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Game Theory Analysis of Farmers Cooperation Behavior in China

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Abstract: The cooperation is an effective way for the farmers to participate in market and improve themselves financially. From the point of view of their interaction, the study gives the reasonable interpretation for their cooperation motive and constraint by game theory model. We can draw the conclusion that stage games and repeated games can not free themselves from the failure of cooperation and infinitely repeated games is very difficult to success in reality, while the introduction of impetus and establishing farmers voluntary cooperative organization are the way to the cooperation between farmers suitable for China.

Key words: Farmers cooperation, repeated games, trigger strategy

INTRODUCTION

Farmers cooperative organization has appeared and developed rapidly in our countryside since 1980s. The booming development depends on not only agricultural industrialization but also the modernization of rural China. According to department of agriculture's statistics, there are more than 689 thousand farmers cooperative organizations and 53 million farmers by the end of 2012. We know scattering management of household is not suited for the requirement of market economy. For this reason, it is an important way for farmers to cooperate with each other in a greater degree to promote the rural economic development and increase farmers income. We can inspire potential of agricultural production only when all of farmers join in the promptly and efficiently cooperation organizations (Deng *et al*., 2010; Kong, 2003). Farmers cooperation researches in the existing literature mainly focuses on cooperative dilemma, development status, existing problems, governance structure, etc. Some researches also give the approach of improving farmers cooperative dilemma. However, for the cause of cooperation failure and the way to promote cooperation success, the current literature only explains from the perspective of qualitative. From the view of game theory, the paper gives the clear and definite explanation of the success and failure of farmers cooperation through the game model (Ortmann and King, 2007; Huang *et al*., 2005). The establishment of game model for farmers cooperation The game can be explained: There are multiple players in the game, we can use f_i (i = 1, 2, ..., n) to present them. The strategy in this game is the output of the production which called q_i (i = 1, 2, ..., n) they choose. We assume the output is continuous which means each farmer can choose infinite strategies. And the total output of n farmers is:

$$Q = \sum_{i=1}^{n} q_i$$

The market clearing price is decreasing function of the output, this relationship can be described as:

$$P = P(Q) = a - bQ = a - b\sum_{i=1}^{n} q_i \tag{1}$$

Assume the famer i costs c_i to produce one unit product, the profit can be:

$$\pi_i(q_1, q_2 \cdots q_n) = q_i P(Q) - q_i c_i \tag{2}$$

Farmer f_i profit depends on not only his own marginal cost c_i and output q_i, but also the output of other farmers. So farmer f_i must consider other players strategy, when he chooses his own output.

If $q_i^*(q_1^*, q_2^* \cdots q_n^*)$ represents the Nash-equilibrium output and if each farmer has the same fixed cost, as for each participant f_i, q_i^* should meet:

$$\begin{aligned} & q_i^* \in \arg\max \pi_i(q_1^*, \cdots, q_i, \cdots, q_n^*) = \\ & q_i(a - bq_1^* - \cdots - bq_i - \cdots bq_n^* - c) \\ & i = 1, \cdots, n \end{aligned} \tag{3}$$

Farmer f_i strategy q_i should meet the equilibrium conditions according to the definition of the Nash-equilibrium, that is:

$$\frac{\partial \pi_i}{\partial q_i} = 0 \quad i = 1, \cdots, n$$

we can get the reaction function of n farmers:

$$2bq_i = a - c - bq_1^* - \cdots - bq_{i-1}^* - bq_{i+1}^* - \cdots bq_n^* \quad (4)$$

More, we can get function:

$$bq_i = a - c - (b\sum_{j\neq i}^{n} q_j^* - bq_i) \quad (5)$$

We can get the Nash-equilibrium from n functions which is the output when farmer f_i get the profit maximization. That is:

$$q_i^* = \frac{a-c}{(n+1)b} \quad (6)$$

So, farmer f_i Nash-equilibrium profit is:

$$\pi_i^* = \frac{(a-c)^2}{(n+1)^2 b} \quad (7)$$

Above all the functions and conclusions are based on competition between farmers.

If farmers choose cooperation with each other. For simplified analysis, we assume each farmer in the market is a nature person, the price P of the product and the capacity of the market Q have no change. And the nature person is the only provider (monopolist), he chooses Q which he can make his profit maximization and Q = (a-c/2b) and the maximization profit $\pi(Q) = (a-c)^2/4b)$). Then making the nature person restores n farmers, according to the principle of democratic management of the cooperative organization, each farmer's output is 1/n of nature person's output, that is:

$$q_i = \frac{Q}{n} = \frac{(a-c)}{2nb},\ \pi_i = \frac{(a-c)^2}{4nb}$$

it meets the cooperative organization profit maximization. Compared with the maximization output (q_i, q_i*) and profit (π_i, π_i*) of competition and cooperation, we can find $q_i < q_i^*, \pi_i > \pi_i^*$.

