

Boxed Pigs Game Analysis on Raw Milk Resources Investment of Dairy Processing Enterprises in Cluster

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Abstract. With the development of Chinese dairy industry cluster, the competition of raw milk resource is getting keen between the dairy processing enterprises in cluster. Because the investment of raw milk foundation has the characteristic of public goods, dairy processing enterprises in the cluster can all benefit from the output, whether it makes investment or not, so the investment of raw milk resource are not efficient in economics. Game equilibrium of Boxed pigs is the common result of enterprises competition in low cost cluster. In this paper, the boxed pigs' game model is established to analyze the investment behavior of local and extraneous dairy processing enterprises. The analysis of the mode not only explains the reasons of boxed pigs' equilibrium, but also gives guidance for the improvement of the game equilibrium. Finally, the case of Heilongjiang province dairy industry cluster is studied. It is also shown that establishing self-owned pastures and building long term contractual relations with scaled dairy farms or dairy production associations can improve the game result, so as to reach the cooperation equilibrium.

Keywords: dairy processing industry Cluster; boxed pigs; investment of raw milk resources

1. Introduction

The development of dairy processing industry is highly depended on raw milk resources. With the fast development of Chinese dairy industry, it is inevitable for a great number of dairy processing enterprises to aggregate in the area which is full of raw milk resources. Currently, there are nearly 500 dairy processing enterprises, in which more than 70 enterprises locates in Heilongjiang province. In inner-Mongolia province, the annual sales of the dairy processing enterprises Yili and Mengniu, reached 2400 billion Yuan in year 2009, which accounts for one fourth of the whole dairy processing industry in China [1]. The organization forms of Chinese raw milk resources are mainly small scales and scatter cattle farms. In order to guarantee the raw milk supply and improve the quality of raw milk, dairy processing enterprises usually make a series of investment on raw milk resource, including proving fund, milking facilities and cow vaccines for the dairy farmers. The investment of raw milk foundation has the characteristic of public goods, because enterprises in the cluster can all benefit from the output, whether it makes investment or not [2]. Even though dairy farmers had signed contract to provide raw milk exclusively to the investor, the commitments are not liable, because for scattered and small scales farmers, breach of commitment will not bring any cost of punishment, or the revenue of breaching contract is much more than the punishment cost. When other dairy processing enterprises offer a more favorable price, rational dairy farmers have no doubt to sell the raw milk at the higher price.

In order to discuss the investment behaviors of dairy processing enterprises, dairy industry can be seen as a biological market. There are two types of enterprises in the market, local enterprises and extraneous enterprises. From the point of economics, the goal of industrial development is to realize the efficiency, so to differentiate the enterprises by local and extraneous is parochial and meaningless. While according to the current conditions of Chinese dairy industry, the attitudes and behaviors about raw milk resource of local

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enterprises and extraneous enterprises are quite different. The assortment of local and extraneous enterprises can facilitate the game theory analysis, so as to study the strategic competitive behavior of dairy enterprises. Local enterprises are usually small in scale, and have developed for long time, which have made some investment of local raw milk resource, while extraneous enterprises are large in scale and rich in capital, which are attracted by the raw milk resource [3]. In the practice of dairy industry, it is known that local enterprises are more willing to make investment on raw milk resources, while extraneous enterprises are seldom make investment in raw milk resources. Extraneous enterprises usually adopt the way of establishing the milk gathering centers and purchasing directly from the dairy farmers. Why the extraneous enterprises which have large amount of capital turn to be the small pigs, the free rider, while the local enterprises which already have difficulty in capital become the big pigs in raw milk resource investment.

Therefore, in this paper, the investment behaviors on raw milk resources of enterprises in cluster are studied by boxed pigs game, which is of great significant for the healthy development of Chinese dairy industry cluster.

2. Establishment of Boxed Pigs Game Model for Dairy Processing Enterprises' Raw Milk Resource Investment

There are two choices for every dairy processing enterprise, which are to make investment and not to make investment of raw milk resource. The raw milk resource investment game has the characteristics of uncertainty of enterprises' behavior, individual rationality, and non win-lose type and repeated games.

2.1 Establishment of the game mode

If there are only two enterprises in certain area (biological market), local enterprise and extraneous enterprise, the products of these two enterprises are different, but substitutive in some degree. The degree of substitution and products' differentiation are in inverse proportion. If there is price competition in the market, Bertrand mode is used to analyze the optimal pricing of the market enterprises providing differentiated products in biological market.

