

STUDY ON FARMER'S PRODUCTION BEHAVIOR BASED ON HOTELLING MODEL

YUNFU HUO, YANG GAO AND SHUANG ZHAO*

College of Economics and Management

Dalian University

No. 10, Xuefu Street, Jinzhou New District, Dalian 116622, P. R. China

*Corresponding author: shuangzhao80@163.com

Received October 2016; accepted January 2017

ABSTRACT. *With the development of agricultural economy, small-scale production of farmers is facing great challenges. The variety of agricultural production and management conforms to the requirements of solving the contradiction between "small farmer" and "big market", but also makes the farmers face the choice of production organization forms. Based on the Hotelling model, the paper compares "farmer + cooperative" and "farmer + company". The conclusion is that when the service level of the cooperatives and the company is in a certain range and conditions, the farmers respectively choosing the two production forms will obtain the welfare maximization, which provides a reference for the farmers to scientifically choose the production organization form.*

Keywords: "Farmer + cooperative", "Farmer + company", Service level, Production behavior, Hotelling model

1. Introduction. Farmers are the basic unit of agricultural production and development, and agricultural products are the daily necessities of people's daily life. The quality and safety of agricultural products are related to the stability of social development. Therefore, it is necessary to theoretically analyze farmer's production behavior [1]. The common forms of production organizations are "farmer+ cooperative" and "farmer + company". The "farmer + cooperative" is the product of farmers seeking to maximize the potential benefits. The "farmer + company" is also designed to solve the contradictions between the "small farmers" and "big market". Both of the two forms supply rich service functions to help famers gain more profits. The farmers also consider service functions supplied when they make decisions to choose production cooperation organization. Jiang pointed out that the service level of farmers' cooperatives is one of the five elements of cooperative development [2].

In recent years, academia community have carried out a lot of researches on the service level and the farmer's production behavior, and achieved a lot of achievements, but there are still further perfect spaces in two aspects. First, there is lack of mathematical research. Most of the literature focused on qualitative analysis and empirical research [3]. Second, less research is conducted on the production behavior of farmers from the perspective of production cooperatives and welfare parameters. Most of them focus on the supply and marketing cooperatives and profit parameter [4]. Based on the existing research literature, the paper studies production cooperatives by theoretical research.

2. Literature Review. Abroad research results between management organization model of agricultural production and farmer production behavior are very rich. Kliebenstein and Lawrence analyzed contracts used in the U.S. hog production phase from the perspective of benefits and risks, and pointed out that farmers use contracts to reduce risks, obtain funds and increase incomes [5]. With the development of economy, the form of transaction organization is changed from market transaction to contract production mode.

In the process of transformation, the quality of service is the key factor to decide whether or not the contract is accepted by farmers [6].

According to the function of cooperative, cooperatives are divided into two types: production cooperative and service cooperative. The object of this paper is production cooperative. Production cooperative refers to all kinds of cooperatives engaged in planting, gathering, breeding, fishing and hunting, shepherding, processing and construction. Guo pointed out that “farmer + cooperative” can play the role of an alternative market, but it is to what extent replaces the market according to specific circumstances [7]. Judgment is based on the comparison between management costs of organization and transaction costs of market. As a result, the supply of services by cooperative is limited and the services provided are mainly concentrated in technical services. Huang et al. also pointed out that at present “farmer + cooperative” provides members with varying degrees of service, and service has played an active role in improving farmers’ agricultural production and management, etc [8]. However, on the whole, the service function of “farmer + cooperative” is still weak and very different. Subsequently, the “farmer + company” becomes one of important agricultural industrialization models. Its basic characteristic is that the company establishes the long-term contractual relationship between the company and the farmer in the way of the cooperative organization. In essence, in this model the company is raw material base and production workshop. The company controls the cooperative’s decision-making power and profit distribution rights, and farmers are the company’s “wage earners”. The company provides farmers with the services of variety selection, input supply, production technical guidance, working capital protection, product recovery and improvement of productive infrastructure. The company undertakes business risks.

Whether it is “farmer + cooperative” or “farmer + company”, the overall trend changed from market transactions to contract production, strategic alliances and vertical integration, and the collaboration tightness was higher and higher. Therefore, it is necessary to formulate the coordination, pricing, production planning and control strategies of agricultural production, and to design an effective incentive mechanism so that the results of these independent decision makers automatically make the global optimal. Based on the service level, this paper explores how farmers choose “farmer + cooperative” and “farmer + company” based on cooperative welfare maximization, profit maximization and farmer utility maximization.