That means if all of the farmer are cooperative, each farmer can get profit:

$$\pi_i = \frac{(a-c)^2}{4nb}$$

If there is only famer f_i agrees to cooperate, while others do not, f_i can get profit:

$$\pi_i = \frac{(3n-1)(a-c)^2}{4n^2(n+1)b}$$

while others can get:

$$\pi_j = \frac{(3n-1)(a-c)^2}{2n(n+1)^2 b}$$

If all of farmers except f_i agree to cooperate, f_i can get:

$$\pi_i = \frac{(n^2+1)(a-c)^2}{2n(n+1)^2 b}$$

others can get:

$$\pi_j = \frac{(n^2+1)(a-c)^2}{4n^2(n+1)b}$$

If all of farmers do not cooperate, each farmer can get profit:

$$\pi_i = \frac{(a-c)^2}{(n+1)^2 b}$$

ANALYSIS OF THE FARMERS COOPERATION GAME MODEL

Finitely repeated games and noncooperation: Repeated games are the games of the same structure repeat several times, each time the game is called a stage game. There are three basic characteristics of the repeated games: (1) There is no physical contact among stage games; (2) All participants can observe the past history of the game; (3) The total payment of the participants is the sum of the discounted value or weighted average value of the game paid at all stages. At each stage of the game, all participants may act simultaneously or not. In the latter case, each stage of the game itself is a dynamic game. Therefore, the repeated game may be imperfect-information or perfect-information game. The main factors affecting the equilibrium result of the repeated game are the repetitions of the game and the completeness of the information. The importance of the repetitions comes from the participants' equilibrium between short-term benefit and long-term benefit. When the game is conducted only once, each participant only concerns about one-time benefit; But if the game repeats several times, people may be involved in the long-term benefit at the expense of immediate benefit to choose a different equilibrium strategy (Beghin and Karp, 1991; Li and Guo, 2008).

For the convenience of analysis, we discuss the case of two farmers (farmer1 and farmer2) finitely repeated game firstly.

According to the farmers' profit formula, take n=2 and Table 1 gives the payoff matrix of two farmers.

We can conclude that two farmers do not cooperate from the analysis that the only one-shot game Nash equilibrium (noncooperation, noncooperation).

Suppose that the two players will participate in the simultaneous game twice, the results of the first game can be observed before the start of the second game, Assuming that the gain of the entire process of the game is equal to the sum of the incomes of the two-stage games (without considering discount factor), as shown in Table 2.

The game matrix shown in Table 2 has a unique Nash-equilibrium(noncooperation, noncooperation).Thus, the unique sub-game perfect solution of the two-stage game is (non-cooperation, non-cooperation) in the first stage and (non-cooperation, non-cooperation) in the subsequent stage. In the sub-game perfect solution, no stage can reach the cooperation and cooperation results. This is a prevalent phenomenon in the economic field, that is, each decision makers chooses their strategy only depends on rational individual behavior, they hope to get the maximum profit from their own benefit. But it isn't the case. Each farmer' taking such a strategy leads to an unsatisfied Nash-equilibrium eventually. For farmer 1 and farmer 2, if they choose to cooperate, their benefits will be better obviously. From the above analysis, we can see that (cooperation, cooperation) is the Pareto optimal strategy.

Analysis shows that as long as the game is finite by the number of repetitions and the game has a unique Nash-equilibrium, repeating itself does not change the equilibrium result of the game. Noting that the uniqueness of the Nash-equilibrium of a single-stage game is an important condition. If the Nash equilibrium is not unique, the conclusion above is not necessarily ruled out. Therefore, when the number of times of the game is finite and there is only a single-stage game Nash-equilibrium, cooperation is difficult to reach.

Infinitely repeated games and cooperation: Let's continue to consider a two-farmer game. Assuming that the game is repeated infinitely, we can prove that if participants

Table 1: Two farmers finitely repeated game farmer 2

	Farmer 2	
Farmer 1	Non cooperation	Cooperation
Non cooperation	$\frac{(a-c)^2}{9b}, \frac{(a-c)^2}{9b}$	$\frac{5(a-c)^2}{36b}, \frac{5(a-c)^2}{48b}$
Cooperation	$\frac{5(a-c)^2}{48b}, \frac{5(a-c)^2}{36b}$	$\frac{(a-c)^2}{8b}, \frac{(a-c)^2}{8b}$