If local enterprise is company 1, extraneous enterprise is company 2, the general function of company demand is $q_i(p_i, p_j) = a - b_i p_i + d p_j$, $i \neq j$, $p_i \in [0, \infty)$. The profit functions of company 1 and company 2 are:

$$\pi_1 = q_1 p_1 - C_1 = a - b_1 p_1^2 + d_1 p_1 p_2 - C_1 \quad (1)$$

$$\pi_2 = q_2 p_2 - C_2 = a - b_2 p_2^2 + d_2 p_2 p_1 - C_2 \quad (2)$$

In the function, a is the total potential demand of dairy products, b_i is the demand elasticity of the dairy enterprise i , p_i is the product price of dairy enterprise i , d_i is substitution coefficient of enterprise i and enterprise j , ignoring the marginal cost of production, C_i is the investment of raw milk resource. Since local enterprises are mature in the local market, which can lock part of the consumers by its distribution channel, especially the daily family distribution, so the demand elasticity of local enterprises are smaller than that of the extraneous ones, that is to say $b_1 < b_2$. Because local enterprises have long term brand penetration, so the substitution coefficient of local enterprises is higher than extraneous ones, that is to say $d_1 > d_2$.

According to the necessary conditions of Nash equilibrium, in order to maximum the benefit, first differential coefficient should be 0, that is:

$$\frac{\partial \pi_1}{\partial p_1} = a - 2b_1 p_1 + d_1 p_2 = 0 \quad \frac{\partial \pi_2}{\partial p_2} = a - 2b_2 p_2 + d_2 p_1 = 0$$

From which, the optimal pricing can be gotten:

$$p_1 = \frac{d_1 p_2 + a}{2b_1} \quad (3)$$

$$p_2 = \frac{d_2 p_1 + a}{2b_2} \quad (4)$$

Through function (3) and (4), the optimal prices are calculated as:

$$p_1^* = \frac{(2b_2 + d_1)a}{4b_1b_2 - d_1d_2} \quad (5)$$

$$p_2^* = \frac{(2b_1 + d_2)a}{4b_1b_2 - d_1d_2} \quad (6)$$

p_1^* , p_2^* is the Nash equilibrium, put it into the function, the maximum benefit of the enterprises is:

$$\pi_1 = b_1p_1^* - C_1 \quad (7)$$

$$\pi_2 = b_2p_2^* - C_2 \quad (8)$$

Combining the optimal pricing, benefit of local enterprises and extraneous enterprises, and their investment strategy of raw milk resources, payoff table can be shown as fig.1.

		Extraneous enterprises	
		To invest	Not invest
Local enterprises	To invest	$\Delta\pi_1 - C_1, \Delta\pi_2 - C_2$	$\frac{\Delta\pi_1 - C_1}{2}, \frac{\Delta\pi_2}{2}$
	Not invest	$\Delta\pi_1, \Delta\pi_2 - C_2$	0, 0

Fig.1 Payoff Table of Dairy Processing Enterprises' Raw Milk Resource Investment Strategy

2.2 Discussion of the game equilibrium

According to the payoff table, it is shown that in dairy industry cluster, the raw milk resources investment game between local dairy processing enterprises and extraneous ones mainly have three results, namely cooperation equilibrium (both local enterprise and adventitious enterprises make investment on raw milk resources), boxed pigs equilibrium and prison dilemma equilibrium. In low cost cluster, the stable results of enterprises competition is usually the equilibrium of boxed pigs [4]. Usually the equilibrium of boxed pigs is shown as that the big pigs who are strong in scale and rich in capital, while the small pigs will wait and get a free ride from the investment of the big pigs. So for the big pigs, the stimulation of investment is not enough, which also affects the efficiency of industry cluster. The realization of boxed pigs' equilibrium is conditional. If the equilibrium conditions are destroyed, the game result may turn to prisoners' dilemma, which is the deterioration of boxed pigs. The deterioration of boxed pigs refer to that the investment benefits of big pigs are mostly gained by small pigs, the benefits of investment are less than the cost. Therefore, the game result becomes prisoners' dilemma, that is to say, there is no enterprises make investment in raw milk resource. After the deterioration of boxed pigs, the dairy industry cluster will be short of investment. Considering the homogeneity of products and information asymmetry, it is inevitable for the dairy processing enterprises to make vicious competition. The forming of lemon market will decrease the competitiveness of industry cluster.