In the part of model construction, the paper first analyzes the model of cooperative and company without service level (I). Then add service level in model (II), and the coefficient of service level of cooperative and that of company is the same. The main point focused in this part is how the relationship between market price, farmers’ matching cost and service level coefficient will affect farmers’ production choice.

3. Modeling Assumptions. In order to facilitate the analysis, the paper makes such assumptions without losing the generality of the conditions.

There are two oligopolies in the market, A represents cooperative and B represents company. The two sides attract farmers by determining their own service levels and purchase prices, where the service level is expressed as S_i , $i \in (A, B)$. Farmers choose production organization form according to their own wishes and external factors, but the choice result may not be exactly in line with their expectation, and the matching cost is caused, denoted by t , and $t > 0$. The utility of farmers is U_i , $i \in (A, B)$. Social welfare is expressed as W_i , $i \in (A, B)$. Purchase price of cooperative and company is P and P_B , and the purchase price of cooperative is equal to market price, so $P > P_B$. The maximum number of farmers participating in cooperative is x^* . The number of sales of agricultural products is expressed as q_B . The operational objective of cooperative is to achieve farmer surplus maximization. Suppose that each farmer produces one unit of agricultural

product. Cooperative and company’s decision-making process is determining their service level at first, and then determining their purchase price, and finally attracting farmers to choose to cooperate with whom. Reverse calculation is adopted in the model calculation process. Farmer chooses the ownership as $U_A = U_B$ at first, then cooperative and company make purchase price P and P_B , and service level is determined by cooperative and company at last S_A and S_B .

4. Basic Model Construction and Analysis.

4.1. Model (I): The duopoly competition model without service level. There are cooperative and firm in the duopoly market, we abstract the market as a length 1 of segment, cooperative is located at line 0 and company is located at line 1. x represents the uniform distribution farmers and $x \in (0, 1)$. The schematic diagram of the model is as follows:



The utility of farmer when he chooses “farmer + cooperative” is:

$$U_A = P - tx \tag{1}$$

The utility of farmer when he chooses “farmer + company” is:

$$U_B = P_B - t(1 - x) \tag{2}$$

When $U_A = U_B$, utility indifference point $x^* = \frac{1}{2} + \frac{P - P_B}{2t}$.

The company profit is:

$$\pi_B = (P - P_B)q_B \tag{3}$$

When company profit is maximized (that is, $\frac{\partial \pi_B}{\partial P_B} = 0, \frac{\partial^2 \pi_B}{\partial P_B^2} < 0$), the company purchase price $P_B^* = P - \frac{t}{2}$.

Farmer surplus when farmers choose cooperative and company is:

$$CS_A = \int_0^{x^*} U_A dx \tag{4}$$

$$CS_B = \int_{x^*}^1 U_B dx \tag{5}$$

Based on the above analysis we obtain Lemma 4.1 as follows.

Lemma 4.1. Under the premise that without considering cooperative and company’s service level, utility indifference point $x^* = \frac{3}{4}$, the company profit maximization $\pi_B^* = \frac{t}{8}$, the farmer surplus obtained by choosing cooperative is $CS_A^* = \frac{3}{4}P - \frac{9}{32}t$, and the farmer surplus obtained by choosing company is $CS_B^* = \frac{1}{4}P - \frac{5}{32}t$.

4.2. Model (II): The duopoly competition model with service level. Service level coefficient k is added to the model, which reflects the service function diversity and service quality of cooperative and company. We assume that the service level coefficient of cooperative is equal to that of company.

The utility of farmer when he chooses “farmer + cooperative” is:

$$U_A = P + S_A - tx \tag{6}$$

The utility of farmer when he chooses “farmer + company” is:

$$U_B = P_B + S_B - t(1 - x) \tag{7}$$

When $U_A = U_B$, utility indifference point $x^* = \frac{P - P_B + t + (S_A - S_B)}{2t}$.

The company profit is:

$$\pi_B = (P - P_B)q_B - \frac{k}{2}S_B^2 \tag{8}$$

$\frac{k}{2}S_B^2$ represents the company's effort costs and k is service level coefficient.

The company social welfare is:

$$W_B = \pi_B + CS_B$$

The farmer surplus obtained by choosing company is:

$$CS_B = \int_{x^*}^1 U_B dx$$

The cooperative social welfare is:

$$W_A = CS_A - \frac{k}{2}S_A^2 \tag{9}$$

$\frac{k}{2}S_A^2$ represents the cooperative's effort costs.

