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Analysis of the Relationship Between the Enterprise Technological Absorptive Capacity and External Corporate Profit Outside of Joint R and D Organization

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Abstract: The research introduced enterprise technological absorptive capacity into joint R and D game analysis. By constructing a two-stage of three enterprises joint R and D game model, we got the equilibrium solution of cooperative R and D behavior under enterprises different technological absorptive capacity. In three situations, we discussed the relationships between enterprise technological absorption capacity with the external corporate profit and its enthusiasm to participate in joint R and D.

Key words: Joint R and D, technological absorptive capacity, technological spillover, external corporate profit

INTRODUCTION

Joint R and D is an important way of technological innovation which can share the development costs and risks. Realizing the scale effect of R and D. But in reality, Joint development has a higher failure rate, especially when the cooperative company has different absorbing capacity. Perhaps, because of the inequality profit of both sides, they are not willing to undertake R and D investment. As a result, the cooperation is difficult to happen and continue. In the same industry, for the enterprise outside of joint R and D organization, other firms to cooperate in research and development will have an impact on the external companies, but in different situations have different effects, at the same time, the positivity of external enterprise to join the cooperative R and D organization is also different.

Cohen and Levinthal (1989) growing empirical evidence strongly supports that a firms' R and D will contribute to realizing spillovers from other firms' R and D efforts as well as enhancing its innovative ability. This is the second face of R and D, namely, absorptive capacity. Deriving from its own R and D efforts as a measure of its ability to benefit from other firms' R and D activities. Kostopoulos *et al.* (2011), the empirical evidence with a sample of 461 Greek enterprises participating in the third Community Innovation Survey demonstrates that absorptive capacity are directly related to external R and D knowledge and contributes to firms' innovation. Moreover, Del Carmen Haro-Dominguez *et al.* (2007), show the degree of absorptive capacity influences positively both external and internal acquisition types of technology over 250 Spanish engineering consulting firms. Grunfeld (2003) probed into how R and D investment decision is affected by spillovers with absorptive capacity. Leahy and Neary (2007) specified a general model of the absorptive capacity process and showed that costly absorptive capacity both raises the effectiveness of its own R and D and lower the effective spillover coefficient.

Kim and Inkpen (2005) develop a model of technology learning by integrating technological capabilities and alliance knowledge in a framework of absorptive capacity.

They also differentiate between absolute and relative components of absorptive capacity. Their study of the chemical-pharmaceutical industry found that technology learning was higher when firms were quick to adopt new technologies and when they have accumulated experience via alliances. Among alliances, cross-border R and D alliances have the strongest effect on technology learning. Overall, the findings show the pronounced effect of absolute absorptive capacity on technology learning.

Poyago-Theotoky (1995) has constructed a model of oligarchs in which exists technology spillover to analyze the equilibrium scale and optimum size of R and D alliance (RJV research joint venture) under spillover; In cartel Alliance mode, the number of balanced union memberships are about half of the total number of enterprises and increase with increased technology spillover. Kaiser (2002) study showed that level spillover has a very weak positive significantly effect on promoting enterprise cooperation, bigger companies are more likely to engage in cooperative R and D .Through the investigation of 1800 companies in France, Negassi (2004) found that technology spillover have a positive effect on cooperative R and D, but the impact strength is very low.

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The existing studies are generally assume that technology overflow is two-way quits to both sides of cooperation, but actually there is always differences in the technological absorption capacity of the cooperative enterprise, which will generate a critical impact on joint R and D. Under the condition of unchanged industry environment, due to the cooperative development can improve the R and D enterprises' technology competitive advantage, change the relative competitive position among enterprises in the industry and thus affect external corporation profit and its enthusiasm to participate in joint R and D. Therefore, in this paper, enterprises' technology absorption capacity was introduced in a game model of joint R and D and then it discusses relationship between enterprise technological absorptive capacity with the external corporate profit and its enthusiasm to participate in joint R and D.

