Vertical Integration and Reverse Engineering of Agricultural Enterprises

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Abstract This paper studies the potential effects of agricultural enterprise's vertical integration and reverse engineering on downstream firms. Suppliers who invest reverse engineering technology can exploit customer's information. An integrated supplier can obtain at no cost the information from its subsidiary. Based on repeated game and considered corporate "good" or "bad" type, this paper analysis supplier's selection and downstream investment in innovation. The results showed that: when the cost is higher than the threshold value no company invest in reverse engineering, when the cost is lower than the threshold value the integration company invest in reverse engineering; in the second period, vertical integration reduce the downstream independent enterprise's innovation investment and profits, integrated enterprise increase innovation investment and profits; during the first period of the game, the independent downstream firms being "completely foreclosure".

Key words Agricultural Integration, Vertical Integration, Market foreclosure, Reverse Engineering, Repeated Game

1 Introduction

Agricultural integration, also known as the industrialization of agriculture, is the combination of agricultural producers (farmers, farms, *etc.*) and other related sectors (industrial, commercial, service, financial, *etc.*) economically and organizationally, to achieve a certain kind of collaboration and unification, and seek common development[1]. China has implemented the development strategy of agricultural integration for more than 10 years, which largely promotes the transition of traditional agriculture in China to modern agriculture. The practice proves that the agricultural integration can break through the smallholder bottleneck constraints, and rule out the traditional institutional barriers, becoming the inherent power and effective way to enhance market agricultural development[2].

The vertical integration of agricultural enterprises is an important way of agricultural integration. For a long time, a lot of literature has studied and explored the vertical integration. Spengler (1950) analyzed the vertical integration process of upstream and downstream enterprises, and believed that the vertical integration can increase profits, reduce the final product price, and eliminate the double marginalization effect[3]. Stigler (1951) developed the life cycle theory of vertical integration, and believed that vertical integration is related to the life cycle of industry[4]. From the point of view of uncertainty, Arrow (1975) pointed out that when there was asymmetric information in the perfectly competitive market, the downstream enterprises can draw on the backward vertical integration, and enhance the market price forecasts, in order to avoid the production efficiency loss caused by the lack of information[5]. Williamson (1971, 1985) expanded Coase's theory of transaction cost, and portray the vertical integration from asset specificity, transaction uncertainty and transaction frequency[6-7].

The Chinese scholars Zhang Disheng and Chen Hongmin (2001) used the game theory and differential analysis technique to analyze the motivation and externality of vertical integration under the general assumption[8]. Based on the upstream enterprises engaged in R & D investment, the downstream enterprises engaged in R & D investment, and the upstream and downstream firms engaged in R & D investment at the same time, Huo Peijun and Xuan Guoliang (2000, 2001, 2002) analyzed the vertical integration cooperation and non - cooperation effects, indicating that the vertical R & D cooperation was conducive to promoting the corporate R & D activities, and increasing the yield of the final product, which will help improve the industry profits and social welfare, and verify the positive effects of vertical R & D cooperation[9-11]. Jing Hui and Xun Zhijian (2007) thought that the vertical integration enterprises can reduce their costs, but it will increase the cost of enterprises which are not integrated, leading to unfair competition, ultimately not conducive to industrial development[12]. Vertical integration will produce the market foreclosure effect, that is, the monopolistic sellers or buyers effectively use their monopoly power, to exclude competitors or reduce competition between competitors, and achieve the purpose of increasing monopoly profits.

These extremely rich and profound researches provide the theoretical reference and logical starting point for this article. This paper argues that in the duopoly structure, when the downstream enterprises carry out innovation, the upstream suppliers can decide whether to invest in reverse engineering, so that they can decipher the relevant information of customers (downstream enterprise), but the suppliers after vertical integration can obtain the information on their subsidiaries at no cost. Whether it is the information obtained from reverse engineering or subsidiaries, the

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suppliers can sell it to other downstream enterprises for profits.

Moreover, after one supplier is vertically integrated with one downstream enterprise, if the independent downstream enterprise chooses this integrated enterprise as its supplier, it will make its products likely to be copied. The market foreclosure arising from vertical integration reduces the independent downstream enterprises' innovation investment and profits, but increases the integrated enterprises' innovation investment and profits.

2 Hypotheses and model

Assuming that one system consists of the upstream market and the downstream market; two upstream enterprises (enterprise U_A and enterprise U_B) produce the homogeneous intermediate products; two downstream enterprises produce (enterprise D_1 and enterprise D_2) use these products to produce the final products.