The farmer surplus obtained by choosing cooperative is:

$$CS_A = \int_0^{X^*} U_A dx$$

$\Delta CS^* = CS_A^* - CS_B^*$ represents farmer surplus difference under equilibrium condition caused by selecting cooperative or company. $\Delta W^* = W_A^* - W_B^*$ represents social welfare difference between cooperative and company under equilibrium condition. From the first derivative $\frac{\partial \pi_B}{\partial P_B} = 0$, $\frac{\partial W_A}{\partial S_A} = 0$, $\frac{\partial \pi_B}{\partial S_B} = 0$, three reaction functions are obtained:

$$P_B = \frac{2P - t + (S_A - S_B)}{2} \tag{10}$$

$$S_B = 3P + (3 - 4tk)S_A - P_B + t \tag{11}$$

$$S_A = t + (1 - 4tk)S_B \tag{12}$$

From the second derivative $\frac{\partial^2 \pi_B}{\partial P_B^2} = -\frac{1}{t} < 0$, we can see that the company can achieve profit maximization under the equilibrium condition. From $\frac{\partial^2 W_A}{\partial S_A^2} < 0$, $tk > \frac{3}{4}$ is established. tk represents the relationship between sense of loss and satisfaction when they choose different organizational forms. From the above analysis we obtain Lemma 4.2 as follows:

Lemma 4.2. *Under the condition of service level k , utility indifference point is*

$$x^* = \frac{1}{2} + \frac{4t^2k^2 - 3tk + 2Pk + 1}{2(8t^2k^2 - 7tk + 1)},$$

the company purchase price is

$$P_B^* = \frac{8Pt^2k^2 - 5Ptk + P - 4t^3k^2 + 4t^2k}{8t^2k^2 - 7tk + 1},$$

the cooperative service level is

$$S_A^* = \frac{4Ptk - P + 3t^2k - t}{8t^2k^2 - 7tk + 1},$$

the company service level is

$$S_B^* = \frac{-P + 2t^2k - 2t}{8t^2k^2 - 7tk + 1},$$

the company profit is

$$\pi_B^* = \frac{k(P + 2t - 2t^2k)(4tk - 1)}{2(8t^2k^2 - 7tk + 1)^2},$$

the cooperative social welfare is

$$W_A^* = \frac{(tk - 1)kP^2 + 4(24t^3k^3 - 38t^2k^2 + 19tk - 3)tkP}{2(8t^2k^2 - 7tk + 1)^2} + \frac{(-36t^4k^4 + 87t^3k^3 - 73t^2k^2 + 25tk - 3)t}{2(8t^2k^2 - 7tk + 1)^2},$$

the farmer surplus difference is:

$$\Delta CS^* = \frac{16(2tk - 1)tk^2P^2 + 2(32t^3k^3 - 44t^2k^2 + 29tk - 7)tkP}{2(8t^2k^2 - 7tk + 1)^2} + \frac{(-16t^4k^4 + 48t^3k^3 - 43t^2k^2 + 18tk - 3)t}{2(8t^2k^2 - 7tk + 1)^2},$$

the social welfare difference is:

$$\Delta W^* = \frac{4(4tk - 3)tk^2P^2 + 4(16t^3k^3 - 24t^2k^2 + 13tk - 3)tkP}{2(8t^2k^2 - 7tk + 1)^2} + \frac{(-32t^4k^4 + 75t^3k^3 - 61t^2k^2 + 21tk - 3)t}{2(8t^2k^2 - 7tk + 1)^2}.$$

5. Comparison and Analysis of Model (I) and (II). Comparing the utility indifference point of model (I) and (II), Proposition 5.1 can be obtained.

Proposition 5.1. *If the service level is not considered in the business process, the utility indifference point $x^* > \frac{1}{2}$ is constantly established; if the service level is considered, when $tk > \frac{3}{4}$, $x^* > \frac{1}{2}$ is constantly established.*

If the service level is not considered in the business process $x^* = \frac{1}{2} + \frac{P-P_B}{2t}$, and because $P > P_B$, the utility indifference point $x^* > \frac{1}{2}$ is constantly established; if the service level is considered, $x^* = \frac{1}{2} + \frac{4t^2k^2-3tk+2Pk+1}{2(8t^2k^2-7tk+1)}$, if $tk > \frac{3}{4}$, then $\frac{4t^2k^2-3tk+2Pk+1}{2(8t^2k^2-7tk+1)} > 0$, $x^* > \frac{1}{2}$ is constantly established. From Proposition 5.1, if both cooperative and company do not provide service functions for farmer, the farmer will choose to join cooperative. Compared to participating company, joining cooperative reduces the transaction costs and farmer can enjoy cooperative surplus. When both cooperative and company all provide service functions for farmers, the more service functions and the higher service quality cooperative provides, the more farmers choose to join cooperative. Because farmers are the owners of cooperative, the better the cooperative service, the higher the farmers' income.

