

An Evolutionary Game Model for Quality Control of Agricultural Supermarket Matched Supply Chain with Government Participation

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Abstract. Based on the basic problems such as the motivation of the quality and safety management and control of the agricultural supermarket docking supply chain, this paper studies the game behavior of the three parties involved in the agricultural professional cooperatives, large chain supermarkets and government regulatory departments in the agricultural supermarket docking supply chain under the influence of government participation. To build a three-party evolutionary game model for the quality and safety management and control of agricultural supermarket docking supply chain with the participation of the government, the goal is to find a stable strategy for the game parties to maintain cooperation, so as to ensure the safety of agricultural supermarket docking supply chains.

1. Introduction

Under the guidance of the national policy of "rural revitalization and quality promotion of agriculture", agriculture-supermarket docking supply chain model is an innovative cooperative relationship between retail and supply of agricultural products [1]. The quality and safety of agricultural products is an important part of agricultural modernization [2-3]. The academic and industrial circles at home and abroad have done a lot of theoretical and practical exploration on the issues related to the docking of agricultural supermarket supply chain [4-7]. Based on evolutionary game theory, some scholars have carried out various researches on the supply chain of agricultural supermarket docking [8-10]. In general, many researchers have carried out extensive and targeted in-depth research and analysis on the quality control means and relevant game methods of agricultural supermarket docking supply chain under different situations and conditions. In the actual operation process of agricultural supermarket docking supply chain quality control, the behavior choices of relevant government regulatory departments have an important impact on the behavior of all parties in the game of agricultural product quality management under the mode of agricultural supermarket docking supply chain. Therefore, this paper describes the evolutionary game process of the quality and safety management and control of agricultural supermarket docking supply chain under the influence of government participation, and analyzes the complex game relationship between agricultural professional cooperatives, large supermarket chains and government regulatory departments in detail. The research goal is to reveal the root causes of the quality and safety problems of the supply chain of agricultural supermarket docking.

2. Problem description

From the perspective of government supervision, the first consideration for the generation, operation and promotion of the supply chain mode of agricultural supermarket docking is to improve the quality and safety of agricultural products, enrich the types of agricultural products and ensure the freshness of fresh agricultural products.

2.1 Game subject hypothesis

Three-party game. Considering the participation of the government, the relevant players of the quality and safety management and control of the supply chain of agriculture-supermarket docking based on the evolutionary game theory are selected as follows: the government supervision department group, the agricultural professional cooperative group, and the large chain supermarket group.

Bounded rationality. The management and control of the quality and safety of agricultural products involves multiple links, and is a systematic project that requires the input of human, material and financial resources from the agricultural professional cooperative group, the large chain supermarket group and the government supervision department group. Due to the limitations of information, environment, knowledge level and other factors, all participants in the supply chain cannot be completely rational.

Learning ability. Because the agricultural professional cooperative group and the large chain supermarket group are bounded rational, the

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evolutionary stable equilibrium in the process of agricultural supermarket docking supply chain generation is not the result of a single choice. The game subjects will achieve the final stable equilibrium state through constant and repeated adjustment, improvement, readjustment and improvement.

2.2 Game process assumptions

Complexity. As a group of agricultural professional cooperatives in the supply chain, agricultural supermarket is a non-governmental organization formed by different farmers spontaneously or through contractual relationship. The limitations of its members' operation and management level and the limitations of production technology capabilities lead to complex interest relations within the group of agricultural professional cooperatives. In addition, the policy supervision and management system of the corresponding government supervision departments and the principal-agent relationship of the third-party professional testing institutions, as well as the relevant mechanisms and even laws and regulations are not perfect. Therefore, the multiple game process between the government supervision department group and the agricultural professional cooperative group and the large chain supermarket group has certain complexity.

Long-term dynamics. There are many links in the operation of the supply chain of the agricultural supermarket, and the participants are complex. There is information asymmetry in all parts of the participants. This determines that the game between the agricultural professional cooperative group and the large chain supermarket group in the supply chain of agricultural supermarket docking is not a short-term and one-time game, but a long-term and repeated game.

3. Parameter setting

3.1 Game subject

The government supervision department group, the agricultural professional cooperative group and the large chain supermarket group jointly constitute the three sides of the game. It is also assumed that the agricultural professional cooperative group and the large chain supermarket group are enterprises in a completely competitive market. In addition, the three parties are randomly matched and play games repeatedly.

