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A Study on the Relationship Between the Different Technological Absorptive Capacity and Cooperative R and D Income in Cooperative R and D

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Abstract: The research introduced enterprises technological absorption capacity into cooperation R and D game analysis. By constructing a two-stage cooperative R and D game model of three enterprises, we got the equilibrium solution of coovvperative R and D behavior under enterprises different technological absorption capacity. In three situations, we discussed the relationships between enterprise different technological absorption capacity and the R and D income. The results show that Cooperative R and D income is affected by the technological absorptive capacity and external enterprises.

Key words: Cooperative R and D, technological absorptive capacity, technological spillover, R and D income

INTRODUCTION

Cooperative 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, Cooperation development also has higher failure rate. Andersen (2000) has carried on an investigation against nearly hundred enterprise alliance in 2000. The results show that 30% of member enterprises think alliance is unsuccessful and other 27% of enterprises are disappointed with that. Cooperative R and D has a logic problem with the “prisoner’s dilemma”, especially when the cooperative company has different absorbing capacity. Perhaps, because of the inequality income of both sides, they are not willing to undertake R and D investment. As a result, the cooperation is difficult to happen and continue. Hamel (1991) argues that different proficiency in learning (organizational technological absorption capacity) that will change partners “bargain” relative ability and eventually affect enterprise collaboration performance.

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.

D’Aspremont and Jacquemin (1988, 1990) build a duopoly game model (model AJ), laying the research basis of cooperative R and D problem among competitive enterprises. In AJ model, we assume that the investment of research and development spillover levels and yield are symmetrical and manufacturers have full information. AJ model concludes that if technology spillover is large enough, relative to the noncooperation, the cooperative research and development agreement from competition manufacturers will increase the level of investment in research and development, but less than socially optimal level.

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, balanced union membership is about half of the total number of enterprises and increases 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 has a positive effect on cooperative R and D, but the impact strength is very low.

Haruna and Goel (2011) employ a three-stage game model with cost-reducing research and development

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(R and D) that is subject to spillovers to consider the problem of excess entry under free-entry equilibrium relative to the social optimum. They demonstrate that research spillovers hold the key to whether established results regarding socially inefficient entry hold. Specifically, excessive entry occurs as long as research spillovers are relatively small, but this is not necessarily the case with large spillovers.

Hurmelinna-Laukkanen (2012) collected data from 335 firms was utilized to perform regression analyses. The empirical evidence suggests, first, that the strength of the appropriability regime has a positive effect on absorptive capacity (especially the acquisition of knowledge) together with good connectedness to external knowledge sources and high levels of internal R and D. In addition, support can be found for the idea of absorptive capacity and the appropriability regime being positively related to innovation performance. Both direct and moderating effects can be found but they are slightly different for knowledge acquisition and application. Hurmelinna-Laukkanen *et al.* (2012) collected data from 213 R and D-intensive firms, demonstrate that stability and absorptive capacity are most relevant for the alliance level success.

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 cooperative R and D. In this study, Enterprises' technology absorption capacity is introduced in a game model of cooperative R and D and then it discusses relationship between enterprise technology absorption capacity differences and cooperative R and D income.

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. Company 1 and 2 form a cooperative 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. Q_i represents the company i's yield decision-making space, the representative of company i's investment in R and D decision-making space is y_i
- 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
- Marginal cost of three enterprises producing products is c_i, without considering the fixed cost. 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
- Three companies have uncoordinated technology absorption capacity β_i, the value range of β_i is varies from 0 to 1, if β_i is close to 1, it means that the absorption ability of enterprise i is stronger and more close to 0 prove that the absorption ability of enterprise i is weaker
- 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 $\alpha>\gamma$
- 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 the maximization of their own profit p_i as their goal

The description of key variable in the model is shown in Table 1 and the description of key parameter in the model is shown in Table 2.