Assuming that the marginal cost of upstream and downstream enterprises is always zero, and the upstream suppliers provide the intermediate products for the downstream enterprises at total cost T.

The downstream enterprises can increase the profits through innovation, and when one enterprise carries out innovation, the relative advantage makes them increases profits. However, when both of the enterprises carry out innovation, the competition makes part of the profits disappear and each enterprise obtains additional profits.

Assuming that the profit is zero when the enterprises do not innovate; each downstream enterprise Di decides its own level of innovation investment; the probability of innovation is $\rho_i[0, 1]$; the input cost is $C(\rho_i)$.

Assuming that $C(\rho_i)$ is quadratic differentiable convex function and it meets $C''(\cdot) > \Delta - \delta$.

Repeated game is as follows:

(i) Time period 1 ($t = 1$). In phase 1, D_1 and D_2 select their own level of innovation investment at the same time, the probability of innovation is ρ_1 and ρ_2, and the innovation success or failure is visible for all enterprises.

In phase 2, U_A and U_B provide the intermediate products to the downstream enterprises at the same time. D_1 and D_2 choose their own suppliers.

Phase 2 can also be changed to: vertical integration between U_A and D_1. For D_2, there will be a risk: when it chooses U_A as the supplier, its innovation may be copied by D_1. If so, we use $\theta > 0$ to represent the probability of imitation.

Suppliers finally decide whether to invest in reverse engineering at cost of A, and the suppliers investing in reverse engineering can decipher customer information, but the integrated supplier can obtain the information on its subsidiaries at no cost. Whether it is the information obtained from reverse engineering or subsidiaries, the suppliers can sell it to other downstream enterprises at the cost of δ.

(ii) Time period 2 ($t = 2$). There are two phases same as above.

3 Vertical integration and reverse engineering

Before vertical integration, assuming $A > \delta$, the cost A does not bring any additional profit, and the suppliers will not invest in reverse engineering, therefore, for the two vertically separated suppliers, the only equilibrium is the case, and no one invests in reverse engineering.

In contrast, the integrated enterprises may find that it is profitable investment, conducive to preventing the resulting market foreclosure effect (Hart & Tirole, 1990)[13].

Assuming that U_A and D_1 are vertically integrated into $U_A - D_1$, we need to first consider the game in Time period 2 ($t = 2$). Even if the integrated enterprises have invested in reverse engineering, they will protect their subsidiaries; the independent enterprises never invest in reverse engineering.

If D_2 thinks that U_A does not invest in reverse engineering in Time period 1 (U_A is expected to never invest in Time period 2), then the upstream competition is still symmetrical, so the suppliers set price, the innovation probability of downstream enterprises in Time period 2 and expected profit based on the cost.

If D_2 believes that U_A previously invested in reverse engineering, the asymmetrical upstream competition will make the intermediate product price of U_B greater than zero, that is, the vertical integration results in the rising intermediate product price, and the market foreclosure is generated ("partial foreclosure").

Now we consider the game in Time period 1, and assume that the discount factor is β. When both of the downstream enterprises carry out innovation, or neither of them innovates, the upstream competition is symmetric, making the suppliers set price based on cost, and the two downstream enterprises obtain δ or 0. In both cases, there are no suppliers investing in reverse engineering.

If the innovator is D_1, U_A can not benefit from reverse engineering, because even if U_A wants to sell the innovation of its subsidiary business, it can be easily obtained from D_1.

If the innovator is D_2, the net loss for U_A to invest in reverse engineering is $A - \theta\delta$, but the integrated enterprises' profit is increased by $\pi_{A1}^I - \pi^*$ in Time period 2.

Therefore, it meets the following condition:

$$A - \theta\delta < \beta(\pi_{A1}^I - \pi^*) \quad (1)$$

$U_A - D_1$ is selected as supplier, and it will invest in reverse engineering. U_A is willing to provide intermediate products at the cost of T_A.

$$T_A = A - \theta\delta - \beta(\pi_{A1}^I - \pi^*) < 0 \quad (2)$$

In contrast, U_B is willing to provide intermediate products at the cost of T_B:

$$T_B = \beta\pi_B^I > 0 \quad (3)$$

Proposition 1: When $A > \beta(\Pi^I - \Pi^S) - \theta(\Delta - 2\delta)$, there will be no enterprises investing inreverse engineering, but in Time period 1 ($t = 1$), there will be market foreclosure; when $A < \beta(\Pi^I - \Pi^S) - \theta(\Delta - 2\delta)$, the integrated enterprises invest in reverse engineering, and in Time period 2 ($t = 2$), there is market foreclosure ($\Pi^I - \Pi^S = \pi_{A1}^I + \pi_2^I + \pi_B^I - 2\pi^*$).