3.2 Policy collection

Agricultural professional cooperative strategy (high quality, low quality), large-scale supermarket chain strategy (inspection, no inspection), government regulatory department strategy (incentive, punishment).

1) For the agricultural professional cooperative group, they have the ability to provide, manage and control the quality of fresh agricultural products, so the strategic choice of the agricultural professional cooperative group

is (high quality, low quality). The strategy adopted by agricultural professional cooperatives (high quality, low quality) depends on the cost of punishment and the benefits obtained from the management and control of agricultural product quality and the provision of quality and safety agricultural products under the group policy supervision and technical supervision of the government regulatory department. For the agricultural professional cooperative group, the strict punishment system with the participation of the government supervision department group is positively related to whether the agricultural professional cooperative group provides high-quality and safe agricultural products. However, the relationship between the expected profits of low-quality agricultural products provided by agricultural professional cooperative groups and the expected costs of providing high-quality and safe agricultural products (high-quality agricultural products) is negatively related.

2) For the large supermarket chain enterprise group, there are two strategies, namely, willingness to manage and control the quality of agricultural products (defined here as "inspection" strategy) and refusal to manage and control the quality of agricultural products (defined here as "no inspection" strategy). For the large chain supermarket group, the practical performance of the participation of government regulatory departments in the quality control of the agricultural supermarket supply chain is the probability of implementing incentive and punishment strategies, as well as the benefits and costs obtained during the daily operation and management of the large chain supermarket stores. This is an important basis for the organizational behavior decision-making of the large chain supermarket. The operation mechanism of the daily quality management and control of agricultural products implemented by the large chain supermarket group through advanced and efficient "inspection" means is negatively related to the cost of the daily quality management and control of agricultural products rejected by the large chain supermarket group. When the large chain supermarket group implements the daily quality management and control of agricultural products, and once the unsafe agricultural products supplied by the large chain supermarket flow into the hands of end consumers. As a result of trust disputes and civil problems, the penalty cost and various benefits of the large supermarket chain are positively correlated.

3) For the group of government supervision departments, their strategy choices are incentive strategy and punishment strategy. The final strategic choice of the government regulatory group is to ensure the well-being of the people and improve the credibility of the government, which belongs to public benefits. For the convenience of research, the third party testing agency entrusted by the government is integrated into the category of the government regulatory group. The government supervision departments should strengthen the system and mechanism construction of quality and safety management and control of agricultural supermarket supply chain to ensure the quality and safety of agricultural products in the whole circulation process.

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3.3 Order of action

Because the game subjects only have limited rationality and repeated games, and because there is still competition among the game subjects, the speed of learning among the three parties of the game is relatively slow, so the speed of strategy adjustment is expressed by copying the dynamic equation.

3.4 Specific parameters

Suppose that the probability of agricultural professional cooperative group choosing to provide high-quality agricultural products strategy is x , and the probability of choosing to provide low-quality agricultural products strategy is $1 - x$; Similarly, the probability of large chain supermarket groups willing to manage and control the quality of agricultural products is y , the probability of refusing to manage and control the quality of agricultural products is $1 - y$, the probability of government regulatory departments selecting incentive strategies is z and the probability of corresponding punishment strategies is $1 - z$, and $0 \leq x, y, z \leq 1$.

When the agricultural professional cooperative group chooses to provide the low-quality agricultural product strategy, the basic income is π_1 and the basic income of the large chain supermarket group choosing to refuse to manage and control the agricultural product quality strategy is π_2 . If the agricultural professional cooperative group chooses to provide the high-quality agricultural product strategy, it will have to pay the corresponding cost c_1 . When large supermarket chains choose to manage and control the quality of agricultural products, they also have to pay the corresponding cost, which is expressed as c_2 .

After the agricultural professional cooperative group and the large chain supermarket group have strictly managed and controlled the quality of agricultural products, the consumers have obtained high-quality products, the agricultural professional cooperative group and the large chain supermarket group have improved their credibility, brand image, and the agricultural supermarket docking project has been recognized by the public. At this time, the agricultural professional cooperative group and the large chain supermarket group have obtained additional income of $\Delta\pi_1$ and $\Delta\pi_2$ respectively. The basic income obtained by the government supervision department group in the connection of agricultural supermarket is π_3 . When the agricultural professional cooperative group and the large chain supermarket group establish a stable monitoring relationship of agricultural product quality, the overall efficiency of the supply chain system of agricultural supermarket connection is improved, the government credibility is improved, and additional public income $\Delta\pi_3$ can be obtained.

