cooperate with the farmers' market (Pm2-Cm2) is smaller than the net benefit provided by the farmers' market for their cooperation (Pm3-Cm3). Consequently, large agricultural households are more likely to choose strategy 1, i.e., to cooperate with the farmers' market. On the other hand, the farmers' market tends to choose strategy 0, i.e., to attract large agricultural households by providing value-added services.

When Pm3=58 (i.e., when Pm2-Cm2=Pm3-Cm3), the net benefit for the farmers' market to reduce the cost of attracting large agricultural households and providing value-added services is equivalent. Therefore, the farmers' market remains neutral in its choice, resulting in a non-linear relationship between the cooperation benefits of large agricultural households and the farmers' market, as well as the evolution path of their strategies.

When Pm3=50 (i.e., when Pm3 is smaller), the net benefit for large agricultural households to cooperate with the farmers' market (Pm2-Cm2) is higher than the net benefit provided by the farmers' market for their cooperation (Pm3-Cm3). Consequently, large agricultural households tend to choose strategy 1, i.e., to cooperate with the farmers' market. At the same time, the farmers' market also tends to choose strategy 1, i.e., to attract large agricultural households by reducing their cost.

It is evident that when the farmers' market decides to provide value-added services to attract large agricultural households, a higher cooperative gain encourages the farmers' market to adopt this approach. Increasing the cooperative revenue between the farmers' market and large agricultural households helps to enhance the motivation for cooperation. Additionally, when the farmers' market provides value-added services to large agricultural households, it facilitates the expansion of farmers, agricultural wholesalers, and other participants in the agricultural supply chain. This, in turn, promotes market competitiveness and establishes the brand effect of the farmers' market. Moreover, it fosters stable cooperative relationships between the two parties and improves the overall system stability.

In summary, understanding the influence of the cooperative gain on strategy choices is vital for optimizing the cooperation between large agricultural households and farmers' markets. By adjusting the cooperative gain, both parties can enhance cooperation enthusiasm, extend cooperation to other participants in the agricultural supply chain, improve market competitiveness, and establish stable and mutually beneficial relationships, thereby ensuring system stability.

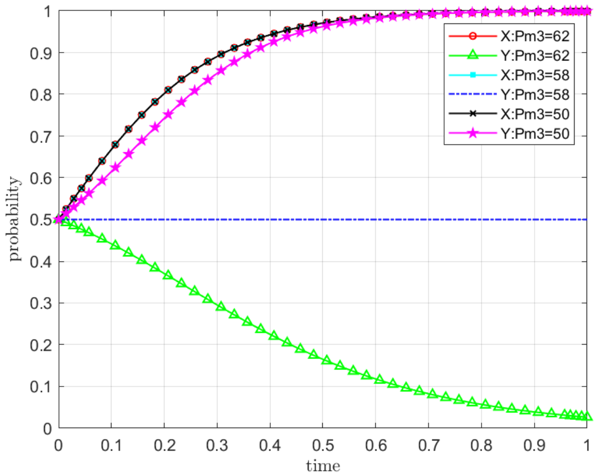

Figure 9: The Influence of Farmers' Market's Cooperative Gain (Pm3) on Strategy Choices of Both Parties.

6.4.2. Impact of Farmers' Market's Cooperation Cost Cm3

To the impact of cooperation cost size on the strategy evolution of both parties when the farmers' market provides value-added services to attract large agricultural households, simulations were conducted with different values of cooperation cost (Cm3 = 15, 19, 25). The results are presented in Figure 10.

When Cm3=15 (i.e., when the cooperation cost is smaller), the net benefit for large agricultural households to cooperate with the farmers' market (Pm2-Cm2) is smaller than the net benefit provided by the farmers' market for their cooperation (Pm3-Cm3). Consequently, large agricultural households are more likely to choose strategy 1, i.e., to cooperate with the farmers' market. On the other hand, the farmers' market tends to choose strategy 0, i.e., to attract large agricultural households by providing value-added services.

When Cm3=19 (i.e., when Pm2-Cm2=Pm3-Cm3), the net benefit for the farmers' market to reduce the cost of attracting large agricultural households and providing value-added services is equivalent. Therefore, the farmers' market remains neutral in its choice, leading to a non-linear relationship between the cooperation benefit of large agricultural households and the farmers' market, as well as the evolution path of their strategies.

When Cm3=25 (i.e., when the cooperation cost is larger), the net benefit for large agricultural households to cooperate with the farmers' market (Pm2-Cm2) is higher than the net benefit provided by the farmers' market for their cooperation (Pm3-Cm3). Consequently, large agricultural households

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tend to choose strategy 1, i.e., to cooperate with the farmers' market. At the same time, the farmers' market also tends to choose strategy 1, i.e., to attract large agricultural households by reducing their cost.