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

$$\begin{cases} C_1 = c_1 - x_1 - \beta_1 \alpha x_2 - \beta_1 \gamma x_3 \\ C_2 = c_2 - x_2 - \beta_2 \alpha x_1 - \beta_2 \gamma x_3 \\ C_3 = c_3 - x_3 - \beta_3 \gamma x_1 - \beta_3 \gamma x_2 \end{cases} \quad (1)$$

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:

Table 1: Description of key variable in the model

Variable	Representative character	Relation
R and D investment	y_i	$y_i = \frac{1}{b_k} x_i^2$
Unit cost reduction	x_i	$x_i = \sqrt{b_k y_i}$
Product yield	q_i	$\sum_{i=1}^{3} q_i = a - p$
Product price	p	$p = a - \sum_{i=1}^{3} q_i$

Table 2: Description of key parameter in the model

Parameter	Code symbol	Relation	Value area
Technology spillover coefficient among enterprises in cooperative R and D organization	α	$\alpha>\gamma$	$0\le\alpha\le1$
Technology spillover coefficient among enterprises out of cooperative R and D organization	γ	$\alpha>\gamma$	$0\le\gamma\le1$
Coefficient of enterprise absorptive capacity	β_i (i = 1, 2, 3)	$\beta_1\ne\beta_2\ne\beta_3$	$0\le\beta_i\le1$
Success rate of enterprise technology development and innovation in cooperative R and D organization	β_k	$b_1>b_2$	$0\le\beta_k\le1$
Unit cost	c_i (i = 1, 2, 3)	$c_1 = c_2 = c_3$	$c_i>0$
Parameter of demand curve	a	$a>c_i$	$a>0$

$$\pi_i = (p - C_i)q_i - y_i \tag{2}$$

Get the enterprise revenue function is:

$$\begin{cases} \pi_1 = [a-(q_1+q_2+q_3)-(c_1-x_1-\beta_1\alpha x_2-\beta_1\gamma x_3)]q_1 - \frac{1}{b_1}x_1^2 \\ \pi_2 = [a-(q_1+q_2+q_3)-(c_2-x_2-\beta_2\alpha x_1-\beta_2\gamma x_3)]q_2 - \frac{1}{b_1}x_2^2 \\ \pi_3 = [a-(q_1+q_2+q_3)-(c_3-x_3-\beta_3\gamma x_1-\beta_3\gamma x_2)]q_3 - \frac{1}{b_2}x_3^2 \end{cases} \tag{3}$$

GAME EQUILIBRIUM SOLUTION

Output decision stage: The enterprise cost and investment level is given, three firms conduct a Cournot game, each enterprise according to maximizing their own interest requirement to select the production, to maximize profits by solving the first-order condition, the selection of the output response function is:

$$\begin{cases} \frac{\partial\pi_1}{\partial q_1} = a-2q_1-q_2-q_3-(c_1-x_1-\beta_1\alpha x_2-\beta_1\gamma x_3)=0 \\ \frac{\partial\pi_1}{\partial q_2} = a-q_1-2q_2-q_3-(c_2-x_2-\beta_2\alpha x_1-\beta_2\gamma x_3)=0 \\ \frac{\partial\pi_1}{\partial q_3} = a-q_1-q_2-2q_3-(c_3-x_3-\beta_3\gamma x_1-\beta_3\gamma x_2)=0 \end{cases} \tag{4}$$

The enterprise equilibrium output is:

$$\begin{cases} q_1^* = \frac{1}{4}[a-3c_1+c_2+c_3+(3-\beta_2\alpha-\beta_3\gamma)x_1+(3\beta_1\alpha-1-\beta_3\gamma)x_2+(3\beta_1\gamma-1-\beta_2\gamma)x_3] \\ q_2^* = \frac{1}{4}[a-3c_2+c_1+c_3+(3-\beta_1\alpha-\beta_3\gamma)x_2+(3\beta_2\alpha-1-\beta_3\gamma)x_1+(3\beta_2\gamma-1-\beta_1\gamma)x_3] \\ q_3^* = \frac{1}{4}[a-3c_3+c_1+c_2+(3-\beta_1\gamma-\beta_2\gamma)x_3+(3\beta_3\gamma-1-\beta_2\alpha)x_1+(3\beta_3\gamma-1-\beta_1\alpha)x_2] \end{cases} \tag{5}$$