BUILD THE GAME MODEL

- There is asymmetric absorption capacity of three companies within the same industry ,i = 1, 2, 3 the enterprise products can substitute each other. firm 1 and 2 form a joint R and D alliance to compete with the third one in product market.Meanwhile, there is no other cooperative R and D alliance in this industry
- Marginal cost of three enterprises producing products is c_i (i = 1, 2, 3), $c_1 = c_2 = c_3$ and $c_i>0$,without considering the fixed cost. The Parameter of demand curve is indicated by a (a>0 and $a>c_i$. Enterprises can reduce product costs in cooperative R and D through technology spillover and absorption, the degree of cost reduced is indicated by x_i
- Threecompanieshave uncoordinated technology absorptioncapacity β_i (i = 1, 2, 3), namely $\beta_1 \neq \beta_2 \neq \beta_3$, $0<\beta_i<1$, if β_1 is close to1, it meansthatthe absorptionabilityofenterpriseiis stronger and more close to 0 prove that the absorption ability of enterprise i isweaker
- Technology spillover coefficient is indicated by α and γ, α means the degree of internal technology spillover of cooperative R and D organization, γ represents the degree of external technology spillover of cooperative R and D organization and $\alpha>\gamma$, $0<\alpha, \gamma<1$
- The success rate of enterprise technology development and innovation in cooperative R and D organization is b_k ($0<b_k<1$, k = 1, 2). b_1 represent joint R and D firm's Success rate, b_2 represents the other and $b_1 > b_2$
- Enterprises set their own profit maximization as the goal. Enterprises of cooperative R and D take aim at the overall profit maximization of cooperative organization. Enterprises except which belong to cooperative R and D Organization set themaximization of theirownprofitp_i astheirgoal.
- Three companies conduct a two-stage dynamic game with complete information. First phase is decision-making phase of investment in R and D, companies choose their level of investment in R and D that represented by y_i, in order to reduce the cost of the product; Second one is a process of production decision, Cournot game is carried on the product market, selecting the respective yield q_I to maximize your own profits .Each Stage enterprise making the decision at the same time with only one choice; Enterprise income is equal to the profit p_i of the second stage minus the R and D investment y_I of the first phase

Using x_i to represent the degree of cost reduced, As R and D investment is decreasing returns to scale, get the relationship between R and D investment y_I and the degree of product unit cost reduced:

$$x_i = \sqrt{b_k y_i} \quad y_i = \frac{1}{b_k} x_i^2 \tag{1}$$

Corporate demand function is linear form,p represents the market price of a homogeneous product, the product yield and product price relationship are:

$$p = a - \sum_{i=1}^{3} q_i \quad \sum_{i=1}^{3} q_i = a - p \tag{2}$$

Enterprise production cost is expressed by C_i, its function expression is:

$$\begin{cases} C_1 = c_1 - x_1 - \beta_1 \alpha x_2 - \beta_1 \gamma x_3 \\ C_2 = c_2 - x_2 - \beta_2 \alpha x_1 - \beta_2 \gamma x_3 \\ C_3 = c_3 - x_3 - \beta_3 \gamma x_1 - \beta_3 \gamma x_2 \end{cases} \tag{3}$$

Using C_i to represent the three enterprises marginal cost and fixed costs are zero .The benefit function is the profit function of enterprise R and D investment, namely, the profit of the second phase minus the R and D investment of the first stage. Get the enterprise revenue function is:

$$\begin{cases} \pi_1 = [a - (q_1 + q_2 + q_3) - (c_1 - x_1 - \beta_1 \alpha x_2 - \beta_1 \gamma x_3)]q_1 - \frac{1}{b_1} x_1^2 \\ \pi_2 = [a - (q_1 + q_2 + q_3) - (c_2 - x_2 - \beta_2 \alpha x_1 - \beta_2 \gamma x_3)]q_2 - \frac{1}{b_1} x_2^2 \\ \pi_3 = [a - (q_1 + q_2 + q_3) - (c_3 - x_3 - \beta_3 \gamma x_1 - \beta_3 \gamma x_2)]q_3 - \frac{1}{b_2} x_3^2 \end{cases} \tag{4}$$

GAME EQUILIBRIUM SOLUTION

Output decision stage: The enterprise cost and investment level are given, three firms conduct a Cournot game, each enterprise according to maximizing their own interest requirement to select the production, to meet the enterprise profit maximization first-order condition for:

$$\frac{\partial \pi_1}{\partial q_1}=0,\frac{\partial \pi_2}{\partial q_2}=0,\frac{\partial \pi_3}{\partial q_3}=0 \tag{5}$$