When $A > \beta(\Pi^I - \Pi^S) - \theta(\Delta - 2\delta)$, we can get:

$$\Delta - T_B + \beta\pi^* > \Delta - \theta(\Delta - \delta) + \beta\pi_2^I - T_A \quad (4)$$

U_B wins in the competition, and the integrated enterprises do not invest in reverse engineering. Since $T_B > T_A$, it means that thevertical integration raises the prices of intermediate goods, unfavorable to the downstream independent enterprises, and the market foreclosure is generated ("partial foreclosure").

When $A < \beta(\Pi^I - \Pi^S) - \theta(\Delta - 2\delta)$, U_A wins in the competition in Time period 1 ($t = 1$), and there is no market foreclosure, but as long as formula (1) is valid, the integrated enterprises find it profitable to invest in reverse engineering. We can see from the preceding discussion that since $T_B > T_A$, there is market foreclosure ("partial foreclosure") in Time period 2 ($t = 2$).

4 Repeated game

Assuming that some suppliers must spend $A > \delta$ to use customer information (for example, by investing in reverse engineering), while some suppliers can attain this at zero cost. The former is known as "good" type, while the latter is known as "bad" type.

To simplify the model, we assume that only the supplier U_A type is uncertain, that is, the probability of "good" is $p(0 < p < 1)$, and the probability of "bad" is $1 - p$. The probability of "good" in U_B is 1. To simplify the model, we assume that $\theta = 1$, $\delta = 0$. Even if the profit is negligible, "bad" suppliers still choose to use customer information.

4.1 Game in Time period 2 Since $\delta = 0$, the profit can be only earned by one enterprise D_i. Now D_i is assumed to be independent, and U_A is selected as the supplier.

Since the income stemming from the utilization of information on D_i is zero, only when U_A is "bad" type can this be done. This also means that regardless of the type, U_A obtains the same profit "zero", and the upstream price competition then reaches a standard asymmetric Bertrand game $T_A = 0$, $T_B = (1 - p)\Delta$.

Proposition 2: When $t = 2$, before vertical integration, the downstream enterprises' innovation investment and profits increase along with the increase in p; after vertical integration, the independent downstream enterprises' innovation investment and profits decline, while the integrated enterprises' innovation investment and profits increase.

Before being vertically integrated, the expected profit of independent enterprise D_i is:

$$\Pi_i = \rho_i(1 - \rho_j)(\Delta - T_B) - C(\rho_i) = \rho_i(1 - \rho_j)\rho\Delta - C(\rho_i) \quad (5)$$

The innovative efforts of the downstream enterprises are balanced:

$$\rho_1 = \rho_2 = \rho^*(p) < \rho^*(1) \quad (6)$$

Therefore, the profits of upstream and downstream enterprises are:

$$\pi_1 = \pi_2 = \pi^*(p) = \rho^*(p)[1 - \rho^*(p)]p\Delta - C[\rho^*(p)] \quad (7)$$

$$\pi_A = 0 \quad (8)$$

$$\pi_B = 2\rho^*(p)[1 - \rho^*(p)](1 - p)\Delta \quad (9)$$

According to the envelope theorem, we get:

$$\pi^{*\prime}(p) = \rho^*(p)[1 - \rho^*(p)]\Delta - \rho^*(p)\rho^{*\prime}(p)p\Delta \quad (10)$$

Based on the first order condition of formula (7), we can get:

$$C'[\rho^*(p)] = [1 - \rho^*(p)]p\Delta \quad (11)$$

By formula (10), (11), we can get:

$$\rho^{*\prime}(p) = \frac{[1 - \rho^*(p)]\Delta}{C''[\rho^*(p)] + p\Delta} > 0 \quad (12)$$

$$\pi^{*\prime}(p) = \frac{\rho^*(p)[1 - \rho^*(p)]\Delta C''[\rho^*(p)]}{C''[\rho^*(p)] + p\Delta} > 0 \quad (13)$$

Therefore, with the increase of p from 0 to 1, the downstream enterprises' innovation investment and profit increase, and $\pi^*(p)$ is increased from $\pi^*(0) = 0$ to $\pi^*(1) = \pi^*$.