It is evident that when the farmers' market provides value-added services to large agricultural households, a lower cooperation cost encourages the farmers' market to adopt this approach. By reducing the cooperation cost between farmers' markets and large agricultural households, the farmers' market can increase the probability of cooperation with large agricultural households and enhance its competitiveness. Furthermore, when the farmers' market provides value-added services to large agricultural households, it facilitates the expansion of the farmers' market to include more participants in the agricultural supply chain, ultimately establishing and enhancing the brand effect of the farmers' market.

Therefore, establishing a stable development mechanism that involves the concerted participation of multiple stakeholders requires collective efforts from large agricultural households and farmers' markets. Large agricultural households must consider both economic and development benefits, maximizing their interests through stable and sufficient agricultural production and collaborations with farmers' markets. Additionally, farmers' markets should focus on improving standardized operations, assisting large agricultural households in renting stalls at reasonable prices to reduce operating costs, and providing support to enhance the value of agricultural products. Stable cooperation between large agricultural households and farmers' markets contributes to the mature operation of large agricultural households and enhances the market competitiveness and brand value of farmers' markets.

Moreover, forming a stable supply chain between the two parties enhances their ability to withstand risks, provides emergency protection in public welfare functions, and leverages the agility of the supply chain to respond swiftly during extraordinary times.

Currently, the cooperative relationship between large agricultural households and farmers' markets in China mainly revolves around leasing. Farmers' markets adopt different means to attract stable large agricultural households. However, in the future, to establish a stable long-term cooperation and form a closer supply chain, both parties may adopt a joint business approach. This approach would involve large agricultural tenants becoming part of the farmers' market and enjoying substantial profits, while the farmers' market strengthens its brand competitiveness and gains a stronger market position.

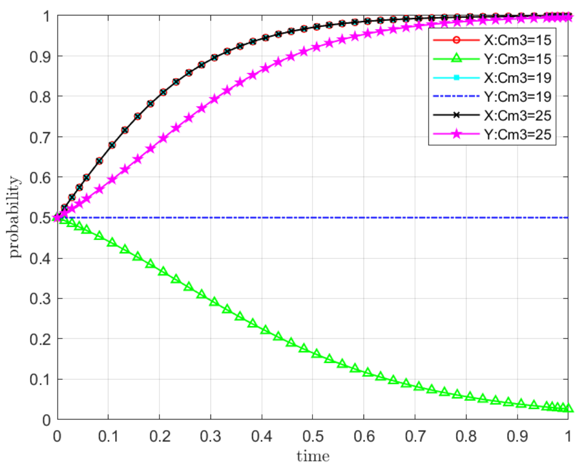

Figure 10: The Influence of Farmers' Market's Cooperation Cost (Cm3) on Strategy Choices of Both Parties.

7. Conclusion

The emergence of large agricultural households in the agricultural product circulation market has injected new vitality into the environment due to their significant volume of agricultural products. As a result, farmers' markets make efforts to attract and retain large agricultural households to sell their agricultural products, aiming to ensure the integrity of the products sold. Simultaneously, large agricultural households assess the costs and benefits of collaborating with farmers' markets.

The presence of large agricultural households has diversified the distribution channels of agricultural products and has impacted the operation of farmers' markets. These households purchase agricultural products from retail farmers, enabling them to accumulate a considerable quantity of agricultural goods and eventually dominate a specific category of products within a smaller area. Consequently, large agricultural households assess the costs and benefits of entering into a cooperative relationship with farmers' markets while considering their own developmental prospects based on the conditions offered by the market.

The parameters of participants' interests significantly influence the evolution of the agricultural supply chain system. Specifically, the benefits and costs of cooperation between large agricultural households and farmers' markets, the benefits, costs, and losses incurred from non-cooperation, and the benefits and costs associated with farmers' markets choosing to reduce costs or provide value-added services to large agricultural households all impact the decision-making process of both parties. Considering the stabilization strategies and factors affecting large agricultural households, it can be inferred that higher cooperation benefits and lower costs between large agricultural households and farmers' markets will lead to the attainment of an ideal state within the system.

This research is based on the assumption that both large agricultural households and farmers' markets have limited rationality. However, in real life, decision-making is often influenced by various factors, including market demand fluctuations, policy changes, technological innovations, and shifting consumer preferences. Large agricultural households and farmers' markets may consider these factors comprehensively during their decision-making processes, responding and adapting to changes through market research, adjusting product variety and quality, and optimizing the supply chain.

In the future, it is anticipated that the aforementioned influencing factors will be incorporated to further explore the cooperation patterns and strategies between large agricultural households and farmers' markets. Additionally, the study can delve into the bi-directional cooperation between large agricultural households and farmers' markets, where large agricultural households engage in market operation and management activities in addition to selling agricultural products. Furthermore, other participants in the agricultural supply chain, such as wholesalers, retailers, and consumers, can be examined comprehensively. Considering all parties' interests parameters aims to create a more efficient, fair, and sustainable environment for the distribution of agricultural products.

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