2.3 Discussion of the investment strategy

Since the dairy processing enterprises are rational, the decision whether invest in raw milk resource will decide by the compare of interest increase $\Delta\pi$ and cost of investment C_i . Firstly, from the angle of $\Delta\pi$, it is a price competition between the two companies, because $b_1 < b_2$, so $p_1^* > p_2^*$ and $\Delta\pi_1 > \Delta\pi_2$, that is to say, in local market, local enterprises have the advantages of pricing, can gain more benefit from the higher price. While from the cost of investment, because local enterprises already have certain foundation of raw milk resource's establishment, the foregoing investment had become sunk cost, the local enterprises have the tendency of commitment escalation. Besides, the supplemental investment costs of local enterprises are lower than the Greenfield investment costs of extraneous enterprises. Since for the local enterprises, benefit of investment is higher than the cost of investment, the preponderant strategy of local enterprises is to invest raw milk resource. In this precondition, not to invest becomes the best choice of extraneous enterprises. So the Nash equilibrium is local enterprises invest, while extraneous enterprises do not invest in raw milk resource. This is the equilibrium of boxed pigs, see Fig. I. Local enterprises, which are not rich in the capital, become the big pigs in the game, have to afford the huge investment of raw milk resource. The extraneous enterprises become the

small pigs; they do not invest in raw milk resource, but only purchase from the dairy farmers, by increasing the price when demand is over supply, lowering the price when supply is over demand in the market.

2.4 Improvement of the game equilibrium

The equilibrium of boxed pigs means the behavior of free ride, which is directly related with the lack of property definition and inefficacy of property allocation [5] [6]. In fact, if extraneous enterprises make investment in raw milk resource, local enterprises would have gain part of the benefit by its price advantages. For extraneous enterprises, it can not gain all the interest of investment. What's more, if the market strategy changes, all the investment had made to dairy farmers would be sunk cost.

Currently, the investment modes of raw milk resource are rational for local and extraneous enterprises. But the investment strategy of extraneous enterprises has disturbed the order of raw milk market, which has affected the development of Chinese dairy industry cluster. In order to alter this situation, the production mode of raw milk should be changed. The scale of raw milk production should be enlarged, so as to realize the efficiency of property allocation, that is to say, who invests, who benefit from the investment. In the condition of scale production, extraneous enterprises will be willing to invest in raw milk resources. The investment can be made by two ways. The first way is to invest and establish self owned pastures, realizing the integration of raw milk production and dairy processing. The second way is a kind of gradual change that extraneous enterprises control the scaled cow farms by investing the shares. In this way, not only the raw milk supply can be guaranteed, but also the cow farms are regulated compared with individual farmers. So even the market strategy of enterprises is shifted, the investment of shares could be withdrawn.

3. A Case Study of Dairy Industry Cluster in Heilongjiang Province

Heilongjiang province is located in the world milk belt, which is endowed with the particular weather and nature conditions for the dairy industry. The advantages of raw milk resources have fostered great number of dairy farmers. Up to the end of 2009, the scaled dairy farmers is over 200 thousand, the raw milk output has reached 4.6 billion tons, which takes one forth of the Chinese national production. The raw milk resources have also attracted many dairy processing enterprises. There are 70 dairy processing enterprises in Heilongjiang province in 2009, which forms the dairy industry cluster. At one hand, the industry cluster has promote the development of dairy industry in Heilongjiang province, at the other hand, the entrance of many extraneous enterprises has led to the disordered competition in raw milk and products market, and centralized effect and advantages can not be brought into play in the cluster. Among the 70 enterprises, 39 of them are local enterprises, in the other 31 extraneous enterprises, 12 are of foreign investment base, which is shown in table I.

TABLE I THE CONSTITUTION OF DAIRY PROCESSING ENTERPRISES IN HEILONGJIANG PROVINCE

Sort		Amount
Local company		39
Extraneous enterprises	Foreign based company	12
	National company	19

The investment of extraneous enterprises in Heilongjiang province has two reasons. One is to compete for the raw milk resource. Since dairy products are putrescible, the raw milk can only be processed by enterprises nearby. The other is to develop the dairy consumption market. The local dairy processing enterprises usually take milk powder as the main products, whose competition is weak in the production line of liquid milk. The extraneous enterprises, like Yili, Mengniu, Bright dairy, which have great competitiveness in liquid milk products, hoped to develop the market of liquid milk in Heilongjiang province. Motivated by these reasons, most of the extraneous enterprises put their efforts on processing and market development and seldom make investment in the development of raw milk resource.