Enterprises in the equilibrium yield profit function are:

$$\begin{cases} \pi_1 = \frac{1}{16}[a-3c_1+c_2+c_3+(3-\beta_2\alpha-\beta_3\gamma)x_1+(3\beta_1\alpha-1-\beta_3\gamma)x_2+ \\ (3\beta_1\gamma-1-\beta_2\gamma)x_3]^2 - \frac{1}{b_1}x_1^2 \\ \pi_2 = \frac{1}{16}[a-3c_2+c_1+c_3+(3-\beta_1\alpha-\beta_3\gamma)x_2+(3\beta_2\alpha-1-\beta_3\gamma)x_1+ \\ (3\beta_2\gamma-1-\beta_1\gamma)x_3]^2 - \frac{1}{b_1}x_2^2 \\ \pi_3 = \frac{1}{16}[a-3c_3+c_1+c_2+(3-\beta_1\gamma-\beta_2\gamma)x_3+(3\beta_3\gamma-1-\beta_2\alpha)x_1+ \\ (3\beta_3\gamma-1-\beta_1\alpha)x_2]^2 - \frac{1}{b_2}x_3^2 \end{cases} \tag{6}$$

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 COOPERRATIVE R AND D INCOME

On the assumption that the enterprise3 R and D input is zero ($y_3 = 0$), then the product cost decrease that caused by its own R and D investment is zero ($x_3 = 0$) but the absorption capacity of enterprise3 is not zero ($\beta_3 \neq 0$), it can absorb other enterprises overflowing technology to reduce their production costs. In addition, we assume that the product costs are equal before cooperative R and D and represent by c ($c_1 = c_2 = c_3 = c$), 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, $b_1 = 0.8$.

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_1, π_2 with β curves which are shown in Fig. 1, it is concluded that:

- Along with the absorbing ability continuously improve, two enterprises profit have some different changes. When the absorption capacity of the enterprise which has strong absorption capacity is increasing, its profit will gradually improve, but when the enterprise with relatively weak absorption capacity is increased, its profit first increases and then decreases. This is because the technology absorption and transformation between different enterprises effectiveness growth rate is not the same, when the absorption capacity of the enterprise with strong absorption capacity is increased to a certain extent, it will increase the conversion rate of absorption of external knowledge, although the absorption capacity of the enterprise with low absorptive capacity is improved, in contrast with the enterprise with high absorptive capacity, its conversion rate of absorption is not effective, so the enterprise income will not increasing all the time, the income gap getting bigger, this will do harm to the cooperative R and D organization
- In different technology spillovers, their profits show a growth trend. For different enterprises, the higher degree of technology spillover, the more profit they are, but the profits gap of different absorption capacity of enterprises will be bigger. This shows

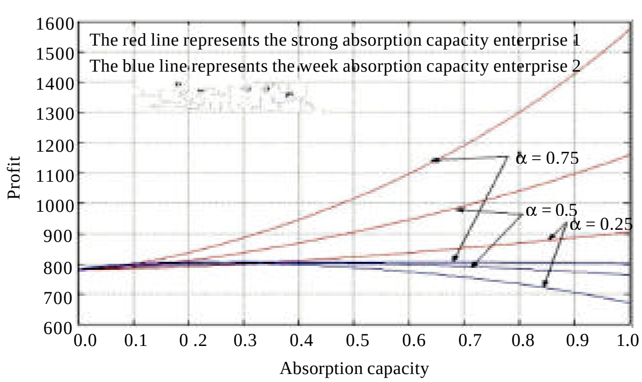

Fig. 1: Relationship between technology absorptive capacity and cooperative R and D profit (situation1)

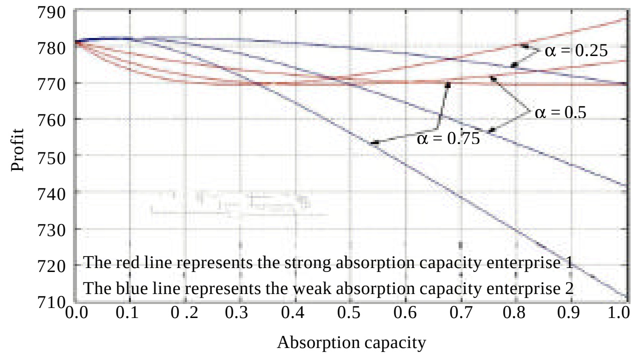

Fig. 2: Relationship between technology absorptive capacity and cooperative R and D profit (situation 2)

that the close cooperation and mutual trust degree is higher, the better the enterprise cooperation development, the efficiency will improve