After U_A and D_i are vertically integrated:

$\rho_2 = \rho^-(p) < \rho^*(p) < \rho^+(p) = \rho_1$, $\pi_{A1}^2 \geqslant \pi^*(p)$, $\pi_2^2 \leqslant \pi^*(p)$

where $\rho^-(p)$ and $\rho^+(p)$ signify the innovation probability of the independent downstream enterprises and the integrated enterprises respectively; π_2^2 and π_{A1}^2 signify the profit of the independent downstream enterprises and the integrated enterprises in Time period 2, respectively.

4.2 Game in Time period 1 Proposition 3: When $t = 1$, before vertical integration, the downstream enterprises actively invest in innovation and achieve positive expected profits; after vertical integration, if $A < A(p) = \beta(\pi_{A1}^2 - \pi^*)$, the integrated enterprises fully foreclose the independent downstream enterprises.

Before vertical integration, is assumed to be the only innovator, and is selected as the supplier. will always get zero profit in the future, and total profit of is as follows:

$$\pi_i = (1 - p) \times 0 + p(\Delta + \beta\pi^*) = p(\Delta + \beta\pi^*) \quad (14)$$

U_A is vertically integrated with D_1, and U_A will protect the innovation of its subsidiaries. D_2 is assumed to be the only successful innovator, and U_A is selected as the supplier.

If U_A is "bad" type, it copies the innovation of D_2 and benefits in the game of Time period 2.

If U_A is "good" type, it does not copy the innovation and obtains profit in the game of Time period 2.

The imitation and uncertainty of the type make the integrated enterprises get π_{A1}^2. If the following condition is met:

$$A < A(p) = \beta[\pi_{A1}^2 - \pi^*] > 0 \quad (15)$$

Regardless of the type of U_A, U_A will always use information on D_2, because the market foreclosure benefits exceed the costs of reverse engineering. Therefore, when $A < A(p)$, D_2 should not trade with $U_A - D_1$, which causes the expected total income of D_2 to be $\theta\delta + (1 - \theta)\Delta = 0$. The value of innovation of D_2 completely disappears due to imitation, and U_A will get income $\theta\delta = 0$ by imitation.

U_A will provide the intermediate goods at the price of $T_A = -\theta\delta = 0$. So, D_2 chooses U_B as the supplier, and the net profit of D_2 is as follows:

$$\theta\delta + (1 - \theta)\Delta - T_A = \Delta - TB \quad (16)$$

By formula (16), we can find that when $\theta = 1$ and $\delta = 0$, $T_B = \Delta$, that is, U_B can extract the full value from the innovation of

D_2 ("complete foreclosure").

5 Conclusions

Based on repeated game, this article considers the "good" or "bad" type of enterprises, and studies the impact of vertical integration between one upstream enterprise and one downstream enterprise on the independent downstream enterprises in a duopoly market. Meanwhile the suppliers can invest in reverse engineering, which will also affect the downstream enterprises' innovation and profits.

The study results show that when the cost is higher than the threshold value $\beta(\Pi^I - \Pi^S)\theta(\Delta - 2\delta)$, there will be no enterprise investing in reverse engineering; when the cost is lower than the threshold value, the integrated enterprises will invest in reverse engineering; in the game of Time period 2, the downstream enterprises' innovation investment and profits increase with the increase in the "good" probability of suppliers before vertical integration; after vertical integration, the independent downstream enterprises' innovation investment and profits decline, but the integrated enterprises' innovation investment and profits increase; in the game of Time period 1, the vertical integration makes the independent downstream enterprises "totally foreclosed".

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developing high -tech industries and equipment manufacturing to constantly improve the city's service function, and strive to keep the economic development ahead. The development of secondary and tertiary industries is balanced in Gaoling County, Yanliang District, Baqiao District and Chang'an District, so the overall economic strength is also great. They should give full play to their strengths to make the central city facilities serve Chang'an and Gaoling, speed up the construction of Chang'an Aerospace Industrial Base, Jinghe Industrial Park, Yanliang Aviation Industrial Base, and take active support policies and measures, to promote a new round of rapid development of the economy. The secondary and tertiary industries are underdeveloped in Lantian County, Zhouzhi County, Lintong District, and Huxian County. Based on their own characteristics, they should rely on the industrial park, undertake the relocation of the central city businesses, and form "supporting industry + featured agriculture "functional area by providing support services for large enterprises. In summary, it is reasonable to use principal component analysis and cluster analysis to carry out comprehensive evaluation of the overall economic strength of districts and counties in Xi'an City. In fact, it is also consistent with the actual situation of Xi'an. Through the division of the economic conditions of 13 districts and counties, it provides data support for further economic development and policy establishment in Xi'an City.

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