Local enterprises attach importance to the development of raw milk resource. Although foreign based enterprises do not have self owned pastures, they pay great attention on the production quality, so the purchasing and management of raw milk are regulated. For example, Nestle dairy enterprise in Shuangcheng city of Heilongjiang province, which was established in 1986, has made fine cooperation with the dairy farmers. While national dairy processing companies are eager for quick success and instant benefit in raw milk resource. In order to control the maximum raw milk resource by least cost, these national companies established the milk gathering center and made pure contractual business with dairy farmers. When the raw milk is in shortage, they raises the raw milk price, when the raw milk is over supply, they lowed the price and even refuse to buy. This kind of short term behaviors have seriously affect the transaction order of the raw milk market, disputes between extraneous enterprises and dairy farmers often arise. Bright Jiayuan dairy Co. ltd., one of the subsidiary company of Bright dairy, is the biggest dairy processing enterprises in Jaiyuan County. Most of the dairy farmers in Jiayuan are selling raw milk to this company. In the first half year of 2008, Bright Jaiyuan dairy has lowered the raw milk prices. The raw milk prices had decreased to 2.2 Yuan from the original 2.8 Yuan. At the same time, the reference price made by the dairy processing association of Heilongjiang province is 2.7yuan. The Bright Jiayuan dairy also refuse to pay for raw milk from 25th Feb. of 2008, the total arrearage is over RMB 1 billion, which made the production and lives of thousands of dairy farmers in Jiayuan in trouble. Because the raw milk can not be sold, some farmers had to sell the cows.

In order to change the game equilibrium, avoid the free ride behaviors of extraneous enterprises, many local enterprises have established self-owned pastures. According to the investigation from internet, currently there are 5 enterprises have pastures in Heilongjiang province, and all of which are local enterprises, see table II.

TABLE II DEVELOPMENT OF PASTURES OF LOCAL ENTERPRISES

Name of the enterprises	Conditions of pastures
Heilongjiang Wonder Sun Dairy Co. Ltd.	43 pastures, 150 million heads of cows
Heilongjiang Longdan Dairy Technology Co. Ltd.	2pastrures , 200 million heads of cows
Heilongjiang Geqiushan Dairy Co. Ltd.	25pastures ,6000 heads of cows
Mudanjiang Sandao Dairy Co. Ltd.	1 pasture, 1000 heads of cows
Qiqihar Yuanye Dairy Co. Ltd.	1pastuer, 1000 heads of cows

The investment behavior of local enterprises changes the result the boxed pigs' game. Since extraneous enterprises can no longer get free ride, the payoff of the strategy *not invest* become 0, so the rational choice will be to invest in the raw milk resource. Besides, with the development of cooperative organization, individual and scattered dairy farmers are organized. So the gradual integration of extraneous enterprises with dairy farmers can be realized by signing long term contracts.

4. Conclusion

This paper discusses the investment behaviors of dairy processing enterprises in cluster. A game theory model is built to study the raw milk resource investment behaviors between local processing enterprises and extraneous enterprises in dairy industry cluster. From the analysis of game equilibrium, it is known that under current condition, boxed pigs equilibrium is the result of the game. In order to improve the game result, property allocation should be redefined in the raw milk production. The case study of dairy industry cluster in Heilongjiang province proves the research findings. It is also shown that establishing self-owned pastures and building long term contractual relations with scaled dairy farms can improve the game result, so as to reach the cooperation equilibrium.

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6. References

- [1] Liu Chengguo. The Year Book of Chinese Dairy Industry .Beijing: Publishing House of Chinese Agriculture, 2010, pp.108.
- [2] Wang Jici. Research on Definitions of Chinese Industrial Cluster. Geographical Periodical. 2004, (10),pp. 47-52.
- [3] Jiang Haiyan. Evaluation and Compare of Chinese Dairy Industry's Longitudinal Organizational Relations. vol. 2. Technology and Management,2008,pp.52-55.
- [4] Lin Jian, Fan Jiafeng. "Boxed Pigs" Game Analysis on Innovation Behavior of Enterprises in Cluster. Vol. 24. System Enigeering, 2006, pp.31-35.
- [5] Xu Xiaojun. Social Distance and the Cooperative Behaviors between the Farmers. vol. 2. Zhejiang Social Science, 2004, pp.17-21 .
- [6] Zhang Weiying. Game Theory and Information Economics. Shanghai: Shanghai People Publishing House, 1996,pp. 213-224.