In order to maintain the stability of the supply chain partnership between the agricultural supermarket and the supermarket, the government supervision department group gives corresponding incentive strategies to the agricultural professional cooperative group that provides high-quality agricultural products and the large chain supermarket group that is willing to manage and control the quality of agricultural products, namely, the fund subsidy a_1 and a_2 . The agricultural professional cooperative groups that provide low-quality agricultural products and the large chain supermarket groups that refuse to manage and control the quality of agricultural products will be given corresponding punishment strategies, that is, the amount of punishment generated will be f_1 and f_2 .

4. Model construction

4.1 Payment Matrix

Establish the payment matrix of tripartite evolutionary game income of agricultural professional cooperative group, large chain supermarket group and government regulatory department group, and the specific information is shown in Table 1.

Table 1. Payment Matrix of Tripartite Game

		Government supervision department			
		Encourage (z)		Punish ($1 - z$)	
		Large chain supermarkets			
		Inspect (y)		No-inspect ($1 - y$)	
Agricultural professional cooperatives	High-quality (x)	$\pi_l + \Delta\pi_l - c_l + a_l$	$\pi_l - c_l + a_l$	$\pi_l + \Delta\pi_l - c_l$	$\pi_l - c_l$
		$\pi_2 + \Delta\pi_2 - c_2 + a_2$	$\pi_2 - f_2$	$\pi_2 + \Delta\pi_2 - c_2$	π_2
		$\pi_3 - a_1 - a_2 + \Delta\pi_G$	$\pi_3 - a_1 + f_2$	$\pi_3 + \Delta\pi_G$	π_3
	Inferior quality ($1 - x$)	$\pi_l - f_l$	$\pi_l - f_l$	π_l	π_l
		$\pi_2 - c_2 + a_2$	$\pi_2 - f_2$	$\pi_2 - c_2$	π_2
		$\pi_3 - a_2 + f_l$	$\pi_3 + f_l + f_2$	π_3	π_3

$$\begin{cases} F(x) = 0 \\ \frac{\partial F(x)}{\partial x} < 0 \end{cases}; \quad \begin{cases} F(y) = 0 \\ \frac{\partial F(y)}{\partial y} < 0 \end{cases}; \quad \begin{cases} F(z) = 0 \\ \frac{\partial F(z)}{\partial z} < 0 \end{cases}$$

4.2 Dynamic replication equation

After calculating and sorting out the expected income of the agricultural professional cooperative group when adopting the strategy of providing high-quality agricultural products, we can get the dynamic replication equation of the evolutionary game of the agricultural professional cooperative group, the large chain supermarket group, and the government regulatory department group, which are respectively expressed as follows.

$$F(x) = x(1-x)[\Delta\pi_1 y + (a_1 + f_1)z - c_1]$$

$$F(y) = y(1-y)[\Delta\pi_2 x + (a_2 + f_2)z - c_2]$$

$$F(z) = z(1-z)[(-a_1 - f_1)x + (-a_2 - f_2)y + f_1 + f_2]$$

According to the stability theorem of the differential equation and the nature of the evolution strategy, the dynamic equation of the agricultural professional cooperative group, the large chain supermarket group and the government supervision department group is solved by copying the dynamic equation. If a game subject wants to reach the state of the evolution stable strategy, the probability of the agricultural professional cooperative group, the large chain supermarket group and the government supervision department group adopting the strategy is x , y , z . At this time, the following conditions need to be met:

4.3 Strategy analysis

(1) strategy analysis of agricultural professional cooperatives

When $F(x)$ is equal to 0, $y^* = \frac{c_1 - (a_1 + f_1)z}{\Delta\pi_1}$ is obtained.

1) When $y = y^*$, it is stable for all x .

2) When $y \neq y^*$, assuming $F(x) = 0$, it is concluded that $x = 0$ or $x = 1$ is the stable state of the agricultural professional cooperative group, and the derivative of $F(x)$ is obtained, which can be divided into two situations:

First, when $y > y^*$, $\frac{\partial F(x)}{\partial x}(x=1) < 0$, $\frac{\partial F(x)}{\partial x}(x=0) > 0$, so $x = 1$ is the balance point, that is, the decision of agricultural professional cooperative groups to provide high-quality agricultural products.