The enterprise equilibrium output is:

$$\begin{cases} q_1^*=\frac{1}{4}[a-3c_1+c_2+c_3+(3-\beta_2\alpha-\beta_3\gamma)x_1+(3\beta_1\alpha-1-\beta_3\gamma)x_2+(3\beta_1\gamma-1-\beta_2\gamma)x_3] \\ q_2^*=\frac{1}{4}[a-3c_2+c_1+c_3+(3-\beta_1\alpha-\beta_3\gamma)x_2+(3\beta_2\alpha-1-\beta_3\gamma)x_1+(3\beta_2\gamma-1-\beta_1\gamma)x_3] \\ q_3^*=\frac{1}{4}[a-3c_3+c_1+c_2+(3-\beta_1\gamma-\beta_2\gamma)x_3+(3\beta_3\gamma-1-\beta_2\alpha)x_1+(3\beta_3\gamma-1-\beta_1\alpha)x_2] \end{cases} \tag{6}$$

R and D Investment decision stage: In the enterprise R and D input stage, enterprises choose their R and D investment level y_i to reduce the product cost at the same time, research and development organizations outside the enterprise can choose R and D investment, also cannot input, to meet the enterprise profit maximization conditions for:

$$\frac{\partial(\pi_1+\pi_2)}{\partial x_1}=0,\frac{\partial(\pi_1+\pi_2)}{\partial x_2}=0,\frac{\partial \pi_3}{\partial x_3}=0 \tag{7}$$

The enterprise equilibrium output is:

$$\begin{cases} q_1^*=\frac{1}{4}[a-3c_1+c_2+c_3+(3-\beta_2\alpha-\beta_3\gamma)x_1^*+(3\beta_1\alpha-1-\beta_3\gamma)x_2^*+(3\beta_1\gamma-1-\beta_2\gamma)x_3^*] \\ q_2^*=\frac{1}{4}[a-3c_2+c_1+c_3+(3-\beta_1\alpha-\beta_3\gamma)x_2^*+(3\beta_2\alpha-1-\beta_3\gamma)x_1^*+(3\beta_2\gamma-1-\beta_1\gamma)x_3^*] \\ q_3^*=\frac{1}{4}[a-3c_3+c_1+c_2+(3-\beta_1\gamma-\beta_2\gamma)x_3^*+(3\beta_3\gamma-1-\beta_2\alpha)x_1^*+(3\beta_3\gamma-1-\beta_1\alpha)x_2^*] \end{cases} \tag{8}$$

The enterprise equilibrium profit is:

$$\begin{cases} \pi_1^*=\frac{1}{16}[a-3c_1+c_2+c_3+(3-\beta_2\alpha-\beta_3\gamma)x_1^*+(3\beta_1\alpha-1-\beta_3\gamma)x_2^*+(3\beta_1\gamma-1-\beta_2\gamma)x_3^*]^2-\frac{1}{b_1}x_1^{*2} \\ \pi_2^*=\frac{1}{16}[a-3c_2+c_1+c_3+(3-\beta_1\alpha-\beta_3\gamma)x_2^*+(3\beta_2\alpha-1-\beta_3\gamma)x_1^*+(3\beta_2\gamma-1-\beta_1\gamma)x_3^*]^2-\frac{1}{b_1}x_2^{*2} \\ \pi_3^*=\frac{1}{16}[a-3c_3+c_1+c_2+(3-\beta_1\gamma-\beta_2\gamma)x_3^*+(3\beta_3\gamma-1-\beta_2\alpha)x_1^*+(3\beta_3\gamma-1-\beta_1\alpha)x_2^*]^2-\frac{1}{b_2}x_3^{*2} \end{cases} \tag{9}$$

RELATIONSHIP BETWEEN TECHNOLOGICAL ABSORPTIVE CAPACITY AND THE EXTERNAL CORPORATION PROFIT

On the assumption that three firms have R and D investment ($y_i \neq 0$), then the product cost decrease that caused by its own R and D investment is not zero ($x_i \neq 0$). In addition, we assume that the product costs are equal before cooperative R and D and represent by c ($c_1 = c_2 = c_3$), doing some simple processing on the absorbing ability, that is, $\beta_{Max} = \beta^*$, $\beta_{Mid} = 0.5\beta^*$, $\beta_{Min} = 0.25\beta^*$, $\gamma = 0.5\alpha$, $\alpha = 0.25$, 0.5 and 0.75, respectively, $b_1 = 0.8$, $b_2 = 0.5$.