- We assume that the external enterprise does not have a large effect on the profit of the enterprises within cooperative R and D organization, so they also do not have a negative impact on those enterprises

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 ($\beta_1 > \beta_3 > \beta_2$), through the MATLAB analysis of π_1, π_2 with β curve which are shown in Fig. 2, it is concluded that:

- When absorption capacity of the enterprise with absorption capacity in relative dominant position within the cooperative R and D organization is improved, their profit will gradually increasing, However, the profit of the enterprise with a weak absorption capacity will gradually reducing. In situation 2, the gap of profit between two enterprises is smaller than the situation 1, but absolute value of the profit is reduced. This is mainly due to enterprise 3, outside of cooperative R and D organization, with an absorption capacity of an absolutely dominant force in the industry, has a negative influence on the cooperative origination. Because the enterprise 3 can acquire technical knowledge of cooperative R and D enterprises through technology spillovers, gained an advantage at the product market all the same. So the market shares of cooperative R and D enterprises are declined, the profit is decreased. So the cooperative R and D in situation 2 is not stable
- In the different knowledge spillover level, each enterprise profit increases. For R and D cooperation enterprises, the more knowledge spillover, the more profit they are. This shows that the close cooperation and mutual trust degree is higher, the better the enterprise cooperation development, the efficiency will improve
- From the previous analysis which can be drawn that the enterprise outside of the cooperative R and D organization have a negative impact on cooperative R and D enterprises. Cooperative R and D organization is unstable in the presence of a powerful external enterprise. There is a greater impact on the enterprise with a weak technology position in particular

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_1, π_2 with β curve which are shown in Fig. 3, we may safely draw the conclusion:

- When the enterprise with strong absorption capacity which absorption capacity is increasing, its profit will gradually improve but when the enterprise with relatively weak absorption capacity is increasing, its profit first increases and then decreases
- In the different knowledge spillover level, each enterprise profit presents certain trend for R and D cooperation enterprises. The more knowledge spillover, the more profit they are. This shows that the close cooperation and mutual trust degree is higher, the better the enterprise cooperation development, the efficiency will improve
- We assume that the external enterprise does not have effect on the profits of the enterprises within cooperative R and D organization, so they also do not have a negative impact on those enterprises. This shows that as long as the external enterprises

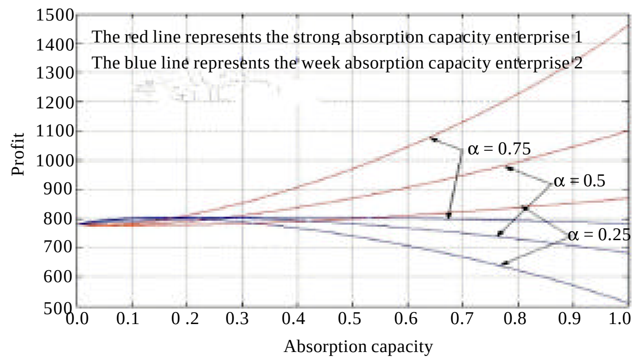

Fig. 3: Relationship between technology absorptive capacity and cooperative R and D profit (situation 3)

are not the strongest technology absorption capacity in the industry, cooperative R and D is relatively stable and it is also beneficial to cooperative enterprises

CONCLUSION AND DISCUSSION

For enterprises, although the cooperative R and D is an important way to acquire outside technological knowledge, but the different enterprise technological absorption capacity will affect the success rate. By way of introducing the enterprise technological absorption capacity and referring to the relationship between the Cooperative R and D enterprises and independent enterprise, this study builds a two-stage game model of three enterprise Cooperative R and D. It analyzes the effect of the different enterprise technological absorption capacity on the cooperative R and D income and make a conclusion:

- The strength of enterprise technological absorption capacity will affect the R and D income
- The Cooperative R and D income will suffer from the effect of the outside enterprise. When the non-Cooperative R and D enterprise is dominating, the Cooperative R and D income will decrease
- Especially, the one Cooperative R and D enterprise in a low-level technology position will expose his proprietary technology, decrease his enterprise income and finally difficult to succeed if it cannot master others core technology fully because of the weak technology absorption capacity

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 cooperative R and D revenue and have a study on the influence law that cooperative R and D apply to enterprise income in the case of three companies. But model assumes that each stage game for each enterprise is 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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