Second, when $y < y^*$, $\frac{\partial F(x)}{\partial x}(x=1) > 0$, $\frac{\partial F(x)}{\partial x}(x=0) < 0$, so $x = 0$ is the balance point, that is, the decision of agricultural professional cooperative groups to provide low-quality agricultural products.

When the agricultural professional cooperative group chooses to provide low-quality agricultural products strategy, that is, there is $0 < y < y^* < 1$. If the

government supervision department group adopts punishment mechanism, such as increasing fines, or adopts incentive mechanism, such as increasing subsidies, to maintain the quality management and control of the supply chain of agricultural supermarkets, the situation of $0 < y^* < y < 1$ will occur, Then the agricultural professional cooperative group will evolve from the strategy of providing low-quality agricultural products to the strategy of providing high-quality agricultural products.

(2) Stability strategy analysis of large chain supermarkets

When $F(y)$ is equal to 0, $x^* = \frac{c_2 - (a_2 + f_2)z}{\Delta\pi_2}$ is obtained.

1) When $x = x^*$, it is stable for all y .

2) When $x \neq x^*$, assuming $F(y) = 0$, it is concluded that $y = 0$ or $y = 1$ is the stable state of the large chain supermarket group, and the derivative of $F(y)$ is obtained, which can be divided into two situations:

First, when $x > x^*$, $\frac{\partial F(y)}{\partial y}(y=1) < 0$, $\frac{\partial F(y)}{\partial y}(y=0) > 0$, so $y = 1$ is the balance point, that is, the large chain supermarket group is willing to manage and control the quality of agricultural products.

Second, when $x < x^*$, $\frac{\partial F(y)}{\partial y}(y=1) > 0$, $\frac{\partial F(y)}{\partial y}(y=0) < 0$, so it is the balance point $y = 0$, that is, the decision of the large chain supermarket group to refuse to manage and control the quality of agricultural products.

When large chain supermarkets choose to manage and control the quality of agricultural products, that is, there is $0 < x < x^* < 1$. If the government supervision department group adopts to increase fines or use incentive mechanism to increase subsidies or tax incentives in order to maintain the quality and safety of agricultural products in the supply chain of agricultural supermarkets, there will be $0 < x^* < x < 1$, then the quality of agricultural products of large chain supermarkets will evolve from inspection to inspection strategy.

(3) Stability strategy analysis of government regulatory departments

When $F(z)$ is equal to 0, $y^* = \frac{(f_1 + f_2) - (a_1 + f_1)x}{a_2 + f_2}$ is obtained.

1) When $y = y^*$, it is stable for all z .

2) When $y \neq y^*$, assuming $F(z) = 0$, it is concluded that $z = 0$ or $z = 1$ is the stable state of the

large chain supermarket group, and the derivative of $F(z)$ is obtained, which can be divided into two situations:

First, when $y > y^*$, $\frac{\partial F(z)}{\partial z}(z=1) < 0$, $\frac{\partial F(z)}{\partial z}(z=0) > 0$, so $y = 1$ is the balance point, that is, the government regulatory department chooses the incentive strategy.

Second, when $y < y^*$, $\frac{\partial F(z)}{\partial z}(z=1) < 0$, $\frac{\partial F(z)}{\partial z}(z=0) > 0$, so it is the balance point $y = 0$, that is, the government regulatory department chooses the punishment strategy.

5. Conclusion

In the evolutionary game process of agricultural supermarket docking with supply chain quality and safety management and control, there are many related factors for the selection of the game subject's strategy. The change of any single game subject's strategy will not only lead to the change of some related factors, but also lead to the change of the income status of the other two game subjects, which will lead to the change of their decision. As the strategic choices of agricultural professional cooperatives, large chain supermarkets and government regulatory departments interact and influence each other, they constantly adjust their strategic choices in the process of mutual game. Therefore, it can be concluded that the government supervision department must accurately identify the key elements of the game revenue of agricultural professional cooperatives and large chain supermarkets, and then take corresponding strategic measures to regulate the key elements of the tripartite game, and guide the agricultural professional cooperatives and large chain supermarkets to choose the ideal goal that the government supervision department wants.

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