Situation 1: In three enterprises of absorptive capacity larger two enterprises are cooperative R and D, the smallest is not a member of cooperative R and D organization ($\beta_1>\beta_2>\beta_3$), through the MATLAB analysis of π_3 with β curves which are shown in Fig. 1, it is concluded:

- The outside corporation of Joint R and D organization profit is negative and it present overall downward trend. When the cooperative R and D organization more powerful technical force, the higher absorptive capacity, the external corporate profit will be lower ,when the level of its own absorptive capacity increases, Profit decrease extent will slow somewhat, but the decreasing trend still will not change. Here we can explain: joint R and D as a form of technological development is attractive to the enterprise which has a weaker technical force in the industry, it will have a greater willingness to cooperate in research and development, this situation is also basically consistent with other scholars in the field study
- Technological spillover has a negative impact on the external corporate profit, can inspire it to join the cooperative R and D organization. Under the condition of joint R and D organization higher technology spillover degree, due to the technological absorptive capacity of external enterprise is weaker,

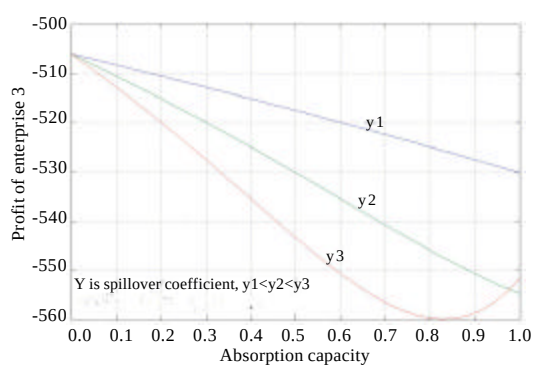

Fig. 1: Relationship between technological absorption capacity and corporation profit outside of joint R and D organization (situation 1)

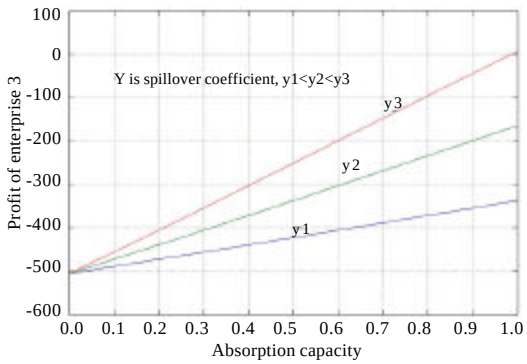

Fig. 2: Relationship between technological absorptive capacity and corporation profit outside of joint R and D organization (situation 2)

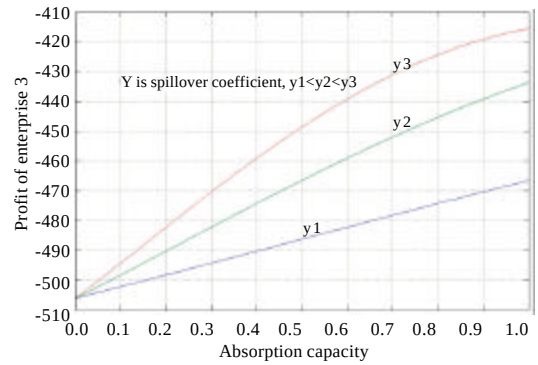

Fig. 3: Relationship between technological absorptive capacity and corporation profit outside of joint R and D organization (situation 3)

in the same circumstances, Conversion technology from outside of their own enterprise is less, still can not change the relative competitive position, which is not conducive to business survival. But on the other hand, it can strengthen the motivation to join R and D cooperation. Therefore, it is conclude that in this condition, the higher technological spillover degree, the more conducive to the enterprise to carry out cooperative research and development

- Due to disadvantaged businesses within the industry have weaker absorptive capacity, the other technical advantages of their enterprises to cooperate in research and development is a competitive threat, not conducive to their survival. On the contrary, it actually increased their participation in collaborative R and D initiative, so there is a strong desire to join cooperative R and D organizations