Table 2: Two farmers finitely repeated game

	Farmer 2	
Farmer 1	Non cooperation	Cooperation
Non cooperation	$\frac{2(a-c)^2}{9b}, \frac{2(a-c)^2}{9b}$	$\frac{(a-c)^2}{4b}, \frac{31(a-c)^2}{4b}$
Cooperation	$\frac{13(a-c)^2}{144b}, \frac{(a-c)^2}{4b}$	$\frac{17(a-c)^2}{72b}, \frac{17(a-c)^2}{72b}$

Table 3: Two farmers finitely repeated game

	Farmer 2	
Farmer 1	Non cooperation	Cooperation
Non cooperation	$\frac{2(a-c)^2}{9b}, \frac{2(a-c)^2}{9b}$	$\frac{(a-c)^2}{4b}, \frac{31(a-c)^2}{4b}$
Cooperation	$\frac{13(a-c)^2}{144b}, \frac{(a-c)^2}{4b}$	$\frac{17(a-c)^2}{72b}, \frac{17(a-c)^2}{72b}$

have enough patience, (cooperation, cooperation) is a sub-game perfect Nash-equilibrium result, just as shown in Table 3.

We use trigger strategy to analyze. Its game process: (1) Selecting disavowal firstly; (2) Selecting disavowal firstly until the other selects confession and then confession forever. According to this strategy, if one farmer in the game at any stage chooses noncooperation, he will always choose noncooperation. we can prove the trigger strategy is Nash-equilibrium. Assuming farmer2 selects the trigger strategy, Is the trigger strategy an optimal strategy for farmer 1? Because it is infinitely repeated game, it can not be solved by backward induction algorithm. Making δ[1] be the discount factor (assuming the two farmers has the same discount factor), if farmer1 chose noncooperation in a certain stage of the game firstly, he will get $5(a-c)^2/36b$, not $(a-c)^2/8b$, so his current net income is $(a-c)^2/72b$. But his opportunistic behavior will trigger the punishment of farmer2, as farmer2 will choose noncooperation forever and the earnings of farmer 1 in each subsequent stage is $(a-c)^2/72b$. Therefore, if the following conditions are met, given that the farmer2 not choosing noncooperation, farmer1 will not choose noncooperation either:

[1]Discount factor can be understood as the value of the discount rate, which is the current value of one share after a period of time. The discount factor is different from the discount rate in finance is that it is determined by the degree of patience of the participants. Patience is essentially the endurance involved in human psychology and economy. Different participants' mental capacity may vary in negotiations and the ones who have strong mental endurance will eventually get more. Similarly, if there is someone who has greater economic bearing capacity than any other participants, he will gain extra advantage.

$$\frac{5(a-c)^2}{36b} + \delta * \frac{(a-c)^2}{72b} + \delta^2 * \frac{(a-c)^2}{72b} + S \leq \frac{(a-c)^2}{8b} + \delta * \frac{(a-c)^2}{8b} + \delta^2 * \frac{(a-c)^2}{8b} + S$$

We can get that:

$$\delta \geq \frac{1}{9}$$

That's to say, if:

$$\delta \geq \frac{1}{9}$$

given farmer2 insists on the trigger strategy he will not choose noncooperation firstly, then farmer1 will not choose noncooperation firstly either.

Now assume farmer2 has chosen noncooperation firstly. Does farmer1 have the patience to insist on trigger strategy to punish the farmer 2 noncooperation behavior? Supposing that farmer 2 insists on the trigger strategy, which means if the farmer2 chooses noncooperation firstly then he will always chooses noncooperation. If farmer 1 insists on the trigger strategy, his income of each subsequent stage is $(a-c)^2/72b$. However, if he chooses other strategies, his income will not be more than $(a-c)^2/72b$. At any stage, if choosing noncooperation, his income will be up to $(a-c)^2/72b$; otherwise the income will be up to $(a-c)^2/8b$. Consequently, whatever the δ is, farmer1 will insist on the trigger strategy. Similarly, given farmer1 insists on the trigger strategy, even if he chooses noncooperation firstly, persisting in the trigger strategy is also optimal. Thus that the trigger strategy is a Nash equilibrium has been proved.

Next, we can prove that the Nash-equilibrium is a sub-game perfect Nash equilibrium, which constitutes Nash-equilibrium at each sub-game stage. Because the game repeats infinitely, a sub-game from any stage is the same as the game in structure. In the trigger strategy Nash-equilibrium, the sub-game can be divided into two types: in type1, there is no participant who was noncooperation once; in type2, there is at least one participant who was noncooperation ever. Now we have proved that the trigger strategy in type1 sub-game forms the Nash-equilibrium. According to the trigger strategy, participants just repeat the Nash equilibrium of one-stage game, then sub-game in type2 will naturally be the Nash equilibrium of all the sub-games.