Comparing the service level of cooperative and company in model (II), Proposition 5.2 can be obtained.

Proposition 5.2. *When $tk > \frac{3}{4}$, $S_A^* - S_B^* > 0$ is constantly established.*

From Lemma 4.2, we can know $S_A^* - S_B^* = \frac{4Ptkt^2k+t}{8t^2k^2-7tk+1}$, when $tk > \frac{3}{4}$, then $8t^2k^2 - 7tk + 1 > 0$ and $S_A^* - S_B^* > 0$. From Proposition 5.2, if cooperative uses social welfare maximization as business goal, the service level of cooperative is always higher than that of company. This result tells us that cooperative should pursue social welfare maximization rather than profit maximization, which confirms the failure of many cooperatives that pursue profits. As long as cooperative insists social welfare maximization, it will consider farmer surplus, and farmers will benefit.

Comparing the farmer surplus of cooperative and company in model (II), Proposition 5.3 can be obtained.

Proposition 5.3. *When $P > \frac{-21+\sqrt{39411}}{48k}$, $CS_A^* > CS_B^*$ is established; when $\frac{-21+\sqrt{39411}}{48k} > P > 0$, $CS_A^* < CS_B^*$ is established.*

We regard ΔCS^* as a quadratic equation of P , by analyzing the root of the quadratic equation of this one yuan, and then determine the size of CS_A^* and CS_B^* in different intervals. From Proposition 5.3, cooperative and company can adjust service level according to market prices, make its farmer surplus larger than that of competitors, and attract more farmers. Farmers should not only consider the benefits brought by cooperative and company, but also should consider the relationship between market price and service level.

Proposition 5.4. *When $7.114 > tk \geq 2.602$ and $P > 0$, $W_A^* > W_B^*$ is constantly established; when $tk > 7.114$ and $P > 20.032$, $W_A^* > W_B^*$ is established; when $tk > 7.114$ and $0 < P < 20.032$, $W_A^* < W_B^*$ is established; when $2.602 > tk > 0.74$ and $P > 0$, $W_A^* > W_B^*$ is constantly established.*

We regard ΔW^* as a quadratic equation of P , by analyzing the root of the quadratic equation of this one yuan, and then determine the size of W_A^* and W_B^* in different intervals. From Proposition 5.4, with the changes in the relationship between utility loss borne by farmers choosing production organization form and the positive effect brought by service level, the size of cooperative and company's social welfare will change accordingly. The extent to which cooperative and firm contribute to society depends on market price and the product of utility loss borne by farmers choosing production organization form and the positive effect brought by service level. Therefore, when company and cooperative consider the business strategy, they should evaluate and anticipate the size of market price, service level and matching costs, and then decide whether to keep on improving service level to attract farmers or giving up. The government should know when to issue policy to support company or cooperative.

6. Management Significance and Conclusion.

6.1. Improving service level and reducing service cost. This study shows that service quality has a direct impact on the choice of farmers' production organization. Service level is the first consideration for the farmers to choose the form of production. Only by improving service level can the participation of more farmers be attracted. Both cooperative and company should diversify their service functions, such as capital loans, sales channels, and agricultural supplies. Only by doing so can the farmers be locked in and the loyalty of farmers' participation can be enhanced. While improving service levels, it is also necessary to control service cost, which may reduce cooperative social welfare and company profit, and reduce the incentives for cooperatives and companies to provide services.

6.2. Making rational decision-making, moderately encouraging farmers to participate. In this paper, it is found that, in the coefficient range of matching cost and service level, it is the most advantageous for farmers to choose cooperative or company. Therefore, taking account of business objectives, the relationship between market price and service level, cooperative and company make more informed decisions. Otherwise, too much emphasis on improving service and no thinking about other factors will reduce social welfare.

6.3. Encouraging the development of production cooperatives. In this paper, it is concluded that the production cooperative is a production organization that can meet the needs of farmers. Although the operating objectives of cooperatives are not as clear as those of companies, management structures are still constantly exploring, and there are also many problems in the operation, but this paper concluded that cooperatives have a great advantage in the process of competition with the company, as long as they operate properly, and they can attract more farmers to participate.

This article has made some useful management significance, but there are still many problems left for future research and settlement. For example, this paper only considers

the relationship between services, matching costs and market prices, and does not take account of the effect of network effects. In real life, the choice of production behavior among individual farmers in the same region has great influence on the choice of individual farmers. Therefore, network effect will be discussed in the future study.

Acknowledgment. This work is partially supported by National Natural Science Foundation of China No. 71372120. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

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