Situation 2: In three enterprises, of which two smaller absorption ability of enterprises to cooperate in R and D, the largest enterprise do not participate in ($\beta_3>\beta_1>\beta_2$), through the MATLAB analysis of π_3 with β_3 curves which are shown in Fig. 2, we may safely draw the conclusion:

- External corporate profit is negative, but the profit change is a growing trend. When a cooperative research and development appear in the industry, it will have a negative impact on enterprises which not participate in join R and D. However, due to external company strong technical force, higher level of technical digest ability, it can gradually reverse this situation and the adverse effect on the cooperative research and development enterprises. As compared with the previous case, the enterprise enthusiasm for collaborative R and D is weak
- In the Situation 2, technological spillover is beneficial for company 3. Because of higher absorption capacity and technological absorption conversion efficiency, it can fully absorb the overflowing technical knowledge and have fewer affected on relative competitive advantage within the industry. So the company 3 will not have a strong motivation for collaborative R and D. meanwhile, it will inhibit other enterprises to carry out joint R and D
- It can be drawn from the analysis, the leading enterprises to other enterprises in collaborative R and D is both a threat and the driving force. When the competition status gap is small, other companies can research together to catch up with the technological superiority enterprise. When the competition status gap is larger, it can not change the relative competitive position within the industry, the leading enterprise's threat is greater than its power

Situation 3: In three enterprises, of which the absorptive of the smallest and the largest of the two enterprises to cooperate in R and D, the largest enterprise do not have to participate in collaborative R and D ($\beta_1>\beta_3>\beta_2$), through the MATLAB analysis of π_3 with β_3 curves which are shown in Fig. 3, it is concluded that:

- External corporate profit is negative, but the profit change is a growing trend, lower growth rate compared with situation 2. The main reason is that the technology advantages of company 3 is not obvious, the technological transformation efficiency is not high enough. Thus the threat to joint R and D internal company is weak
- When the technology spillover coefficient is larger, external corporate profit growth is also larger. But compared with situation 2, the profit growth rate is

lower. And because the external firm has not prominent technological advantage and higher technical conversion rate, so it is not a strong threat for R and D enterprises

- In the Situation 3, joint R and D will have an adverse impact on the external enterprise, but this kind of unfavorable situation will change because of its relatively higher absorption capacity. Therefore, joint R and D attractive to outside business, but the firms' motives unlike its strong in situation 1

CONCLUSION AND DISCUSSION

By way of introducing the enterprise technological absorption capacity and considering the relationship between the joint R and D enterprises and independent business, this paper builds a two-stage game model of three enterprises joint R and D. it analyzes the effect of the enterprise technological absorption capacity on external corporate profit and draw the following conclusions:

- The strength of enterprise technological absorptive capacity will affect the external corporate profit and its enthusiasm to participate in joint R and D
- In the fierce market competition, cooperation development is not good for every cooperative enterprise. When the external enterprise takes up advantage position in the industry, such as mastered the vast majority of the related technology patents or controlled the industry technical standards, for cooperative research and development enterprise, because it is difficult to change the relative competitive potential, The increase of the joint R and D investment will also be detrimental to the enterprise, joint R and D has poor stability and the initiative of external enterprise to join the collaborative R and D is not strong. When the external enterprise occupies a technical weak position, the other companies to carry out joint R and D will have a greater impact on it and it has larger willingness to cooperate
- Disadvantaged businesses and vulnerable enterprises or absorption capacity gaps larger enterprises to develop joint R and D is not stable enough. We can found from the analysis, if technical weak companies to carry out cooperation in R and D, due to the threat of other external advantage enterprises, cooperative enterprises investment and profits have declined, it cannot change the relative competitive position within the industry, joint R and D enterprises cooperation willingness will decline, eventually lead to the failure cooperative R and D. For the technology gap larger enterprises, because of the different technical knowledge conversion efficiency, it will not conducive to the development of disadvantaged businesses and diminish the vulnerable enterprises enthusiasm, eventually also lead to the collapse of cooperative organizations

By using game theory methods in this research, we make model building and simulation of the impact that enterprise technological absorptive capacity act on the external corporate revenue and have a study on the influence law that joint R and D apply to external enterprise income in the case of three companies. But model supposes that each stage game for each enterprise has only one choice and assuming that R and D investment is one-off, it will have some different with the reality and also need further improvement of the model construction.

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