If $\delta \geq \frac{1}{9}$, we have proved that participants have enough patience, the trigger strategy is a sub-game perfect Nash-equilibrium of infinite farmers game, which means Pareto optimality (cooperation, cooperation) is the equilibrium result of each stage and farmers step off the dilemma of one-shot game dilemma. In the condition of the game repeats infinitely; every participant having enough patience; any income of opportunism behavior on short-term being negligible; participants are motivated to build a pleasant cooperation for their own reputation, meanwhile they have initiative to punish others' opportunistic behavior.

Introduction of the rewards and punishment mechanism of long-term cooperative game (introducing incentive mechanism to achieve Pareto optimality): We can see that the faith of cooperation of production is the basis of farmers cooperation and there must be a kind of restriction and trapping mechanism to make it exist in the long time. Pursuing revenue maximization makes farmers interested in noncooperation. Therefore, External force involved is imperative to change farmers income to achieve Pareto optimality. Taking consideration of the introduction of external restriction and trapping mechanism and adopting some measures to punish the farmers who don't cooperate, as shown in Table 4.

When k is big enough:

$$k \succ \frac{(a-c)^2}{72b}$$

By using the underline method we know that the game model has a unique Nash-equilibrium (cooperation, cooperation), which is also the Pareto optimal strategy. This method of introducing external force to restrict farmers from speculative production is "team incentive mechanism". It aims to reward the cooperative behavior and punish the noncooperation behavior primarily. Certainly the penalty is not only confined to economic means, it also can take other measures.

From the analysis above we consider that there are two effective ways to restrict farmers speculative production: One is compulsory, that is, government forces to give farmers some forms of organization through its action. However, too much administrative intervention leads to that cooperative organizations easily become governmental subordinate departments . In order to make

Table 4: Two farmers finitely repeated game

	Farmer 2	
Farmer 1	Non cooperation	Cooperation
Non cooperation	$\frac{(a-c)^2}{9b}-k, \frac{(a-c)^2}{9b}-k$	$\frac{5(a-c)^2}{36b}-k, \frac{(a-c)^2}{48b}-k$
Cooperation	$\frac{5(a-c)^2}{48b}-k, \frac{(a-c)^2}{48b}-k$	$\frac{(a-c)^2}{8b}, \frac{(a-c)^2}{8b}$

management convenient, or to pursue record of achievements, lots of local government sometimes do their utmost to obstruct the establishment of some cooperative organizations and sometimes they set up cooperative economic organization artificially and compulsively by the means of running movements, accordingly make farmers join involuntarily and exit without freedom. Compared with the cooperative organizations established voluntarily, the adaptability of the huge organizations supported by administrative resorts to market competition is not strong enough and it is inefficient in transferring market information and the higher cost of organization and monitoring, so this kind of genetically modified farmers cooperative organization is often glitzy but empty in essence. The other method is voluntary, namely, to establish cooperative organization that farmers can join voluntarily and exit freely. The spontaneous role of farmers forms the authentic credit foundation, which is not only maintained by morals standard, but relies on effective mechanism designing and it can constrain the speculative behavior of individual farmer effectively.

The cooperative organization established for satisfying farmers demand plays an important role in economic society. Internationally, one of the critical reasons that the United States, Japan and other developed countries can achieve rapid development of high efficient agricultural goods, is that they set up high efficient and developed farmers cooperative organization and organize farmers to enter into the market together through this type of farmers united self-service organization like the association of farmers and farmers cooperative unions, which can overcome the individual speculation effectively. Adjust and redistribute cooperative benefits reasonably through the cooperative principal, authoritative farmers cooperative organization can effectively restrict farmers. For instance, capital, information, service and so on, can be taken to punish the farmers who deviate from cooperation and simultaneously make the faith of mutual cooperation proceed in the long run. Meanwhile, a kind of serving and being served relationship is formed between government and farmers professional cooperative organization and government will transfer its function of compulsory administrative intervention to guide and provide services, accordingly creating space for the development of the agricultural cooperative economic organizations and the farmers. (Grimes-Casey *et al*., 2007; Borgen, 2011).

CONCLUSION

Farmers cooperation process is a process of game. This study through the analysis of a cooperative game model of farmers cooperation shows that, by repeated games can build the basis of credibility, cooperation is possible, which also provides the basis of cooperation for the cooperative organization. Under the condition of complete information, repeated games can not free farmers from the failure of cooperation. As for unlimited repeated games, if participants have enough patience, any acceptable payoff vector which meets the individual rational can be got through a specific sub-game perfect equilibrium, that is, cooperation can be reached. But it is difficult to realize in reality. Only through introducing the incentive mechanism, establishing farmers voluntary cooperative organization, changing the external environment of cooperation, restraining farmers speculative production, avoiding short-term cooperation, can make the cooperation for a long time to proceed.

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